Vital Signs Protocol

Water Availability and Quality

Version 2.0

March 2014

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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 • Take water samples and analyze them • Perform rapid water assessments • Clean, maintain and store equipment
Technical Manager	• Supervises teams • Ensures equipment is well-managed and team is safe • Ensures consistency and quality of measurements • Ensures data are uploaded to the VS server daily (or weekly if internet access is limited) • Ensure back-ups and data entry sheets are properly archived
Country Director	• Supports team with a complete understanding of the protocol manual • Trains technicians • 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 • Reviews data when uploaded • Approves protocol updates and sends out

	update notifications to field teams
Protocol Manager	• Receives and archives comments about the protocol from the field team • 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.

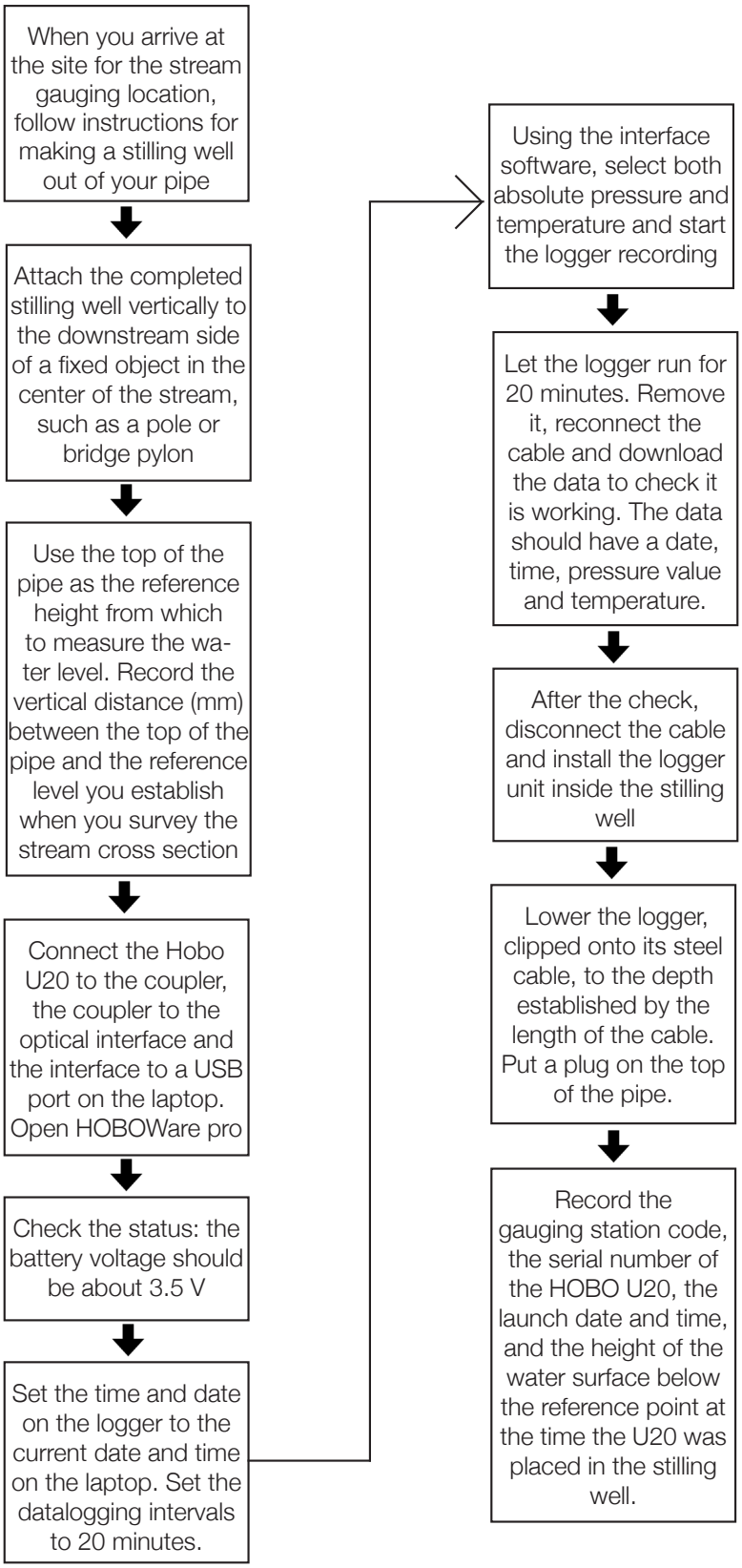
3. Attach the stilling well to its support using brackets strong enough to withstand floods.

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.

Workflow 1: Setting up a Gauging Station



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.

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

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.

