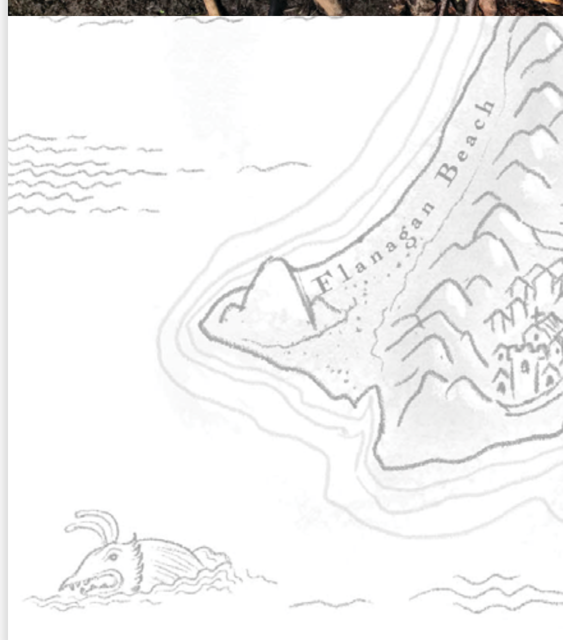
QiQuac M5: Highlander

Operating Manual



Fathom Scientific Ltd.

Contents

CHAPTER 1

Prologue

In which the reader is introduced to the
QiQuac and its many extraordinary talents.

The QiQuac is a handsome fellow. When he's near water he's calm and mellow.

Introduction

The Quick Instream Q(flow) & Uncertainty Analysis Calculator (QiQuac) is a serial datalogging / conductivity instrument intended to measure Q in active watercourses with lateral mixing. The Graphical User Interface (GUI) is intended to aid the hydrographer by presenting a visual representation of the conductivity over time, calculating Q and the associated uncertainty. The datalogger records continuous data at a regular interval onto an internal SD card[1]. The Q±% calculations are in the RAM and don't affect the logged data, which can be reprocessed at a later time. Along with photos and site notes, the recorded data provides a Qualified Professional (QP) all the necessary information to allow a Data Grade A designation, provided proper technique and protocol is followed.

The QiQuac: Highlander Edition features a 3 rd Upstream Probe to measure background conductivity upstream of the point of injection. This allows for a more accurate measure of the background ECT after compensation for probe offset and transit time.

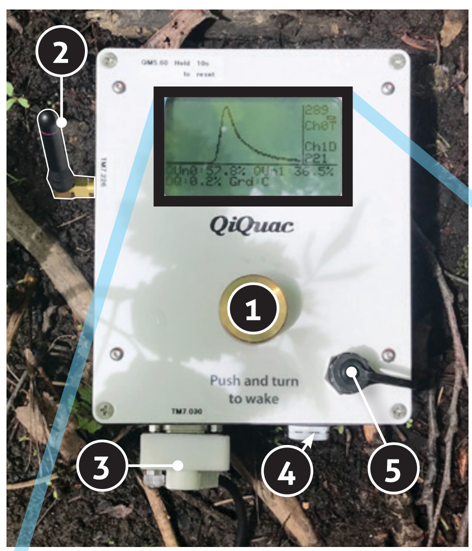
1 Data can be logged at 5 seconds for >1 year with a 2 GB SD card.

Device Description

1. Brass Dial / Push Button. Push, Release, and Turn to wake the sleeping QiQuac. Push to Begin Q measurement. Rotate to change settings. Press and hold >1s to go back. Hold for >10s to reset QiQuac.
2. Ch1 Radio Antenna: for best performance, raise both T-HRECS and QQ antenna as high as possible.
3. Ch0 Connector: Power for the T-HRECS is on pin 9. Short pin 4&5 to reset QiQuac.
4. Mini-USB port: Connect to USB port to charge internal Li-Ion battery and access the SD Card. To access the SD Card, the QQ must first be powered down.
5. Waterproof Vent
6. Y-Axis Max
7. Battery Icon (cycles when charging)
8. Most Recent Transmission (MRT). Indicates which Ch received MRT.
9. Current Display Channel Ch0D or Ch1D or Ch0S (Solo Mode) or Ch1S
10. Y-Axis Min
11. Pre-Background EC.T (uS/cm)
12. Measurement Diagnostics
13. Last measured Temperature Compensated Electrical Conductivity (EC.T) (uS/cm) a.k.a Specific Conductance at 25oC using nlf compensation (EU standard 27888)
14. Ch0 (solid-Displayed)
15. Ch1 (dashed)
16. Ch2 (upstream sensor dotted)
17. 3rd U/S Probe Transit Time
(Available only on the Highlander edition with CH2 set to 3rd U/S Probe)

