# VITAL SIGNS

## Field Manual

Biophysical Protocols

March 2014

## MANUAL CONTENTS

# Vital Signs Protocol

## E-Plot Biomass Measurements

Version 2.0

March 2014

## ACKNOWLEDGMENTS

Vital Signs would like to acknowledge Tony Knowles for his contributions to this protocol.

# CONTENTS

# 1. INTRODUCTION

This manual describes the steps and procedures for making **detailed vegetation measurements in the Vital Signs E-plots**. The measurements are used to estimate biomass, species composition and vegetation structure, among other purposes.

## *1.1 Understanding the E-Plot and Sub-Plots*

The tasks described in this manual cover the vegetation measurements taken in the Vital Signs E-plots, which are approximately one hectare in size. These plots are revisited every 3-5 years.

**An E-Plot is designed to undertaken by two to four people in 2-4 hours**. It is called an “E-plot” because of its shape (see Figure 1).

**Each E-plot has 36 circular sub-plots**. Neither the E plots nor the subplots are physically marked out with strings. The sub-plots are numbered according to the pathway taken to complete the E-plot: starting at sub-plot 1 and ending at sub-plot 36. Herbaceous Layer Mass, Herbaceous Species Ranking, and Woody Plant Measurements are made in every sub-plot, with additional measurements (geo-location using the GPS, canopy cover, and Landscape Functional Analysis) made at sub-plots 1, 6, 11, 16 and 23 (the four corners and near the centre of the E plot).

An E-plot is sampled teams of two people. If only one team is used, they do the tasks sequentially. Two teams can do the vegetation and soil measurements simultaneously:

- One team of two people starts with the tree and herbaceous measurements described in this protocol.

- The other team of two people begins making the soils measurements described in the soil sampling protocol.

- Whichever team finishes their measurements first joins the other team, and all four people complete the remaining measurements.

The main objective is to take accurate measurements in a time-efficient manner.

### *1.2 Definitions of Key Technical Terms*

**Landscape**: a 10 km x 10 km area in which Vital Signs develops an understanding of the spatial and temporal dynamics of agriculture, ecosystems and human well-being.

**Plot**: the area over which a Vital Signs sample is taken, with a specific location and dimensions. In Vital Signs, E-plots are approximately square and 1 hectare in size, with dimensions 100 x 100 m. The location is defined by the precise latitude and longitude of the four corners.

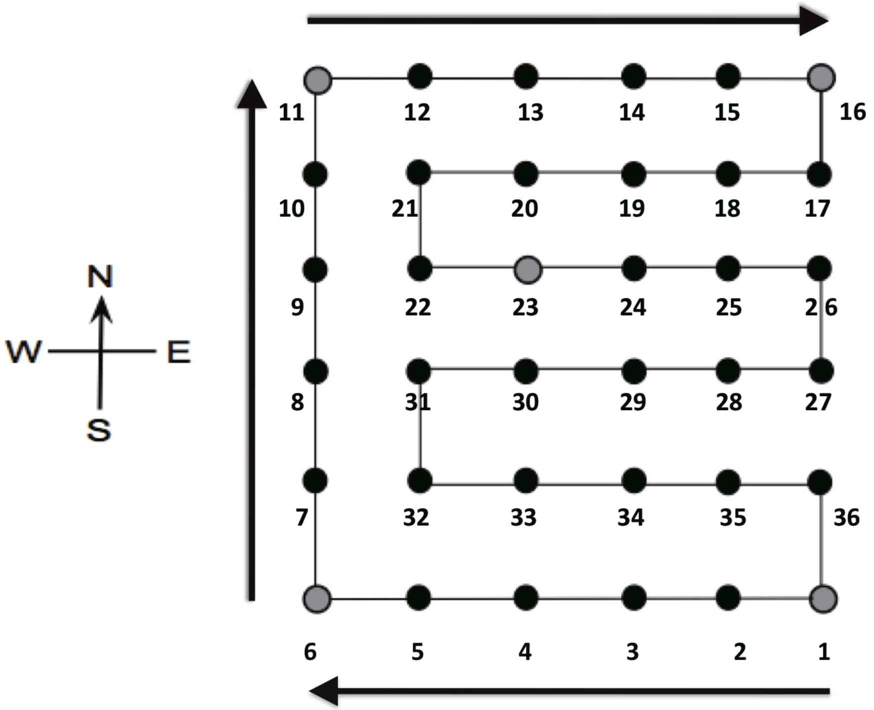



Figure 1: The Vital Signs E-plot and sub-plots

**Sub-plots**: Vital Signs E-plots have 36 circular subplots of variable diameter (2-10 m radius) arranged within the 1-hectare area on an approximately 20 m grid.

**Quadrat**: a portable frame of known size (typically 0.5 m x 0.5 m), that is part of the field team equipment. This frame is used for sampling field crops, the herbaceous layer in semi-natural areas, and litter layer and soil surface condition.

**Point**: a geographic location at which an observation is made. Points have latitude, longitude, date and time and one or more measurement variables.

### *1.3 Standard Conventions Used in this Document*

The following conventions are used throughout this document:

- The use of **bold** in the text indicates a critical point. **Please pay special attention to terms, sentences and paragraphs marked in bold** as they are key to the understanding of the protocol.

- Workflow diagrams are used in this document to provide a visual outline of the steps and timeline required to complete tasks in the E-plots and subplots.

## 2. ROLES AND RESPONSIBILITIES

The following table introduces the roles and responsibilities of the members of a Vital Signs field team:

| Role | Responsibility |
|---|---|
| Technicians | • Lay out 1-hectare E-plots, determine and record the sub-plot size in each plot<br>• Measure and record the vegetation and soil data for the E-plot<br>• Clean and store equipment |
| Technical Manager | • Supervises teams laying out E-plots and collecting data in sub-plots<br>• Ensures equipment is well-managed and team is safe<br>• Ensures consistency and quality of measurements<br>• Ensures data are uploaded to the VS server daily (or weekly if internet access is limited)<br>• Ensure back-ups and data entry sheets are properly archived |
| Country Director | • Develops and submits sampling schedule for approval<br>• Supports team with a complete understanding of the protocol manual<br>• Trains technicians in laying out E-plot and sampling sub-plots |

| | |
|---|---|
| | • Leads technicians in fieldwork and sampling and assists with measurements as required |
| Africa Field Director | • Approves sampling schedule<br>• Helps train technicians and ensure consistency of protocol implementation across Vital Signs countries<br>• Reviews data when uploaded<br>• Approves protocol updates and sends out update notifications to field teams |
| Protocol Manager | • Receives and archives comments about the protocol from the field team<br>• Updates and re-circulates the protocol |

## 3. EQUIPMENT LIST

The following equipment is required to carry out the activities described in this manual. Before traveling to the field to carry out sampling, **use this list to ensure you have all the equipment needed for the day**.

At the end of each day's work, equipment should be wiped down and stowed correctly so that the team can start working immediately the next morning. This practice also ensures that all equipment is accounted for and does not go missing.

The tablet is the preferred way to record data. In an emergency (such as when the tablet is not working), a paper form may be used, and the data uploaded to a working tablet as soon as possible. **At least one on-site backup to a laptop and, preferably, at least one off-site backup should be made at the end of each day**.

*General Supplies*

- Data entry tablet with forms loaded
- 30 meter nylon rope
- Roll of insulation tape
- Goggles (for eye protection in dense brush)
- Clipboards, notebooks and pens
- Water to drink and to conduct texture tests
- Packs for carrying equipment
- Hat
- Sun Lotion
- Vital Signs brochures in local language
- Identity cards
- Letters of introduction

*Equipment for Laying Out the E-Plot*

- GPS unit: GPSMAP 60Cx
- Spare batteries for GPS unit (2 AA batteries)
- Suunto compass
- 30 m measuring tape
- 4 corner pegs with red flags

*Recording Plant Species*

- Field guides for identifying plants
- Digital camera (your tablet can also be used to take photos)
- Plant press
- Labels (sticky-back or jewelers tags)
- Ziploc re-sealable plastic bags (about A4 size)

*Measuring Stems, Trees and Bushes*

- Haglof DME System (ensure all four pieces are included: receiver, transponder, transponder adaptor and plot staff)
- Haglof clinometer
- Convex densiometer for measuring tree cover
- Two 2-meter stem circumference measuring tapes marked in cm (don't use a forestry tape that converts the circumference to diameter)
- 2.5 meter ranging rod

*Measuring Herbaceous Layer and Ground Cover*

- 0.5 x 0.5 steel quadrat

## *3.1 Using the GPS Unit*

The **Garmin GPSmap 60Cx** is the GPS device used for Vital Signs. An instruction manual comes with the device and should be read for detailed instructions on the use and care of the device.

The following sections include instructions for:

1. Setting the correct data collection formats and units.
2. Navigating to specific points.
3. Setting waypoints.
4. Taking area measurement.

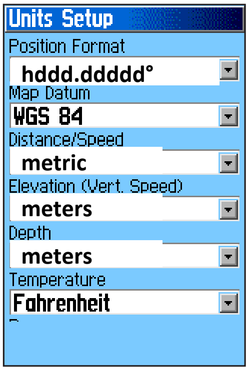
*3.1.1 Setting Position Format, Map Datum and Units*

It is important ensure the GPS unit has the correct settings before using the GPS in the field. To make sure the settings are correct, follow these instructions before going into the field:

- Press **Menu** twice to get to the **Main Menu**
- Select **Setup** to get to the **Setup Menu** page
- Select **Units** (see figure below) to get to the **Units Setup** page


- On the **Units Setup** page (see figure below), make sure the following are selected from the drop-down menus:
    - Position Format = hddd.ddddd°
    - Map Datum = WGS 84
    - Distance/speed = metric
    - Elevation = meters
    - Depth = meters
    - Temperature = Celsius


Units icon

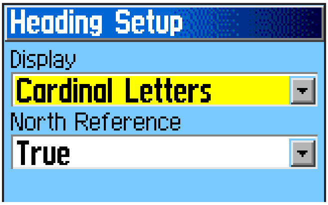



*3.1.2 Setting the Directional Heading*

To set the directional heading:

- Press **Menu** twice to get to the **Main Menu**
- Select **Setup** to get to the **Setup Menu** page
- Select **Heading** to get to the **Heading Setup** page (see figure below)

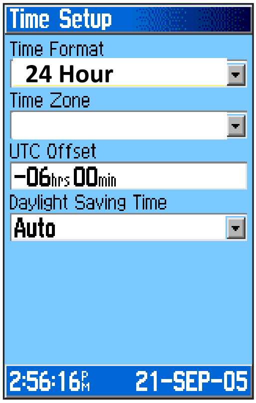
- On the **Heading Setup** page (see figure below), make sure the following are selected from the drop-down menus:
    - Display = Cardinal Letters
    - North Reference = True




*3.1.3 Setting the Time*

To set the time:

- Press **Menu** twice to get to the **Main Menu**
- Select **Setup** to get to the **Setup Menu** page
- Select **Time** to get to the **Time Setup** page (see figure below)
- On the **Time Setup** page (see figure below), make sure the following are selected from the drop-down menus:
    - Time Format = 24 hour
    - Time Zone = [select a city in your time zone]




*3.1.4 Navigating to an E-Frame Sampling Waypoint*

The E-frame sampling points will be preset into the GPS unit as waypoints. The waypoints for each day will be discussed and determined with the supervisor.

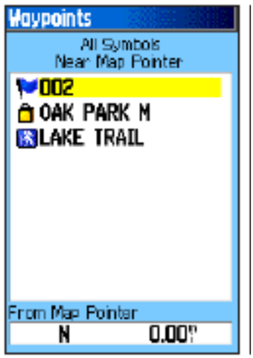

To get to a way point:

1. Press the **Find** key/button to get to the **Find Menu**.

2. Highlight the **Waypoints** icon and press **Enter** to open the **Waypoints** page.

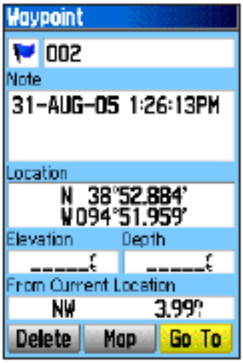
3. Use the rocker to find the waypoint you need and press **Enter**. That will open the page for that waypoint.


Waypoints icon




4. Highlight the **Go To** button and press **Enter** to begin navigation. This page will provide information on the distance to the waypoint, a compass or directional map for navigating to the E-frame sampling waypoint.

5. A map will appear with your location (triangle) and your destination point (a blue flag, with the **Waypoint** number). Use the **In** and **Out** buttons on the GPS to zoom in and out in needed.




6. Walk towards the preset **Waypoint** number, correcting course as you go around obstacles that do not allow you to walk in a straight line. Proceed until the GPS indicates you that you have arrived.

### *3.1.5 Marking a Location and Setting a Waypoint*

One of the Vital Signs activities will be to mark the location of specific places where samples or observations were taken. To mark these locations, follow these steps:

1. When you have arrived at the sampling point, turn the GPS on and let the GPS unit average the position for at least 5 minutes. Try to have an open view of the sky (no trees or obstacles above).

2. Press and hold the **Mark** key until the **Mark Waypoint** page appears.

3. Assign a Location Name to the Waypoint:

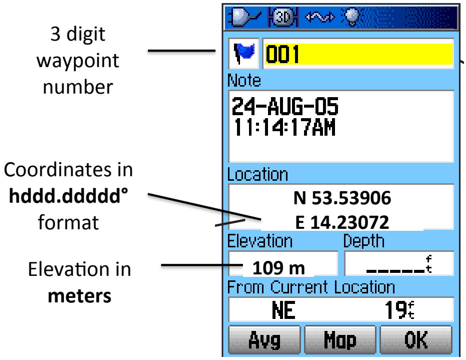
- After marking the waypoint, a default three-digit code is automatically assigned to the **Waypoint** (3 spaces provided).

- To enter a name or code to the waypoint, maneuver the rocker to the **Waypoint ID** field and press **Enter**. Type in the name/code of the location.

GPS unit with the **Mark** key.


- The **Note** field can be used to indicate specific remarks about the location, such as water quality, farm field etc.

**Mark Waypoint** Page.




- Record the information of the code, longitude, latitude of the waypoint into the appropriate Vital Signs data entry sheet.

4. To accept the waypoint with the information, highlight **Ok**, and press **Enter**.

*3.1.6 Taking Area Measurements of Sample Plots and Fields*

The area of fields and plots can be measured using the **Tracks** page of the GPS device. Areas of fields and plots that are less then 25 m on a side should not be measured with a GPS, but instead measured using the pacing method.

1. Go to a corner of the field or plot you want to measure.

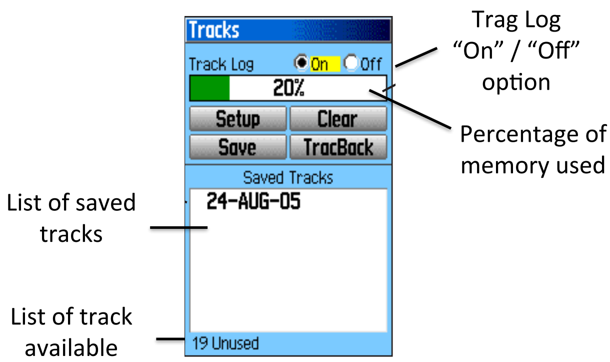
2. Open the device and let the GPS unit average the

position for at least 5 minutes. Try to have an open view of the sky (no trees or obstacles above). Press **Menu** twice to open the **Main Menu**.

3. Select the Tracks icon, and press **Enter** to open the **Tracks** Page.

4. Highlight the **Clear** button. A confirmation message appears “Do you really want to clear the track log?” Press **Enter** to clear the track log.

**Tracks** Page.




5. Move Track Log from **Off** to **On** and press **Enter**.

6. Press the **Menu** button once, highlight the **Area Calculation** option and press **Enter**. A Start

button should appear on the bottom of the screen.

7. Press **Enter**. The **Start** button should change **Stop**.

8. Begin walking around the edge of the field.

9. While walking the perimeter you will see your path drawn on the screen, as well as the origin of your path. You can zoom in or out with the **In** or **Out** button. If either the path or the origin is missing, go back to the starting point and start over from Step 1.

10. When you reach a corner, pause and slowly count to 30. This will allow the GPS unit to take many points at the corners.

11. Continue walking around the field/plot, stopping at each corner for 30 seconds.

12. Once you return to the original corner and are done defining the area, press **Enter** to open the **Calculated Area** page.

13. The area will appear on the bottom of the screen. Record this area in square meters. If the result is given in another unit, scroll down and select square **meters: $m^2$**.

14. Press **Enter** to save the new track to the **Saved Tracks** list on the **Tracks** page.

15. At the end of each day, upload these files to a computer and saved as gpx files, using an appropriate GIS software program (Mapsource, Basecamp, Google Earth).

**WARNING**: Because the capacity of GPS to store tracks is very limited (no more than 20 tracks can be saved simultaneously on the GPSMAP 60Cx) you must **transfer tracks to the computer every day and then clear the tracks from the GPS unit**. If this is not done, the GPS will not be able to save and an error message will appear: "Track memory full."

### *3.2 Using the Haglof DME Instrument*

The Haglof DME system has been chosen for the Vital Signs project as it is both accurate and easy-to-use. Most importantly, it improves the efficiency of teams and assists them in quickly assessing which trees are located in a sub-plot without having to lay strings around the subplot.

**The Haglof DME system is comprised of four components**:

1. Distance Measuring Equipment (DME) handset with which you measure distance to the transponder.

2. Sonic transponder (yellow) mounted on the monopod in the centre of the subplot
3. 360$^{o}$ adapter to allow the transponder to respond all round.

4. Monopod – a spiked pole 1 m tall to hold the transponder in the middle of the subplot.


The DME system uses sound waves to measure distance, allowing it to provide an **accurate estimate (with cm accuracy) of distance between the transponder and the unit**. As long as there is a clear open line-of-sight between the yellow transponder and the hand-held unit, it will be able to measure the distance accurately.

The yellow transponder is mounted onto the 360° adapter on a monopod in the centre of the sub-plot. When the observer (who is working their way around the sub-plot measuring each tree), wants to check the distance to the centre point, they point the DME instrument at the transponder to obtain a measurement. Hold the DME at about the same height as the transponder.

To use the DME system:

1. Switch on the yellow transponder so that it starts to send out a signal. To do this, you need to:

- Take the transponder off the 360° adapter (to have a clear view of the speaker in the node on the bottom side)

- Hold the DME unit pointing at the speaker (1-2 cm away)

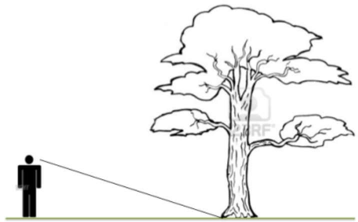
2. Press the red button on the DME unit until 2 short beeps are heard from the transponder. Since it uses little battery power, **you can leave the yellow transponder on while completing the 36 sub-plots in each E-plot**. When the E-plot is completed, turn the transponder off. Remove the transponder from the adapter, point the DME unit at the speaker (1-2 cm away), and press the red button for 10-15 seconds until the signal stops (the signal can be heard as a faint sound). If the battery needs to be replaced, the battery compartment is accessed through unscrewing the lid of the transponder unit in an anti-clockwise direction. The hand-held DME unit has a built-in battery saving function and will switch itself off after use.

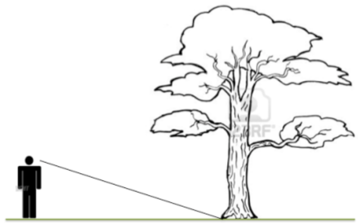
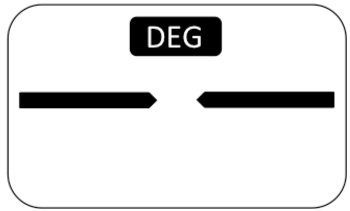
3. Before you start an E plot, calibrate the DME system by holding the handset exactly 10 m from the transponder (use the tape to determine this). Enter the calibration mode on the handset by repeated short presses on the red button until you reach F9 (calibration). **The DME should read 10.0 m**; if it does calibration is complete. Check that the units are registered in meters (not feet).

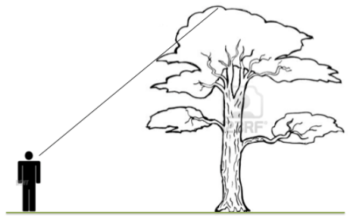
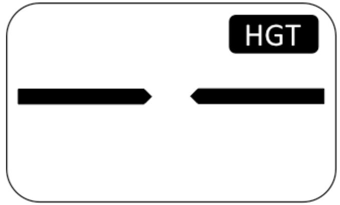
4. Mount the yellow transponder on the 360 adapter on the monopod in the center of the sub-plot. When you would like to check the distance from a tree to the centre point, hold the DME unit next to the tree (pointed at the transponder), and then press the red button once (to the [F1] function page) to obtain a measurement in meters.

### *3.3 Using the Clinometer*

The Haglof EC clinometer has been chosen for Vital Signs Project, as it is a robust, easy-to-use but accurate instrument. The key is to keep both eyes open while looking 'through' the instrument, and to **keep the unit steady** while it measures the angle to the bottom of the tree and the height of the tree. Each press on the button should be a short, quick press. Do not hold the button down.

| Step | Angle | Screen shot |
| --- | --- | --- |
| **Check Distance**<br>• Press the main button once to turn on the unit<br>• The screen will show the distance between you and the tree (15 m)<br>• If the distance is incorrect, change with the ± buttons |  |   |

| | | |
|---|---|---|
| **Measure the angle to the bottom of the tree**<br>• Press the button again to enter the degrees screen<br>• Aim the cross-hairs in the viewfinder at the bottom of the stem, press the button again, and keep the unit still so that it can take a measurement<br>• The angle measurement will flash up quickly and then the unit will start measuring height<br>• You do not need to record this angle measurement |  |  |

| | | |
|---|---|---|
| **Measure height of tree**<br>• Aim the cross-hairs in the viewfinder at middle of the upper canopy of the tree<br>• Hold the unit still and press the button again.<br>• The height of the tree in meters will then be shown on the screen e.g. 12,1. |  |   |

# 4. SAMPLING THE E-PLOT

The following instructions outline the process for sampling the E-plot, including specific instructions for which measurements are made in each sub-plot.

## *4.1 Navigating to the E-Plot*

**The 1-hectare E-plot must be precisely geo-located**, as the plot will be revisited every 3-5 years. The E-plot should not be permanently marked.

At least one day before traveling to the field, check that the E-plot locations have been loaded into the GPS.

The night before going into the field, review the equipment list and load the equipment into the vehicle.

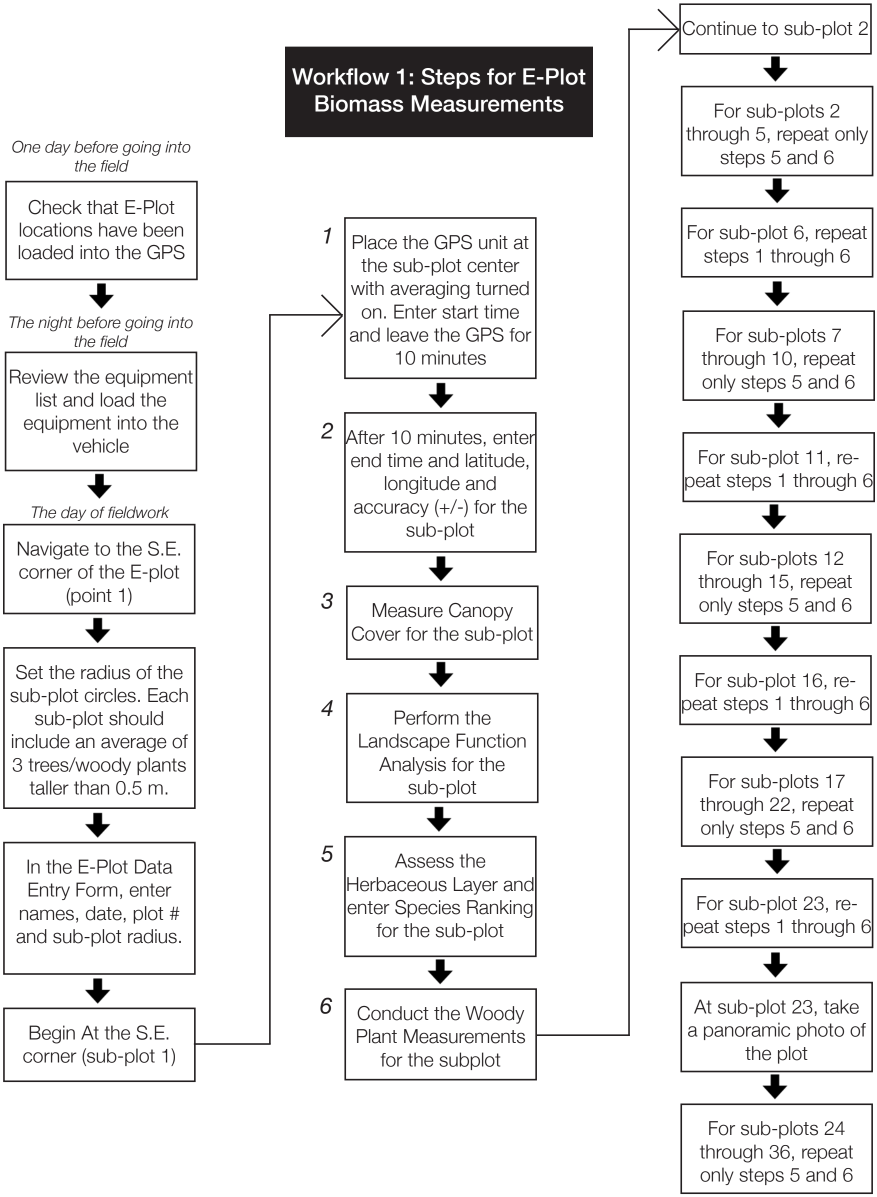
On the day you go into the field:

1. Navigate to the S.E. corner of the E-plot (point 1).

2. Determine the two field teams (two people in each team). One team will begin the vegetation measurements, and the other team will make the soil measurements and then join the first team to complete the biomass measurements in the remaining sub-plots.

## *4.2 Determining the Size of the Sub-Plots*

The 36 sub-plots within the plot are circular in shape. **The objective is to measure approximately 100 individual**


Workflow 1: Steps for E-Plot Biomass Measurements
One day before going into the field
Check that E-Plot locations have been loaded into the GPS
The night before going into the field
Review the equipment list and load the equipment into the vehicle
The day of fieldwork
Navigate to the S.E. corner of the E-plot (point 1)
Set the radius of the sub-plot circles. Each sub-plot should include an average of 3 trees/woody plants taller than 0.5 m.
In the E-Plot Data Entry Form, enter names, date, plot # and sub-plot radius.
Begin At the S.E. corner (sub-plot 1)
1
Place the GPS unit at the sub-plot center with averaging turned on. Enter start time and leave the GPS for 10 minutes
2
After 10 minutes, enter end time and latitude, longitude and accuracy (+/-) for the sub-plot
3
Measure Canopy Cover for the sub-plot
4
Perform the Landscape Function Analysis for the sub-plot
5
Assess the Herbaceous Layer and enter Species Ranking for the sub-plot
6
Conduct the Woody Plant Measurements for the subplot
Continue to sub-plot 2
For sub-plots 2 through 5, repeat only steps 5 and 6
For sub-plot 6, repeat steps 1 through 6
For sub-plots 7 through 10, repeat only steps 5 and 6
For sub-plot 11, re-peat steps 1 through 6
For sub-plots 12 through 15, repeat only steps 5 and 6
For sub-plot 16, re-peat steps 1 through 6
For sub-plots 17 through 22, repeat only steps 5 and 6
For sub-plot 23, re-peat steps 1 through 6
At sub-plot 23, take a panoramic photo of the plot
For sub-plots 24 through 36, repeat only steps 5 and 6

**woody plants in the 1-hectare plot**; in other words, on average about three trees per subplot.

The size of sub-plots is varied depending on the number of trees per unit area of trees in the plot: denser plots will need smaller circles. **Set the circular sub-plot radius so that there will be an average of about three woody plants in each sub-plot**.

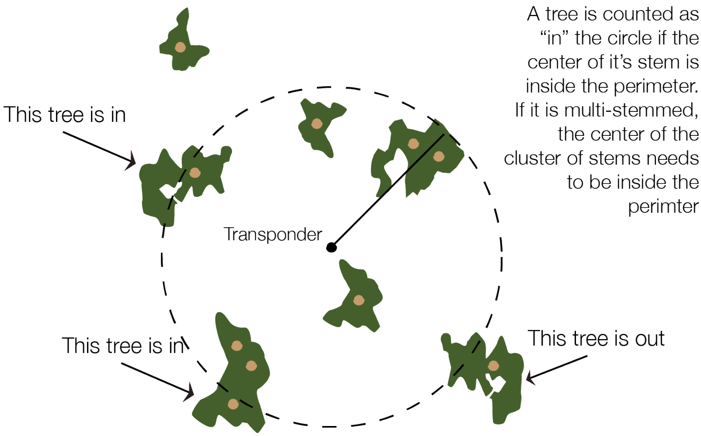



*Figure 2. Schematic representation of circular sub-plot. A sonic transponder is placed at the centre of the plot and the distance of a plant to the transponder checked with a sonic distance measurer or a piece of string or a ranging rod. The plot should ideally have three woody plants rooted within it, but this will range from 0 to many.*

The maximum subplot radius is 10 m (you would use this in an open grassland with less than 100 trees per hectare). As a guide, the plot radius should be about the same as the average distance between trees.

You will soon learn to estimate the appropriate radius, and if you get it a bit wrong it does not matter much – it just increases the time you will take if you make it too big, and reduces the accuracy if you make it too small. **The same radius will be used for all 36 subplots in the E-plot, and must be recorded on the tablet or paper form**.

The diagram below illustrates how you determine whether trees are included in your sub-plot circle or not. Trees with the center of their stem inside the circle are counted as being inside the sub-plot, while trees with the center of their stem outside the circle are not counted.

Some of the subplots will have no trees in them. This is fine – don't add extra subplots to compensate!

Once you have determined the radius of your circular subplots, start at the origin (S.E. corner of the plot, sub-plot 1) and proceed around the E in a clockwise direction.

### *4.3 Instructions for Sampling Order*

**The below instructions match Workflow 1, and outline the steps for completing the E-plot biomass measurements**. Detailed instructions for the types of measurements you will make follow in sections 6 through 8.

**The plot should be oriented with the base of the E in an East-West direction, and the upright back of the E in a North-South direction**. It makes no difference if you use magnetic north (from the compass) or true north (from the GPS) for this purpose.