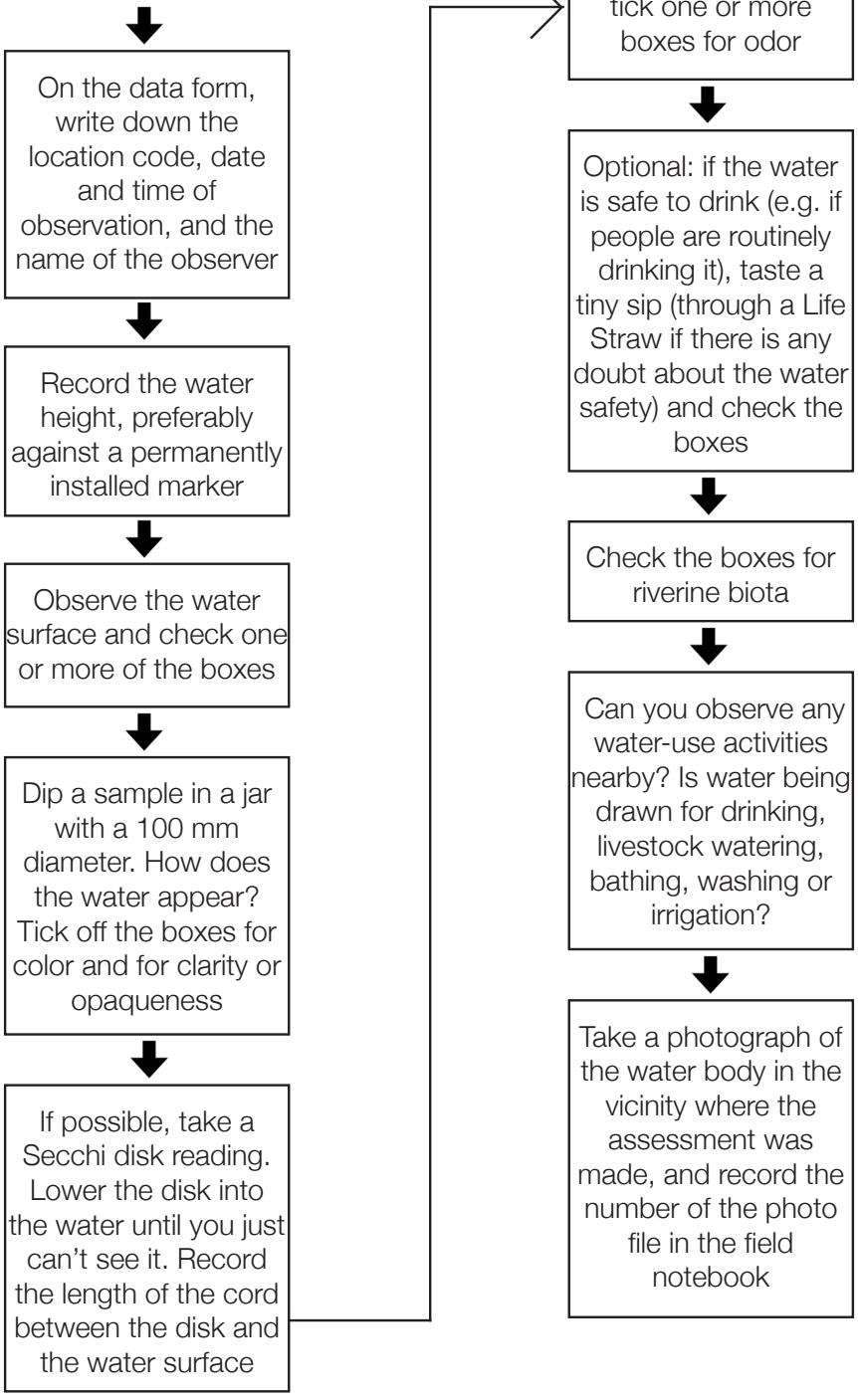
This activity is mostly a **visual assessment of the river stage (i.e. water depth) and quality**, and should take no more than a few minutes. It is done repeatedly (about monthly is ideal, but in the worst case quarterly) at easily-reached, well-known places that you pass on the way to and from other 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.

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)



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.

5.2 Indicator Organism River Health Assessment

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.

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.

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

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.