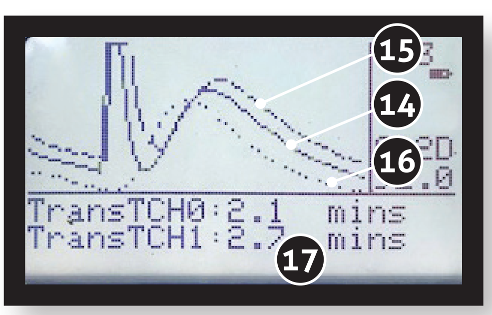
Figure 1 Measurement Diagnostics

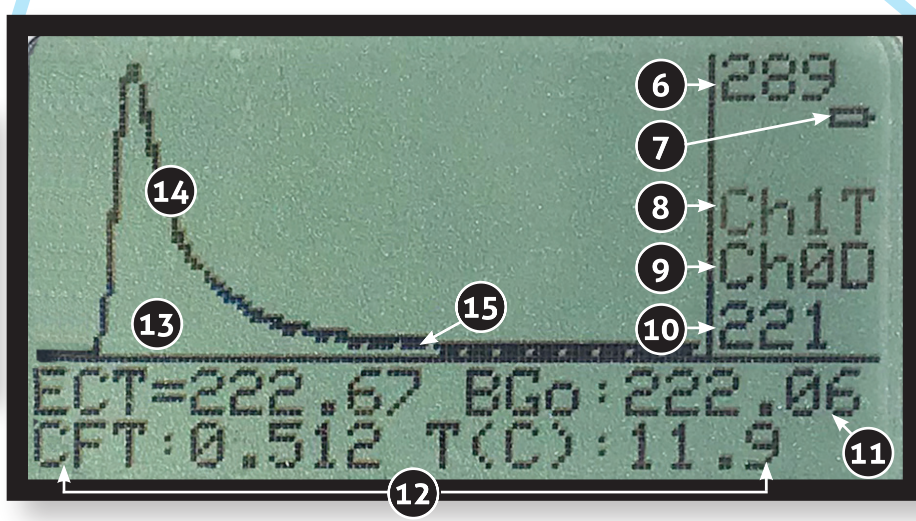
≈ dQ/dt: This is the change in derived Q per measurement.
≈ mins: elapsed time in minutes.
≈ Grd: The current Data Grade (A,B, or C).
≈ QUnc: Resulting uncertainty in Q.
≈ T: Temperature in °C.
≈ DQ: When two channels are used, the %Difference between derived Q.
≈ Q: Derived Q (m³/s)
≈ CF.T: Temperature compensated Calibration Factor
≈ Dose: Salt Mass per Q (kg/(m³/s))
≈ QUn0: Resulting uncertainty in Q for Ch0
≈ QUn1: Resulting uncertainty in Q for Ch1
≈ TTrans: Transit Time when Ch2 is set to 3rd Upstream Probe.



Notes

- Ch0 (RS232 device) is always the solid plot, Ch1 (Radio device) is always the dashed, and Ch2 (Radio device is always dotted. Ch2 is either the 3rd Upstream Probe or 3rd Downstream Probe.
- QiQuac enters the main menu when turned on. Select calibration and measurement default values in "Setup".
- To shut off QQ, select Power Down from the main menu or Push and Hold the dial for >10s.
- To practice a measurement, or reprocess the last measurement, select Replay from the main menu.
- To change Mass, push button and select Adjust Mass.





Kit Description

The QiQuac kit contains everything required to make a Grade A flow measurement in turbulent watercourses. The Radio T-HRECS unit connects to Ch1 of the QiQuac. The Serial unit connects to Ch0. If the T-HRECS are on opposite banks of the watercourse and measure a Q that is not significantly different, then a Grade A measurement is possible. Figure 1 shows the contents of the kit.

Figure 2

1. QiQuac
2. Radio T-HRECS
3. Serial T-HRECS
4. Salt Standard for CF.T calibration
5. Pipettor for CF.T calibration
6. Quickflask for CF.T calibration
7. Scales
8. Duckbox
9. E.C.T Probes
10. Cables, manuals and accessories

CHAPTER 2

Theory

In which the Theory by which the QiQuac makes a Salt Dilution flow measurement is explained to the reader.