This orientation allows for easy navigation as opposed to navigating at obscure angles (e.g. WNW-ESE, NNE-SSW). To navigate through the E-plot, use a compass to keep you going straight in dense vegetation, and pace out the distances rather than measuring them with a tape. The plot does not have to be exactly square and the circular plots do not have to be in exact places, as long as you don't cheat but only putting them in easy-to-measure places. The subplots must not overlap one another, which is why the maximum radius is 10 m.

1. Begin at the S.E. Corner (sub-plot 1)

    a. **Obtain the exact latitude and longitude of this corner using the GPS unit, allowing it to average for about 5 minutes while you organize your equipment**. For detailed instructions see Section 6: Geo-Locating the Corners of the Plot.

    b. **Measure Canopy Cover for the sub-plot**. For detailed instructions see Section 7: Canopy Cover and Landscape Function Analysis.

    c. **Perform the Landscape Function Analysis for the sub-plot**. For detailed instructions see Section 7: Canopy Cover and Landscape Function Analysis.

d. **Assess the Herbaceous Layer and enter species ranking for the sub-plot**. For detailed instructions see Section 8: Species Ranking and Woody Plant Measurements.

e. **Conduct the Woody Plant Measurements for the sub-plot**. For detailed instructions see Section 8: Species Ranking and Woody Plant Measurements.

2. Move to sub-plot 2. Using a compass to orient yourself West, take 20 large paces in that direction (i.e. 20 m). It helps to find a prominent object far beyond the plot to aim at. When you reach the 20$^{th}$ pace, you are at the second sub-plot. Spike the DME transponder monopod into the ground where you toe ends.

3. **For subplots 2 through 5, perform the following measurements,** pacing westwards 20 m to reach each new sub-plot.

    a. **Assess the Herbaceous Layer and enter species ranking for the sub-plot**. For detailed instructions see Section 8: Species Ranking and Woody Plant Measurements.

    b. **Conduct the Woody Plant Measurements for the sub-plot**. For detailed instructions see Section 8:

Species Ranking and Woody Plant Measurements.

4. When you reach sub-plot 6:

   a. Obtain the latitude and longitude of the corner using the GPS unit. **You need not average for a full 5 minutes here: the time you take to do the measurements is enough**. For detailed instructions see Section 6: Geo-Locating the Corners of the Plot.

   b. **Measure Canopy Cover for the sub-plot**. For detailed instructions see Section 7: Canopy Cover and Landscape Function Analysis.

   c. **Perform the Landscape Function Analysis for the sub-plot**. For detailed instructions see Section 7: Canopy Cover and Landscape Function Analysis.

   d. **Assess the Herbaceous Layer and enter species ranking for the sub-plot**. For detailed instructions see Section 8: Species Ranking and Woody Plant Measurements.

   e. **Conduct the Woody Plant Measurements for the sub-plot**. For detailed instructions see Section 8:

Species Ranking and Woody Plant Measurements.

5. Move north to sub-plot 7. Using a compass to orient yourself North, pace in that direction for 20 m. When you reach 20 m, you are at the seventh sub-plot.

6. **For subplots 7 through 10, perform the following measurements.** Continue pacing northwards 20 m to reach each new sub-plot.

    a. **Assess the Herbaceous Layer and enter species ranking for the sub-plot**. For detailed instructions see Section 8: Species Ranking and Woody Plant Measurements.

    b. **Conduct the Woody Plant Measurements for the sub-plot**. For detailed instructions see Section 8: Species Ranking and Woody Plant Measurements.

7. **For the NW corner sub-plot 11**, follow instructions above for sub-plots 1 and 6.

8. Move East to sub-plot 12. Using a compass to orient yourself East, take 20 big paces in that direction to reach sub-plot 12.

9. **For sub-plots 12 through 15**, follow instructions above for sub-plots 2 through 5 and 7 through 10.

10. **For sub-plot 16 (NE corner)**, follow instructions above for the other corner sub-plots: 1, 6 and 11.

11. **For sub-plots 17 through 22**, follow instructions above for sub-plots 2 through 5, 7 through 10, and 12 through 15. For navigation, see Figure 1 – take 20 paces south to subplot 17, then turn west for subplots 18 to 21, turn south for 20 m for 22, and then east for 20 paces to 23.

12. **For sub-plot 23 (the near-centre subplot)**, follow instructions above for corner sub-plots 1, 6, 11 and 16.

    a. In addition to these measurements, **at sub-plot 23 you must also take a 360° panoramic photo of the plot**. Begin pointing north and turn clockwise.

13. **For sub-plots 24 through 36**, follow instructions above for sub-plots 2 through 5, continuing to navigate around the E.

14. When you finish subplot 36, the vegetation measurements for the E-plot are complete.

15. When you have completed filling out the measurements in the tablet data entry form, upload the form to the Vital Signs server. If you have used a paper form, upload it to a tablet as soon as possible, then upload to the server.

# 5. GEO-LOCATING THE CORNERS OF THE PLOT

The following instructions are for geo-locating the corners of the plot to get the latitude, longitude and accuracy. This is done using the GPS Unit (instructions for using the GPS unit are in Section 3.1)

## *5.1 Geo-locating the S.E. Corner of the E-Plot*

1. **Place the GPS unit in sub-plot 1, with averaging turned on**. Enter start time and leave the GPS unit for 10 minutes while you begin other tasks.

2. After 10 minutes, enter:

    a. GPS Start Time
    b. GPS End Time
    c. Latitude
    d. Longitude
    e. Accuracy (+/-) in meters with 5 decimal degrees resolution
    f. Number of measurement counts in average

## *5.2 Geo-locating the Remaining Three Corners of the Plot*

After geo-referencing the S.E. corner, each of the other three corners (points 6, 11, and 16 in figure 1) must be geo-located within a 5 m accuracy. This accuracy is usually achieved within seconds.
**For the remaining three corners, sub-plots 6, 11 and 16:**

1. Use the GPS Unit to geo-locate the corner.

2. In the data entry form, enter:
   g. Latitude
   h. Longitude
   a. Accuracy (+/-) in meters with 5 decimal degrees resolution

Only the four corners of the plot are geo-located, therefore teams need not measure the precise location of the sub-plots.

## 6. CANOPY COVER AND LANDSCAPE FUNCTION ANALYSIS

The following table summarizes the measurements you will make for Canopy Cover and Landscape Function Analysis:

| Measurement | Metric | Accuracy | Required equipment |
|---|---|---|---|
| Measurements are made at the four corners of the plot (points 1, 6, 11, 16) and plot center (point 23) | | | |
| Canopy cover | Percent | 20% | Densiometer |
| Landscape Function Analysis | Condition of ground surface | 10% | Visual inspection |

## Workflow 2: Canopy Cover and Landscape Function Analysis

Begin after you have geo-located the subplot

↓

To begin measuring canopy cover, hold the densiometer level approximately 1.4 meters above the ground

↓

On the Woody Canopy Cover data sheet, enter a score for each square on the sheet. Scores are between 0-5, where:
a. 0 = no cover
b. 1 = some cover
c. 2 = half covered by canopy
d. 3 = nearly covered by canopy
e. 4 = full, complete cover

↓

Add up the scores as you enter them into the squares. The sum of the scores should be rounded to the nearest 10% and recorded in the entry form as a value between 0-10

→

After scoring canopy cover in the sub-plot, perform the Landscape Function Analysis (LFA)

↓

Place your quadrat

↓

Estimate what fraction of the ground in the quadrat has herbaceous cover above it. Enter a score between 1 and 10 for herbaceous crown cover.

↓

Rate the ground in the quadrat for soil erosion. Enter a score between 0 and 3.

↓

Score the ground inside the quadrat for the presence of the conditions listed on the data sheet.

### *6.1 Measuring Canopy Cover*

The following steps for measuring Canopy Cover and Landscape Function Analysis are to be **completed in the four corners of the plot (points 1, 6, 11, and 16) and the center of the plot (point 23)**.

Estimates of canopy cover are made using a densiometer. **A densiometer is a domed mirror that has 24 squares engraved on its surface**.

To measure Canopy Cover percentage:

1. **Hold the densiometer level approximately 1.4 meters above the ground**. Hold your arm stiffly at your side, with your elbow bent so that your forearm is horizontal and the densitometer is pointing upward in your palm. By looking at the bubble level, make sure the densitometer is horizontal throughout the measurement.

2. Assign a score between 0 and 4 for each of the squares on the densitometer mirror, where:

    0 = square reflects no overhead tree cover (empty)
    1 = some cover located just inside the square
    2 = square half covered by reflected canopy
    3 = square more than half but not completely full of reflected canopy
    4 = the square has full, complete cover

1. **Add up the scores in your head**. The sum of the scores (out of a possible 96) should be rounded to the nearest 10% (“decile”) and recorded as a value between 0-10 on the datasheet. For example, a sum of 48 should be rounded to 50% and recorded as 5 on the datasheet, or a sum of 23 should be rounded to 20% and recorded as 2. A sum of ending in 5 should be rounded up.

*Figure 3: An estimate of canopy cover is taken using a densiometer. The observer is required to score the amount of canopy cover reflected in each of the 24 squares marked on the mirror surface.*

2. If no woody plant canopy cover is present, a value of 0 must be recorded.

<u>*6.2 Performing the Landscape Function Analysis*</u>

The concept (but not the method) is loosely based on Ludwig and Tongway (1995). Do this after you have done the Dry Weight Ranking for the subplot.

1. Place the quadrat to the northeast of the subplot centre, with its SW corner on the centre point. If you cannot do so because of an obstacle (like a tree trunk) adjust it to the nearest possible position.
2. By looking from above down into the quadrat, estimate what fraction of the ground has standing live or dead herbaceous cover above it (excluding litter, which is dead plant material on the soil surface)

3. Score the herbaceous cover between 1 and 10 (i.e. the percentage cover divided by 10) and enter number on the tablet or data entry sheet.

4. Note evidence of soil erosion. Evidence includes soil pedestals, exposed roots, rills, sediment deposits, soil splash, or debris dams.

5. Rate the ground in the quadrat for soil erosion: 0=none, 1= present but uncommon (<10%), 2=common (11-50%), 3= ubiquitous (> half of quadrat). Enter number on the tablet or data entry sheet.

6. If you cannot see the soil surface clearly, clip the herbaceous layer about 2 cm above the ground level. If for some reason you need to estimate the herbaceous aboveground mass (it is not required by VS, but is often used in fire or grazing research) you could collect this material, dry it and weigh it.

7. Score the ground inside the quadrat for the presence of the following conditions. The percent contribution of each surface condition class should be scored and recorded 0 to 10 (i.e. 10% intervals of ground cover) with the sum of deciles across classes equaling 10.

    a. Bases of rooted plants
    b. Litter cover (dead leaves, grass or herbs)
    c. Fallen wood (logs or twigs)
    d. Stone or gravel
    e. Dung
    f. Recently disturbed soil (obviously tilled, hoof-pitted, excavated by animals or insects)
    g. Bare but porous soil (Put on a few drops of water test this if you are unsure. If it is absorbed within two seconds, the soil is porous)
    h. Bare but sealed soil (clay-capped, compacted or hydrophobic)
    i. Sodic soil (a hard whitish surface found on sodium-affected soils)
    j. Microfloral crust (algal, fungal, lichen or moss)
    k. Termite mound

8. Enter the ground cover scores for each category on the tablet or data entry sheet.

At this point you have completed the Landscape Functional Analysis.

# 7. SPECIES RANKING AND WOODY PLANT MEASUREMENTS

The following table summarizes the Vegetation Measurements you will make in every sub-plot:

| At each subplot: Herbaceous layer measurements – within a 0.5x0.5 m quadrat | | | |
|---|---|---|---|
| Herbaceous layer composition | Top three species by mass identified by Latin binomial names | - | If unknown - field guides, camera |
| **Woody plant measurements – for each plant with basal diameter of > 5cm** | | | |
| Species name | Latin binomial name | - | If unknown - field guides, camera |
| Plant basal area | Circumference (mm) | 10 mm | Measuring tape |
| Plant height | meters | 0.1 meter | < 5m height – Ranging rod |
| | | 1 m | > 5m height – Clinometer |
| Plant crown max width | meters | 0.1 meter | Measuring tape |

At the corners and center of the plot (sub-plots 1, 6, 11, 16 and 23) you will make these measurements before the Landscape Functional Analysis. In all other sub-plots, these are the only measurements you are making in the sub-plot.

## Workflow 3: Woody Plant Measurements

The following measurements are made in each sub-plot.

↓

Place your quadrat

↓

In the data entry form, enter the top three species that fall inside the quadrat in rank order. The most prevalent species is Rank 1, the second Rank 2 and the third, Rank 3.

↓

Place the transponder unit on a pole in the center of the sub-plot and measure the distance to the center point using the hand-held sonic transducer unit

↓

Determine which trees are in the subplot. Trees must be taller than your knee (0.5m) and greater than 50mm in diameter (about the size of your wrist)

→

Starting with the first tree, enter the species name. If you cannot identify a tree, follow the steps outlined in the protocol, including steps for photographs.

↓

Enter the number of stems on the tree.

↓

Measure the basal circumference of the tree 50 cm above ground level, using a measuring tape

↓

Record the height of the tree to an accuracy of 0.1 m

↓

Record the canopy width of the tree to an accuracy of 0.1 m

↓

Repeat for the next tree in the sub-plot.

↓

When you have finished the previous steps for all trees/ plants taller than 0.5m and greater than 50 mm in diameter in the sub-plot, you have completed woody plant measurements in that sub-plot

## *7.1 Herbaceous Species Composition Using the Dry-Weight-Rank Method*

The Dry-Weight-Rank Method (DWR, Jones and Hargreaves 1979) requires the observer to quickly **record the three most abundant species in the 0.5 x 0.5m quadrat**. Before you start, enter names of manager, scribe and measurers, date and plot number on the Dry Weight Rank data entry pages of the tablet or a paper form.

1. Place your quadrat NE of the centre point of the subplot (do the scoring before you clip the plot, if this is a corner plot and you are doing landscape function analysis as well).

2. **In the line for Subplot 1, enter the top three species that fall inside the quadrat in rank order**. The most prevalent species by aboveground dry mass gets listed first, the second next and the third, last.

   **If a single species constitutes over two-thirds of the biomass within the quadrat, it should be ranked both 1st and 2nd**. If all the biomass within the quadrat is constituted by a single species, it gets first, second and third.

Calculation of the species composition will be done at the VS office. The procedure is to give the species 8 points for ranking first, 2.4 points for second and 1 point for third, summing for each species over all the quadrats, and then summing the subtotals for each species. The percentage contribution by a species to the dry mass is given by the species subtotal/grand total x 100. A slightly better approach (Jones and Hargreaves 1979) is to weight the points in each quadrat by some index of how much vegetation there is in that quadrat.

### *7.2 Measuring Woody Plants in the Sub-Plot*

**A woody plant is a tree or shrub with one or many stems**. It must be taller than your knee (0.5 m) and greater than 50 mm in diameter (about the size of your wrist). The Vital Signs **standard for stem diameter measurement is at 0.5 m (knee height) for trees that branch below 1.5 m**; or at the more conventional 1.3 m (breast height) for tall, straight trees that only branch above this level.

1. Place the transponder unit on a pole in the center of the sub-plot.

2. Determine which trees are in the subplot by measuring the distance to the center point using the handheld sonic transducer unit. You will soon be able to judge whether most of the trees are in or out of the subplot without taking a distance measurement, and only need to measure the ones near the edge.

3. Starting with the first tree (work clockwise around the circular plot from the north, so that you don't lose track of which trees you have recorded), enter the species name. Each plant in the sub-plot should be recorded by its scientific (Latin) binomial

name, rather than its name in a local language or English. The species names are available on a pick list on the tablet. **The first time a species is listed on a paper datasheet or in a document, it should be written out in full** (e.g. Dichrostachys cinerea). After this, you can use a species code.

4. If you cannot identify the species, follow steps below in section 8.6 for documenting unknown plants.

5. Enter the number of stems on the tree.

*7.3 Measuring Basal Circumference*

1. **Measure basal circumference at the standard height above the ground (see above)**, **using a measuring tape** (measurements are recorded in cm). Make sure your measurement is where the diameter of the stem is fairly constant, before the stem begins to taper or branch. If the standard height coincides with a basal swelling or scar, basal circumference should be measured just above or below the swelling or scar.

2. **Call out the circumference of the stem to the scribe**. If the tree has more than one stem, for example, call out ‘species x, three stems, first stem 20 cm, second stem 35 cm, third stem 36 cm.’

Special Cases:

1. In the case of **trees** branching below 0.5 m, each stem above the branch should be measured and recorded separately.

2. In the case of highly **multi-stemmed bushes (> 5 stems, each small, but together adding up to the equivalent of a 50 mm diameter stem)**, measure an average stem circumference record it along with a count of the number of stems. The fact that the observer is recording a multi-stemmed bush should be clearly indicated on the paper data-entry sheet as circumference (number).

3. In the case of **lianas (vines)**, the basal diameter of individual plants rooted within the sub-plot should be measured. In place of a height measurement, a conservative visual estimate of the length of the vine should be recorded (in meters).

You are likely to encounter a wide variety of circumstances in which a slightly different approach may be required to obtain an appropriate estimate of basal area. This may either be due to the unique growth form of the plant, its location (e.g. a steep slope), or the way in which it has been pruned by humans, livestock or game.

The set of diagrams below illustrate where the basal area measurement should be taken under different circumstances. These diagrams illustrate common forms or situations that may be found, but by no means form a comprehensive list of potential field conditions.

When a situation arises that is not illustrated here, apply the general principles. For example, in the case of a buttressed tree, measurement should be taken just above the exaggerated root buttress (Figure 4).

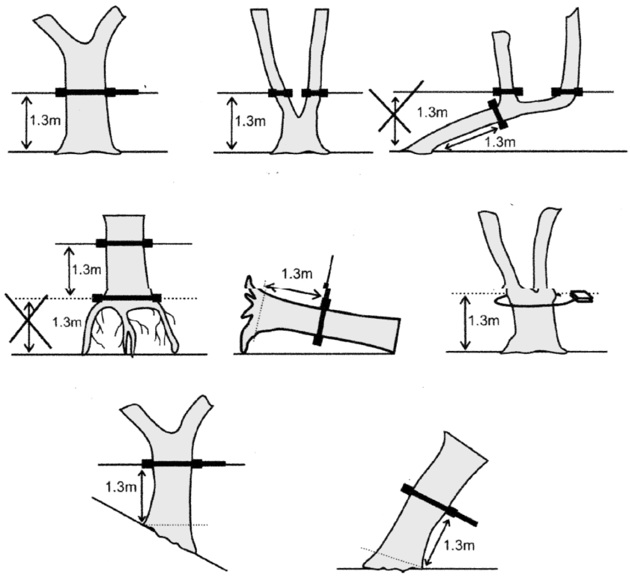



*Figure 4: Field observers measuring basal area are likely to encounter a considerable amount of variation in the type and position of the plant stems. When faced with such variation, apply the general principle of measuring the basal area of the stem above the basal swelling, where the diameter of the stem is fairly constant and before the stem begins to taper or branch.*

## *7.4 Measuring the Height of Woody Plants*

Plant height is measured from ground level at the base of the stem to the highest point in the plant's canopy. It is separately estimated for each stem in the case of a multi-stemmed plant, since the stem circumference and the height are needed to estimate the biomass.

- **Record the height of plants to an accuracy of 10 cm or 0.1 m** (for example, 0.8 m or 12.6 m) if shorter than 5 m, and the nearest m if taller than 5 m.

- If the tree is rooted on a steep slope, the lower measurement should be taken at ground level in the centre of the root base.

- When measuring tall trees with an extensive canopy, take the upper measurement from the centre of the top of the canopy, not from the edge of the canopy.

**The height of trees and shrubs shorter than 2.5 m can be directly measured using a ranging rod.** Trees taller than 2.5 m but shorter than 5 m can be indirectly measured with the ranging rod by having one team member hold it vertical next to the stem while the other steps about 5 back and visually extrapolates the height; alternately the helper can hold the rod on their head (about 2m).

**Measure bushes and trees that are taller than 5 m with a clinometer.**

A clinometer is an instrument used to measure vertical angles. It is used for measuring the height of trees as well as in estimating the angle of a slope. To measure the height of a tree:

1. **Stand exactly 15 meters from the base of the tree** when taking the angle measurement. The DME can help measure this, or a 30 m tape, or a pre-measured rope 15m long. Some clinometers have a built-in distance meter based on the same technology as the DME.

2. Work out the angle between the base of the tree and its crown. From this angle and the distance, the height can be estimated.

Calculating tree height using a clinometer:

The calculation of tree height is based on trigonometry. If one assumes that the tree is growing at $90^{\circ}$ angle to the ground, a measure of the horizontal distance to the tree (the adjacent side of the triangle) and the vertical angle between the bottom and the top of the tree can be used to calculate the height of the tree (Figure 5).
The calculation essentially works out the dimensions of two triangles – one below and one above the height at which the angle is measured – and adds the two 'opposite sides' of the triangles to calculate the height of the tree.

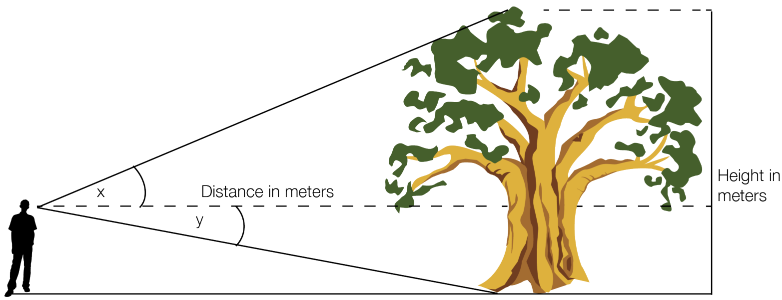



*Figure 5: An illustration of the two vertical angle measurements that need to be taken if the height of the tree is to be calculated manually. The observer should take extra care to ensure that they are standing the required set distance from the tree (e.g. 15 meters).*

Tree Height Calculation:

$$H = (D * \tan x^{o}) + (D * \tan y^{o})$$

Where: H = tree height in meters (m)

D = the horizontal distance between the observer and the tree in meters (m)

$x^{o}$ = the vertical angle between top of the tree (in the centre) and a horizontal level (measured in degrees)

$y^{o}$ = the vertical angle between the based on the tree (in the centre) and a horizontal level (measured in degrees)

**Note**: In a MS Excel spreadsheet, the equation above would be entered in a cell as:

=(D*TAN(RADIANS(x))+ (D*TAN(RADIANS(y))

### *7.5 Measuring Canopy Width*

Measure the canopy width (which is an alternate way to estimate crown cover) of each woody plant to the nearest meter for trees with a canopy >5 m across, or to 0.5 m for smaller trees.

1. Take an average diameter measurement of the crown of the plant, i.e. the midpoint between the long axis of the canopy and the short axis (Figure 6). This can be done by two team members using a measuring tape, or a ranging rod, or the team can use a sonic distance instrument.

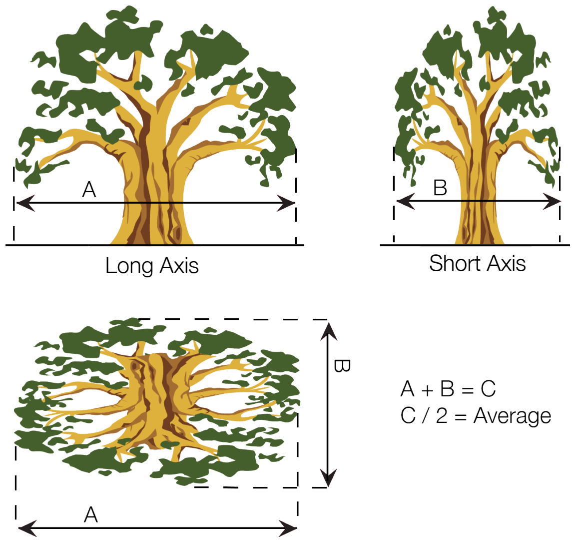



*Figure 6: Canopy width measurements are generally taken by two observers using a sonic distance measurement device or a*

*30m measuring tape or a 2.5 m ranging rod. Both the long and short axis of the crown is measured, and then averaged.*

### *7.6 Documenting an Unknown Plant Species*

If the name of a species is unknown:

1. **Try to identify the plant using a field guide** that has pictures of local plants and their parts (leaf type, flowers, type and color of bark, etc.).

2. If the plant cannot be identified using a field guide, **record the essential attributes of the plant** and standard meta-data:

    a. Size
    b. Shape
    c. Color
    d. Location
    e. Name of the observer
    f. Date
    g. Time
    h. Geographical co-ordinates
    i. Slope and aspect

3. If the team is carrying a digital camera, **take several clear photographs of the plant**, including:

    a. Photo of the entire plant
    b. Photo of a branch with leaves and buds
    c. Photo of both sides of a leaf, with a measuring tape next to the leaf

   d. Photo of bark, with measuring tape next to bark
   e. Photo of flowers and fruit, if present

4. **Take a sample of the plant** and preserve using a plant press. This sample can be a small branch with several leaves, and a sample of flowers or fruit if present.

5. Record the following meta-data on a collector's tag and attach firmly to the sample:

   a. Observer's full name and affiliation
   b. Observer's email address and telephone number
   c. Date and time
   d. Geographic co-ordinates (GPS) of the plant and name of the area

6. When you have returned from the field, communicate with a colleague who knows the area and may have seen the species before.

It is likely that numerous unknown plants will be recorded, especially during the initial field sessions in an area that is new.

Photographs and descriptions need to be filed in a structured, orderly manner to avoid confusion between samples. A unique unknown specimen number or code should be assigned to each unknown plant. The unique code should be included in photograph and description file names and the images themselves where possible.

The more clear, descriptive notes recorded on the plant, the better. The observer should note down any information they believe may be helpful to the taxonomist. The best thing is to get a **well-pressed specimen to the taxonomist with the location, date, GPS co-ordinates and a set of clear photographs**.