6. BIBLIOGRAPHY

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7. APPENDIX

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

Table 1: The SASS Version 5 scoring sheet

SASS Version 5 Score Sheet	**Taxon**		**S**	**Veg**	**GSM**	**TOT**	**Taxon**		**S**	**Veg**	**GSM**	**TOT**	**Taxon**		**S**	**Veg**	**GSM**	**TOT**
	PORIFERA	5					**HEMIPTERA**						**DIPTERA**					
Date: / /200__	**COELENTERATA**	1					Belostomatidae*	3					Athericidae	10				
	TURBELLARIA	3					Corixidae*	3					Blepharoceridae	15				
Collector: . .	**ANNELIDA**						Gerridae*	5					Ceratopogonidae	5				
	Oligochaeta	1					Hydrometridae*	6					Chironomidae	2				
Grid Reference: WGS-84 Cape datum	Leeches	3					Naucoridae*	7					Culicidae*	1				
S: ° ' , " E: ° ' , "	**CRUSTACEA**						Nepidae*	3					Dixidae*	10				
	Amphipoda	13					Notonectidae*	3					Empididae	6				
Site code:	Potamonautidae*	3					Pleidae*	4					Ephydridae	3				
	Atyidae	8					Veliidae/M...veliidae*	5					Muscidae	1				
River:...	Palaemonidae	10					**MEGALOPTERA**						Psychodidae	1				
	HYDRACARINA	8					Corydalidae	8					Simuliidae	5				
Site description:…..……..	**PLECOPTERA**						Sialidae	6					Syrphidae*	1				
	Notonemouridae	14					**TRICHOPTERA**						Tabanidae	5				
Weather Condition:…..……..	Perlidae	12					Dipseudopsidae	10					Tipulidae	5				
	EPHEMEROPTERA						Ecnomidae	8					**GASTROPODA**					
Temp:.....°C pH:……..	Baetidae 1sp	4					Hydropsychidae 1 sp	4					Ancylidae	6				
	Baetidae 2 sp	6					Hydropsychidae 2 sp	6					Bulininae*	3				
DO:……..mg/l Cond:……mS/m	Baetidae > 2 sp	12					Hydropsychidae > 2 sp	12					Hydrobiidae*	3				
	Caenidae	6					Philopotamidae	10					Lymnaeidae*	3				
Biotopes sampled:	Ephemeridae	15					Polycentropodidae	12					Physidae*	3				
SIC ..... Time.....minutes	Heptageniidae	13					Psychomyiidae/Xiphocen	8					Planorbinae*	3				
SOOC..... Time.....minutes	Leptophlebiidae	9					**Cased caddis:**						Thiaridae*	3				
Average size of stones……cm	Oligoneuridae	15					Barbarochthonidae SWC	13					Viviparidae* ST	5				
Bedrock.....	Polymitarcyidae	10					Calamoceratidae ST	11					**PELECYPODA**					
Aquatic veg'n..... Dom. sp.....	Prosopistomatidae	15					Glossosomatidae SWC	11					Corbiculidae	5				
MvegIC…… Dom. sp.....	Teloganodidae SWC	12					Hydroptilidae	6					Sphaeriidae	3				
MvegOOC…… Dom. sp.....	Tricorythidae	9					Hydrosalpingidae SWC	15					Unionidae	6				
Gravel..... Sand.....	**ODONATA**						Lepidostomatidae	10					**SASS Score**					
Mud.....	Calopterygidae ST,T	10					Leptoceridae	6					**No. of Taxa**					
Hand picking/Visual observation……	Chlorocyphidae	10					Petrothrincidae SWC	11					**ASPT**					
Flow: Low/Medium/High/Flood	Chlorolestidae	8					Pisuliidae	10										
Turbidity: Low/Medium/High	Coenagrionidae	4					Sericostomatidae SWC	13					Sample collection effort exceeds method?					
Riparian land use:	Lestidae	8					**COLEOPTERA**											
	Platycnemidae	10					Dytiscidae*	5										
Disturbance in the river: eg. sandwinning,	Protoneuridae	8					Elmidae/Dryopidae*	8					**Other biota including juveniles:**					
cattle drinking point, floods etc.	Aeshnidae	8					Gyrinidae*	5										
	Corduliidae	8					Haliplidae*	5										
	Gomphidae	6					Helodidae	12										
Observations: eg. smell and colour of	Libellulidae	4					Hydraenidae*	8					**Comments:**					
water, petroleum, dead fish, etc.	**LEPIDOPTERA**						Hydrophilidae*	5										
	Pyralidae	12					Limnichidae	10										
							Psephenidae	10										

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)

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
Analysis notes	**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, used to correct EC value	numeric	None	23.2	Required	Measured during the EC calibration process and used to convert EC to salinity if required
	Sample code	A unique water sample code that is linked to the rapid water assessment code. The code contains three components: "3-letter country code - WS (water sample) - Rapid Water Assessment Number" 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.	alphanumeric	None	TAN_WS_0004	Required	Note that the date and location (GPS co-ords) of the sample is recorded in the rapid water assessment form, so by linking through the shared code you have access to this information and the date and observer who did the sampling
	pH measurement	pH is a measure of the acidity or alkalinity of the water sample: the negative log10 of the concentration of hydrogen ions (H+). Pure water has a pH of 7.0; pH <7 is acidic and pH >7 is 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
ata	**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

Water sample d	**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	Most Probable Number of E coli organisms per 100 ml of sample. Estimated from compartments which changed colour via a look-up table	numeric	{0-100}	50	Required	See Aquagenx guidance sheet for the MPN associated with different combinations of compartment bags showing colour.