"It's all Relative!" the QiQuac summarized; but the T-HRECS didn't understand as their brains are pea-sized.

Theory of Operation

Salt Dilution is a method of flow measurement that has been in use more than 55 years (Østrem, 1964), and is experiencing a renaissance in popularity in the last 15 years as people discover its accuracy, relative ease, and convenience (Hudson and Fraser 2002, Moore 2005, Richardson et al 2017). We have developed the QiQuac system to facilitate fast and accurate SDIQ measurements, with uncertainty calculations, so that a user can leave the site confident that their measurements are reliable.

In Salt Dilution, a measured amount of table salt, NaCl, is injected into the watercourse and the conductivity is measured downstream of a turbulent section of flow. [NaCl] and Electrical Conductivity are nearly linearly related (R2 of 1.000) over small ranges (ie >200 µS/cm)), but changes slightly over larger ranges (Richardson et al 2017). Using the Calibration Factor (aka Concentration Factor or CF), we can convert the measured conductivity to delta [NaCl] over time. If we divide the measured mass of NaCl by the area under the [NaCl]-time curve, we can calculate the Q. Using a dimensional analysis, it is easy to see how this works:

$$SDIQ = \frac{mass}{[\frac{mass}{volume}] \bullet time} = \frac{volume}{time} \quad (1)$$

The uncertainty of the resulting SDIQ can be <5% if all sources of uncertainty are controlled for. However if things are not controlled, the uncertainty can easily be >100% (for example if the mixing is not complete). One of the benefits of the QiQuac is to provide QA/QC in the field on the quality of the measurement.

Theory of SDIQ Measurement

The dry salt (a.k.a. slug) method is based on the following expression:

$$Q = \frac{M}{CF_T \bullet A_{BC}} \quad (2)$$

where Q is stream discharge (m^3s^{-1}), M is the mass of salt injected (kg), CF_T is a calibration factor for converting temperature-compensated electrical conductivity to salt concentration, and A_{BC} is the area under the "Breakthrough Curve" commonly calculated as

$$A_{BC} = \Delta t \sum \left[EC(t) - EC_{BG}\right] \quad (3)$$

where Δt is the recording interval (s), EC(t) is the electrical conductivity as a function of time recorded downstream of the point of salt injection (μS cm-1), EC_{BG} is the background electrical conductivity of the stream water, and the summation is carried out over the duration of the salt wave passage (i.e., the period with EC(t) > EC_{BG}). As recommended in Richardson et al (2017), we use temperature compensated EC, or ECT[2].

Equation (2) is based on two key assumptions: (1) there is no loss of salt between the injection and monitoring points, and (2) the salt or solution is "completely" mixed across the stream width at the monitoring location. Complete mixing is the state of a watercourse where the water on the left bank has travelled to the right bank at least once. It coincides with the area under a salt tracer EC.T Breakthrough Curve (BC) where the area under the [NaCl]-time integral is equal at any point in the transect.

A typical breakthrough curve is shown in Figure 1A. Figure 1B shows the same trace after being resampled to the more common resolution of 0.1μS/cm. The T-HRECS and QiQuac have a resolution of 0.001uS/cm and a stability of 0.01%. This means that for an EC.T of 100μS/cm, the standard deviation of the noise should be 0.01 μS/cm. This implies that much less salt can be used and still achieve a low uncertainty on the resulting SDIQ.