# 8. BIBLIOGRAPHY

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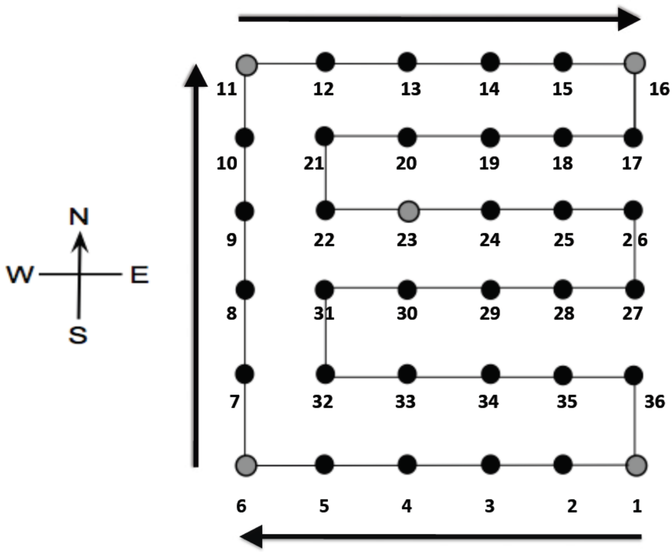
# 9. APPENDICES

Appendix 1: E-Plot Data Entry Form

Appendix 2: E-Plot Data Dictionary

# Vital Signs: E-Plot Field Data Entry Form

| **Team member** | First name | Last name | **Plot code** | | |
|---|---|---|---|---|---|
| Manager | | | Country code | Landscape code | Plot number |
| Scribe | | | | | |
| Measurer 1 | | | **Date** | | |
| Measurer 2 | | | Day (DD) | Month (MM) | Year (YYYY) |
| **Sub-plot radius (m):** | | | | | |
| **Geographic co-ordinates** | | | | | |
| | **Latitude** | | **Longitude** | | **Accuracy** |
| | North /South | Degrees | East / West | Degrees | (m) |
| **1 SE Corner** | | | | | |
| **6 SW Corner** | | | | | |
| **11 NW Corner** | | | | | |
| **16 NE Corner** | | | | | |
| **SE Corner additional observations** | GPS Start Time | GPS End Time | Number of measurements in average | | |
| | | | | | |



## Projected Canopy Cover and Ground Cover Observations

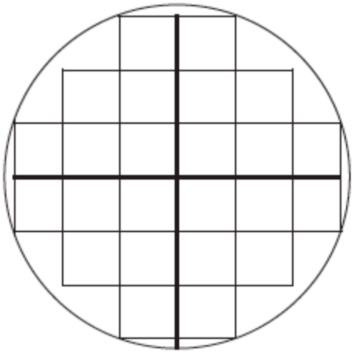
(5 measurements: Measured at the 4 corners of the E-plot and the Centre)

| | **1 SE Corner** | **6 SW Corner** | **11 NW Corner** | **16 NE Corner** | **23 Centre** |
|---|---|---|---|---|---|
| ***Woody Canopy Cover**** | | | | | |
| Densiometer (% cover) | | | | | |
| ***Landscape Functional Analysis*** | | | | | |
| **1. Canopy Cover Score (0-1)*** | | | | | |
| **2. Herb. crown cover (0-1)** | | | | | |
| **3. Soil Erosion (0.1.2 or 3)** | | | | | |
| **4. Condition score (0.10)** | | | | | |
| Rooted plants | | | | | |
| Litter cover | | | | | |
| Downed wood | | | | | |
| Stone or gravel | | | | | |
| Dung | | | | | |
| Disturbed soil | | | | | |
| Undisturbed, bare but porous | | | | | |
| Undisturbed, bare but sealed | | | | | |
| Sodic soil | | | | | |
| Microfloral crust | | | | | |
| Termite mound | | | | | |
| **Total = 10** | | | | | |
| **Photograph file name** | | | | | |

* Please see densiometer diagrams to aid calculation on the next series of pages

**Woody Canopy Cover: Densiometer calculation**

**Subplot 1: SE Corner**



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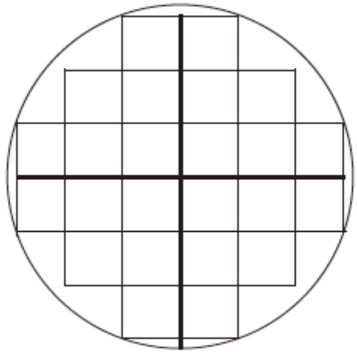

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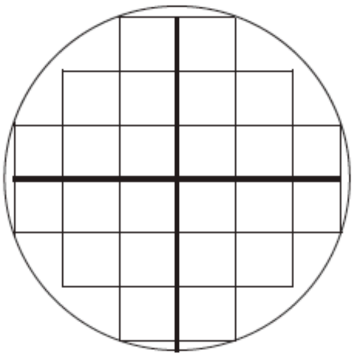

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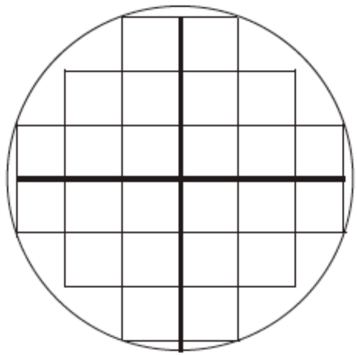

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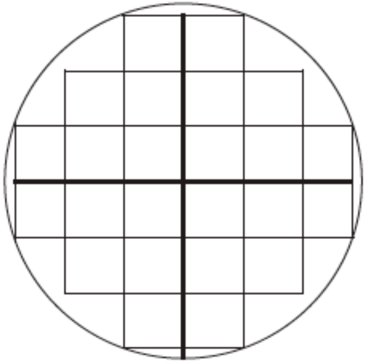
**Subplot 6: SW Corner**



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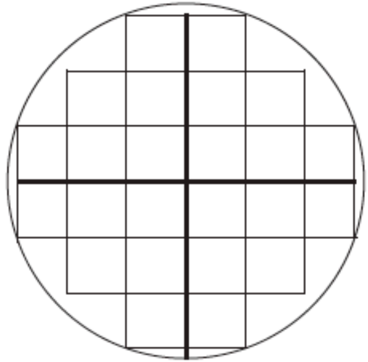

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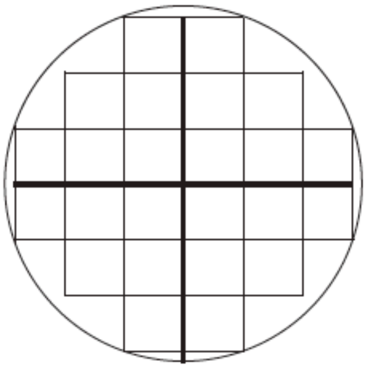

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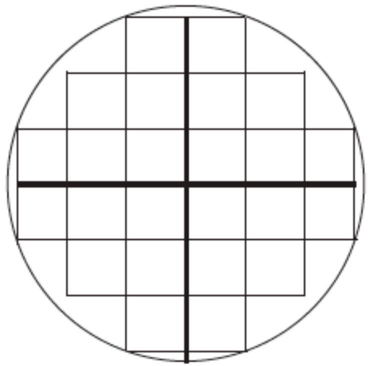
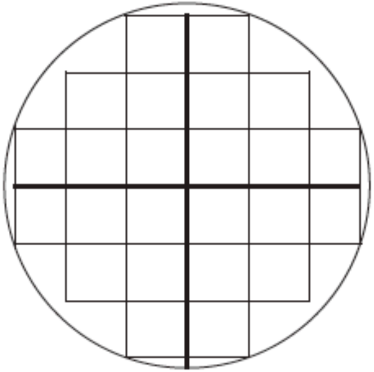


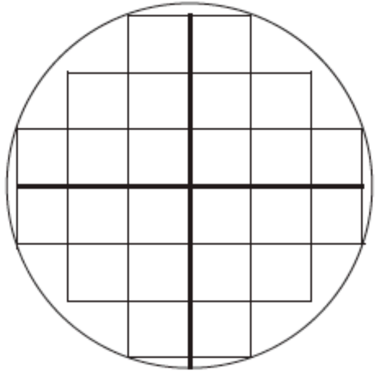
W

**Woody Canopy Cover: Densiometer calculation continued**

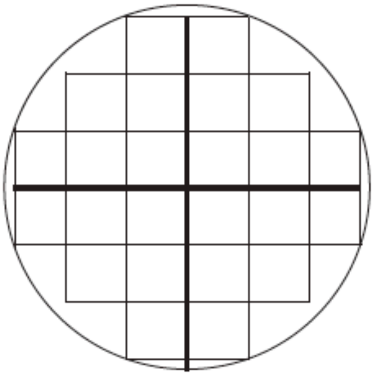
**Subplot 16: NW Corner**



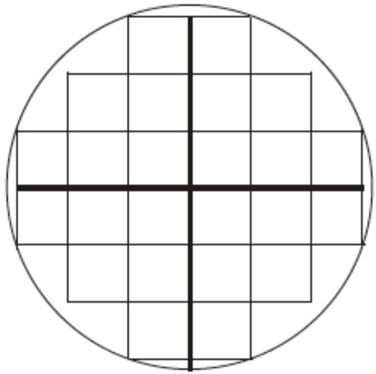
N



E

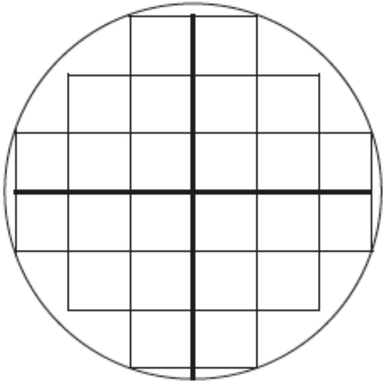


S

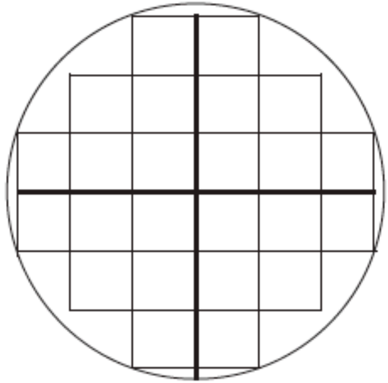


W

**Subplot 23: NE Corner**



N



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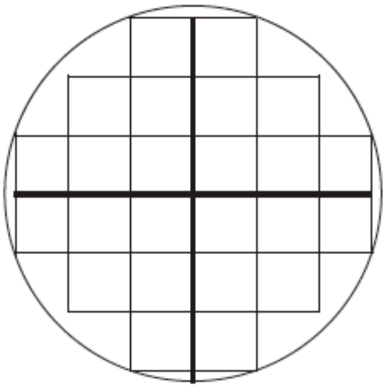

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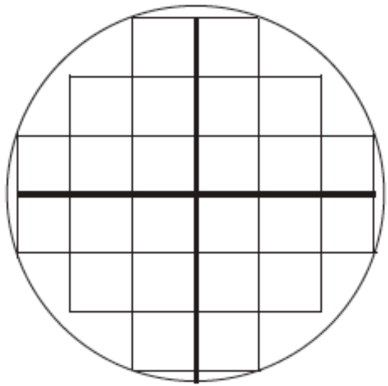
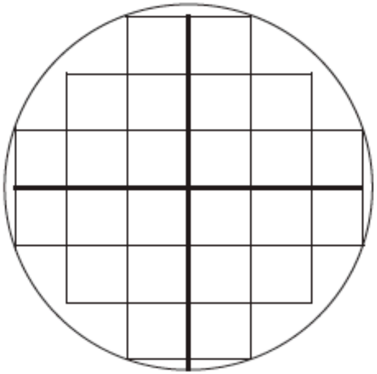


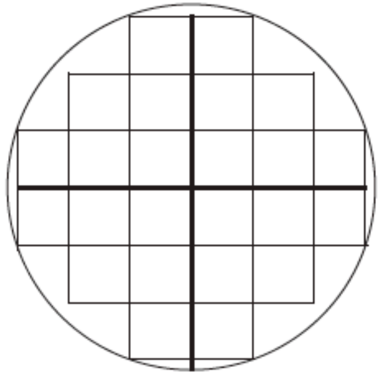
W

**Woody Canopy Cover: Densiometer calculation continued**

**Subplot 23: Centre sub-plot**



N



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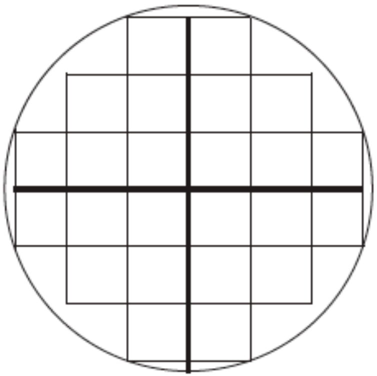

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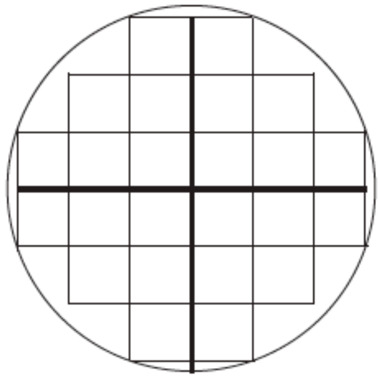

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**Herbaceous Layer Mass and Dry Weight Rank Method**

| Sub-plot | Mass | Species Rank 1 | | Species Rank 2 | | Species Rank 3 | |
|---|---|---|---|---|---|---|---|
| | (0-10) | Genus | Species | Genus | Species | Genus | Species |
| **1** | | | | | | | |
| **2** | | | | | | | |
| **3** | | | | | | | |
| **4** | | | | | | | |
| **5** | | | | | | | |
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| **31** | | | | | | | |
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| **33** | | | | | | | |
| **34** | | | | | | | |
| **35** | | | | | | | |
| **36** | | | | | | | |

## Woody Plant Measurements

For multi-stemmed plants, record each stem individually $z_1 / z_2 / z_3$/…. If there are multiple stems that have the same circumference first record the number of stems n and then the circumference e.g. n x $z_1 / z_2 / z_3$/….

The number of stems n must come first to avoid misinterpretation.

| **Sub-plot number** | **Species name** | | **No. of stems** | **Basal Circ (cm)** | **Height (m)** | **Canopy width (m)** | **Photo name** |
|---|---|---|---|---|---|---|---|
| | *Genus* | *Species* | | | | | |
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| Sub-plot number | Species name | | No. of stems | Basal Circ (cm) | Height (m) | Canopy width (m) | Photo name |
|---|---|---|---|---|---|---|---|
| | *Genus* | *Species* | | | | | |
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| Sub-plot number | Species name | | No. of stems | Basal Circ (cm) | Height (m) | Canopy width (m) | Photo name |
|---|---|---|---|---|---|---|---|
| | *Genus* | *Species* | | | | | |
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| Sub-plot number | Species name | | No. of stems | Basal Circ (cm) | Height (m) | Canopy width (m) | Photo name |
|---|---|---|---|---|---|---|---|
| | *Genus* | *Species* | | | | | |
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| Sub-plot number | Species name | | No. of stems | Basal Circ (cm) | Height (m) | Canopy width (m) | Photo name |
|---|---|---|---|---|---|---|---|
| | *Genus* | *Species* | | | | | |
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**Biomass Metadata**
Version: 1.0

| | Form Value | Definition | Data Type | Values List | Example | Empty Value | Rules/Comments |
|---|---|---|---|---|---|---|---|
| | Country | The VS country three-letter abbreviation. | string | None | TAN | Required | May need suffix for region in country |
| | Landscape no. | The landscape number within the particular VS country above | alphanumeric | None | L10 | Required | |
| | E-plot no. | The unique sequential number assigned to each E-plot in each country - 000-999 | numeric | None | 004 | Required | Sequential number from 000 - 999 |
| | E-plot code: | The unique i.d. code for each E-plot in a country.<br>The E-plot code contains three components: 3-letter country code - landscape id number (if not within a landscape then insert 000) - E-plot i.d. number<br>For example, TAN-L10-004 refers to E-plot number 4 in landscape 10 in Tanzania.<br>The id numbers will be assigned automatically. | formula | None | TAN-L10-004 | Required | A combination of country code, landscape number and E-plot number above |
| Latitude and Longitude (Entry form format) | Latitude - Cardinal direction | Latitude of each corner point of the E-plot - cardinal direction (North or South) | string | North or South | North | Required | North or South |
| | Latitude - Reading | Latitude of each corner point of the E-plot in decimal degrees (to five decimal points). | numeric | 0 to 90 | 10,14564 | Required | Decimal degrees, five decimal points |
| | Longitude - Cardinal direction | Longitude of each corner point of the E-plot - cardinal direction (East or West) | string | East or West | East | Required | East or West |
| | Longitude - Reading | Longitude of each corner point of the E-plot in decimal degrees (to five decimal points) | numeric | 0 to 180 | 3,65456 | Required | Decimal degrees, five decimal points |
| Latitude and Longitude (Database format) | Latitude | Latitude of each corner point of the E-plot in decimal degrees. | numeric | 90 to -90 | -10.41199 | Required | Decimal degrees, five decimal points, negative south |
| | Longitude | Longitude of each corner point of the E-plot in decimal degrees | numeric | 0 to 360 | 84.00677 | Required | Decimal degrees, five decimal points |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| GPS Accuracy Measurements (South East Corner Only) | GPS Start Time | The time at which the GPS reading began (hour and minutes) | time | 00:00 - 23:59 | 10:43 | Required | 24-hour clock, recorded as hour and minutes |
| | GPS End Time | The time at which the GPS reading ended (hour and minutes) | time | 00:00 - 23:59 | 10:58 | Required | 24-hour clock, recorded as hour and minutes |
| | Number of measurements in average | The number of measurement counts in the average | numeric | None | 6 | Required | |
| | Accuracy | The accuracy measurement reported on the GPS unit (reported in meters) | numeric | None | 3 | Required | The measurement should be recorded in meters |
| Date of Metadata | Year | The year metadata created.(YYYY) | numeric | {>=2013} | 2013 | Required | |
| | Month | The month metadata created. (MM) | numeric | {1-12} | 03 | Required | |
| | Day | The day metadata created. (DD) | numeric | {1-31} | 19 | Required | |
| Name of Manager, Scribe or Measurer | First Name | The first name of the person recording information into the Field Form. | string | None | Sandy | Required | |
| | Last Name | The last name of the person recording information into the Field Form. | string | None | Andelman | Required | |
| Photograph file name | Photo file name | The file name of five photographs taken at each corner and the centre point (sub-plot 23) of the E-plot. This is only required for photographs that are upload from an external device onto the tablet | Formula | None | TAN-L10-004-SE | Required | The file name should start with the E-plot code e.g. TAN-L10-004, followed by the corner or centre designation i.e. SE, SW, NE, NW or CEN |
| | Comments | Any notes regarding the E-plot plot. These may be as specific as needed but should be relevant to the entire E-plot or to a major portion of it. | string | None | acent to a large garb | NULL | |

E-Plot Biomass Survey
Version: 1.0

| Form Value | Definition | Data Type | Values List | Example | Empty Value | Rules/Comments |
|---|---|---|---|---|---|---|
| Country | The VS country three-letter abbreviation. | string | None | TAN | Required | May need suffix for region in country |
| Landscape no. | The landscape number within the particular VS country above | alphanumeric | None | L10 | Required | |
| E-plot no. | The unique sequential number assigned to each E-plot in each country - 000-999 | numeric | None | 004 | Required | Sequential number from 000 - 999 |
| Tier 2a E-plot code: | The unique i.d. code for each E-plot in a country. The E-plot code contains three components: 3-letter country code - landscape id number (if not within a landscape then insert 000) - E-plot i.d. number For example, TAN-L10-004 refers to E-plot number 4 in landscape 10 in Tanzania. The id numbers will be assigned automatically. | formula | None | TAN-L10-004 | Required | A combination of country code, landscape number and E-plot number above |
| Subplot radius (m) | Radius of sub-plot in meters | numeric | numeric | 20 | Required | Area should be the same for every sub plot within a given E-plot |
| Basal circumference measurement height (cm) | The height above ground level at which the basal circumference of woody plant is measured. This height is recorded in centimeters | numeric | numeric | 30 | Required | |
| Observations | General observations made by the observer that may help explain the collected data to a remote analyst. e.g. the existence of a recent fire or wood harvesting activities | string | None | Approximately 50% of this plot appears to have burned in the last 3 months. | NULL | |
| Photograph file name | The file name of the photograph as assigned by the camera after the capture of the image | string | None | IMG_4026.jpg | Required | A panoramic photograph needs to be taken in the E-plot. The file name of the photograph should be recorded on the form. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Geog. co-ord's of the 4 corners of the E-Plot | Sub-Plot Latitude | Latitude of the center point of each corner sub-plot in decimal degrees. | numeric | 90 to -90 | -10.41199 | Required | The geographical co-ordinates of the four corner sub-plots within the E-plot need to be recorded as per the procedure described. Decimal degrees, five decimal points, negative south |
| | Sub-Plot Longitude | Longitude of the center point of each corner sub-plot in decimal degrees. | numeric | 0 to 360 | 84.00677 | Required | The geographical co-ordinates of the four corner sub-plots within the E-plot need to be recorded as per the procedure described. Decimal degrees, five decimal points. |
| Date of plot survey | Year | The year of the plot survey.(YYYY) | numeric | {>=2013} | 2014 | Required | |
| | Month | The month of the plot survey. (MM) | numeric | {1-12} | 03 | Required | |
| | Day | The day of the plot survey. (DD) | numeric | {1-31} | 19 | Required | |
| Name of Manager, Scribe or Measurer | First Name | The first name of the person recording information onto the Field Form. | string | None | Mark | Required | |
| | Last Name | The initials and last name of the person recording information onto the Field Form. | string | None | M Musumba | Required | Will be a pick list on tablet version |
| | Woody canopy cover score | Landscape Function Analysis canopy cover score recorded as a value between 0-10 | numeric | {0-10} | 4 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |
| | Herbaceous crown cover | Landscape Function Analysis herbaceous cover score recorded as a value between 0-10 | numeric | {0-10} | 2 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |
| | Soil erosion | Landscape Function Analysis soil erosion score (0=none, 1=slight, 2=moderate or 3=severe) | numeric | {0-3} | 2 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |
| | Surface condition score - Rooted plants | Part of the Landscape Function Analysis surface condition assessment. Measured as the proportion of the ground surface area covered by the rooted base of plants, including moss, at about 1 cm above the ground . The proportion is estimated and recorded using a score between 0-10 | numeric | {0-10} | 1 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |
| | Surface condition score - Litter | Part of the Landscape Function Analysis surface condition assessment. Measured as the proportion of the ground surface area covered by litter. The proportion is estimated and recorded using a score between 0-10 | numeric | {0-10} | 2 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Landscape Function Analysis Scores | Surface condition score - Downed wood | Part of the Landscape Function Analysis surface condition assessment. Measured as the proportion of the ground surface area covered by twigs or logs lying on or near the surface. The proportion is estimated and recorded using a score between 0-10 | numeric | {0-10} | 1 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |
| | Surface condition score - Stone or gravel | Part of the Landscape Function Analysis surface condition assessment. Measured as the proportion of the ground surface area covered by rock, stone or gravel. The proportion is estimated and recorded using a score between 0-10 | numeric | {0-10} | 2 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |
| | Surface condition score - Dung | Part of the Landscape Function Analysis surface condition assessment. Measured as the proportion of the ground surface area covered by dung. The proportion is estimated and recorded using a score between 0-10 | numeric | {0-10} | 1 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |
| | Surface condition score - Disturbed soil | Part of the Landscape Function Analysis surface condition assessment. Measured as the proportion of the ground surface area covered by disturbed soil (recent hoof print, burrowing or cultivation). The proportion is estimated and recorded using a score between 0-10 | numeric | {0-10} | 2 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |
| | Surface condition score - Undisturbed, bare and porous soil | Part of the Landscape Function Analysis surface condition assessment. Measured as the proportion of the ground surface area covered by undisturbed, bare and porous soil. The proportion is estimated and recorded using a score between 0-10 | numeric | {0-10} | 1 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |
| | Surface condition score - Undisturbed, bare but sealed soil | Part of the Landscape Function Analysis surface condition assessment. Measured as the proportion of the ground surface area covered by undisturbed, bare but sealed (i.e. water-shedding or low porosity) soil. The proportion is estimated and recorded using a score between 0-10 | numeric | {0-10} | 2 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |
| | Surface condition score - Sodic soil | Part of the Landscape Function Analysis surface condition assessment. Measured as the proportion of the ground surface area covered by sodic soil. The proportion is estimated and recorded using a score between 0-10 | numeric | {0-10} | 1 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |
| | Surface condition score - Microfloral crust | Part of the Landscape Function Analysis surface condition assessment. Measured as the proportion of the ground surface area covered by microfloral crust - typically algae, fungal hyphae or lichen. The proportion is estimated and recorded using a score between 0-10 | numeric | {0-10} | 2 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Surface condition score - termite mound | Part of the Landscape Function Analysis surface condition assessment. Measured as the proportion of the ground surface area covered by termite mound. The proportion is estimated and recorded using a score between 0-10 | numeric | {0-10} | 1 | Required | Part of the Landscape Function Analysis. Estimated at each of the four corner sub-plots and a sub-plot near the centre of the E-plot |
| Herbaceous layer measurements | Dry Mass Score | The mass of herbaceous biomass within the sub-plot is scored on a scale from 0-10, where 0 is bare ground and 10 is a tall, dense grass layer | numeric | {0-10} | 3 | Required | |
| | DWR first ranked - Genus name | The Genus name of the plant. The Latin binomial name of each herbaceous species observed during the adoption of the Dry-Weight-Rand method is required. | string | None | Panicum | NULL | |
| | DWR first ranked - Species name | The Species name of the plant. The Latin binomial name of each herbaceous species observed during the adoption of the Dry-Weight-Rand method is required. | string | None | maximum | NULL | |
| | DWR first ranked - Sub-species name | The latin sub-species name of the plant, if required or available | string | None | campylacantha | NULL | |
| | DWR first ranked - Common name | The common name of plant if required (typically the English or local name) | string | None | Guinea grass | NULL | |
| | DWR second ranked - Genus name | The Genus name of the plant. The Latin binomial name of each herbaceous species observed during the adoption of the Dry-Weight-Rand method is required. | string | None | Panicum | NULL | |
| | DWR second ranked - Species name | The Species name of the plant. The Latin binomial name of each herbaceous species observed during the adoption of the Dry-Weight-Rand method is required. | string | None | maximum | NULL | |
| | DWR second ranked - Sub-species name | The latin sub-species name of the plant, if required or available | string | None | campylacantha | NULL | |
| | DWR second ranked - Common name | The common name of plant if required (typically the English or local name) | string | None | Guinea grass | NULL | |
| | DWR third ranked - Genus name | The Genus name of the plant. The Latin binomial name of each herbaceous species observed during the adoption of the Dry-Weight-Rand method is required. | string | None | Panicum | NULL | |
| | DWR third ranked - Species name | The Species name of the plant. The Latin binomial name of each herbaceous species observed during the adoption of the Dry-Weight-Rand method is required. | string | None | maximum | NULL | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | DWR third ranked - Sub-species name | The latin sub-species name of the plant, if required or available | string | None | campylacantha | NULL | |
| | DWR third ranked - Common name | The common name of plant if required (typically the English or local name) | string | None | Guinea grass | NULL | |
| Woody plant measurements | Woody plant - Genus name | The Genus name of the plant. The Latin binomial name of each observed woody plant | string | None | Acacia | NULL | |
| | Woody plant - Species name | The species name of the plant. The Latin binomial name of each observed woody plant | string | None | nilotica | NULL | |
| | Woody plant - Subspecies name | The latin sub-species name of the plant, if required or available | string | None | campylacantha | NULL | |
| | Woody plant - Common name | The common name of plant if required (typically the English or local name) | string | None | Egyptian thorn | NULL | |
| | Basal Circumference (cm) | Woody plant circumference measurement in cm. All woody plants with a circumference >= 20.0cm should be measured. Measurements should be rounded to the nearest centimeter. | numeric | {>=20.0} | 24 | Required | Measurement should be recorded in cm. |
| | Height (m) | Woody plant height is measured in meters to one decimal point (e.g. 8.2m or 0.7m). | numeric | None | 10.7 | Required | Measurement should be recorded in meters to one decimal point. |
| | Canopy width (m) | The average canopy width of woody plants in recorded in meters to one decimal point (e.g. 5.2m or 0.8m) | numeric | None | 8.6 | Required | Measurement should be recorded in meters to one decimal point. |
| | Voucher | The voucher ID is a field collection number or an official herbarium code. If there are multiple voucher IDs for one specimen then they should be separated by a comma. Internal notes should be kept so that the source of the codes (e.g. a specific herbarium) can be referenced in the future. | string | None | BTTP179 | NULL | This could also point to one or more photographs taken in the field. |


# Vital Signs Protocol

## E-Plot Soil Sampling and Processing

Version 3.0

March 2014

## ACKNOWLEDGMENTS

Vital Signs thanks the AfSIS team members and protocols for informing this Vital Signs protocol.

## CONTENTS

# 1. INTRODUCTION

In the E-Plots, soils will be sampled in two ways (as indicated in Figure 1):

- **Cumulative Soil Mass**: 0-20 cm, 20-50 cm, 50-80 cm, and 80-100 cm
- **Soil Health**: Surface (0-20 cm) and Subsoil (20-50cm)

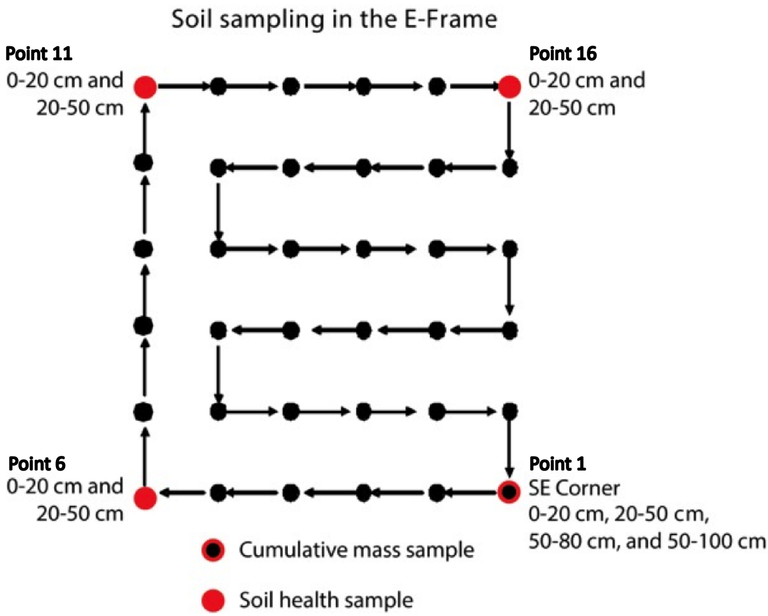



*Figure 1. E-plot layout indicating the red dots with black center points where the cumulative soil mass is sampled at four depths (0-20 cm, 20-50 cm, 50-80 cm and 80-100 cm) and the red dots where soil health is sampled at two depths (0-20 cm and 20-50 cm).*

## Workflow 1: Soils Protocol Outline

**Start here**

1. Review equipment list and load soil sampling equipment into vehicle
2. Travel to E-plot
3. Begin at the S.E. Corner of the E-plot (point 1)
4. Follow steps for Cumulative Mass Soil Sampling at the S.E. corner (see workflow 2)
5. For the 50-80 cm and 80-100 cm cumulative mass samples, perform the analysis of texture by feel
6. Continue to the S.W. corner of the E-plot (point 6)
7. Follow steps for Soil Health Sampling at the S.W. corner (see workflow 3)
8. Continue to the N.W. corner of the E-plot (point 11)
9. Follow steps for Soil Health Sampling at the N.W. corner (see workflow 3)
10. Continue to the N.E. corner of the E-plot (point 16)
11. Follow steps for Soil Health Sampling at the N.E. corner (see workflow 3)
12. Follow steps for sub-sampling from the 2 depth samples (see workflow 3)
13. For each of the soil health samples, perform the analysis of texture by feel
14. BEFORE LEAVING THE SITE, CHECK TO SEE YOU HAVE THE FOLLOWING SOIL SAMPLES: 4 tins containing cumulative mass soil samples and 4 plastic bags containing subsamples for soil health
15. At this spoint you should have entered the soils data into the entry form on the tablet
16. When you have completed the tablet form and have a connection, upload the data to the Vital Signs server
17. When you return to the Vital Signs office, follow instructions for drying and processing soils.

**Cumulative soil mass sampling** is for estimating the weight of the soil and nutrients taken from a given volume, and is sampled only at the S.E. corner of the E-plot (Figure 1).

**Soil health sampling** is for determining various chemical and physical characteristics of the soil that will be determined in a laboratory. In addition, soil texture is estimated in the field by performing the 'texture by feel method.' The soil health samples are taken from the four corners of the E-plot (Figure 1).

Following fieldwork, the soils kept in the tins from the cumulative mass sampling need to be **oven or air dried** and **weighed**. The soils from the soil health sampling need to be **air dried, sieved**, and the **fine fraction prepared for shipping**.

**Labeling soil samples is critical!**

For each of the soil samples in the field (subsamples, drying samples, and samples sent for laboratory analysis) you need to include the following information:

- **Location**: Country code, E plot code, Depth of Sample
    - **Depth**:
        - 0-20 cm =1
        - 20-50 cm=2
        - 50-80 cm =3
        - 80-100 cm=4
- **Date**: Year, Month, Day (YYYY/MM/DD)

Sample IDs should be legibly recorded with a permanent marker on the outside of the plastic bag.  A paper label containing the same information (written in pencil) should also be placed inside the bag.

### *1.1 Definitions of Key Technical Terms*

**Soil texture**: the amount of sand, silt and clay in the soil. Texture is important for determining many soil properties, including soil aggregation and structure, which influence water and air movement through the soil.

**Soil health**: an assessment of the soil chemical and physical conditions that determines the suitability for plant growth.

**Soil nutrients**: plants require 16 nutrients for growth. The major ones (or macronutrients) are nitrogen (N), phosphorus (P), sulfur (S), potassium (K), calcium (Ca), and magnesium (Mg). In addition, there are many micronutrients that are required in small quantities. If any of these nutrients are at levels insufficient for the plant, then plant growth will be inhibited and for crops the yields will be reduced.

**Soil pH**: the reaction of a soil is measured by pH. Optimal pH for crop growth is between 5.5 and 7.5. Soils with a pH of less than 5.5 are considered acidic, due to the presence of exchangeable aluminium that affects root growth and the uptake of nutrients.

**Soil organic matter content**: a critical component of soil that determines the nutrient supplying and storage capacity. Soil organic matter influences the aggregation of smaller particles and the structure of soils that determine the movement and storage of water in the soil. The structure of the soil is also important for protecting the soil from erosion.

### *1.2 Standard Conventions Used in this Document*

The following conventions are used throughout this document:

- The use of bold in the text indicates a critical point. **Please pay special attention to terms, sentences and paragraphs marked in bold** as they are key to the understanding of the protocol.