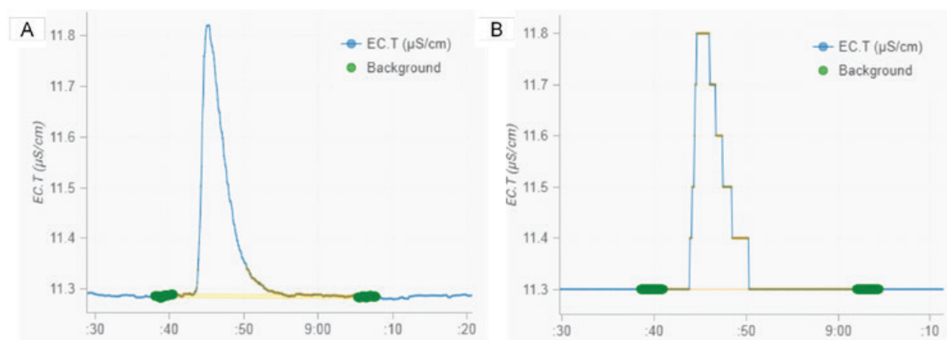


Figure 3. A & B

A typical low amplitude, high SNR Breakthrough Curve showing some noise in the EC_{BG} that is averaged out with 30 samples Pre- and Post-BC. This measurement used 5.042 kg to measure 91 m^3/s with a resulting uncertainty of ±4.5%. It is from a manual injection using the T-HRECS probe, which has a resolution of 0.001 μS/cm. This curve is an example of good mixing but noisy background from some slight aeration. B) Shows the same curve but rounded to 0.1 μS/cm, a conventional EC Probe resolution. This same sample results in a Q of 100 m^3/s±54% due to the quantification error of ±0.05 μS/cm. (Screenshots from salt.fathomscientific.com SDIQ web portal)

2 A.k.a Specific Conductance. Richardson et al.(2017) goes on to recommend Non-Linear Function (nlf) compensation based on European standard (ÖNORM EN 27888 1993) to 25°C. Above 10°C, this is essentially 2.0%/°C and below 10°C it is reduced to 1.9%/°C at zero °C. The CF.T of 0.486 mg·cm·μS-1·lt-1 ± 2.8% can only be applied to properly calibrated meters using temperature compensation to 25°C. The QiQuac and T-HRECS use nlf temperature compensation to 25°C.

Theory of CF.T Measurement

The Calibration Factor (aka Concentration Factor) is the relationship between [NaCl] and Electrical Conductivity (EC). The QiQuac uses the temperature compensated EC, denoted by EC.T (aka specific conductivity) and the associated CF.T. This results in a consistency of CF.T values between sites and measurements and allows a degree of QA/QC if we know what to expect for the CF.T. Before each SDIQ the user can either enter the CF.T manually, or derive it in situ. The calculation to derive it is

$$CF.T = \frac{\Delta [NaCl]}{\Delta EC.T} \qquad (4)$$

We use units of (mg/lt)/(μS/cm). Richardson et al (2017) found that the average CF.T for water in British Columbia was 0.486 (mg/lt)/(μS/cm)±2.8% with a small (1.5%) positive dependence on background EC.T. We use a "Salt Standard" which is a solution made in the lab of 5.00g NaCl in 1.00 lt of distilled water. During a CF.T calibration we inject 1.00ml of salt standard into 1.00 lt of stream water. There are two considerations to accurately calculate CF.T in our methodology.

1. Each time an injection of 1.00ml of salt standard is injected the volume of water increases by 1.0ml, so after the first injection the [NaCl] is

$$\Delta \left[NaCl\right] = \frac{5.00mg/ml \bullet 1.00ml}{1001ml} = 4.955 \text{ mg/lt} \qquad (5)$$

2. Each time there is an injection of salt standard, the solution is also diluted by the distilled water water in the salt standard. Since the EC.T of distilled water is different from the EC_{BG} of the stream water to be calibrated, a distilled water correction is applied. As secondary solution is added, the effective EC_{BG} of the calibration stream water, $EC_{BG,eff}$, can be calculated as follows:

$$EC_{BG,eff} = \frac{EC_{BG} \bullet V_s + EC_{T,d} \bullet V_D}{V_t} \qquad (6)$$

where V_S is the volume of the stream water sample, $EC_{T,d}$ is the EC.T of the diluent (typically distilled water), V_d is the volume of secondary solution added, and V_t is the total volume of the stream water sample and secondary solution added. The difference in CF.T values will increase as the difference in EC_{BG} and $EC_{T,d}$ increases. Equation 6 is a simple mixing equation based on the assumption that the EC.T behaves like a conservative ion, which should be reasonable for relatively dilute solutions typically involved in salt dilution gauging. Alternatively, a distilled water correction can also be retroactively applied to a CF.T value after calibration without needing to adjust each ECT reading. A complete discussion and derivation is provided in Appendix 1 of Richardson et al (2017). The correction from Equation 6 (or the approach described in Appendix 1) can be used with any type of water that is used in the secondary solution (e.g., distilled water, tap water, other stream water) because this would change only the value of $EC_{T,d}$. $EC_{T,d}$ of distilled water is set to 5μS/cm in the QiQuac.