## 2. ROLES AND RESPONSIBILITIES

The following table introduces the roles and responsibilities of the members of a Vital Signs field team for soil sampling:

| Role | Responsibility |
|---|---|
| Country Director | • Supports team with a complete understanding of the protocol manual<br>• Trains technicians<br>• Leads technicians in fieldwork and sampling and assists with measurements as required |

| | |
|---|---|
| Technical Manager | • Supervises teams<br>• Ensures equipment is well-managed and team is safe<br>• Ensures consistency and quality of measurements<br>• Ensures data are uploaded to the VS server daily (or weekly if internet access is limited)<br>• Ensure back-ups and that data entry sheets are properly archived |
| Technicians | • Perform soils sampling in the E-Plots and record measurements<br>• Follow process for labeling, storing, processing and drying soils<br>• Clean and store equipment<br>• Report any problems with sampling, field equipment, or data entry to Technical Manager |
| Africa Field Director | • Helps train country teams and ensures consistency of protocol implementation across Vital Signs countries<br>• Reviews data when uploaded<br>• Approves protocol updates and sends out update notifications to field teams |

| | |
|---|---|
| Protocol Manager | • Receives and archives comments about the protocol from the field team and passes comments to the Africa Field Director<br>• Updates and re-circulates the protocol |

## 3. EQUIPMENT LIST

The following equipment is **required** to carry out the activities described in this manual. Before traveling to the field to carry out sampling, use this list to ensure you have all the equipment needed for the day.

If a tablet is being used to record data, at least one on-site backup to team laptops and, preferably, at least one off-site backup should be made at the end of each day.

*General Supplies*

- Data entry tablet
- Goggles (for eye protection in dense brush)
- Clipboards, Notebooks and pens
- Water
- Packs for carrying equipment
- Hat and Sun Lotion
- Vital Signs brochures in appropriate country language
- Identity cards
- Letters of introduction

*Soil Sampling Equipment*

- 2 Colored buckets, one labeled “Topsoil 0-20 cm” and one labeled “Subsoil 20-50 cm”
- Soil auger with 3-foot extension handle (the auger should have white tape to indicate 20 cm, 50 cm, 80 cm and 100 cm from the tip of the auger)
- Metal sampling plate
- Large bottle or bucket with tap water
- 50 sturdy plastic bags
- Labels
- 5 kg ‘kitchen scale’ accurate to 1 gram
- 500 g scale accurate to 0.1 gram
- Mixing trowel
- 8 oz aluminum tins (4 required for each E plot)
- Cloth for wiping scales at tins
- Permanent markers

## 4. CUMULATIVE MASS SOIL SAMPLING

Cumulative soil mass sampling is for **estimating the weight of the soil and nutrients contained within a given volume**. It is essential to get every last piece of soil sampled in the auger to each of the depths sampled, in order to obtain the total amount of soil in the volume of the soil core (the hole that is sampled). **The cumulative soil mass is sampled only from the S.E. corner of the E-plot** (Figure 1).

If a depth restriction is reached, then take that depth sample to that depth only and record the depth of restriction. Make sure that the depth restriction is real (rocky parent material) and not just a tough plow layer. If the restriction is caused by a large root or a large rock, then the sample location can be moved a few centimeters in any direction from the SE corner and the soil sampling restarted with a new set of sample tins and bags (discard soil samples from the aborted sample hole).

The critical point about the cumulative mass sample is that **every bit of soil from that hole needs to be collected and placed in a bag and weighed**. If some of the soil falls out of the auger and onto the ground or sampling plate or falls back into the hole, pick it up and put it in the sample bag. Also, for each depth, make sure to scrape the soil on the inside and outside of the auger into the bag before starting the next depth.

If the soil is very dry and falls out of the auger, then you may need to put water into the hole by pouring from a bucket or bottle and let it infiltrate for a while so that the soil sticks together and is easier to sample. If the soil is sandy or stony and falls out of the auger then use the alternative sand auger.

**Cumulative soil mass sampling consists of four different steps**:

- Soil Sampling to Four Depths
- Weighing Soil from Each Depth
- Sub-Sampling to Determine Soil Moisture at Each Depth

## Workflow 2: Cumulative Mass Soil Sampling

Begin at the S.E. Corner of the E-plot (point 1)

↓

Press the sampling plate firmly on the soil so that the sheet is flush with the ground

↓

Auger down to 20 cm and transfer ALL the soil from the hole, the auger and any soil that fell onto the sampling plate into the plastic bag labeled Depth 1 = 0-20 cm

↓

Auger the soil from 20-50 cm and transfer ALL the soil from the hole, the auger and any soil that fell onto the sampling plate into the plastic bag labeled Depth 2 = 20-50 cm

↓

Auger the soil from 50-80 cm and transfer ALL the soil from the hole, the auger and any soil that fell onto the sampling plate into the plastic bag labeled Depth 3 = 50-80 cm

↓

Auger the soil from 80-100 cm and transfer ALL the soil from the hole, the auger and soil that fell onto the sampling plate into the plastic bag labeled Depth 4 = 80-100 cm

→

Next, obtain the total weight of the cumulative mass soil samples using the 5 kg kitchen scale

↓

Weigh the soil and plastic bag from 0-20 cm depth; record the weight to the nearest gram

↓

Repeat for soil and plastic bag for 20-50 cm depth, 50-80 cm depth, and 80-100 cm depth

↓

For the 0-20 cm depth soil samples, label a sample tin and weigh it (including the lid) on the scale. Record the weight in grams.

↓

Mix the soil in the bag thoroughly, then take 200 g of the mixed soil and place it in the tin

↓

weigh the soil subsample plus the tin and lid, and record weight to the nearest 0.1 gram

→

Repeat the preceding 2 steps for the remaining three soil samples: 20-50 cm, 50-80 cm, and 80-100 cm

↓

Place the soil left from the 0-20 cm of the cumulative soil sample into the bucket labeled “Topsoil - 0-20 cm.”

↓

Place the soil left from the 20-50 cm of the cumulative soil sample into the bucket labeled “Subsoil - 20-50 cm.”

↓

Perform analysis of texture by feel for the soil from 50-80 cm. Place approximately 500 g of the 50-80 cm soil in a plastic bag labeled with depth “50-80 cm” and date of sampling

↓

Perform analysis of texture by feel for the soil from 80-100 cm. Place approximately 500 g of the 80-100 cm soil in a plastic bag labeled with depth “80-100 cm” and date of sampling

↓

Keep the buckets containing the 0-20 cm and 20-50 cm soil sample to continue on to the Soil Health Sampling

- Sub-Sampling to Determine Soil Health

*4.1 Soil Sampling to Four Depths at the SE Corner*

1. Press the metal sampling plate firmly onto the soil so that the sheet is flush with the soil surface (Figure 2). Stand on either side of the plate to press it down into the soil.

*Figure 2. Metal sampling plate for cumulative mass pressed firmly into the soil.*

2. Place the auger in the center of the hole as shown in Figure 3 and begin to auger straight down, using the same auger for all depths.

If the auger is not straight up and down and is at an angle to the ground, stop and start a new hole, otherwise the sample will not give an accurate cumulative mass estimate.

*Figure 3. Metal sampling plate with auger placed in center hole (Photo from AfSIS)*

3. Auger down to 20 cm and **transfer all the soil from the auger and any soil that fell onto the sampling plate or back into the hole** into the plastic bag labeled **Depth 1 = 0-20 cm**.

4. Next, auger the soil from 20-50 cm and **transfer all the soil from the auger and any soil that fell onto the sampling plate or back into the hole** into the plastic bag labeled **Depth 2 = 20-50 cm**.

5. Next, auger the soil from 50-80 cm and **transfer all the soil from the auger and any soil that fell onto the sampling plate or back in the hole** into the plastic bag labeled **Depth 3 = 50-80 cm**.

6. Next auger the soil from 80-100 cm and **transfer all the soil from the auger and any soil that fell onto the sampling plate or back into the hole** into the plastic bag labeled **Depth 4 = 80-100 cm**.

*4.2 Weighing Soil from Each Depth*

**Obtain the total weight of the cumulative mass soil samples using the 5 kg kitchen scale**.

- Weigh the soil and plastic bag from 0-20 cm depth; record the weight to the nearest gram.
- Weigh the soil and plastic bag from 20-50 cm depth; record the weight to the nearest gram.
- Weigh the soil and plastic bag from 50-80 cm depth; record the weight to the nearest gram.
- Weigh the soil and plastic bag from 80-100 cm depth; record the weight to the nearest gram.

*4.3 Sub-Sampling to Determine Soil Moisture*

For each of the soils samples for cumulative mass, **a subsample is needed to determine the wet weight**. These samples will then be dried to calculate the amount of dry soil in each depth.

For the 0-20 cm depth soil samples:

- Label a sample tin with the same codes as the soil sample.
- Weigh the labeled sample tin (including the lid) on the 500 g scale; record the weight in grams, to the nearest 0.1 g.

- Mix the soil in the bag thoroughly by shaking, turning with your hands or a mixing shovel.

- Take approximately 200 g of the mixed soil and place it in the labeled tin.
    - If there are gravel/stones in the soil, include them in the subsample.

- Weigh the soil subsample plus the tin and lid and record weight to the nearest 0.1 gram.

**Follow these instructions for the remaining three soil samples**: 20-50 cm depth, 50-80 cm depth, and 80-100 cm depth.

*<u>4.4 Sub-Sampling to Determine Soil Health</u>*

1. Place the soil remaining from the 0-20 cm depth of the cumulative soil sample into the bucket labeled “Topsoil - 0-20 cm.”

2. Place the soil remaining from the 20-50 cm depth of the cumulative soil sample into the bucket labeled “Subsoil - 20-50 cm.”

3. Place more than 500 g of the soil from the 50-80 cm in a plastic bag labeled with country code, E plot number, depth “50-80 cm.” and date of sampling YYYY MM DD.

    - **Determine texture by feel and record**
    - Place the labeled bag with soil sample in the box.

- Discard the remaining soil from the 50-80 cm depth.

4. Place more than 500 g of the soil from the 80-100 cm in a plastic bag labeled with country code, E plot number, depth “80-100 cm” and date of sampling YYYY MM DD.

    - **Determine texture by feel and record**
    - Place the labeled bag with soil sample in the box.
    - Discard the remaining soil from the 80-100 cm depth.

Keep the buckets containing the 0-20 cm and 20-50 cm soil sample to finish the Soil Health Sampling at the other sample spots as indicated in the next section.

## 5. SOIL HEALTH SAMPLING

Soil health sampling is for determining various chemical and physical characteristics of the soil. **The soil health samples are taken from the four corners of the E-plot** (Figure 1).

Soil health sampling consists of two steps:

1. **Soil sampling to two depths at each corner**. This involves combining the soils from the four corners of the E plot for each of the depths, resulting in two samples: one for 0-20 cm and one for 20-50 cm.

## Workflow 3: Soil Health Sampling

Take the buckets containing the 0-20 cm and 20-50 cm soil sample to the S.W. corner (point 6) of the E-plot

↓

Auger to 0-20 cm. Place the soil sample in the "Topsoil" bucket

↓

Auger to 20-50 cm. Place the soil sample in the "Subsoil" bucket

↓

Take the buckets containing the 0-20 cm and 20-50 cm soil sample to the N.W. corner (point 11) of the E-plot and repeat steps for augering above

↓

Take the buckets containing the 0-20 cm and 20-50 cm soil sample to the N.E. corner (point 16) of the E-plot and repeat steps for augering above

→

When all corners have been sampled, mix the soil in the "Topsoil" bucket thoroughly. Next, mix the soil "Subsoil" bucket thoroughly.

↓

For the soil in the "Topsoil" bucket and the soil in the "Subsoil" bucket, detremine texture by feel and record the result

↓

Take a representative (~500g) subsample from the Topsoil bucket (0-20 cm) and place it in a plastic bag labeled with country code, E plot number, depth "0-20cm" and date of sampling YYYY MM DD.

↓

Take a representative (~500g) subsample of the Subsoil bucket (20-50 cm) and place it in a labeled plastic bag with country code, E plot number, depth "20-50 cm" and date of sampling YYYY MM DD.

→

Before leaving the site, CHECK TO SEE YOU HAVE THE FOLLOWING SOIL SAMPLES: 4 tins containing cumulative mass soil samples and 4 plastic bags containing subsamples for soil health

2. **Sub-sampling from the two composite samples.**

<u>*5.1 Soil Sampling to Two Depths at Each Corner*</u>

The reason behind sampling the four corners of the E-frame is to **get an indication of the average soil condition for the site**. If a corner appears to lie in a different landscape position (wetland vs. upland), different land use (till farm plot vs. woodland or range land), or different soil type (by different colour or different sand content), then **do not sample the soil in that corner.** Instead, go back along the outer edge of the E-frame and select the nearest 20 m point that is in the primary landscape position/land use/soil type representative of that E-plot.

Make a note and record the point where the soil was sampled.

1. The samples for 0-20 cm and 20-50 cm from the S.E. corner were obtained from the cumulative mass sampling and are in two separate buckets labeled “Topsoil 0-20 cm” and “Subsoil 20-50 cm.”

2. **Take the two buckets and auger to the next corner (S.W. corner) of the E-plot**. If this site has a similar landscape position and similar land use as the SE corner, then sample the soil as indicated below.
    - Auger 0-20 cm. Place the soil sample in the “Topsoil” bucket.

- Auger 20-50 cm. Place the soil sample in the “Subsoil” bucket.

If you cannot auger to the specified depths, record the auger depth restriction in cm.

3. **Take the two buckets and auger to the next corner (N.W. corner) of the E-plot**. If this site has a similar landscape position and similar land use as the SE corner, then sample the soil as indicated below.
    - Auger 0-20 cm. Place the soil sample in the “Topsoil” bucket.
    - Auger 20-50 cm. Place the soil sample in the “Subsoil” bucket.

If you cannot auger to the specified depths, Record the auger depth restriction in cm.

4. **Take the two buckets and auger to the next corner (N.E. corner) of the E-plot**. If this site has a similar landscape position and similar land use as the SE corner, then sample the soil as indicated below.
    - Auger 0-20 cm. Place the soil sample in the “Topsoil” bucket.
    - Auger 20-50 cm. Place the soil sample in the “Subsoil” bucket.

If you cannot auger to the specified depths, Record the auger depth restriction in cm.

*5.2 Sub-Sampling from the Two Depth Samples*

1. **When all corners have been sampled**:
    - Mix the soil in the “Topsoil” bucket thoroughly.
    - Mix the soil “Subsoil” bucket thoroughly.
    - For each of these samples, determine texture by feel and record the result

2. Take a representative subsample (more than 500 g) from the Topsoil bucket (0-20 cm) and place it in a plastic bag labeled with country code, E plot number, depth “0-20cm” and date of sampling YYYY MM DD.

   Place a labeled tag inside the bag with exactly the same sample code. This is to assure the sample can be identified if the outside label is lost or smeared.

3. Take a representative subsample (more than 500g) of the Subsoil bucket (20-50 cm) and place it in a labeled plastic bag with country code, E plot number, depth “20-50 cm” and date of sampling YYYY MM DD.

   Place a labeled tag inside the bag with exactly the same sample code.

**BEFORE LEAVING THE SITE, CHECK TO SEE IF YOU HAVE THE FOLLOWING SOIL SAMPLES**:

4 tins containing cumulative mass soil samples – one each for:

- 0-20 cm
- 20-50 cm
- 50-80 cm
- 80-100cm

4 plastic bags containing subsamples for soil health – one each for:

- 0-20 cm – composited from the 4 corners
- 20-50 cm – composited from the 4 corners
- 50-80 cm – from the cumulative mass corner
- 80-100cm – from the cumulative mass corner

## 6. ANALYZING TEXTURE IN THE FIELD

For the **cumulative mass samples for 50-80 cm and 80-100 cm** and the **soil health samples for 0-20 cm and 20-50 cm**, you must determine the **texture 'by feel.'** This can be done easily in the field and should be done before leaving the plot.

Refer to Figure 4 and the flow chart in Figure 5 for determining the soil texture by feel.

1. Starting with the topsoil sample, moisten a handful of soil using water from the water bottle until the soil has

a **putty-like consistency** (free water should not escape when ball is squeezed) (Figure 4).

2. Shape the soil into a ball. If the ball retains its shape, move to step 3.

3. Using your thumb and forefinger, form a ribbon with the soil by smearing the ribbon with your thumb. Observe if the soil is shiny or dull.

4. Classify the texture according to the flow chart (Figure 5) and report in the Soil Sampling Data Sheet for E Frames.

5. Repeat steps 1-45 for the subsoil (20-50); record the texture.

6. Repeat steps 1-4 for the 50-80 cm sample; record the texture.

7. Repeat steps 1-4 for the 80-100 cm sample; record the texture.

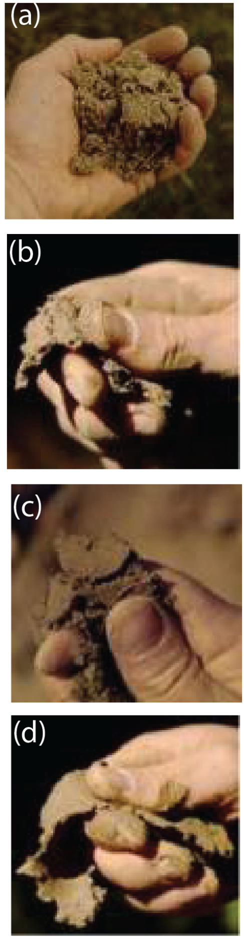
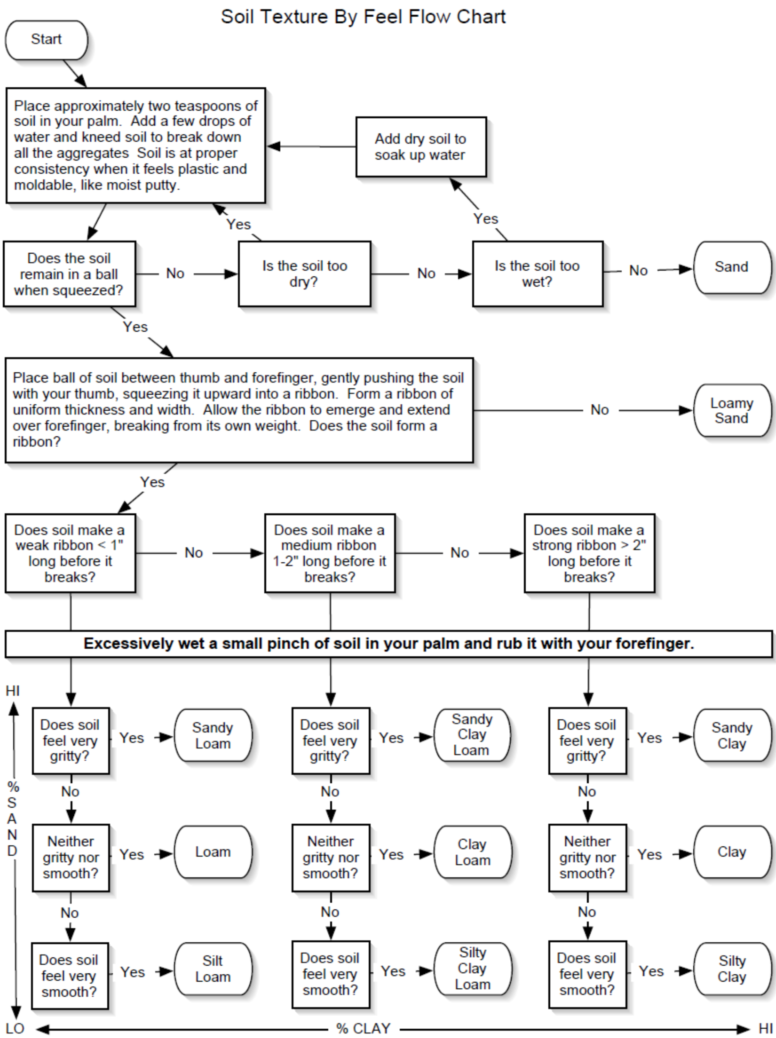



Figure 4. Top to bottom Steps 1, 2, and 3.

# Figure 5


Soil Texture By Feel Flow Chart
Start
Place approximately two teaspoons of soil in your palm. Add a few drops of water and kneed soil to break down all the aggregates Soil is at proper consistency when it feels plastic and moldable, like moist putty.
Add dry soil to soak up water
Yes
Yes
Does the soil remain in a ball when squeezed?
No
Is the soil too dry?
No
Is the soil too wet?
No
Sand
Yes
Place ball of soil between thumb and forefinger, gently pushing the soil with your thumb, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over forefinger, breaking from its own weight. Does the soil form a ribbon?
No
Loamy Sand
Yes
Does soil make a weak ribbon < 1" long before it breaks?
No
Does soil make a medium ribbon 1-2" long before it breaks?
No
Does soil make a strong ribbon > 2" long before it breaks?
Excessively wet a small pinch of soil in your palm and rub it with your forefinger.
HI
% SAND
LO
Does soil feel very gritty?
Yes
Sandy Loam
No
Neither gritty nor smooth?
Yes
Loam
No
Does soil feel very smooth?
Yes
Silt Loam
Does soil feel very gritty?
Yes
Sandy Clay Loam
No
Neither gritty nor smooth?
Yes
Clay Loam
No
Does soil feel very smooth?
Yes
Silty Clay Loam
Does soil feel very gritty?
Yes
Sandy Clay
No
Neither gritty nor smooth?
Yes
Clay
No
Does soil feel very smooth?
Yes
Silty Clay
LO
% CLAY
HI

# 7. DRYING AND PROCESSING SAMPLES

The soils in the tins from the **cumulative mass sampling** need to be:

- Oven (110 C) or air dried.
- Weighed.

The soils from the **soil health sampling** need to be:

- Air-dried.
- Sieved and separated into the fine (less than 2 mm) and coarse (greater than 2 mm) fractions.
- Prepared for shipping.

## *7.1 Oven/Air Drying and Weighing the Cumulative Mass Samples*

The soil samples that were weighed and stored in the tins need to be oven/air dried. The soils in the tins from the cumulative mass sampling should ideally be oven dried at 105°C. In reality very few places have ovens available, so the sample will be air-dried in a place that is clean and the samples will not get wet from rain or soil blown by the wind.

Dry the soils as follows:

**Oven drying**

1. Place the opened tin plus the soil with the lid (fit on the bottom of the tin) into a drying oven at 105 °C for 48 hours, or until a constant weight is obtained.

2. Once soil is dry, close the tin by replacing the lid back on the top of the tin.

3. Weigh the tin plus the oven or air-dried soil, including the lid.

4. Record the weight of the soil and the tin, to the nearest 0.1 g.

**Air-drying**

1. Place all of the soil from each of the tins into separate shallow bowls or basins. (**NOTE**: it is critical that the entire sample from the tin is dried, none of it is lost, and the entire dried soil returned to the tin for obtaining the dry weight)

2. Mark the basin with the code of the sample, or place piece of paper with the code underneath the soil in the basin to assure that it does not blow away.

3. Drying can be done in large room, a custom-made solar dryer, or a forced-air oven at 40 °C.

4. Spread the soil out as a thin layer in the basin.

5. Break up clods as far as possible to aid drying (it

is important to ensure that no material from a sample is lost or discarded as weights of soil fractions are to be recorded on processing).

6. Avoid contamination from dust, plaster or other potential contaminants by placing the samples in a shed or under a protective cover.

7. Mix the soils daily to speed the drying.

8. Drying time depends on the samples and ambient conditions, but the samples should be thoroughly dry (i.e. constant weight)

9. When the samples have dried, place the soil back into the tins. Place the lid on the tin and weigh the tin plus lid and soil to the nearest 0.1 g.

### *7.2 Air Drying the Soil Health Samples*

1. Place all the soil from each of the plastic bags into a separate basin for air-drying.

2. Mark the basin with the code of the sample, or place piece of paper with the code underneath the soil in the basin to assure that it does not blow away.

3. Drying can be done in large room, a custom-made solar dryer, or a forced-air oven at 40 °C.

4. Spread the soil out as a thin layer in the basin.

5. Break up clods as far as possible to aid drying (it is important to ensure that no material from a sample is lost or discarded as weights of soil fractions are to be recorded on processing).

6. Avoid contamination from dust, plaster or other potential contaminants by placing the samples in a shed or under a protective cover.

7. Mix the soils daily to speed the drying.

8. Drying time depends on the samples and ambient conditions, but the samples should be thoroughly dry (i.e. constant weight)

*7.3 Sieving Soil Health Samples*

In this procedure, the soil sample in the bag will be divided into **soil that passes through the 2 mm sieve** (the soil fine fraction) and the **gravel that does not pass through the 2 mm sieve** (called the coarse fraction). No material should be discarded.

1. Once the soils are air dried, weigh the whole soil sample to the nearest gram. Record the weight.

2. Grind the soils using a wooden rolling pin, gently crushing the sample. While crushing, remove any plant materials (e.g. roots).

3. Remove and save any possible pieces of gravel (making sure they are gravel and not soil aggregates)

and place in a separate small plastic bag (the coarse fraction).

4. Sieve the soil sample by passing the crushed sample through the 2 mm sieve. **DO NOT use the sieve as a grinder**: do not rub or mash the soil on the sieve, but **shake the sieve gently** to allow the soil to pass through.

5. Remove and save any gravel that remains on top of the sieve and place it in the plastic bag with the other gravel.

6. Once the entire sample has been sieved, place the soil in a plastic bag.

7. Weigh and record the weight of the soil that passed through the 2 mm sieve, record to the nearest gram.

8. Weigh and record the weight of the gravel fraction that did not pass through the 2 mm sieve, record to the nearest gram.

## 8. BIBLIOGRAPHY

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Brady, N. C. and R. R, Weil. 2008. *The Nature and Properties of Soils*. Pearson Publishing.

# 9. APPENDICES

Appendix 1: Data Entry Form: E-Plot Soil Sampling and Processing

Appendix 2: Data Dictionary: E-Plot Soil Sampling and Processing

## Soil Sample Data Sheet – E –Frame Field Sampling

Version 2 - 13 Dec 2013

**Country:** ______________________________

**Name of person sampling and weighing samples:**

____________________ ________________________
First Name Last Name

**Plot ID#:** __________________________

**Name of Scribe:**

| Corner | Depth (cm) | Depth to sampling restriction, if any (cm) | Total Weight of Cumulative Mass sample (g)<br>to nearest gram 1.0g | Soil Moisture Tin ID# | Weight of soil moisture tin<br>to nearest 0.1 g | Weight of soil moisture tin + fresh soil subsample,<br>to nearest 0.1 g | Hand Texture |
|---|---|---|---|---|---|---|---|
| 1 (SE) | Topsoil (0-20) | | | | | | |
| | Subsoil (20-50) | | | | | | |
| | 50-80 | | | | | | |
| | 80-100 | | | | | | |
| 6 (SW) | Topsoil (0-20) | | | | | | |
| | Subsoil (20-50) | | | | | | |
| 11 (NW) | Topsoil (0-20) | | | | | | |
| | Subsoil (20-50) | | | | | | |
| 16 (NE) | Topsoil (0-20) | | | | | | |
| | Subsoil (20-50) | | | | | | |

## Soil Sample Lab Data Sheet – E –Frame Field Sampling

**Name of person weighing samples:** ______________________ __________________________
First Name Last Name

**Country:** ____________

**Plot ID#:** **Date of weighing dried samples:** - -

| Depth (cm) | **Moisture Tin ID#** | Weight of cumulative soil moisture tin + oven/or air dried soil; | **Sample Bag label ID#** | Total air dried weight of composite sample in bag | Total Weight of composite soil fine fraction (<2mm) | Total weight of composite samplecoarse fraction (>2mm) |
|---|---|---|---|---|---|---|
| | | to nearest 0.1 g | | to nearest g | (to nearest g | (to nearest g) |
| Topsoil (0-20) | | | | | | |
| Subsoil (20-50) | | | | | | |
| 50-80 | | | | | | |
| 80-100 | | | | | | |

**Soil Sampling Metadata**
Version: 2

| | Form Value | Definition | Data Type | Values List | Example | Empty Value | Rules/Comments |
|---|---|---|---|---|---|---|---|
| Locational data | **Country** | The VS countryand region unique code | string | None | TZA | Required | UN Standard Country Codes |
| | **E frame code** | Unique alphanumeric code assigned to each water quality station, lette Q followed by number | alphanumeric | WQ {1-999} | WQ1 | Required | WQ followed by sequential number 1 to 999 |
| | **Latitude** | Latitude of location where sample was taken | numeric real | {-90<=x<=90} 5 decimals | 10.41199 | Required | 5 decimal places; data should be merged with E-plot Latitude and Long |
| | **Longitude** | Longitude of location where sample was taken | numeric real | {0<=x<=360} decimals | -84.00677 | Required | 5 decimal places; data should be merged with E-plot Latitude and Long |
| Date of Metadata | **Year** | The year metadata created.(YYYY) | numeric integer | {>=2013} | 2013 | Required | tablet should automatically generate date |
| | **Month** | The month metadata created. (MM) | numeric integer | {1-12} | 3 | Required | tablet should automatically generate date |
| | **Day** | The day metadata created. (DD) | numeric integer | {1-31} | 19 | Required | tablet should automatically generate date |
| Name of Analyst | **First Name** | The first name of the person conducting analysis. | string | Assign from list of project personnel | Robert | Required | create drop down menu of all project peronnel who collect data in a county |
| | **Last Name** | The last name of the person conducting analysis. | string | Assign from list of project personnel | Scholes | Required | |
| Name of Scribe | **First and Last Name** | First and last name of scribe | string | Assign from list of project personnel | Robert Scholes | Required | |

**Soil Sample E-frame**
Version: 2.0

| | Form Value | Definition | Data Type | Values List | Example | Empty Value | Rules/Comments |
|---|---|---|---|---|---|---|---|
| **metadata** | **Country** | The VS country three-letter abbreviation. | string | None | TZA | Required | UN Standard Country Codes |
| | **E frame code** | The unique alphanumeric code assigned to each E frame in region. | alphanumeric | WQ {1-999} | WQ1 | Required | This should be automatically generated in sequence; primary key - (e frame code; corner; depth) |
| **Location of Southeast Corner of E frame** | **Station Latitude** | Latitude of the location where the sample was taken | numeric real | {-90<=x<=90} 5 decimals | -25.00001 | Required | 5 decimal places; data should be merged with E-plot Latitude and Long |
| | **Station Longitude** | Longitude of the point where sample is taken | numeric real | {0<=x<=360} 5 decimals | -24.00677167 | Required | 5 decimal places; data should be merged with E-plot Latitude and Long |
| **Date of Sample** | **Year** | The year the sample was taken.(YYYY) | numeric integer | {>=2013} | 2014 | Required | |
| | **Month** | The month the sample was taken (MM) | numeric integer | {1-12} | 03 | Required | |
| | **Day** | The day the sample was taken. (DD) | numeric integer | {1-31} | 19 | Required | |
| **Corner** | **Corner** | Corner at which sample was taken | numeric integer | {SE, SW, NE, NW} | SE | Required | primary key - (e frame code; corner; depth) |
| **Depth of sample** | **Depth of sample** | The depth from which the soil sample was taken (0-20 cm=1; 20-50cm=2; 50-80cm=3; 80-100cm=4) | numeric integer | {1-4} | 2 | Required | primary key - (e frame code; corner; depth) |
| **Depth of restriction** | **Depth of restriction** | The depth (cm) at which point it is no longer possible to auger | numeric | {<100} | 65 | Not Required | There will not always be a depth restriction in the top 100 cm |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Cumulative Soil Mass Analysis** | **Total weight of Cumulative mass soil sample** | Total Weight of cumulative mass soil sample | numeric | {>0} | 201.1 | Required | skip if depth restriction reached |
| | **Weight of soil moisture tin** | The weight of the tin + lid for the fresh soils sample (g) | numeric | {0<x<60} 1 decimal | 40.1 | Required | skip if depth restriction reached |
| | **Weight of fresh soil sample + tin** | The weight of the fresh soil sample + tin (g) | numeric | {0<x< 300} 1 decimal | 231.5 | Required | skip if depth restriction reached |
| **Soil Health Analysis** | **Texture by feel** | The category of soil texture obtained by feel | string list | list of soil texture types | sandy loam | Required | |

**Soil Sampling Metadata**
Version: 2

| | Form Value | Definition | Data Type | Values List | Example | Empty Value | Rules/Comments |
|---|---|---|---|---|---|---|---|
| **Locational data** | **Country** | The VS countryand region unique code | string | None | TZA | Required | UN Standard Country Codes |
| | **E frame code** | Unique alphanumeric code assigned to each water quality station, lette Q followed by number | alphanumeric | WQ {1-999} | WQ1 | Required | WQ followed by sequential number 1 to 999 |
| | **Latitude** | | numeric real | {-90<=x<=90} 5 decimals | 10.41199 | Required | 5 decimal places; data should be merged with E-plot Latitude and Long |
| | **Longitude** | Longitude of location where sample was taken | numeric real | {0<=x<=360} decimals | -84.00677 | Required | 5 decimal places; data should be merged with E-plot Latitude and Long |
| **Date of weighing dried samples** | **Year** | The year samples were weighed.(YYYY) | numeric integer | {>=2013} | 2013 | Required | tablet should automatically generate date |
| | **Month** | The month samples were weighed. (MM) | numeric integer | {1-12} | 3 | Required | tablet should automatically generate date |
| | **Day** | The day samples were weighed. (DD) | numeric integer | {1-31} | 19 | Required | tablet should automatically generate date |
| **Name of Person Weiging sampels** | **First Name** | The first name of the person conducting analysis. | string | Assign from list of project personnel | Robert | Required | create drop down menu of all project peronnel who collect data in a county |
| **Name of Person Weiging samples** | **Last Name** | The last name of the person conducting analysis. | string | Assign from list of project personnel | Scholes | Required | |

**Soil Sample E-frame**
Version: 2

| | Form Value | Definition | Data Type | Values List | Example | Empty Value | Rules/Comments |
|---|---|---|---|---|---|---|---|
| **Metadata** | **Country** | The VS country three-letter abbreviation. | string | None | TZA | Required | UN Standard Country Codes |
| | **E frame code** | The unique alphanumeric code assigned to each E frame in region. | alphanumeric | WQ {1-999} | WQ1 | Required | This should be automatically generated in sequence; primary key - (e frame code; corner; depth) |
| **Location** | **Station Latitude** | Latitude of the location where the sample was taken | numeric real | {-90<=x<=90} 5 decimals | -25.00001 | Required | 5 decimal places; data should be merged with E-plot Latitude and Long |
| | **Station Longitude** | Longitude of the point where sample is taken | numeric real | {0<=x<=360} 5 decimals | -24.00677167 | Required | 5 decimal places; data should be merged with E-plot Latitude and Long |
| **Date of Sample** | **Year** | The year the dried samples were weighed.(YYYY) | numeric integer | {>=2013} | 2014 | Required | |
| | **Month** | The month the dried samples were weighed.(MM) | numeric integer | {1-12} | 03 | Required | |
| | **Day** | The day the dried samples were weighed.(DD) | numeric integer | {1-31} | 19 | Required | |
| **Depth of sample** | **Depth of sample** | The depth from which the soil sample was taken (0-20 cm=1; 20-50cm=2; 50-80cm=3; 80-100cm=4) | numeric integer | {1-4} | 2 | Required | primary key - (e frame code; corner; depth) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Cumulative Soil Mass Analysis** | **Total weight of DRIED Cumulative mass soil sample (TIN)** | Weight of cumulative soil moisture tin + oven/or air dried soil; | numeric | {>0} 1 decimal | 201.1 | Required | skip if no sample due to depth restriction |
| **Soil Moisture Analysis** | **DRIED weight of soil moisture sample (BAG)** | Total air dried weight of composite sample in bag | numeric | {>0} 1 decimal | 40.1 | Required | skip if no sample due to depth restriction |
| | **composite sample weight (FINE)** | Total Weight of composite soil fine fraction (<2mm) | numeric | {>0} 1 decimal | 231.5 | Required | skip if no sample due to depth restriction |
| | **composite sample weight (COURSE)** | Total weight of composite sample coarse fraction (>2mm) | numeric | {>0} 1 decimal | 231.5 | Required | skip if no sample due to depth restriction |

# Vital Signs Protocol

## Rapid Roadside Assessments

Version 2.0

March 2014

# CONTENTS

# 1. INTRODUCTION

The goal of the Tier 2b Rapid Roadside Assessments is to provide validation information on **land-use** and **vegetation cover** to analysts developing land-cover maps. The maps are created using satellite data, and need to be tested against the real, on-the-ground land cover and land use to ensure they are realistic and accurate.

Rapid roadside assessments are used to capture key qualitative and semi-quantitative data, supported by photographs, for a large number of sites across the landscape in a quick, efficient manner. E-Plots provide the detailed, quantitative information which rapid roadside assessments cannot, but the sample size of rapid assessments is high enough (several thousand, eventually) to validate land cover classes with acceptable statistical certainty.

The Rapid Roadside Plot (RRP) assessments should be done at regular distance or time intervals as observation teams are traveling in the field (perhaps one per hour, or one every 20 km along the road), and should take 10 minutes to complete. The data entry sheet (Appendix 1) illustrates the scope of information that will be recorded.

## *1.1 Definitions of Key Technical Terms*

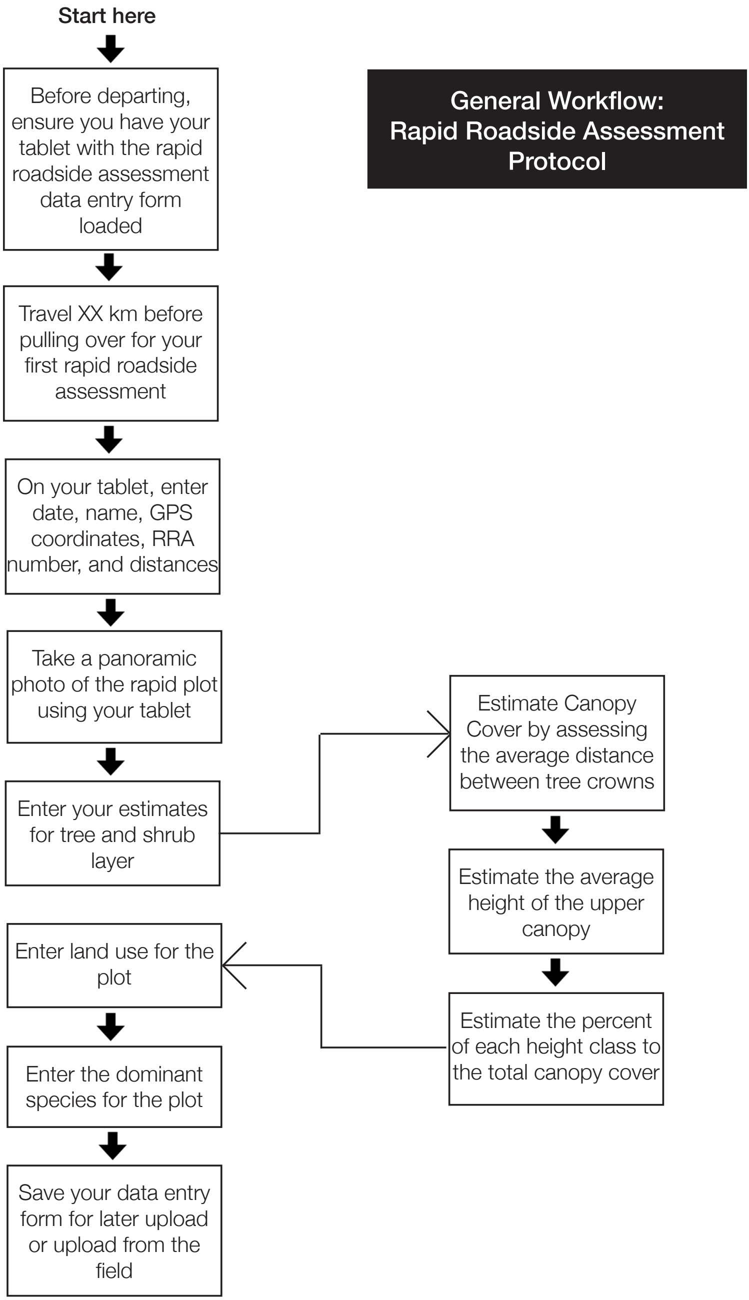
**Land Cover**: “The observed (bio)physical cover on the earth’s surface” (definition used by the Land Cover Classification System of the FAO). The observer should be careful not to confuse ‘land cover’ with ‘land use.’ Land cover describes what is covering the surface of the land: for example, vegetation, man-made features and as other surfaces, e.g. bare rock or bare soil.

**Land Use**: The manner in which land is being used, characterized by the “arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it” (LCCS, FAO). For example, where the land cover of an area may be grassland or open savanna, the land use type may be “nature conservation” or “cattle farming.”

**Vegetation type**: A collective term for the class of vegetation covering an area of ground, for example grassland, savanna, woodland or forest.

**Canopy Cover**: the area of ground covered by a canopy of plants. It is measured at the area covered by the vertical projection of the outermost perimeter of the canopy (small openings in the canopy are included). It may be recorded per plant (e.g. 3 $m^2$) or as a proportion of an area containing several plant canopies (e.g. 20% canopy cover).

**Tree**: a woody plant taller than your knee (0.5 m) and with a stem greater than 50 mm in diameter. A diameter of 50 mm is about the size of your wrist, depending on hand size, and your thumb and finger should just be able to wrap around the stem. This allows you to quickly decide which individuals should be considered. It may have one or many stems.


General Workflow: Rapid Roadside Assessment Protocol
Start here
Before departing, ensure you have your tablet with the rapid roadside assessment data entry form loaded
Travel XX km before pulling over for your first rapid roadside assessment
On your tablet, enter date, name, GPS coordinates, RRA number, and distances
Take a panoramic photo of the rapid plot using your tablet
Enter your estimates for tree and shrub layer
Estimate Canopy Cover by assessing the average distance between tree crowns
Estimate the average height of the upper canopy
Estimate the percent of each height class to the total canopy cover
Enter land use for the plot
Enter the dominant species for the plot
Save your data entry form for later upload or upload from the field

**Shrub**: a perennial woody plant that is not a tree as defined above.

**Herbaceous Layer**: the non-woody vegetation layer, consisting of grasses and forbs (flowering plants). The plants may be annual or perennial.

**Crop**: species that are cultivated and harvested for food, fodder, clothing or other forms of production, e.g. maize, cotton or soybeans. Can be short-lived or perennial; if the latter, it is usually a 'tree crop'.

**GPS**: a Global Positioning System that uses space-based satellites to provide the user with the geographic coordinates of a specific location.

### *1.2 Standard Conventions Used in this Document*

The following conventions are used throughout this document:

- The use of bold in the text indicates a critical point. **Please pay special attention to terms, sentences and paragraphs marked in bold** as they are key to the understanding of the protocol.

## 2. ROLES AND RESPONSIBILITIES

The following table introduces the roles and responsibilities of the members of a Vital Signs field team:

| Role | Responsibility |
| --- | --- |
| Country Director | • Supports team with a complete understanding of the protocol manual<br>• Trains technicians<br>• Leads technicians in fieldwork and sampling and assists with measurements as required |
| Technical Manager | • Supervises teams<br>• Ensures equipment is well-managed and team is safe<br>• Ensures consistency and quality of measurements<br>• Ensures data are uploaded to the VS server daily (or weekly if internet access is limited)<br>• Ensure back-ups and data entry sheets are properly archived |
| Technicians | • Perform rapid roadside assessments and record measurements<br>• Clean and store equipment |
| Africa Field Director | • Helps train technicians and ensure consistency of protocol implementation across Vital Signs countries<br>• Reviews data when uploaded<br>• Approves protocol updates |

| | |
|---|---|
| | and sends out update notifications to field teams |
| Protocol Manager | • Receives and archives comments about the protocol from the field team<br>• Updates and re-circulates the protocol |

## 3. EQUIPMENT LIST

The following equipment is required to carry out the activities described in this manual. **Before traveling to the field to carry out sampling, use this list to ensure you have all the equipment needed for the day**.

**Record the information directly into the form on the tablet**. In the event that the RRP cannot be captured on a tablet in the field (for example, if the tablet is broken or its battery is flat), a paper form can be used. The data should be entered into the tablet as soon as possible. If you have to use a digital camera, make sure the photograph is loaded onto the tablet and selected when asked on the tablet form.

If a tablet is used to record data, at least one on-site backup to a laptop and, preferably, at least one off-site backup should be made at the end of each day.

*General Supplies*

- Tablet with data collection form loaded
- As backup: digital camera, GPS, paper forms and pencil
- Clipboards, notebooks and pens

## 4. RAPID ROADSIDE PLOT DATA ENTRY

The rapid roadside plot assessment records the **GPS coordinates**, **canopy cover**, **tree height**, **dominant species** and **land use**.

*4.1 Entering Metadata*

When you arrive at a designated rapid roadside plot, pull over onto the side of the road and park the vehicle. Enter the following information into your tablet within the RRP form:

- Date
- Observer Name
- GPS Coordinates: latitude and longitude
- Rapid Roadside Assessment Number

- Distance from the closest notable town just passed through (one that can be located on a map), and the name of the next closest town on your route.

*4.2 Taking a Panoramic Photograph*

**With the tablet, take a 360° panoramic photograph of the rapid assessment plot** from the point where you recorded the GPS coordinates, starting off pointing north and turning clockwise.

You can use a digital camera capable of taking a 360° photo if the tablet is unavailable, but then ensure that you **load this photo to the tablet** so you can select and upload the photo when entering data on the tablet. If there is only a digital camera with no panoramic capability, take eight standard, horizontal format photos in sequence (with the lens set on 'wide angle') aiming N, NE, E, SE, S, SW, W, and NW, and stitch them into a panoramic photo back at headquarters using a panoramic mosaic software.

In some (rare) situations only one side of the road may be usable as a RRP. You have two choices. The preferred action is to walk 50 to 100 m into the usable side and take the GPS location, a 360° photo and do the RRP there. If that is also not possible, take a 180° panorama from the road.

Photographs should be captured in large JPG format – equivalent to a file size of approximately 2-4 MB.

In a similar manner to all electronic field data, photograph files need to be saved and backed-up every day.

### *4.3 Making Tree and Shrub Layer Estimates*

Three semi-quantitative estimates of features of the tree and shrub layer are required in order to classify the land cover: **Canopy Cover**, **Average Height of the Upper Canopy**, and **Percentage of Each Height Class contribution to the Total Canopy Cover**.

A list of the 1 to 5 dominant species (you can record them in local language or in scientific (latin) binomials) is very helpful. If you do not know the name of the plant, take a sample and one or more photos for later identification and give the species a temporary code or 'nickname' until you have a proper identity.

#### *4.3.1 Estimating Canopy Cover*

Canopy cover is estimated by assessing the average distance between tree crowns. Look at the tree crowns in the landscape, and use the following guidelines to determine canopy cover:

- If tree crowns are **two diameters apart**, canopy cover equals **9%**
- If tree crowns are **one diameter apart**, canopy cover equals **20%**
- If tree crowns are **half a diameter apart**, canopy cover equals **35%**

- If tree crowns are **touching**, canopy cover equals **75%**

You can use this as a framework to estimate the canopy cover (your accuracy will not be better than ± 5%) or to place it into a canopy cover class (0-9%, 10-39%, 40-59%, 60-100%), which correspond to the cutoffs between different vegetation types (grassland, savanna, woodland and forest, respectively).

*4.3.2 Estimating Average Height of the Upper Canopy*

The average height of the upper canopy is estimated as being in one of five classes, which correspond to cutoffs between different vegetation types:

- Less than 1 meter (low shrubland)
- Between 1 and 2 meters (shrubland)
- Between 2 and 5 meters (bushland or thicket)
- Between 5 and 20 meters (savanna, woodland or forest, depending on height)
- Greater than 20 meters (tall forest)

**Estimate the average height of only the upper canopy, not the average canopy height of all trees and shrubs in the landscape**. A useful technique is to consider the upper canopy height at 6-8 points around you (N, NE, E, SE…) and then record the average estimate across the set of points.

You can also imagine a very large sheet of light but stiff board settling down onto the canopy. How high above the ground will it come to rest?

*4.3.3 Estimating Percentage contribution of Each Height Class to Total Canopy Cover*

The percentages you record next to each height class must add up to 100. Again, a useful technique is to consider the contribution of each height class of trees and shrubs to the total projected canopy cover at 6-8 points around you (N, NE, E, SE…), then to record the average estimate across the set of points.

*4.4 Judging the Land-Use*

**The predominant types of land-use within 50 m of the rapid assessment point needs to be recorded**. It may differ on opposite sides of the road, and note that one land cover can have more than one land use. Look at the landscape for clues and select one or more of the following, or add your own description:

- Protected (eg national park, forest reserve etc)
- Livestock grazing (look for cattle, goats etc or their dung)
- Woody harvesting (look for cut stumps, piles of firewood or charcoal)
- Short duration cropping (there will be current or recent fields)

- Tree crops (species such as bananas or mango will be present)

- Habitation and business (buildings present)

*4.5 Recording Dominant Species*

**Dominant tree, herbaceous and crop species within 50 m of the rapid assessment point need to be recorded**. The emphasis should be on listing the 1 to 5 dominant species quickly and efficiently. The order in which the species are listed does not matter, as long as each species is recorded using a traceable name that can later be linked to a species code or scientific name.

# 5. APPENDICES

Appendix 1: Rapid Roadside Assessment Data Entry Sheet

Appendix 2: Rapid Roadside Assessment Data Dictionary

<table>
<tr><th colspan="8">Vital Signs Africa: Rapid Roadside Assessment Data Entry Sheet</th></tr>
<tr><td>Date:</td><td></td><td colspan="2">Observer name:</td><td colspan="2"></td><td colspan="2">GPS coordinates<br>Lat:<br>Long:</td></tr>
<tr><td colspan="2">Rapid Road Assess no.</td><td colspan="4">Photograph file name:</td><td colspan="2">Distance (km) from ______________ to ______________, _____ km</td></tr>
<tr><td colspan="8">TREE / SHRUB LAYER</td></tr>
<tr><td colspan="3">Tree / shrub total projected canopy cover (tick one)</td><td>< 10%</td><td>10 – 39%</td><td>40 – 59%</td><td>> 60%</td><td></td></tr>
<tr><td colspan="8">General guide to above: tree crowns that are 2 crown diameters apart = 9 % canopy cover, 1 diameter apart = 20%, ½ a diameter apart = 35%, crowns touching = 75%</td></tr>
<tr><td colspan="3">Average height of upper canopy (tick one)</td><td>< 1m</td><td>1 - 2m</td><td>2 - 5m</td><td>5 - 20m</td><td>> 20m</td></tr>
<tr><td colspan="3">% Contribution of height class to total projected canopy cover</td><td>__ %</td><td>__ %</td><td>__ %</td><td>__ %</td><td>__ %</td></tr>
<tr><td colspan="8">LAND-USE</td></tr>
<tr><td>Select one or more (tick)</td><td>Prot-ected</td><td>Live-stock grazing</td><td>Wood harvest-ing</td><td>Short duration cropping</td><td>Tree crops</td><td>Habitat-ion / business</td><td>Other</td></tr>
<tr><td colspan="8">DOMINANT SPECIES (within 50m of observation point)</td></tr>
<tr><td colspan="5">Tree species</td><td colspan="3">Herbaceous and crop species</td></tr>
<tr><td colspan="5"></td><td colspan="3"></td></tr>
<tr><td colspan="5"></td><td colspan="3"></td></tr>
<tr><td colspan="5"></td><td colspan="3"></td></tr>
<tr><td colspan="5"></td><td colspan="3"></td></tr>
</table>

| | Rapid Road Side Assessment Form<br>Version: 1.0 | | | | | | |
|---|---|---|---|---|---|---|---|
| | Form Value | Definition | Data Type | Values List | Example | Empty Value | Rules/Comments |
| | **Country** | The VS country three-letter abbreviation. | string | None | TAN | Required | |
| | **Rapid Road Side Assessment no.** | A unique alphanumeric code assigned to each rapid roadside assessment in a country. Prefixed by R, sequential number 0 to 9999 | alphanumeric | None | R0001 | Required | |
| | **Tier 2b Rapid Roadside Assessment code** | A unique i.d. code for rapid road side assessment in each country.<br>The code contains two components: "3-letter country code - Rapid Roadside Assessment Number"<br>For example, TAN-R0004 refers to rapid road side assessment number 4 in Tanzania.<br>The id numbers will be assigned automatically. | formula | None | TAN_R0004 | Required | |
| **Date of Road Side Assessment** | **Year** | The year of assessment.(YYYY) | numeric | {>=2013} | 2014 | Required | |
| | **Month** | The month of the assessment (MM) | numeric | {1-12} | 03 | Required | |
| | **Day** | The day of the assessment (DD) | numeric | {1-31} | 19 | Required | |
| **Observers name** | **First Name** | The first name of the person recording information onto the Field Form. | string | None | Mark | Required | Will be generated by pick list on tablet |
| | **Last Name** | The last name of the person recording information onto the Field Form. | string | None | Musumba | Required | Will be generated by pick list on tablet |
| **Geog. co-ord's of the rapid assessment** | **Assessment Latitude** | Latitude of the point at which the rapid roadside assessment is taken in decimal degrees | numeric | 90 to -90 | -10.41199 | Required | Decimal degrees, five decimal points, negative south |
| | **Assessment Longitude** | Longitude of the point at which the rapid roadside assessment is taken in decimal degrees | numeric | 0 to 360 | 84.00677 | Required | Decimal degrees, five decimal points |

| | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Location information | **Distance from marker (km)** | Distance in kilometers from a town/marker towards another town or marker | numeric | None | 24 | Required | precision of 0.1 km required |
| | **Name of marker** | Name of the marker (e.g. town or road junction) to which the distance measurement above relates | string | None | Arusha | Required | |
| | **Towards marker** | Direction of travel on road | string | None | E | Required | e.g. 'towards Dar es Salaam' or E |
| Photo | **Photograph file name** | The file name of the photograph as assigned by the tablet or camera after the capture of the image | string | None | IMG_4026.jpg | Required | A panoramic photograph needs to be taken at the point at which the rapid road side assessment is been undertaken. Note that the camera will generate a standard info file of metadata itself, including latitude longitude, date, and exposure values. |
| / shrub layer | **Average height of upper canopy (m)** | The observer is required to pick one of the following five canopy height classes (<1m, 1-2m, 2-5m, 5-20m or >20m) | integer | {<1m, 1-2m, 2-5m, 5-20m or >20m} | 1 | Required | The observer should only choose one of the 5 upper canopy height class options |
| | **Percentage contribution of height class to total projected canopy cover (<1m)** | The observer is required to estimate the percentage contribution of woody plants in the <1m height class to total projected canopy (within 50m of the point at which the rapid road side assessment is undertaken) | numeric | {0-100} | 20 | Required | There are relative cover, not absolute. They should be rescaled to sum to 100% |
| | **Percentage contribution of height class to total projected canopy cover (1-2m)** | The observer is required to estimate the percentage contribution of woody plants in the 1-2m height class to total projected canopy (within 50m of the point at which the rapid road side assessment is undertaken) | numeric | {0-100} | 30 | Required | There are relative cover, not absolute. They should be rescaled to sum to 100% |

| | | | | | | | |
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| Rapid assessment of the tree | **Percentage contribution of height class to total projected canopy cover (2-5m)** | The observer is required to estimate the percentage contribution of woody plants in the 2-5m height class to total projected canopy (within 50m of the point at which the rapid road side assessment is undertaken) | numeric | {0-100} | 20 | Required | There are relative cover, not absolute. They should be rescaled to sum to 100% |
| | **Percentage contribution of height class to total projected canopy cover (5-20m)** | The observer is required to estimate the percentage contribution of woody plants in the 5-20m height class to total projected canopy (within 50m of the point at which the rapid road side assessment is undertaken) | numeric | {0-100} | 30 | Required | There are relative cover, not absolute. They should be rescaled to sum to 100% |
| | **Percentage contribution of height class to total projected canopy cover (>20m)** | The observer is required to estimate the percentage contribution of woody plants in the >20m height class to total projected canopy (within 50m of the point at which the rapid road side assessment is undertaken) | numeric | {0-100} | 20 | Required | There are relative cover, not absolute. They should be rescaled to sum to 100% |
| | **Tree / shrub projected canopy cover** | The observer is required to pick one of the following four total projected canopy cover classes (<10%, 10-39%, 40-59%, >60%) | integer | {<10%, 10-39%, 40-59%, >60%} | 10-39% | Required | The observer should only choose one of the four projected canopy cover classes |
| | **Land-use** | The observer is required to pick one or more of the following six land-use classes (Protected, Livestock grazing, Wood harvesting, Short duration cropping, Tree crops, Other and / or Habitation / business) | integers | {Protected, Livestock grazing, Wood harvesting, Short duration cropping, Tree crops, Other, Habitation / business} | Protected | Required | The observer may choose more than one of the land-use classes |
| Dominant species | **Tree Code** | 4 letter alphanumeric code e.g. acse for Acacia senegal | string | None | acse | NULL | It can happen that no tree species occur within 50m of the observation point |
| | **Herbaceous/crop code** | 4 character alphanumerical code e.g. maiz for maize | string | None | maiz | NULL | It can happen that no herb or crop species occur within 50m of the observation point |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Code translation | **Genus** | Genus name. The Latin binomial species name corresponding to the 4-letter code | string | None | Panicum | NULL | These codes are likely to vary from observer to observer and over time. In the tablet version, they will be generated by a pick-list |
| | **Species** | Species name. The Latin binomial species name corresponding to the 4-letter code | string | None | maximum | NULL | These codes are likely to vary from observer to observer and over time. In the tablet version, they will be generated by a pick-list |


# Vital Signs Protocol

## Water Availability and Quality

Version 2.0

March 2014

# CONTENTS

# 1. INTRODUCTION

Water is one of the most important ecosystem services yielded by the landscape: fundamental to human welfare, agriculture and biodiversity. It is a multi-dimensional service, since **both the amount of water and its quality is important**, and both of those broad dimensions have many sub-elements.

Comprehensive monitoring of the hydrological resources of a region requires a sampling effort much higher than is generally adopted within the scope of Vital Signs alone – a spatial density of recording stations in the order of one every 2000 $km^2$ is recommended, with continuous (or at least monthly recording). Most countries have some form of national hydrological data collecting system, and it is not the role of Vital Signs to replace this, but to supplement it.

Water quality monitoring is generally even more complicated than flow monitoring. Furthermore, models to predict many important aspects of water quality are rudimentary. Vital Signs makes use of regional or national water quality testing laboratories where they exist, but has no plans to create them where they do not. Instead, **Vital Signs has selected a small number of key water quality variables** that can be simply, reliably and economically assessed in the field, and will monitor these in its target landscapes.

This manual is therefore not a comprehensive guide to hydrological modeling, but an extremely selective one, for Vital Signs purposes and objectives.

*1.1 Definitions of Key Technical Terms*

**Channel profile**: a cross section of the river channel at a given point.

**Gauging station:** a location on a river, dam, lake or aquifer at which water depth is measured (and in the case of a river, the flow of water is estimated from the depth and the channel profile).

**Landscape**: a 10 km x 10 km area in which Vital Signs develops an understanding of the spatial and temporal dynamics of agriculture, ecosystems and human well-being.

**Water quality:** the 'fitness of the water for use', which varies by use and is measured using several criteria.

*1.2 Standard Conventions Used in this Document*

The following conventions are used throughout this document:

- The use of bold in the text indicates a critical point. **Please pay special attention to terms, sentences and paragraphs marked in bold** as they are key to the understanding of the protocol.

## 2. ROLES AND RESPONSIBILITIES

The following table introduces the roles and responsibilities of the members of a Vital Signs field team:

| Role | Responsibility |
| --- | --- |
| Technicians | • Install, maintain and read gauging stations<br>• Take water samples and analyze them<br>• Perform rapid water assessments<br>• Clean, maintain and store equipment |
| Technical Manager | • Supervises teams<br>• Ensures equipment is well-managed and team is safe<br>• Ensures consistency and quality of measurements<br>• Ensures data are uploaded to the VS server daily (or weekly if internet access is limited)<br>• Ensure back-ups and data entry sheets are properly archived |
| Country Director | • Supports team with a complete understanding of the protocol manual<br>• Trains technicians<br>• Leads technicians in fieldwork initially, assisting with measurements as required, and occasionally later |

| | |
|---|---|
| Africa Field Director | • Helps train technicians and ensure consistency of protocol implementation across Vital Signs countries<br>• Reviews data when uploaded<br>• Approves protocol updates and sends out update notifications to field teams |
| Protocol Manager | • Receives and archives comments about the protocol from the field team<br>• Updates and re-circulates the protocol |

## 3. EQUIPMENT LIST

The following equipment is required to carry out the activities described in this manual. **Before traveling to the field to carry out sampling, use this list to ensure you have all the equipment needed for the day**.