The QiQuac uses the closed-form approximation from Appendix 1 of Richardson et al. It is

$$CF_{T,\,corr} = CF_{T,\,est}\left[1 - \left(\frac{0.486(EC_{T,\,d} - EC_{BG})}{[s]}\right)\right] \quad (7)$$

Where $CF_{T,corr}$ is the corrected CF.T, $CF_{T,est}$ is the estimated CF.T without the distilled water correction based on Equation 4. $EC_{T,d}$ is the EC.T of the distilled water (or diluent used in the salt standard), EC_{BG} is the background EC.T of the streamwater, and [s] is the concentration of the salt standard i.e. 5.00g/lt. These values are all entered into the Setup menu of the QiQuac.

In low conductivity streams (<100μS/cm) the distilled water correction is small, around 1%, but in high conductivity streams it can be >5%. The QiQuac reports the CF.T correction after each CF.T calibration.

Properties of Water and NaCl

Water is a mysterious substance. We take it for granted, but it's actually quite unusual, as liquids go.

1. It has the highest surface tension (besides liquid mercury). This facilitates critical biological function such as the capillary action allows trees to heft several kilograms of water 10s of m in the air.
2. It has the highest specific heat (energy required to heat one gram of a substance by 1˚C) of any liquid which provides an energy buffer for ecosystems, keeping temperatures relatively steady, and also promotes circulatory actions of weather
3. It is one of the few substances that becomes less dense as it cools.

It's weird behavior has made life possible on earth. If the density of water didn't increase below 4˚C, then ice wouldn't float to the surface of water bodies and insulate the seething life below from the sub-zero temperatures of a hostile environment. This is shown in Figure. The mass of water is also the reference for the metric system. 1 Litre of water at 4˚C weighs 1 kg. 1 Litre is 10cm by 10cm by 10cm. We can use this fact to our advantage when calibrating our volumetricware.

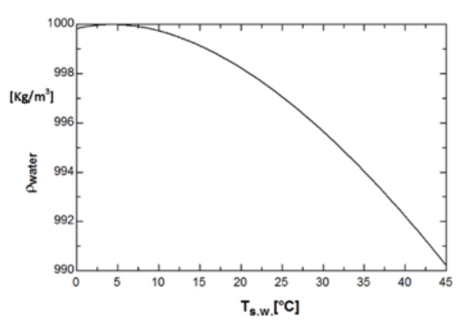
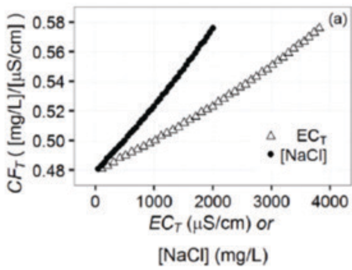


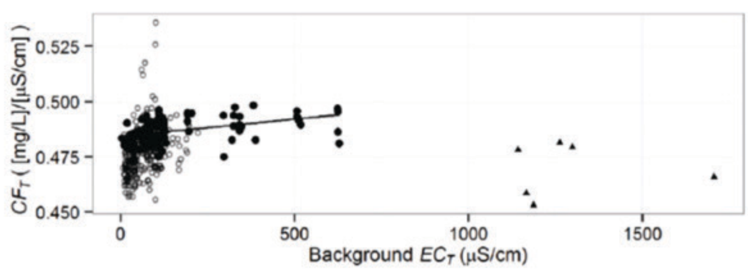
Figure 4: The density of water

The temperature of maximum density is 4˚C, a feature that allows cooling water to fall to the bottom of lakes and prevents eutrophocation, and freezing water to float, thereby trapping heat (albeit chilly 4˚C) in the water and thereby preserving life on land. It's very lucky for us. It's no coincidence that water weighs 1000g at 4˚C; the metric system is based on the density of water. At room temperature (25˚C) water weighs 997g. In most field conditions (between 10˚C-15˚C) the water is so close to 1000g we recommend directly translating its mass to volume when calibrating.

Water is known as the universal solvent because of its ability to pull molecules apart in solution, due to it's polarized structure. This allows ions to freely travel between attractors and repellents. It's this increased conductivity (lowered resistance) that the Salt Dilution method exploits to measure the time varying [NaCl]. Conductance varies nearly linearly with [NaCl], and we've called this linear correlation the Calibration Factor (CF). To normalize this relationship, we use the Non-Linear Funciton (nlf) correction to 25˚C and call this the CF.T. In this way, we can compare and predict CF.T values from different probes, sites, and times. The theoretical CF.t, as a function of both [NaCl] and EC.T, is shown in Figure. This figure is taken from Figure 3 of Richarson et al (2017). In general, Salt Dilution measurements are made at EC.T values less than 1000 µS/cm, and so we expect a CF.T of less than 0.50 [mg/L]/[µS/cm].