At the end of each day's work, equipment should be wiped down and stowed correctly so that the team can start working immediately the next morning. This practice also ensures that all equipment is accounted for and does not go missing.

If a tablet is been used to record data, at least one on-site backup to a laptop and, preferably, at least one off-site backup should be made at the end of each day.

*General Supplies*

- Tablet with data entry forms downloaded
- Clipboards, notebooks and pens
- Water
- Packs for carrying equipment
- Hat and Sun Lotion
- Vital Signs brochure in local language
- Identity cards
- Letters of introduction

*For Setting Up a Gauging Station*

- A strong steel pipe, 25 mm internal diameter, up to about 5m long, drilled at top for cable and screw
- Cap to fit the pipe, which may be threaded to fit it
- Hobo U20 datalogger
- An optical interface (BASE-U-4) and COUPLER-2-B
- 5m tape
- Stainless steel self-tapping screw, about 2mm long
- 5m of 1.5mm stainless steel cable, preferably Teflon coated
- 2 copper crimps
- Pliers
- Hacksaw to cut the pipe to length
- Pipe cap to fit over its end
- Wire to attach the pipe to a support in the river

*For Calibrating the Gauging Station*

- Laser level on a tripod (with fresh batteries)

- 20m tape
- 5m tape marked in mm
- 2.5 m ranging rod marked at 0.5 m intervals
- Ball of string 50m long
- 2 pegs about 700 mm long (wooden poles or steel fence droppers)
- Hammer
- One roll of insulation tape
- Compass
- Flow Velocity Measurement Instrument

*For In-Field Analysis*

- Combination pH, EC and temperature probe with good batteries, two pH buffer solutions and a standard EC calibration solution.
- Nitrate ion probe and at least one standard calibration solution.
- Phosphate spectrophotometer, cuvettes, reagent and a standard phosphate calibration solution
- Kit of Aquagenx compartment bag tests (CBT) for E. coli
- Portable field incubator
- 10 50 ml test tubes in which to do the analyses and a test tube rack
- 500 ml squeeze bottle containing clean water (distilled or de-ionized water is best, but commercial bottled water will do if that is all that is available)
- 12 500 ml clean sample bottles (Nalgene or PET)
- Sampling rod with bottle holder

# 4. GAUGING STATIONS

**A 'gauging station' takes near-continuous measurements of the amount of flowing water**. This is typically done by measuring the height of the water (the 'stage') relative to an established reference level. The flow in the river (known as the 'river discharge' and expressed as $m^3/s$) is then calculated from the relationship between the water surface height above the reference level and the flow through the river cross section at that location (a 'stage-discharge relationship'). Establishing this relationship is called 'calibrating the gauging station.'

In its simplest form, the flood stage height is visually measured off a pole standing vertically in the river, like a giant ruler clearly marked in 1 or 10-cm intervals. To be useful, however, this has to be done frequently, so it is generally more effective to install an automatic device to do this job.

Modern automated water depth sensors work on the principle of recording the water pressure in the deepest part of the river. The sensor is part of an integrated, waterproof unit with a small, battery-powered datalogger and a water temperature sensor. It collects measurements at intervals that can be adjusted – for Vital Signs we use intervals of 30 minutes.

The depth sensor also includes a water temperature sensor, since the temperature affects the pressure measurement. The observed pressure at the measurement depth is also affected by the atmospheric pressure above the water, so an automated atmospheric pressure sensor is installed nearby, as part of a comprehensive automatic weather station collecting rainfall, radiant energy, air temperature, humidity and wind speed.

**There is a separate Vital Signs manual describing how to set up and operate a weather station**. The air pressure sensor should be within a few kilometers of the river gauging station, but need not be at precisely the same altitude. The clocks of the water depth dataloggers and the atmospheric pressure datalogger are synchronized. It is best to synchronize them exactly, i.e. to within a second, by ensuring that the laptop used to collect data from both is itself set to the correct time. In practice, a time error within a minute would be fine since air pressure changes quite slowly. Make sure the date is correct in both dataloggers as well.

**The data from both loggers are downloaded every few months**. The two datasets are then merged at the Vital Signs regional office using software, and the water depth is calculated. Then the flow in the river is estimated by applying the calibration curve.

The World Meteorological Organization sets the international standards for measurement of the flow in river systems. Its two-volume manual (WMO 2008) is a primary source for the following methods. Many of the standards for water sampling are also set by the International Standards organization (ISO). There may in addition be national standards.

## *4.1 Selecting a Stream Gauging Location*

The site must satisfy the objectives of the monitoring. **The catchment must be mostly within one of the Vital Signs landscapes**, and that landscape must be equipped with a full weather station.

Requirements for the site include:

1. The site should be **easily accessible all year round** (ideally within a few hundred meters of a road).

2. The **cross-sectional profile of the stream should be well defined** (avoid places were the stream is braided or switching) and reasonably stable over time (a rocky bottom is better than a shifting sandbank).

3. **Select a straight section of the river with a consistent relationship between depth and flow**. The water flow lines in the river should be parallel to one another and perpendicular to the river cross section (rather than eddying).

4. The water should be unobstructed by aquatic vegetation.

5. The minimum **flow velocity should be greater than 0.15 m/s** and the **depth greater than 0.3 m**.

6. It must be possible to anchor an upright pipe (‘stilling well’) from the deepest point to above the likely water height so that a flood will not wash it away. The presence of a pre-existing rigid structure (like a bridge

pier or pumping weir) is useful, otherwise a strong pole driven into the riverbed may suffice.

7. The site and catchment weather station must be reasonably secure against tampering or theft.

*4.2 Setting up a Gauging Station*

Vital Signs uses the **Hobo U20 water level datalogger**, U20-001-04. If you use a different one, follow the instructions that came with it – the procedure will be similar.

The U20 logger can store 21700 complete records, which at the recommended interval of 30 minutes is over a year. The battery should last several years.

To set up the gauging station:

1. Make a ‘stilling well’ out of the pipe.

    i. Cut the pipe to length from the bottom. The top end should already have been threaded for the end cap and drilled to accept the cable and retaining screw. The pipe must be long enough so that when the bottom rests on the deepest part of the riverbed (a stone foundation is better than a muddy one), the top is above the normal flood height.

    ii. Measure the length of the pipe (mm) and write it in the field notebook.

iii. Measure and cut a length of the stainless steel cable to the same length as the pipe. Make a 10mm loop in one end and secure it with a copper crimp. Thread the other end of the cable from the outside through the lower of the two holes in the pipe and attach the loop to the pipe on the outside using the screw in the upper hole.

iv. Make a 10 mm loop in the cable about 180 mm from its other end and hold it with a copper crimp. Attach the clip that holds the HOBO-U20 to this lower loop.

v. When the U20 datalogger, which is 150 mm long, hangs on the end of the cable inside the tube, the bottom of the datalogger should be about 30mm above the bottom of the pipe. You do not need to measure this distance – you will work it out from the water depth you record when you install the logger, and the record it takes.

2. Attach the completed stilling well vertically to the downstream side of a fixed, immobile object in the center of the stream, such as a pole or bridge pylon.

3. Attach the stilling well to its support using brackets strong enough to withstand floods.

4. The bottom of the stilling well should rest on the bottom of the stream, but the inlet hole (the open

bottom of the tube) must not be blocked by mud – make a small foundation out of stones.

*Figure 1: attaching the stilling well to a bridge over a stream.*

5. Use the top of the pipe as the ‘reference height’ from which to measure the water level, and make sure you measure and write in the field notebook the vertical distance, in mm, between the top of the pipe and the reference level you establish when you survey the stream cross section.

6. Connect the Hobo U20 to the coupler, the coupler to the optical interface and the interface to a USB port on the laptop. Switch on the laptop and open HOBOWare pro.

## Workflow 1: Setting up a Gauging Station

When you arrive at the site for the stream gauging location, follow instructions for making a stilling well out of your pipe

↓

Attach the completed stilling well vertically to the downstream side of a fixed object in the center of the stream, such as a pole or bridge pylon

↓

Use the top of the pipe as the reference height from which to measure the water level. Record the vertical distance (mm) between the top of the pipe and the reference level you establish when you survey the stream cross section

↓

Connect the Hobo U20 to the coupler, the coupler to the optical interface and the interface to a USB port on the laptop. Open HOBOWare pro

↓

Check the status: the battery voltage should be about 3.5 V

↓

Set the time and date on the logger to the current date and time on the laptop. Set the datalogging intervals to 20 minutes.

→

Using the interface software, select both absolute pressure and temperature and start the logger recording

↓

Let the logger run for 20 minutes. Remove it, reconnect the cable and download the data to check it is working. The data should have a date, time, pressure value and temperature.

↓

After the check, disconnect the cable and install the logger unit inside the stilling well

↓

Lower the logger, clipped onto its steel cable, to the depth established by the length of the cable. Put a plug on the top of the pipe.

↓

Record the gauging station code, the serial number of the HOBO U20, the launch date and time, and the height of the water surface below the reference point at the time the U20 was placed in the stilling well.

7. Check the status; the battery voltage should be about 3.5 V (and certainly above 3.1V).

8. Set the time and date on the logger to the current date and time on the laptop (we suggest using the national time standard, without applying daylight saving adjustments; if you do use daylight saving time, ensure that this is noted in the logbook, and corrected for when the data are processed).

9. Set the datalogging intervals to 30 minutes.

10. Using the interface software, select both absolute pressure and temperature to be recorded, and start the logger recording ('launch' it). The light on the logger should blink once every 4 seconds if it is logging.

11. It is a good idea to let the logger run for 30 minutes, preferably in its installed position in the stilling well, and then remove it, reconnect the interface cable and download the data to check that the logger is in fact working. **The data record should consist of a date, a time, a pressure value and a temperature**. The last data record should be the current date and time, the temperature in the range 0 to 40 °C and the pressure around 100 kPa if the logger was out of the water, and bit higher if in the water.

12. After this check, disconnect the interface cable and lower the logger unit down the inside the stilling well, until it reaches the end of its cable.

13. Put a plug on the top of the pipe to keep out debris, insects and curious people.

14. In the field notebook, record the unique gauging station code, the serial number of the HOBO U20, the date and time of the ‘launch’, and the height of the water surface below the reference point (the top of the stilling well (mm)) at the time the U20 was placed in the stilling well.

### *4.3 Calibrating a Gauging Station*

The ‘stage-discharge calibration curve’ is a graphical **relationship between the measured water depth and the flow in the river** for a given gauging station. This relationship is used at VS regional headquarters to convert water depth measurements to flows.

In order to construct this curve you need to measure:

1. The **cross-section of the river** (in other words, the depth to the river bottom at a number of locations across the river). You need to measure this cross section perpendicular to the flow direction, up to the highest point that could be reached by a flood, and passing through the point where your logger is installed.

2. The **velocity of water flow** through this profile at a number of places and depths; for at least two but preferably three or more ‘flow stages’ (e.g. low flow and normal flow).

The following methods assume that the river (stream) is small – a few meters across, and less than 1 m deep. This will typically be the case for the small catchments monitored by Vital Signs. The same principles apply to a larger river, but you may need a boat and a longer tape to perform the task.

*4.3.1 Measuring the River Channel Cross Section*

This procedure needs to be performed **when the automatic depth measuring equipment is installed**, and then repeated at intervals of about one year in case the stream profile has changed due to erosion or deposition of sediments. At least two people are needed for this task, and the following equipment:

- Laser level on a tripod (with fresh batteries)
- 20 m tape
- 5 m tape marked in mm
- 2.5 m ranging rod marked at 0.5 m intervals
- Ball of string 50 m long
- Two pegs about 700 m long (they can be wooden poles, or steel fence droppers)
- Hammer
- One roll of insulation tape
- Compass

1. Start a new page in the field logbook. Write the date, the latitude and longitude of the gauging station (measured by GPS, at the point where the water depth logger will be installed), the unique code of the gauging station (if there is one), and a few words or a sketch to describe the location.

2. Write a heading “Stream Cross Section Measurements” and draw up a table with two columns, on for distance across the stream (in meters) and one for height (mm).

3. Set up a laser level on a tripod at the highest point the flood will reach on one bank at the place you have installed the water level logger.

4. Mark this point with a peg, with strip of tape wrapped around it on it to show the ‘reference height’ at which the laser beam is set.

5. Level the laser in all directions, and then shine it through the point where the data logger is installed to the other bank.

6. Mark the point the laser beam reaches the other bank with another peg, and mark the reference height on this peg too.

7. Stretch a tape or string with knots at 1 m intervals between the two pegs.

8. Use a compass to work out the direction of the cross section line, and write it in the notebook, along with the direction of flow of the river. Also note the vertical distance from the top of the stilling well to the reference height (the laser beam). Write this in the field logbook as a negative number if the top of the stilling well is below the reference height, and a positive number if it is

above it.

9. From the horizontal distance between the pegs, work out how many places you will be measuring the vertical distance between to the ground or riverbed and the reference height and their locations. Make sure one of them is at the logger, which should be in the deepest part of the river. There should be at least 10. If the pegs are more than 10 m apart, take a measurement every meter.

10. Wade through the river, along the line between the two pegs, with the ranging rod. At every point where you need to measure the height from the ground or river bottom to the reference height marked by the laser beam, hold the ranging rod vertically and note where the laser beam shines on the rod.

11. Measure the vertical distance in mm from the laser spot to the next lower mark on the ranging rod using the 5 m tape, and add it to the height, also in mm, from the bottom of the ranging rod to that mark.

12. Write down the distance along the 20 m tape from the first peg, and next to it, the corresponding height between the ground (or river bottom) and the reference level marked by the laser beam.

13. Note the measurement location at which the logger is installed, and the depth of the water at

the logger installation point.

Once you have measured the height at all the points, the data collection is complete. Back at base, or in another comfortable place, you can draw a graph with distance along the horizontal axis, and height vertically downward from this axis. This graph is a picture of the river cross-section. Mark the water level, the date you measured the cross section, and the position and height of the top of the stilling well and depth of the datalogger.

### *4.3.2 Measuring Water Flow Though the River Cross Section*

For this measurement you only need to work with the part of the river that actually has water in it at the time of measurement.

You will need the following equipment:

- 20 m tape
- 5 m tape
- Ranging rod
- Flow velocity measuring instrument
- Two pegs (You can use the same two pegs and reference height you used above, or you can set up two more pegs, on the same line, but at water level, with the string or tape stretched tight between them)
- 50 m string

1. Start a new page in the field notebook. Write the heading ‘River Velocity Measurements,’ the unique code for the gauging station (or the latitude and

longitude), the date, time and your name.

2. Create a table (at least 10 lines long) with 4 columns: distance (m), water depth (mm), surface flow (m/s), mid flow (m/s) and near-bottom flow (m/s).

3. At 10 or more points across the river, measure the flow velocity at the three depths:

   i. If the river is less than 10 times the diameter of the flow measuring instrument propeller, then take the measurements one propeller diameter apart

   ii. If the river is wider than 10 m, take them every meter.

4. To take a measurement, stand 0.5 to the side of the point, or 0.5 m downstream of it, so that you don’t disturb the water flow too much. Write in the table the distance on the line across the river from the peg. Measure the depth (mm) from the river bottom to the water level, using the ranging rod and 5 m tape, and write it in the table.

5. Next measure the flow velocities perpendicular to the line, using the velocity measurement instrument, which is mounted on a pole.

6. Hold the instrument pole vertically, with the propellers on the downstream side, at the bottom of the pole.

7. Lower the pole vertically into the river until the propeller is fully submerged and the propeller shaft is one propeller diameter below the water surface. Hold it there for 30 seconds until the velocity measurement stabilizes, and write down the velocity reading (m/s).

8. This is the 'surface flow' measurement. Lower it further, until the propeller shaft is halfway between the surface and the bottom, and take the 'mid flow' measurement after 30 seconds.

9. Lower it until the propeller shaft is one diameter above the bottom (make sure it is not obstructed by weeds) and take the 'near-bottom' flow after 30 seconds.

10. In the event that the river is very shallow at the measurement point (less than twice the propeller diameter), the surface flow, mid flow and bottom flow measurements will all be the same.

Once you have completed all the velocity measurements, the fieldwork is complete. **Back at base you can work out the flow through the river cross section**.

If $b_1$, $b_2$ ..$b_n$ are the distances in meters from the bank at which measurements were taken, $d_1$, $d_2$ ..$d_n$ are the water depths at those points and $v_{1s}$ ,$v_{2s}$ …$v_{ns}$ are the near-surface velocities at those distances; $v_{1m}$ ,$v_{2m}$ …$v_{ns}$ the velocities at mid-depth and $v_{1b}$ ,$v_{2b}$ …$v_{nb}$ are the near-bottom velocities at those points, calculate for each distance point the mean velocity, $v_1$, $v_2$… $v_n$. Applying a minor modification of the 3-point method, WMO (2008)

$$v_x = 0.25\ (v_{xs} + 2v_{xm} + v_{xb})$$

Then the flow through the river, Q ($m^3/s$) is given by $q_1 + q_2 + \ldots + q_{n-1}$, the flows through n-1 vertical sections of the river, where:

$$q_x = ((v_x + v_{x+1})/2)((d_x + d_{x+1})/2)(b_{x+1} - b_x)$$

This represents one point on your 'stage-discharge' calibration relationship. On another date, when the river stage (i.e. flow depth) is different, collect another set of flow values through the wetted section (you don't need to repeat the measurement of the whole river valley cross section, unless it has changed due to flooding). From these, and the river valley cross section, a hydrologist can make a stage-discharge relation. Having even more calibration points, at a wide range of stages, makes it more accurate.

### *4.4 Recovering Data from a VS Stream Gauging Station*

This should be done every time you visit the gauging station, which should be **no less than once every 3 months**. After several years of operation, the battery will need to be changed in the datalogger (when the voltage drops to about 3.2 V).

You will need:

- Laptop with HOBOWare pro installed and the laptop clock set precisely to the right time and date.

- Hobo optical interface (BASA-U-4) and coupler (COUPLER-2-B); a dry cloth; 5 m tape.

1. Note in the field logbook the gauging station unique number, the date, time and the name of the person recovering the data.

2. Note in the logbook the exact water depth (mm) from the reference level on the stilling well (the top of the pipe containing the logger) using the 5 m tape.

3. Note any damage to the gauging station, so that it can be repaired. Conduct a rapid visual water assessment (see method below) and fill in the form.

4. Remove the cap from the pipe in which the logger is housed, and pull up the logger by its stainless steel cable. Unclip the logger from the cable and take it to the bank.

5. Dry the logger and attach it via the coupler to the optical interface, which plugs into the USB port on the laptop. Start the laptop and open HoboWare.

6. Check the ‘status’ toolbar, noting the battery voltage (it should be about 3.5V). The battery lasts about 5 years and can only be replaced by the factory. The status bar will tell you if it needs replacing, and if so, bring the logger back to VS regional headquarters.

7. Download the data from the logger, and save it giving it a unique filename [Stationcode_yymmdd].

8. Open the file and write the first date and time of record and the last date and time of record and into the field logbook next to the filename you gave the file.

9. Check that the dates make sense, and that the last date and time correspond to the actual date and time.

10. Check the pressure and temperature values. The pressure values should be around 100 kPa and temperatures 0 to 40° C. If they are outside this range, relaunch the datalogger, checking that the date and time are correctly set, the interval is 20 minutes, and that both absolute pressure and temperature are selected.

11. Allow the logger to run for 30 minutes, and check it again. If the values are still outside the required range, the logger is faulty and must be replaced with a new one.

12. If the values are acceptable, re-launch the logger. Coordinate the logger clock with the laptop clock, (note the precise time and date you restarted it in the field logbook), check that the interval is set to 30 minutes and both absolute pressure and temperature are selected.

13. Disconnect the logger from the coupler, , re-attach

it to the stainless steel cable in the stilling well, and lower it down the inside of the stilling well.

14. Note the distance from the water surface to the reference height (top of the stilling well) in the field notebook, next to the time and date the logger was replaced in the stilling well.

15. Replace the cap on the stilling well.

*4.5 Calculating Water Depth from the Datalogger Values*

The HOBO U20 water depth recorder measures temperature and pressure, in kPa. **To get the depth of the water**, you need to:

1. Correct the pressure for changes in atmospheric pressure

2. Work out the density of water from the temperature

3. Convert the corrected pressures to water depth, using the calculated water density

4. Relate that depth to your 'reference height' on the stream cross section.

We will use the convention that the deepest part of the river has a reference height of zero, and therefore all heights above it are positive. The calculations are done automatically in HOBOWare pro.

1. In HOBOware Pro, open the water depth data file.

The Plot Setup window appears.

2. Uncheck all boxes except Abs. Pressure.

3. Run the Barometric Compensation Assistant.

    a. Click the Process button.

    b. Select the water density box that best describes the water that you are measuring or enter the actual water density.

    c. Check the Use a Reference Water Level box and enter the reference water level (m) that you measured at the beginning of the deployment. This will be $(h_{ref} + h_{still} – h_{wl})/1000$, where $h_{wl}$ is the height (mm) from the water surface to the top of the stilling well, recorded when you installed the logger, $h_{still}$ is the height difference between the reference level of your stream cross section and the top of the stilling well (negative if the stilling well top is below this reference level), and $h_{ref}$ is the height of the reference level above the lowest point in the riverbed.

    d. Select the date and time from the pull-down menu that is closest to the recorded date/time for the measurement.

    e. Check Use Barometric Data file.

    f. Click the Choose button. This will allow you to select the data file to use for barometric pressure compensation, which should come from a nearby weather station.

g. Select and open the data file.

h. Click the Create New Series button. A new Plot Setup window appears.

4. Select the Water Level box and any other series that you want plotted.

5. Click the Plot button to obtain a plot of the resulting water level data.

## 5. ASSESSING WATER QUALITY

Vital Signs should harmonize its methods with national standards as much as possible. These **water quality sampling guidelines** are based on those for the Environmental protection Agency of Australia (Duncan et al 2007), which are in turn based on several other national and international standards.

There are **four methods for assessing water quality in Vital Signs**:

- Rapid Visual Assessment
- In-Field Water Analysis
- Taking Water Samples for Laboratory Analysis
- Indicator Organism River Health Assessment

## Workflow 2: Rapid Water Assessment

*The Rapid Water Assessment is done repeatedly (monthly is ideal) at well-known places you pass on the way to other tasks (e.g. at a place where you cross a bridge, or where people get their water or wash)*

On the data form, write down the location code, date and time of observation, and the name of the observer

Record the water height, preferably against a permanently installed marker

Observe the water surface and check one or more of the boxes

Dip a sample in a jar with a 100 mm diameter. How does the water appear? Tick off the boxes for color and for clarity or opaqueness

If possible, take a Secchi disk reading. Lower the disk into the water until you just can't see it. Record the length of the cord between the disk and the water surface

Sniff the water and tick one or more boxes for odor

Optional: if the water is safe to drink (e.g. if people are routinely drinking it), taste a tiny sip (through a Life Straw if there is any doubt about the water safety) and check the boxes

Check the boxes for riverine biota

Can you observe any water-use activities nearby? Is water being drawn for drinking, livestock watering, bathing, washing or irrigation?

Take a photograph of the water body in the vicinity where the assessment was made, and record the number of the photo file in the field notebook

*5.1 Rapid Water Assessment*

Rapid Water Assessment can be conducted at many locations, since it only takes a few minutes. In terms of the Vital Signs sampling frame, it is an equivalent of the Rapid Roadside Assessments carried out in terrestrial ecosystems or agricultural plots. **It should be done every time a gauging station is visited for data collection, or a sample is taken for in field analysis or laboratory analysis**. This allows the numerous but approximate visual assessment data to be calibrated against the sparser, but more rigorous quantitative assessments.

This activity is mostly a **visual assessment of the river stage (i.e. water depth) and quality**, and should take no more than a few minutes. It is done repeatedly (about monthly is ideal, but in the worst case quarterly) at easily-reached, well-known places that you pass on the way to and from other tasks (for instance, at a place where a road crosses a bridge, or where people get their water, bathe or wash clothes).

At the first visit, record the latitude and longitude of the location, give it a unique code number and write a short description of the place into your field logbook. Thereafter, you just need to record the date and unique code number before the observations.

1. On the rapid water assessment data form, write down the location code, date and time of observation, and the name of the observer.

2. Record the **water height**, preferably against a permanently installed marker (or, if this is not

possible, against reference point, e.g. '1 m below the road level). If all else fails, use a description like 'dry', 'isolated pools' 'low flow,' 'normal flow,' 'high flow' and 'in flood.'

3. Observe the **water surface** and check one or more of the boxes. [floating aquatic weeds/algal scum/flood debris/rubbish/foam/oily sheen/metallic sheen]. Give a cover score between 0 and 10 (ie % of the water body surface area divided by 10).

4. Dip a sample in a clear jar with a 100 mm diameter. How does the water appear? Tick off the boxes for color [no color / milky / blue / muddy / green / rusty / black] and for clarity or opaqueness [clear / slight / moderate / very opaque]. The definitions are: clear (apparently perfect for drinking or washing); slight (noticeable looking through the 100 mm jar but not enough to put you off drinking, fine for washing); moderate (would stain white clothing is used for washing); very opaque (can hardly see through the bottle, unusable for drinking or washing).

5. If possible, **take a Secchi disk reading**. Lower the disk into the water until you just can't see the disk. The measurement is the length of the cord between the disk and the water surface.

6. Sniff the water and tick one or more boxes for odor: [no smell/muddy/rotting plants/sulfurous ('rotten eggs')/rotting

fish/sewage/chemical/metallic] and intensity [none/ slight/moderate/strong] where the definitions are none (no detectable odor except of fresh water); slight (just detectable unpleasant smell, not enough to put you off drinking it); moderate (significantly degrades the quality of water for drinking purposes); strong (unacceptable for drinking).

7. The following item is optional: if the water is in your opinion safe to drink (for instance, if people are routinely drinking it, or it is intended for drinking), taste a tiny sip (through a Life Straw if there is any doubt about the water safety) and check the boxes [not tasted/fresh/muddy/soapy/salty/metallic/rotten-tasting] and score the intensity of the taste [none/slight/moderate/severe] where slight means detectable, but not degrading its usability for drinking; moderate is pronounced to the point where it is unpleasant to drink, but fine for washing; severe is so strong that it is unsuitable for drinking, washing or irrigation.

8. Check the boxes for riverine biota [dead fish/dead animals/flourishing plants/dying plants/dead plants/alien weeds]

9. Can you observe any water-use activities nearby? Is water being drawn for drinking, livestock watering, bathing, washing or irrigation? Is waste water running into it? Is there evidence of fishing?

10. Take a photograph of the water body in the vicinity where the assessment was made, and record the number of the photo file in the field notebook.

*<u>5.2 Indicator Organism River Health Assessment</u>*

Aquatic organisms act as bio-indicators of recent water quality. **You can assess river health by looking for various types of organisms** – which have different water quality requirements – and by calibrating their presence and abundance against known standards for the region.

This is equivalent to the terrestrial measurements taken in an E-plot, but in the case of a river, takes place along a **river 'reach' of about 50 m**, rather than 1 ha plot.

The assessment takes about two hours per site, and requires some training to be able to recognize the organisms. Be very careful doing this assessment in rivers and lakes with known hazards, such as crocodiles, hippos, river-borne diseases (like schistosomiasis), under flood conditions, or with people who may be unable to swim if they fall in accidentally.

What follows is a brief summary of the **South African Scoring System (SASS) Version 5**. For the full method, including the calculations, see Dickens and Graham (2002).

You will need a soft net with a 1 mm mesh, a tray, tweezers and pipette with which to sort organisms, a magnifying glass and a book of illustrations (DWAF 2002) to help the identification into broad groups. You may also need waders and perhaps a life jacket if the water is swift and deep and you are not a good swimmer.

1. Record the date, observer, latitude, longitude and altitude of the sample site and describe it in terms of the:

    a. Geomorphological zone (e.g. headwater, foothills, lowlands)

    b. Hydrological type (perennial, seasonal, ephemeral)

    c. Water level at time of sampling

    d. Degree of riparian habitat integrity

    e. Land use in the catchment, and

    f. Extent of each of the biotypes (aquatic organism habitats) present. The list of biotypes is: Stones In Current (SIC); Stones Out Of Current (SOOC); Marginal Vegetation In Current (MV-IC); Marginal Vegetation Out Of Current (MV-OC); Aquatic Vegetation (AQV); Gravel (G); Sand (S) Silt/mud/clay (M). The biotope abundance is 0 - absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – entire.

2. Kick the stones in current (SIC) and bedrock for 2 minutes if stones are loose or up to maximum 5

minutes if they are immovable. Catch any organisms that are flushed out in the net.

3. Kick stones out of current (SOOC) and bedrock for 1 minute and catch the organisms. SIC and SOOC samples are combined into a single Stones (S) biotope.

4. Sample a total length of two meters of vegetation on the edge of the water including in current and out of current.

5. Sample an area of aquatic vegetation of $1m^2$. Combine the MV-IC, MV-OC and AQV samples into a single vegetation (Veg) biotope sample.

6. Stir and sweep gravel, sand and mud, both in and out of current, for 1 minute total, and combine into a single Gravel, Sand & Mud (GSM) biotope sample.

7. Do hand picking and visual observation for 1 minute, recording the in biotope where the organisms are found.

8. For each of the 3 major biotopes (Stones, Veg, GSM), tip the contents of the net into a tray. Remove leaves and twigs, and score the organism types found for 15 minutes per biotope. Stop if no new taxa seen after 5 minutes.

The abundances are scored per organism group on the data sheet (see Appendix 2), as follows:

1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000.

Back at base you can add up the scores. The calculation of an overall ‘River Health Score’ is quite complicated and will be done automatically at the VS regional headquarters. It depends on having established ‘baseline’ community compositions for a range of situations, and the initial purpose of the VS measurements is to establish such baselines.

*5.3 In-Field Water Analysis*

Some water quality variables change if you store the sample too long, especially if they get warm. These include analyses for pH, nitrates and microbiological variables.

Ideally, **these analyses should be done within 24 hours of collecting the sample, and preferably within 6 hours**. The water should not get warmer than 25° C. The water quality variables selected by VS can be quickly, reliably and easily measured in the field, so making the measurements nearly immediately saves the cost, trouble and delay of transporting the samples to a laboratory. They include pH, electroconductivity (a measure of the dissolved salts in the water) and orthophosphate ($PO_4$), often a measure of pollution from runoff of over-fertilized fields, nitrate and contamination by coliform bacteria.

Review the list of equipment required in Section 3.

Calibrate the combined pH meter, electrical conductivity meter thermometer, the phosphate spectrophotometer and nitrate ion meter before you measure a set of water samples using standard calibration solutions.

What follows is the field procedure to follow at a designated water quality sampling station (which will have a unique number). The frequency of sampling is about once a month to at most twice a year. Conduct a rapid visual water assessment (see method above) and fill in the form at the same time as doing the sampling for in-field analysis.

1. Place a clean, open 500 ml sample bottle in the bottle holder of the telescopic sample rod.

2. Holding the other end of the extended sample pole, dip the bottle quickly but gently about 30 cm below the water surface (without stirring up any bottom sediment), with the opening pointing upstream about a meter or more away from the edge. In still water, move the bottle underwater gently forward as it fills. The bottle should fill without sucking in any surface or bottom scum.

3. Lift it out quickly once it is full and tip out about a cm of water before you put on the bottle lid – this is to keep any microbes in the bottle alive and oxygenated. Dry the outside of the bottle and label it with a waterproof pen with the unique sample station code and the date.

When you have taken several samples on one day you can take the samples to a relatively clean and steady place nearby (keep the samples in an insulted ‘cooler box’ until you analyze them). This will usually be at your field camp or next to your vehicle.

1. Wash your hands thoroughly with soap and water and then with an alcohol-based hand cleaner to ensure that you do not contaminate the sample.

2. Enter the analysis date, your name and the temperature of the sample (as given by the combined temperature, pH and EC meter) into the water quality data form.

3. Follow the detailed instructions that come with the combination pH/EC/temperature meter for this step and for later measuring the sample. Switch on, remove the protective cap, rinse the sensor and calibrate the combined pH/EC/temperature meter using two pH buffers (4.01 and 7.01) and a standard EC solution (12.88 mS/m). Enter the values obtained into the data sheet, and rinse the sensor with clean water. Stand the instrument in clean water between taking sample measurements so that the pH bulb does not dry out.

4. Follow the detailed instructions that come with the nitrate specific ion meter for this step and for later measuring the sample. Switch on and calibrate the nitrate specific ion meter using one or two standard calibration solutions (30 and 150 ppm are appropriate). Write the value given after calibration onto the form. Rinse out the sample chamber of the ion using clean water and close its lid.

5. Follow the detailed instructions that come with the

phosphate meter for this step and for later measuring the sample. What follows is a summary. Switch on the phosphate spectrophotometer.  Zero the instrument using a cuvette filled with clean water. Calibrate the instrument using at least one phosphate standard (a known concentration in the vicinity of 2 ppb), poured into a cuvette and with a sachet of reagent added, and shaken for 2 minutes. Write the calibration value into the data form. Discard the calibration sample into a disposal jar. Rinse out the cuvette with clean water.

6. Without touching the water with your hands, pour out a 40 ml subsample of your first water sample into a test tube in the rack. Record the sample code in a row of its own on the data sheet. Replace the lid on the sample bottle, and only throw the bulk water sample out once you are satisfied with the tests, in case you need to re-do them. If you need to redo the CBT test, the water must be no older than 6 hours. If you are still nearby your sample location, you can re-use your sample bottle to take another sample from the same place for laboratory analysis (see below), if that is required.

7. Pour a few ml of the sample from the test tube into the phosphate cuvette, put the cuvette into the spectrophotometer, close the lid and zero the instrument (this is called a ‘blank’). Into a second cuvette pour another subsample from the test tube and add the contents of one reagent sachet. Close the cap and shake for 2 minutes. Put the cuvette into the spectrophotometer and read the phosphate

concentration. After reading, discard the sample containing the reagent into a waste jar and rinse the cuvette.

8. Put a few drops of the sample into the sample chamber of the nitrate specific ion meter, close the chamber and read the nitrate concentration. Discard the sample, rinse the chamber with clean water, and shake it dry.

9. Put the bulb of the combined pH/EC/temperature meter directly into the test tube with the remaining sample and record the pH and EC onto the datasheet.

10. Label a new CBT bag with the sample code. Pour a sample of about 100 ml in total directly from the sample bottle into the CBT bag for the E.coli test (). Squeeze gently to fill all the compartments. Add a growth medium bud, seal the bag with a clip and put it in the incubator.

11. Repeat from step 6 with the next sample.

12. When you are finished with all the samples, switch off the instruments, rinse them and the test tubes with clean water and airdry them. Close the bottle with the discarded phosphate samples and keep it for proper disposal.

**For the Coliform Bacteria Test:**

1. Incubate the bags for 24 hours at 40° C in a field

incubator (a temperature-controlled thermo-electric 'hot-box' powered off your car battery). If you do not have an incubator, but the air temperature is above 25° C, the CBT can be 'incubated' in an ordinary box, but will take 2 days to develop color.

2. After the incubation period, record on the data sheet which compartments have turned blue.

3. Look up the equivalent E coli MPN (most probable number) on the table that comes with the kit and record the MPN on the datasheet.

*Figure 2: squeezing the CBT bag to fill the compartments.*

4. Place a chlorine tablet (supplied with the CBT kit) in the CBT bag and reseal it to decontaminate. The bag contents can be flushed down a toilet

after about an hour, and the bag can be responsibly disposed in a landfill. Wear gloves while you empty the bags, and wash your hands afterwards.

### *5.4 Taking Water Samples for Laboratory Analysis*

Instead of doing field analyses, you can deliver the samples to a water analysis laboratory if one exists in the region and can be reached within about half a day of taking the sample. The sample station should have a unique code number, which is written in the field notebook, along with the exact GPS location, taken on the first visit to the location. Create one of your own, and keep it short and simple.

**Always take the samples from the same place at the sample site**. For this reason, write a clear description of where the sample was taken the first time the site was visited, and have it available in the field notebook for future visits. This is in addition to recording the latitude and longitude of the sample location, in decimal degrees with 5 significant digits.

Conduct a rapid water assessment (see method above) and if the analysis laboratory requires particular information to accompany the sample that is not already part of the rapid assessment, collect that information.

1. Open a clean 500 ml sample bottle and place it in the bottle holder of the telescopic sample rod

2. Holding the other end of the extended sample

pole, dip the bottle about 10cm below the water surface, so that the bottle fills without sucking in any surface scum. Lift it out quickly once it is full.

3. Put the lid, finger-tight, onto the full bottle.

4. Remove the bottle from the sampling rod, dry it, and fill in the label on the bottle with the location code and the date of sampling.

5. Record the date and time of sampling in the field logbook and fill in any form that the analyzing laboratory might need to accompany the sample.

6. Put the filled, labeled bottle into an insulated storage box (a ‘cooler box’) for transport to the laboratory. Water samples for chemical analysis should be analyzed as soon as possible, and should not be allowed to get hot. If microbial analysis is to be done, the sample must reach the laboratory within 24 hours and must stay cold (in a fridge, or a cool box containing ice).

7. Keep the laboratory sample forms separate, in a dry place, and hand them in with the sample.

8. When the laboratory has completed the analysis, enter the results in the VS water quality database, along with the sample code and date of sampling. File the data report from the laboratory in sequence of analysis date.

9. In most cases the laboratory will supply you with

clean sample bottles. If they return your bottles without first cleaning and sterilizing them, you can do so yourself by removing the label (wipe off the waterproof ink using alcohol). Wash the bottle and their lids in hot water with detergent, then in a solution of 10% sodium hypochlorite solution (bleach) to sterilize them, and finally rinse them several times with clean water before allowing them to air-dry, upside down, on a drying rack. Once dry, seal the bottle with a lid, and pack it into the insulated box ready to return to the field.

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# 7. APPENDICES

| **Vital Signs Water Quality Analysis Data Form** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date of analysis | | | Analyst name | | | | Sample temperature | | | |
| Calibration performed | | | pH 4 | pH 7 | EC | EC | $NO_3$ | $NO_3$ | $PO_4$ | $PO_4$ |
| Calibration result | | | | | | | | | | |
| Sample Code | pH | EC | $NO_3$ | $PO_4$ | Compartment Bag Test color change (mark compartments that turned blue) | | | | | MPN |
| | pH units | mS/m | mg/l | mg/l | 1 ml | 3 ml | 10 ml | 30 ml | 50 ml | #/100 ml |
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**Table 1:** The SASS Version 5 scoring sheet

**SASS Version 5 Score Sheet**

**Date:** / /200__

**Collector:** . .

Grid Reference: WGS-84 | Cape datum

S: ° ' , " E: ° ' , "

**Site code:**

**River:...** ... .... ... .........................

Site description:.........................................

Weather Condition:.......................................

Temp:...................°C pH:.....................

DO:.....................mg/l Cond:...........mS/m

**Biotopes sampled:**

SIC ...................... Time..................minutes

SOOC.................. Time..................minutes

Average size of stones......................cm

Bedrock...............

Aquatic veg'n......... Dom. sp..................................

MvegIC............. Dom. sp..................................

MvegOOC........... Dom. sp..................................

Gravel.................. Sand.................

Mud.......................

Hand picking/Visual observation................

**Flow:** Low/Medium/High/Flood

**Turbidity:** Low/Medium/High

**Riparian land use:**

**Disturbance in the river:** eg. sandwinning, cattle drinking point, floods etc.

**Observations:** eg. smell and colour of water, petroleum, dead fish, etc.

| Taxon | | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **PORIFERA** | 5 | | | | |
| **COELENTERATA** | 1 | | | | |
| **TURBELLARIA** | 3 | | | | |
| **ANNELIDA** | | | | | |
| Oligochaeta | 1 | | | | |
| Leeches | 3 | | | | |
| **CRUSTACEA** | | | | | |
| Amphipoda | 13 | | | | |
| Potamonautidae* | 3 | | | | |
| Atyidae | 8 | | | | |
| Palaemonidae | 10 | | | | |
| **HYDRACARINA** | 8 | | | | |
| **PLECOPTERA** | | | | | |
| Notonemouridae | 14 | | | | |
| Perlidae | 12 | | | | |
| **EPHEMEROPTERA** | | | | | |
| Baetidae 1sp | 4 | | | | |
| Baetidae 2 sp | 6 | | | | |
| Baetidae > 2 sp | 12 | | | | |
| Caenidae | 6 | | | | |
| Ephemeridae | 15 | | | | |
| Heptageniidae | 13 | | | | |
| Leptophlebiidae | 9 | | | | |
| Oligoneuridae | 15 | | | | |
| Polymitarcyidae | 10 | | | | |
| Prosopistomatidae | 15 | | | | |
| Teloganodidae SWC | 12 | | | | |
| Tricorythidae | 9 | | | | |
| **ODONATA** | | | | | |
| Calopterygidae ST,T | 10 | | | | |
| Chlorocyphidae | 10 | | | | |
| Chlorolestidae | 8 | | | | |
| Coenagrionidae | 4 | | | | |
| Lestidae | 8 | | | | |
| Platycnemidae | 10 | | | | |
| Protoneuridae | 8 | | | | |
| Aeshnidae | 8 | | | | |
| Corduliidae | 8 | | | | |
| Gomphidae | 6 | | | | |
| Libellulidae | 4 | | | | |
| **LEPIDOPTERA** | | | | | |
| Pyralidae | 12 | | | | |

| Taxon | | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **HEMIPTERA** | | | | | |
| Belostomatidae* | 3 | | | | |
| Corixidae* | 3 | | | | |
| Gerridae* | 5 | | | | |
| Hydrometridae* | 6 | | | | |
| Naucoridae* | 7 | | | | |
| Nepidae* | 3 | | | | |
| Notonectidae* | 3 | | | | |
| Pleidae* | 4 | | | | |
| Veliidae/M...veliidae* | 5 | | | | |
| **MEGALOPTERA** | | | | | |
| Corydalidae | 8 | | | | |
| Sialidae | 6 | | | | |
| **TRICHOPTERA** | | | | | |
| Dipseudopsidae | 10 | | | | |
| Ecnomidae | 8 | | | | |
| Hydropsychidae 1 sp | 4 | | | | |
| Hydropsychidae 2 sp | 6 | | | | |
| Hydropsychidae > 2 sp | 12 | | | | |
| Philopotamidae | 10 | | | | |
| Polycentropodidae | 12 | | | | |
| Psychomyiidae/Xiphocen | 8 | | | | |
| **Cased caddis:** | | | | | |
| Barbarochthonidae SWC | 13 | | | | |
| Calamoceratidae ST | 11 | | | | |
| Glossosomatidae SWC | 11 | | | | |
| Hydroptilidae | 6 | | | | |
| Hydrosalpingidae SWC | 15 | | | | |
| Lepidostomatidae | 10 | | | | |
| Leptoceridae | 6 | | | | |
| Petrothrincidae SWC | 11 | | | | |
| Pisuliidae | 10 | | | | |
| Sericostomatidae SWC | 13 | | | | |
| **COLEOPTERA** | | | | | |
| Dytiscidae* | 5 | | | | |
| Elmidae/Dryopidae* | 8 | | | | |
| Gyrinidae* | 5 | | | | |
| Haliplidae* | 5 | | | | |
| Helodidae | 12 | | | | |
| Hydraenidae* | 8 | | | | |
| Hydrophilidae* | 5 | | | | |
| Limnichidae | 10 | | | | |
| Psephenidae | 10 | | | | |

| Taxon | | S | Veg | GSM | TOT |
|---|---|---|---|---|---|
| **DIPTERA** | | | | | |
| Athericidae | 10 | | | | |
| Blepharoceridae | 15 | | | | |
| Ceratopogonidae | 5 | | | | |
| Chironomidae | 2 | | | | |
| Culicidae* | 1 | | | | |
| Dixidae* | 10 | | | | |
| Empididae | 6 | | | | |
| Ephydridae | 3 | | | | |
| Muscidae | 1 | | | | |
| Psychodidae | 1 | | | | |
| Simuliidae | 5 | | | | |
| Syrphidae* | 1 | | | | |
| Tabanidae | 5 | | | | |
| Tipulidae | 5 | | | | |
| **GASTROPODA** | | | | | |
| Ancylidae | 6 | | | | |
| Bulininae* | 3 | | | | |
| Hydrobiidae* | 3 | | | | |
| Lymnaeidae* | 3 | | | | |
| Physidae* | 3 | | | | |
| Planorbinae* | 3 | | | | |
| Thiaridae* | 3 | | | | |
| Viviparidae* ST | 5 | | | | |
| **PELECYPODA** | | | | | |
| Corbiculidae | 5 | | | | |
| Sphaeriidae | 3 | | | | |
| Unionidae | 6 | | | | |
| **SASS Score** | | | | | |
| **No. of Taxa** | | | | | |
| **ASPT** | | | | | |

Sample collection effort exceeds method? .....

**Other biota including juveniles:**

**Comments:**

Procedure: 'Kick SIC & bedrock for 2 mins, max. 5 mins; Kick SOOC & bedrock for 1 min; Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m$^2$; Stir & sweep gravel, sand, mud for 1 min total; * = airbreathers; Hand picking & visual observation for 1 min — record in biotope where found; Score for 15 mins/biotope but stop if no new taxa seen after 5 mins; 'Estimate abundances: 1 = 1, A = 2–10, B = 10–100, C = 100–1 000, D = >1 000; S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud; SWC = South Western Cape; T = Tropical; ST = Sub-tropical; Rate each biotope sampled: 1 = very poor (i.e. limited diversity), 5 = highly suitable (i.e. wide diversity)

**Rapid Water Assessment Form**
Version: 1.0

| | Form Value | Definition | Data Type | Values List | Example | Empty Value | Rules/Comments |
|---|---|---|---|---|---|---|---|
| | **Country** | The VS country three-letter abbreviation. | string | None | TAN | Required | |
| | **Rapid Water Assessment no.** | A unique alphanumeric code assigned to each rapid water assessment station in a country. Prefixed by W, sequential number 000 to 999 | alphanumeric | None | W0004 | Required | |
| | **Tier 2b Rapid Water Assessment code** | A unique i.d. code for each rapid water assessment in each country. The code contains two components: "3-letter country code - Rapid Water Assessment Number" For example, TAN_W0004 refers to rapid water assessment number 4 in Tanzania. The id numbers will be assigned automatically. | formula | None | TAN_W0004 | Required | |
| **Date of Rapid Water Assessment** | **Year** | The year of assessment (YYYY) | numeric | {>=2013} | 2014 | Required | |
| | **Month** | The month of the assessment (MM) | numeric | {1-12} | 03 | Required | |
| | **Day** | The day of the assessment (DD) | numeric | {1-31} | 19 | Required | |
| **Observers name** | **First Name** | The first name of the person recording information onto the Field Form. | string | None | Mark | Required | |
| | **Last Name** | The last name of the person recording information onto the Field Form. | string | None | Musumba | Required | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Geog. co-ord's of the rapid assessment | **Assessment Latitude** | Latitude of the point at which the rapid water assessment is taken in decimal degrees | numeric | 90 to -90 | -10.41199 | Required | The geographical co-ordinates of the point at which the water assessment is undertaken |
| | **Assessment Longitude** | Longitude of the point at which the rapid water assessment is taken in decimal degrees | numeric | 0 to 360 | 84.00677 | Required | The geographical co-ordinates of the point at which the water assessment is undertaken |
| Photo | **Photograph file name** | The file name of the photograph as assigned by the camera after the capture of the image | string | None | IMG_4026.jpg | Required | A panoramic photograph needs to be taken at the point where the water sample is taken |
| | **Water sample code (if applicable)** | A unique water sample code that is linked to the rapid water assessment code.<br>The code contains three components: "3-letter country code - WS (water sample) - Rapid Water Assessment Number"<br>For example, TAN_WS_0004 refers to the water sample taken at the location of rapid water assessment number 4 in Tanzania. The id numbers will be assigned automatically. | numeric | None | TAN_WS_0004 | Required | |
| | **Water depth against marker (if applicable) m** | Water depth should be measured against the marker in m, to one decimal point | numeric | None | 1.2 | NULL | Some bridges or weirs will have a metered depth scale attached to them, reading upwards from the lowest water level. |
| | **Open water** | Open water score between 0-10. After assessing the relative proportion of each surface type across the water transect, the observer needs to assign a score between 0-10 for each type | numeric | {0-10} | 2 | Required | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Surface cover on transect across water body | **Algal scum** | Algal scum score between 0-10. After assessing the relative proportion of each surface type across the water transect, the observer needs to assign a score between 0-10 for each type | numeric | {0-10} | 1 | Required | |
| | **Aquatic plants** | Aquatic plants score between 0-10. After assessing the relative proportion of each surface type across the water transect, the observer needs to assign a score between 0-10 for each type | numeric | {0-10} | 2 | Required | |
| | **Exotic weeds** | Exotic weeds score between 0-10. After assessing the relative proportion of each surface type across the water transect, the observer needs to assign a score between 0-10 for each type | numeric | {0-10} | 1 | Required | |
| | **Litter** | Litter score between 0-10. After assessing the relative proportion of each surface type across the water transect, the observer needs to assign a score between 0-10 for | numeric | {0-10} | 2 | Required | |
| | **Foam** | Foam score between 0-10. After assessing the relative proportion of each surface type across the water transect, the observer needs to assign a score between 0-10 for | numeric | {0-10} | 2 | Required | |
| | **Oily / metallic sheen** | Oily / metallic sheen score between 0-10. After assessing the relative proportion of each surface type across the water transect, the observer needs to assign a score between 0-10 for each type | numeric | {0-10} | 1 | Required | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Flow status** | The observer is required to choose only one the following flow status classes (Dry, Isolated Pools, Low, Normal, High, Flood) | string | {Dry, Isolated Pools, Low, Normal, High, Flood} | High | Required | The observer may only choose one flow status class |
| **Appearance colour** | The observer is required to choose only one the following appearance colour classes (Clear, Muddy, Milky, Tea-colour, Green) | string | {Clear, Muddy, Milky, Tea-colour, Green} | Clear | Required | The observer may only choose one appearance colour class |
| **Appearance intensity** | The observer is required to choose only one the following appearance intensity classes (None, Just detectable, Noticeable but drinkable, Not suitable for drinking, Not suitable for washing clothes) | string | {None, Just detectable, Noticeable but drinkable, Not suitable for drinking, Not suitable for | Just detectable | Required | The observer may only choose one appearance intensity class |
| **Smell type** | The observer is required to choose only one the following smell type classes (Clean / none, Peaty / earthy, Rotten / dead fish, Sewage) | string | {Clean / none, Peaty / earthy, Rotten / dead fish, Sewage} | Peaty / earthy | Required | The observer may only choose one smell type class |
| **Smell intensity** | The observer is required to choose only one the following smell intensity classes (None, Noticeable but not offensive, Not suitable for drinking) | string | {None, Noticeable but not offensive, Not suitable for drinking} | Noticeable but not offensive | Required | The observer may only choose one smell intensity class |
| **Taste (optional)** | Optional, as observers discretion. The observer should choose only one the following taste classes (Clean, Salty / brack, Muddy, Soapy, Chemical, Rotten) | string | {Clean, Salty / brack, Muddy, Soapy, Chemical, Rotten} | Clean | NULL | At the observer discretion, but if the observer does proceed with the taste assessment, only one taste class should be chosen. |
| **Taste intensity (optional)** | Optional, as observers discretion. The observer should choose only one the following taste intensity classes (Clean, Unpleasant to drink, Offensive / unsuitable to drink) | string | {Clean, Unpleasant to drink, Offensive / unsuitable to drink} | Clean | NULL | At the observer discretion, but if the observer does proceed with the taste intensity assessment, only one taste class should be chosen. |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Observed use** | The observer is required to choose none, one or more of the following observed use classes (Drinking, Livestock watering, Washing clothes, Irrigation, Mining / industrial) | string | {Drinking, Livestock watering, Washing clothes, Irrigation, Mining / industrial} | Drinking | NULL | The observer can leave this option open if no use is observed or choose one or more use classes. |

**Water Laboratory Analysis Form**

Version: 1.0

| | Form Value | Definition | Data Type | Values List | Example | Empty Value | Rules/Comments |
|---|---|---|---|---|---|---|---|
| **Date of laboratory analysis** | **Year** | The year of assessment.(YYYY) | numeric | {>=2013} | 2014 | Required | |
| | **Month** | The month of the assessment (MM) | numeric | {1-12} | 03 | Required | |
| | **Day** | The day of the assessment (DD) | numeric | {1-31} | 19 | Required | |
| **Analysts name** | **First Name** | The first name of the person performing the laboratory analysis | string | None | Mark | Required | Will be generated by pick list on tablet |
| | **Last Name** | The last name of the person performing the laboratory analysis | string | None | Musumba | Required | Will be generated by pick list on tablet |
| | **Sample note (optional)** | General optional notes regarding the source of the batch of samples or any pertinent issues arising during the analysis process. | string | None | | NULL | |
| | **Temperature** | Temperature of the water samples in degrees Celsius (c) at the time of analysis | numeric | None | 23 | Required | Measured during the EC calibration process and used to convert EC to salinity if required |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ter sample data | **Sample code** | A unique water sample code that is linked to the rapid water assessment code.<br>The code contains three components: "3-letter country code - WS (water sample) - Rapid Water Assessment Number"<br>For example, TAN_WS_0004 refers to the water sample taken at the location of rapid water assessment number 4 in Tanzania.<br>The id numbers will be assigned automatically. | numeric | None | AN_WS_000 | Required | Note that the date and location (GPS co-ords) of the sample is recorded in the rapid water assessment form |
| | **pH measurement** | pH is a measure of the acidity or alkalinity of the water sample that is determined by the relative number of hydrogen ions (H+) to hydroxyl ions (OH-) present. A neutral water sample has a pH of 7,0 while samples with a pH <7 are acidic and samples with a pH >7 are alkaline. | numeric | {0-14} | 7,2 | Required | A value between 1-14, measured to one decimal place |
| | **Conductivity measurement** | Electrical conductivity (EC) can be defined as the ability of a sample to conduct electrical current. It is measured in the units: milliSiemen per m (mS/m). | numeric | {0-20} | 0,75 | Required | A value between 0-20, measured to two decimal places |
| | **NO3 concentration** | The measured concentration of nitrate in the water sample, recorded in the units: milligram per litre (mg/l) | numeric | {0-2000} | 45.1 | Required | Nitrate concentration should be measured in mg NO3/l (ie ppm, whole ion) with no decimal place |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wa | **PO4 concentration** | The measured concentration of phosphate in the water sample recorded in the units: milligram per litre (mg/l) | numeric | {0-200} | 42 | Required | Phosphate concentration should be measured in mgPO4/l (ie ppm)to no decimal places |
| | **Compartment bag 1** | Colour change in the 10 ml compartment | binary | {0-1} | 0 | Required | Use the pattern of colour change across the 5 bags to estimate E coli MPN |
| | **Compartment bag 2** | Colour change in the 30 ml compartment | binary | {0-1} | 0 | Required | Use the pattern of colour change across the 5 bags to estimate E coli MPN |
| | **Compartment bag 3** | Colour change in the 56 ml compartment | binary | {0-1} | 1 | Required | Use the pattern of colour change across the 5 bags to estimate E coli MPN |
| | **Compartment bag 4** | Colour change in the 3 ml compartment | binary | {0-1} | 0 | Required | Use the pattern of colour change across the 5 bags to estimate E coli MPN |
| | **Compartment bag 5** | Colour change in the 1 ml compartment | binary | {0-1} | 0 | Required | Use the pattern of colour change across the 5 bags to estimate E coli MPN |
| | **Ecoli MPN** | Estimated from compartments which changed colour as a Most Probable Number of organisms per 100ml | numeric | {0-100} | 50 | Required | The Most Probable Number score. This should be calculated from a series of 5 tick-boxes marked if a particular culture volume had turned dark. See Aquagenx guidance sheet |

# Vital Signs Protocol

## Weather Stations

Version 1.0

March 2014

## CONTENTS

# 1. INTRODUCTION

Weather data, and the climate data that results from the analysis of long time-series of weather data, is among the most fundamental of environmental information.

It is needed by most parts of Vital Signs (VS) as well as by many users outside VS. Yet reliable weather and climate data is often hard to get for large parts of the world. The VS contribution to help fill this gap is small, nowhere near the measurement density needed for recommended levels of coverage at regional scale. VS expects that national weather services have that responsibility, and VS simply aims to supplement the coverage in places critical to VS needs, namely in the intensively-sampled landscapes.

For regional-scale continuous coverage of weather observations, VS depends on 'data assimilation products,' which fuse information from meteorological satellites, ground stations of national networks, and atmospheric physics models similar to those used for weather forecasting. These products, which currently have a resolution as fine as 10 km at regional scale, are reasonably accurate when aggregated to large areas and over a period of weeks to months, but may be quite far off at a particular point and at the daily time scale.

The function of the VS weather stations is to help calibrate and validate these products at regional scale, and stand in for them at local scale and for hourly to daily data within the landscapes.

**Vital Signs specifies two types of automatic recording weather station**. The first type ("**full station**") records rainfall, temperature, humidity (RH), wind speed, barometric pressure and incoming shortwave radiation. The sensors must conform to World Meteorological Organization (WMO) standards of accuracy and maintenance, and the siting (location) of the station must meet WMO standards for a Class 1 station (Table 1). Since national meteorological services also adhere to these standards, it follows that VS weather data should also satisfy national requirements.

The second type of VS station ("**mini station**") records only rainfall and temperature. The rainfall and temperature sensors are of the same or only slightly lower accuracy to those used in the full weather stations, and the siting requirements for mini stations conform to those for WMO class 3 stations.

The WMO standards do not specify which of the many available types of datalogger should be used. VS has chosen the Onset U30 for its full weather station. The mini-weather stations have a built-in Onset Hobo pendant event and temperature datalogger.

*Table 1: the specifications and standards for sensors linked to the VS full weather station. (The sensor specifications for the VS mini station, which records only rainfall and temperature, are the similar to those for the full station, but the temperature accuracy is only 0.5°C and the location restrictions can be relaxed to having no obstacles within 4 times their height away from the rain gauge.)*

| | Rainfall | Air temperature | Humidity | Atmospheric pressure | Solar radiation | Wind speed |
|---|---|---|---|---|---|---|
| **Units** | mm | °C | % relative humidity | mBar | W/m$^2$ | m/s |
| **Specification** | 15.4 cm orifice (6") | -20 to +70 °C | 0-100% | 660-1070 mBar | 0-1280 W/m$^2$ | 0-45 m/s |
| **Accuracy** resolution | 2% (0.25 mm) | 0.21 (0.02) C° | 2.5% (0.1%) | 3 (0.1) mBar | 10 W/m$^2$ ie 5% (1.25 W/m$^2$) | 1.1 m/s (0.4 m/s) |
| **Exposure and location of the sensor** | No obstacles closer than 10 x their height. Orifice horizontal and at least 30 cm above ground. Preferred height 2 m | In a radiation shield, passively ventilated, at 2 m above ground, away from highly reflective or absorptive surfaces and water bodies | | Inside the instrument cabinet which houses the datalogger with free access to outside air. | Horizontal, no objects obscuring the sky to within 5° of the horizon. | 3 m or higher above the ground, at least 10 x the height of any obstacles away from them |
| **VSA recom-mended model** | Onset RGB-M002 | Onset S-THB-M002 | | Onset S-BPA-CM10 | Onset S-LIB-M003 | Onset S-WDA-M003 |

The Onset U30-GSM was chosen because it is reliable but affordable, meets the accuracy and capacity requirements, has low power consumption (which means that it can be powered for long periods using a battery alone, eliminating the need for solar panels), uses the same download software as other data loggers used in VS and can be communicated with using GSM cell phone technology. Other makes and models of datalogger can be used in the full weather stations, provided that they have at least 5 analog input channels and one pulse sensor channel and 12-bit resolution.

Examples of the questions that can be addressed with this protocol include:

- What were the weather drivers of agricultural and ecosystem service yields observed in the same season?
- What is the climate of a given area, and is it suitable for particular crops?
- Is the climate changing?

*1.1 Definitions of Key Technical Terms*

**Anemometer:** an instrument to measure wind speed, consisting of three cups spinning on a vertical axis.

**Automatic Weather Station (AWS):** a combination of a datalogger, weather sensors, power supply, supporting mast and in some cases communication equipment, which collects weather data continuously and unattended.

**Datalogger:** the electronic device that reads information from the weather sensors, stores it and in some cases sends it via cell phone communication to the VS office.

**GSM:** a cellphone communication technology that allows data to be sent from the weather station to a remote database.

**Landscape**: a 10 km x 10 km area in which Vital Signs develops an understanding of the spatial and temporal dynamics of agriculture, ecosystems and human well-being.

**Pyranometer**: an instrument to measure the energy coming from the sun. In the VS case, this is solar radiation in the wavelengths 300 to 1100 nm (the 'shortwave').

**Relative Humidity (RH)**: the amount of water vapor in the air relative to the amount of water vapor it could hold at that temperature. See note on table 2.

*1.2 Standard Conventions Used in this Document*

The following conventions are used throughout this document:

- The use of **bold** in the text indicates a critical point. **Please pay special attention to terms, sentences and paragraphs marked in bold** as they are key to the understanding of the protocol.

## 2. ROLES AND RESPONSIBILITIES

The following table introduces the roles and responsibilities of a Vital Signs team:

| Role | Responsibility |
| --- | --- |
| Technicians | • Install weather stations<br>• Visit weather stations every 3 months, or as needed, to maintain them and download data. |
| Technical Manager | • Supervises teams<br>• Ensures equipment is well-managed and team is safe<br>• Ensures consistency and quality of measurements<br>• Ensures data are checked and uploaded to the VS server<br>• Performs monthly and annual data analyses and reporting |
| Country Director | • Develops and submits sampling schedule for approval<br>• Supports team with a complete understanding of the protocol manual<br>• Trains technicians, including initially and occasionally later accompanying them in fieldwork |
| Africa Field Director | • Approves sampling schedule<br>• Helps train technicians and ensure consistency of protocol implementation across Vital |

| | |
|---|---|
| | Signs countries<br>• Reviews data when uploaded<br>• Approves protocol updates and sends out update notifications to field teams |
| Protocol Manager | • Receives and archives comments about the protocol<br>• Updates and re-circulates the protocol |

## 3. EQUIPMENT LIST

The following equipment is required to carry out the activities described in this manual. Before traveling to the field to carry out sampling, **use this list to ensure you have all the equipment needed for the day**.

At the end of each day's work, equipment should be wiped down and stowed correctly so that the team can start working immediately the next morning. This practice also ensures that all equipment is accounted for and does not go missing.

*General Supplies (for all visits to weather station)*

- Maintenance logbook (to note work completed)
- Clipboards, notebooks and pens
- Water to drink and to rinse equipment
- Packs for carrying equipment
- Hat, Sun Lotion
- Vital Signs brochures in local languages
- Identity cards and letters of introduction
- Basic toolkit that includes a hammer, pliers, side-cutter, small, medium and large screwdrivers (both flat and star types), multimeter, socket wrench to fit bolts on the mast, cable ties, insulation tape, cleaning cloth, tape measure, level
- Key to the padlock on the full weather station
- Fully charged 4v 10 Ah lead acid battery for the full weather station, box of lithium batteries for mini stations
- Tipping bucket calibration bottle (fig 1) and as many pre-weighed bottles containing exactly 373 ml of water as the number of stations that must be calibrated
- Optic USB cable to connect to mini weather station and USB cable to connect to full weather stations.
- Laptop with HoboWare pro loaded and preregistered with HoboLink, laptop charger
- You may need a short ladder, chair or box to stand on to be able to clean and service the sensors on the crossbar

In addition to the general supplies, you will need:

*For Installing a Mini Weather Station*

- 2.5 long vertical steel tube about 50 cm diameter
  *or*
  2.2 m long wooden pole 20 cm in diameter
- Spade to dig a hole for the pole, concrete to fill it
- GPS and camera when first installing the station.
- Rain Gauge Onset RG3-M
- Radiation Shield RS1 or M-RSA

*For Installing a Full Weather Station*

- Spade and machete to level and clear the site
- GPS and camera when first installing the station.
- U30-GSM in its weatherproof box, SIM card fitted
- 4 V 10 Ah battery with cable
- Tipping bucket raingauge RGB-M002
- Smart sensors for temperature and humidity, shortwave radiation, wind speed and barometric pressure
- Mast kit and crossarm, RS3 radiation shield
- Fencing materials if decided it is needed, for a 3m x 3 m fence 1 m high

## 4. SITE AND SENSOR DESCRIPTION METADATA

When you install the weather stations, collect the following information which describes the station. It will be stored in an **electronic file at the Vital Signs office (plus a paper backup) and must be kept updated when changes occur on the station or its surroundings. This form,** (see Appendix 1) must contain the following information, and the data files need refer to it as the source of 'metadata':

1. Exact GPS location and ground altitude of the station and the name or code that VS gives the station.

2. Make, model and serial numbers of the data logger and all the instruments, noting that the temperature and humidity sensors are in a passively-ventilated radiation shield

3. Height of each of the sensors above the ground surface.

4. Degree of interference from other instruments or obstacles One or more a photos will show this. If you set up the stations as described, there should be no interference between sensors.

5. The near and far surroundings of the weather station, in particular:

    a. The ground cover within 5 m of the station, nearby (within 25 m) major obstacles (buildings, fences, trees) and their size (a panoramic photo and an annotated sketch map will supply this information)

b. The degree of horizon obstruction for sunshine and radiation observations (also backed up by the panoramic photo)

c. Surrounding terrain roughness and the height and cover of vegetation which could influencing the wind

d. All medium-distance (200 m) landscape features such as slopes or hills, paved roads, or water surfaces

e. Major large-scale features (within 5 km), such as coasts, mountains or urbanization.

## 5. FULL WEATHER STATIONS

### *5.1 Choosing a Location for a Full Weather Station*

The purposes of Vital Signs Full Weather Stations are to:

- **Provide the barometric pressure** needed to correct the gauging station water depth sensors;

- **Calculate daily potential evapotranspiration** needed for doing water balance calculations for verifying hydrological models and the water flows measured at the gauging stations; and

# Workflow 1: Full Weather Stations

**Start here**

*Choosing a location for the full weather station*

1. Select the Vital Signs Landscape in which you are going to place the full weather station
2. Ask the local community in the landscape about possible secure locations for the weather station, explaining the key requirements outlined in the protocol
3. Use satellite images of the landscape to help assess potential places, again keeping in mind the key requirements outlined in the protocol
4. When you have identified some candidate locations, negotiate with the people who are responsible for the land to install the weather station

*Installing a full weather station*

1. Follow protocol instructions for checks performed before going to the field
2. Once there, fill in the metadata form for the location and surrounding area of the station
3. Record the GPS location (to within 0.00001 degrees) and altitude (to the nearest m) of the ground below the rain gauge location
4. Assemble the tripod and crossbar, then mount and install the U30 instrument box, sensors, rain guage, and radiation shield
5. Ensure all connectors and cables are installed and plugged in
6. Connect a laptop to the U30 via the USB and open the software. Check that the U30 is collecting data correctly, that the logging interval is 1800 seconds (half an hour) and the connection interval is daily.
7. Disconnect the laptop. Close the door of the U30 with a padlock

*Collecting data from a full weather station (every 3 months)*

1. When you arrive at the weather station for the routine visit, check that the mast is secure
2. Connect the laptop to the U30 USB port, download all data using HoboWare pro, and save the file
3. Check the battery voltage and sensor cable port
4. Clear any debris out of the rain gauge funnel
5. Up-end the bottle with 373 ml of water in the top of the rain gauge so that the water drips out over about 1 hour. The logger should record 98 to 102 tips. Write the # of tips down and record it
6. Check that equipment and cables are undamaged
7. Reset and restart the logger to clear the rainfall data you collected, fill in the service log, and lock up the enclosure

- **Provide comprehensive weather records** to run and validate crop models.

Vital Signs therefore locates full weather stations in places that:

1) Don't already have a full weather station from which the data is available

2) Are in VS landscapes that have VS river gauging stations (this typically amounts to about **2 VS full weather stations per VS region or country**).

Automatic weather stations are quite robust and require little maintenance, but they can be subject to theft, tampering and vandalism. Since they are relatively expensive, and the data is valuable, **it is best to locate full weather stations in secure places**.

It is also desirable to keep them in the same location for many years so that climate data can be accumulated. Locations which are likely to have the same owners or managers in the foreseeable future are desired. The **grounds of government facilities often make good locations**, for example:

- Police Stations
- Schools
- Clinics
- Airports
- Research Stations
- National parks

It helps if the property has a fence to keep out unauthorized people and livestock. The best protection is to have the hosts and community in which the weather station is located feel a sense of ownership and responsibility for the instruments.

Any place within the VS 10 x 10 km landscape is potentially an acceptable location, or even up to 5 km away from its edge. The key requirements are:

- **There are no obstacles which might block the wind or sunlight** from the wind and solar radiation sensors within a distance of 10 times the height of the obstacle

- **The temperature sensor must be well away from large areas that reflect or absorb sunlight** (like dark roads, parking lots or shiny roofs)

- **The RH sensor must be 100 m away from lakes, large rivers or dams**

This means that **you are looking for an open grassy, shrubby or cultivated patch, typically about 50 m across**; preferably neither at the top of a hill nor the bottom of a valley and reasonably level (<19° slope).

A location within range of cell phone reception is highly desirable but not essential, since you can download the data manually. If there is a possibility to mount the wind sensor much higher than 3 m (the ideal is 10 m) on an existing radio mast or other stable structure, that is an advantage.

Ask within the local community in a landscape about possible secure locations for the weather station, and then look on the satellite images of the landscape whether they might have suitable places for a weather station. Once you have located some candidate locations, negotiate with those who are responsible for the land to install a weather station. Explain to them:

- What is does
- That it does not harm the environment or the people around it
- That the data will be freely available and could help guide local decisions
- That it only requires a physical patch of land about 3m x 3m and an agreement not to change the vegetation or buildings immediately around it without letting you know.

You should note that the weather station will be visited by a technician about once every 3 months to download the data and clean the sensors. Electrical power is not needed.

### *5.2 Installing a Full Weather Station*

Once you have decided on a location and negotiated with the owner for permission to place the full weather station there, record the exact GPS location (to within 0.00001 degrees) and altitude (to the nearest m) of the spot on the ground immediately below the rain gauge location.

A detailed description (with photos) of the steps to install, start and collect data from the U30 is given in the manual for the datalogger and the instructions that come with the mast kit and the sensors. Follow those if you are using the U30, or else the instructions that come with other sorts of dataloggers and sensors you may be using. What follows is a summary, assuming you are using a U30 logger and the standard VS sensor set.

Before you go into the field:

- Register the HoboLink software on your laptop via the internet and link it to the specific U30-GSM dataloggers via the serial number inside the box and the VS station name or number.

- Plug the sensors into the U30 in the order (left to right) raingauge, temperature and humidity, pressure, solar radiation, wind speed. This order is not essential (the datalogger recognizes which sensors are plugged in, and where) but it helps with troubleshooting and consistent database structures to do the same on every weather station.

- Plug in the battery and power up the datalogger.

- Connect your laptop to the U30 USB port and configure and test the sensors using HoboLink or HoboWare.

- For the test, set the logging interval to be 5 seconds and manually tip the tipping bucket raingauge a few times (take off the protective rubber band to do this). Check the device status as reported in the software on your laptop and make a few graphs to verify that sensors are reporting correctly and the U30 station is being read out properly.

- When you are satisfied that everything is working properly, change the Logging Interval to 30 minutes (1800 seconds) and Connection Interval (when data is sent by cellphone to the VS office) to 1 day, at midnight.

- Close the software, switch off the logger, disconnect the battery and sensors and repackage them for transport to the field (put the rubber band back on the raingauge so that it does not rattle while travelling).

It may be desired to fence off the weather station in its own enclosure, 3 m x 3 m in area and 1 m high, with an access gate. This is mostly to keep out animals and people who might want to fiddle with the sensors.

**When you are in the field at your chosen site**:

1. Assemble the parts of the mast or tripod following the instructions that come with the kit. (VS often uses a simple pole mast with a welded crossbar, manufactured in-country, to save shipping costs).

2. Place the crossbar at 2.6 m height. Anchor the tripod or pole to the ground with pegs and guy lines, ensuring that the central pole is vertical.

3. Install the lightning protection grounding cable and peg.

4. Bolt the U30 instrument box onto the upright mast at a convenient height for reading (about 1.5 m from the ground) and connect the ground cable to the ground terminal of the U30.

5. Twist the crossbar to point North-South and tighten the bolts.

6. Mount the solar radiation sensor on the end towards the equator and ensure that it is level.

7. On the other end of the crossbar, install the wind speed sensor, ensuring that its axle is vertical (ie. the anemometer cups rotate in a horizontal plane at 3 $\pm$ 0.1 m above the ground).

8. Bolt the rain gauge to the mast near the top of the pole using two 6 cm diameter hose clamps, so that the top of the rain gauge is level, above the crossbar and about 2 m above the ground.

9. Bolt the radiation shield to the main mast between the instrument box and the rain gauge and install the temperature and humidity sensor inside it.

10. Bolt the barometric sensor, in its weatherproof box, immediately below the U30 box.

11. Poke all the cables neatly in through the cable entry ports in the bottom of the instrument box

and pull them almost taut. Strap the cables to the crossbar and mast every 10 cm using cable ties, leaving no slack between the box and the sensor.

12. Tighten the cable ports to seal them and tie the excess cable into a roll inside the box.

13. Plug the RS-12 ‘smart connectors’ on the ends to the sensor cables into the sockets on the U30, in the order described above. Install the 10 Ah 4 v sealed lead-acid battery in the instrument box and connect it to the power input of the U30[1]. The U30 should recognize the sensors itself.

14. Connect a laptop to the U30 via the USB cable, and open the HoboLink or HoboWare software. Start the station and check that the U30 is collecting data correctly, that the logging interval is 1800 seconds (half an hour) and the connection interval is daily, at midnight.

15. When satisfied, close the software and disconnect the laptop.

16. Close the door of the U30 box and put a padlock on it. Make sure a duplicate key is kept in a safe place in the VS office. If the ‘field key,’ which is signed out to the technician serving the station is

[1] Do it in this order. Sensors plugged in once logging has started will not be recognized unless you force a restart using the software. You could also install a 6A 12v solar panel on the mast to charge the battery, if you think that the site is safe from theft.

lost, make a new duplicate – don't send the master key to the field.

*5.3 Maintaining and Collecting Data from a Full Station*

The data should automatically download from the full weather station to the VS office daily, via the cell phone link. Ensure that your HoboLink contract is still working.

Check the data received every day during the week in the VS office, and on Mondays for the data received over the weekend. Add the new data to the data file for that weather station. If a problem is noted (such as data not being received, or the values being unreasonable), send a technician out to the site as soon as possible. Also sent a technician as soon as possible if the host of the station tells you that there is a problem.

**The full weather station should be routinely visited by a technician once every 3 months**.

When you arrive at the weather station for the routine visit:

1. Check that the mast is undamaged and secure, and fix if necessary. Cut down any vegetation near to the sensors.

2. Connect the laptop to the U30 USB port, download all data using HoboWare pro, and save the file. This is a check on the data receive via the cell phone and may cover some gaps in that record. The data on the logger is the 'master record.'

3. Replace the battery with a freshly-charged one, even if the charge in the old one is above 3.5 V. Check the battery voltage of the installed battery as indicated in HoboWare; it must be above 3.5 V. Return the old battery to the VS office to be charged. This can be done many times.

4. Clear any debris out of the funnel of the tipping bucket rain gauge. Take the funnel off and check inside the tipping bucket for any debris, insect nests etc., and remove if necessary. Put a drop of light machine oil on the bearings of the tipping bucket. Replace the funnel.

5. Take the plastic sealing the bottle with 373 ml of water off (Figure 1), and up-end the bottle in the top of the rain gauge so that the water drips out over about 1 hour. You should hear the bucket tipping, and the logger should record 98 to 102 tips. Write this number of tips down and record it in the calibration file in the VS office.

6. While waiting for the rain gauge calibration to finish, wipe the top of the solar radiation sensor gently with a damp cloth and check that it is horizontal. Check that the anemometer has all its cups and is spinning freely. If it is broken it cannot be repaired in the field – it must be replaced and if necessary sent back to the supplier for repair.

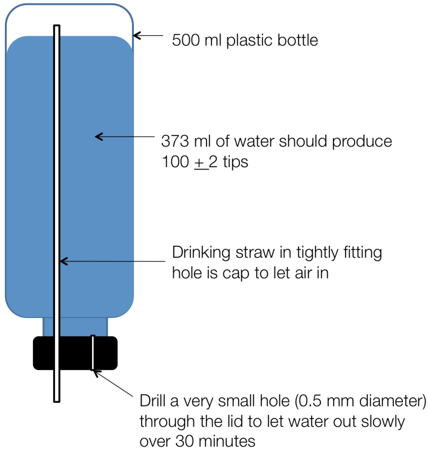


*Figure 1. A 500 ml plastic soft drink bottle with the screw-on lid modified for calibrating tipping bucket rain gauges. Drill a tiny (<1 mm) hole in the lid to let the water out over a period of an hour, and a second hole fitted with a straw to let air in when the bottle is turned upside down.*

7. Check that the radiation shield containing the temperature and humidity sensors is not damaged and has not been occupied by wasps or other obstacles. If the RH sensor is giving clearly wrong results, it can be replaced. Check that all the cables are undamaged and firmly secured to the mast.

8. Reset and restart the logger to clear the rainfall data you collected during calibration, fill in the service log, and lock up the enclosure.

# 6. MINI WEATHER STATIONS

## *6.1 Choosing a Location for a Mini Weather Station*

The purpose of the Vital Signs mini stations is to ensure that the bare minimum of weather data – **rainfall and temperature** – are available in every VS landscape.

There are typically about 10 landscapes per region (of which two should have full weather stations). **VS places a mini weather station in the landscapes that do not already have a reliable and available weather station** to supply daily rainfall and maximum and minimum temperature.

The mini weather stations consist of a tipping-bucket rain gauge with a datalogger, which has a built-in temperature sensor. They need to be placed in an open space, with no objects that will block the rain or sunlight within 4 times the height of that obstacle. Usually this means the weather station will be on a grassy patch or field margin, with low vegetation around it.

The mini weather stations are less expensive and less likely to be vandalized or stolen than the full weather station, so they can often be located in the yards or fields of farmers (though schools, clinics and government offices can also be considered). They should be in or within 5 km of the border of a VS landscape. Once you have chosen a few likely spots, go through the same negotiation process as described for finding a host for the full weather station. The mini weather stations occupy less than 0.5 x 0.5 m of space, and can be moved if necessary to another spot if one becomes unsuitable.

### *6.2 Installing a Mini Weather Station*

Before you go into the field, do the following:

- Open the event/temperature datalogger and install one 3v CR2032 lithium battery (+ side up). This should last about a year.

- Take the top (ring and funnel) off the rain gauge. Pass the logger's black and white cables from the outside through the grommet (a hole filled with a rubber plug) on the side of the rain gauge and connect them to the terminals of the tipping bucket (the order does not matter).

- Connect the Optic USB Base station between the event logger and the laptop and use HoboWare to connect to the logger and check that it is working, by taking off the rubber band securing the tipping bucket and tipping it manually a few times. The temperature should be the same as the temperature in the place you are working.

- When you are satisfied, disconnect the Optic USB and re-secure the equipment for transport to the field.

## Workflow 2: Mini Weather Stations

**Start here**

*Choosing a location for the mini weather station*

1. Select the Vital Signs Landscape in which you will place the mini weather station
2. Ask the local community in the landscape about possible secure locations for the weather station, explaining the key requirements outlined in the protocol
3. Use satellite images of the landscape to help assess potential places, again keeping in mind the key requirements outlined in the protocol
4. When you have identified some candidate locations, negotiate with the people who are responsible for the land to install the weather station

*Installing a mini weather station*

1. Follow protocol instructions for checks performed before going to the field
2. Once there, fill in the metadata form for the location and surrounding area of the station
3. Record the GPS location (to within 0.00001 degrees) and altitude (to the nearest m) of the ground below the rain gauge location
4. Connect the rain gauge to the top of the steel tube/wooden pole and mount the radiation shield just below the rain gauge
5. Insert the Hobo recorder into the radiation shield and secure the cable to the tube
6. Connect the event logger to the laptop using a USB and check that it is working using HoboLink. Ensure it is working and that the temperature logging Interval is 1800 seconds
7. Disconnect USB and put the logger back in the radiation screen

*Collecting data from a mini weather station (every 3 months)*

1. When you arrive at the weather station for the routine visit, check that the mast is secure
2. Carefully pull the temperature/event logger out of the radiation shield and insert it into the Optic USB base station, which is connected to the laptop
3. Use the logger software to read the data and save it to a file
4. Check the battery voltage and sensor cable port. Check that the dessicant is still bright blue and replace if necessary. Clear any debris out of the rain gauge funnel
5. *Perform once a year*: Up-end the bottle with 373 ml of water in the top of the rain gauge so that the water drips out over about 1 hour. The logger should record 98 to 102 tips. Write the # of tips down and record it
6. Make a note of the date and your actions in the maintenance logbook

Choose a location for the mini weather station and negotiate access as described above. We suggest that the mini weather station is either mounted on the top of a 2.5 long vertical steel tube about 50 cm diameter (with the bottom 0.5 m buried in a hole in the ground and anchored with concrete), or on the flat and level top of a vertical wooden pole about 20 cm diameter and 2.2 m long (with the bottom 0.5 m buried securely in a hole in the ground). The mini station could also be mounted on top of a structure such as a wall or building.

To install the station:

1. Connect the rain gauge to the top of the steel tube using hose clamps, or to the top of the wooden pole using three screws (in both cases so that the orifice is at about 2 m and level).

2. Remove the rubber band that protects the tipping bucket during transport.

3. Mount a RS1 or MRSA radiation shield just below the rain gauge, with bolts on the tube or wood screws on the pole.

4. Insert the Hobo Event/Temperature recorder into the radiation shield, connected by cable to the tipping bucket terminals (polarity does not matter) via the grommet on the side of the rain gauge.

5. Secure the cable to the tube with cable ties, or to the pole using electrical cable saddles.

6. Connect the event logger to the laptop using an Optic USB and check that it is working using HoboLink. Once you are sure it is working and that the temperature Logging Interval is 1800 seconds, disconnect the Optic USB and put the logger back inside the radiation screen.

### *6.3 Maintaining and Collecting Data from a Mini Station*

**The mini weather station should be visited by a technician once every 3 months**. When you are at the mini weather station:

1. Check that the mast is undamaged and secure, and fix if necessary. Cut down any vegetation near to the tipping bucket or radiation shield.

2. Carefully pull the temperature/event logger out of the radiation shield and insert it into the Optic USB base station, which is connected to the laptop.

3. Use the logger software to read the data and save it to a file. This file must be added to the database kept at the VS office.

4. Take a look at the battery voltage – if it is low, take the event logger out of the Optic USB, open it up and replace the battery (+ side up). While the logger is open check that the dessicant bag inside the case is still bright blue. If it is not, replace with a dessicant packet which is bright blue after being dried in a warm place, like an oven set on low, for several hours.

6. Clear any debris out of the funnel of the tipping bucket rain gauge. Take the funnel off and check inside, in the tipping buckets, for any debris, insect nests, etc., and remove if necessary. Put a drop of light machine oil on the bearings of the tipping bucket. Replace the funnel.

7. About once a year, perform a calibration. Take the plastic sealing the bottle with 373 ml of water off, and up-end the bottle in the top of the rain gauge so that the water drips out over about 1 hour. You should hear the bucket tipping, and the logger should record 98 to 102 tips. Write this number of tips down and record it in the calibration file in the VS office.

8. Make a note of the date and your actions in the maintenance logbook.

## 7. ANALYZING AND REPORTING WEATHER DATA

The data from both types of weather station is measured continuously, but only recorded by the datalogger every half hour. The smart sensors will determine exactly what is recorded – usually it is the average over that period, but sometimes it is the value exactly at the end of the period, or the maximum or minimum or total during the period.

**When the data is returned to the Vital Signs office, either over the GSM (cell phone) link or from the files downloaded by the technician, it must be compiled**

**into the database for that weather station**, making sure no dates or times are duplicated and, as far as possible, none are missing.

The weather data are then analyzed for daily, monthly and annual periods (this is now 'climate data', see Table 2), and these are output into different files.

**Note 1**. The instrument reports relative humidity (RH as a %). To get the actual water vapour pressure ($e_a$) use this formula:

$e_a = e°(T)* RH/100$

where $e°(T)$ is the saturated vapour pressure at temperature T, given by $e°(T)=0.6108 \exp(17.27*T/(T+237.3))$.

**Note 2**. To get RH from $e_a$ at any time scale, calculate the $e°(T)$ for the average temperature over that period using the formula in note 1, and use the average $e_a$ for the same time period in the following formula $RH = 100*e_a/ e°(T)$.

The data files with the weather station data in them (raw half-hourly data, daily data, monthly data or annual data) must have the following station metadata associated with them, describing the instruments and their exposure.

*Table 2: climate variables which are calculated from the half-hourly weather data.*

| **Variable** | **Daily reporting** | **Monthly** | **Annual** |
|---|---|---|---|
| Air temperature | Daily maximum temperature ($T_{max}$), daily minimum temperature ($T_{min}$) and daily average temperature ($T_{ave}$) over the 48 half-hourly records from 00:30 to 24:00 | Mean daily maximum, mean daily minimum and mean daily average temperature over the days of the month. | Mean of the monthly average temperatures, mean minimum temp of coldest month and mean maximum temperature of warmest month. |
| Humidity | Maximum RH, minimum RH, average vapour pressure of water ($e_a$)[1], and average RH calculated by expressing the average $e_a$ relative to the saturated vapour pressure at the average temperature for the day[2] . | Mean monthly $e_a$ as the mean of the mean daily $e_a$ for the days of the month, RH as the mean monthly $e_a$ relative to the saturated vapour pressure at the mean daily temperature for the month[2]. | Mean annual $e_a$ as the mean of the mean monthly $e_a$ for the 12 months, mean annual RH as the mean annual $e_a$ relative to the saturated vapour pressure at the mean annual temperature for the year[2]. |

| | | | |
|---|---|---|---|
| Solar shortwave incoming radiation | Integral of $W/m^2$ over the day (=MJ) | Sum of daily MJ over the month | Sum of monthly MJ over the year |
| Wind speed | Average daily wind speed<br>Maximum gust speed | Average of daily wind speeds over the month | Average of monthly wind speeds over the year |
| Rainfall | Daily sum of rainfall | Monthly sum of daily rainfall | Annual sum of monthly rainfall |

# Workflow 3:
# Data Archive and Analyses

## For the full weather station

*Every Day*

Each day at the office, check that the data from the full weather station have been recieved

↓

Incorporate the data into the master database, making sure no dates or times are duplicated and, as far as possible, none are missing

↓

*Every Month*

Once per month, perform the monthly summary analyses

↓

*Every Year*

Once per year, perform the annual summary analyses

## For the mini weather station

*Every 3 Months*

Every three months, append the recorded data to the master files

↓

*Every Year*

Once per year, perform the annual summary analyses

# 8. BIBLIOGRAPHY

WMO 2010. Guide to Meteorological Instruments and Methods of Observation. WMO - No.8 2008 edition. Updated in 2010.

# 9. APPENDICES

<table>
<tr><td colspan="2">Vital Signs Weather Station Metadata Form</td><td>Date</td><td>Observer</td></tr>
<tr><td>Station Name</td><td>Latitude</td><td>Longitude</td><td>Altitude</td></tr>
<tr><td colspan="4">Terrain description of the area 200 m to 5 km from location<br><br><br><br>Name of file with a 360 °panoramic photograph</td></tr>
<tr><td>Equipment/sensor</td><td>Make or model</td><td>Serial number</td><td>Height installed (m)</td></tr>
<tr><td>Data logger</td><td></td><td></td><td></td></tr>
<tr><td>Rainguage</td><td></td><td></td><td></td></tr>
<tr><td>Barometric pressure</td><td></td><td></td><td></td></tr>
<tr><td>Temperature</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">in naturally ventilated radiation shield</td></tr>
<tr><td>Relative humidity</td></tr>
<tr><td>Wind speed</td><td></td><td></td><td></td></tr>
<tr><td>SW radiation</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Sketch map of 60 x 60 m surroundings of the location</td></tr>
</table>

**Full Weather Station Record**
Version: 1.0

| | Form Value | Definition | Data Type | Values List | Example | Empty Value | Rules/Comments |
|---|---|---|---|---|---|---|---|
| **Station ID** | **Country** | The VS country three-letter abbreviation. | string | None | TAN | Required | May need suffix for region in country |
| | **Weather station number** | The weather station number within the particular VS country above | alphanumeric | None | 1 | Required | Full an mini weather stations are in same sequence |
| **Date and time of record** | **Year** | The year of the record (YYYY) | numeric | {>=2013} | 2014 | Required | |
| | **Month** | The month of the record (MM) | numeric | {1-12} | 03 | Required | |
| | **Day** | The day of the plot survey. (DD) | numeric | | 31 | Required | |
| | **Hour** | The hour of the end of the record (HH) | numeric | | 12 | Required | |
| | **minute** | The minute of the end of the record (NN) | numeric | {1-31} | 00 | Required | |
| **Weather data** | **Rainfall** | Accumulated rainfall during period (mm) | numeric | {0-200} | 23.2 | -999 | |
| | **Radiation** | Mean SW radiation during period (W/m2) | numeric | {0-1000} | 657.1 | -999 | |
| | **Temperature** | Mean Temperature during period | numeric | {-20 - 50} | 25.2 | -999 | |
| | **Humidity** | Mean RH during period (%) | numeric | {0-100} | 43 | -999 | |
| | **Wind speed** | Mean wind speed during period (m/s) | numeric | {0-50} | 3.5 | -999 | |
| | **Pressure** | Mean atmospheric pressure during period (Pa) | numeric | {0-15000} | 9967 | -999 | |

**Mini Weather Station Record**
Version: 1.0

| | Form Value | Definition | Data Type | Values List | Example | Empty Value | Rules/Comments |
|---|---|---|---|---|---|---|---|
| **Station ID** | **Country** | The VS country three-letter abbreviation. | string | None | TAN | Required | May need suffix for region in country |
| | **Weather station number** | The weather station number within the particular VS country above | alphanumeric | None | 1 | Required | Full an mini weather stations are in same sequence |
| **Date and time of record** | **Year** | The year of the record (YYYY) | numeric | {>=2013} | 2014 | Required | |
| | **Month** | The month of the record (MM) | numeric | {1-12} | 03 | Required | |
| | **Day** | The day of the plot survey. (DD) | numeric | | 31 | Required | |
| | **Hour** | The hour of the end of the record (HH) | numeric | | 12 | Required | |
| | **minute** | The minute of the end of the record (NN) | numeric | {1-31} | 00 | Required | |
| **Weather data** | **Rainfall** | Accumulated rainfall during period (mm) | numeric | {0-200} | 23.2 | -999 | |
| | **Temperature** | Mean Temperature during period | numeric | {-20 - 50} | 25.2 | -999 | |