In practice, however, other ions in the mix interfere with ionic transport, and result in higher CF.T values (remember the higher the CF.T value, the smaller the step when performing CF.T calibration). Figure is taken from Figure 4 in Richarson et al (2017) and is from whence our default value of 0.486±0.02 [mg/L]/[µS/cm] is derived.



This brief introduction to the suspiciously strange properties of water is intended to allow the QiQuac user to better understand the system and its calibration.

Uncertainty

"We demand rigidly defined areas of doubt and uncertainty!"
(Adams, D. 1979).

The QiQuac reports the Q-Uncertainty on each channel, calculated independently, and also the delta Q between channels. This combined approach can determine the independent quality of each measurements, and any uncertainty from incomplete mixing, or other issues.

To calculate the independent channel uncertainty, we rely on the partial differential derivation of equation 2:

$$\frac{\delta Q}{Q} = \frac{\delta M}{M} + \frac{\delta \Delta t}{\Delta t} + \frac{\delta CF_T}{CF_T} + \frac{\delta\left[\sum \left(EC(t) - EC_{BG}\right)\right]DT}{\sum \Delta t\left(EC(t) - EC_{BG}\right)}$$

The %Mass uncertainty term is set in Setup> Meta Settings> Uncert. in Mass % and the default value is ±0.5%. This would correspond to ±5g for a 1kg injection, for example. For injections less than 100g, the gram scale with an uncertainty of 0.01g should be used.

The %time uncertainty term is essentially zero and can be ignored since the QQ calculates the delta time per sample.

The %CFT uncertainty term is set in Setup>Meta Settings> Uncert. in CF.T % and the default value is 2.0% corresponding to plasticware calibration using the 1000μl pipettor and the QuickFlask with a scale to within 5ml (±5g). The uncertainty using the QuickFlask alone is ±1%. The NaCl standard should be within 0.5%when made. If the user can attain an uncertainty of less than 2.0% (glassware could achieve 1.5%) then the user is free to change this setting.

The Area Uncertainty term is more complicated. The Area under the curve is in mg/l converted using CF.T and the uncertainty in the area is also in mg/l using CF.T so those terms are on the top and bottom and cancel out. The CF.T uncertainty term is already included in the equation. The Numerator of the Area Uncertainty term is:

$$\delta\left[\sum\left(EC(t) - EC_{BG}\right)\right]*DT = EC.T_{Unc}*DT = \max\left(SE_{BGEC.T}, \frac{1}{2}R\right)*DT$$

Where $SE_{BGEC.T}$ is the standard error in the BG EC.T and R is the instrument resolution (or the minimum EC.T step in the record, calculated during a measurement). DT is the elapsed time over which the Area has been calculated[3]. The $SE_{BGEC.T}$ using the central limit theorem is:

$$SE_{BGEC.T} = \frac{s_{BGEC.T}}{\sqrt{n}}$$

Where $\boldsymbol{s}_{BGEC.T}$ is the standard deviation of the Pre- and Post- BG EC.T values. In the QQ, this is set to 10 for each period by default, so n = 20 total. In the Salt Portal, there is an option called "Assume Sloping BG ECT" which takes the average Standard Deviation ***s*** of the Pre- and Post- ***s***. When there is a downward sloping BG ECT, the Salt Portal will result in a lower Area Uncertainty by default. If the trace doesn't return to the Pre-BG ECT, then the area uncertainty will also be larger. Neither the QQ nor the Salt Portal currently can discriminate between a naturally sloping BG ECT or a trace that doesn't return to BG ECT. It's left up to the user to determine this by context and professional judgement. The Salt Portal gives the user the tools to assign an appropriate uncertainty.

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3 Because of the DT term, the longer a pulse takes to come down the larger the Area Uncertainty term. Therefore there is a "Sweet Spot" of complete mixing and shorter duration pulse that the SD practitioner is aiming for. When watching the QUncertainty on the QQ during a measurement, the user may often see the QUn reach a minimum and then begin to increase again because of this increasing DT term.

"There is an art, it says, or rather, a knack to flying. The knack lies in learning how to throw yourself at the ground and miss." (Adams D. 1979)

Uncertainty Example

The following example is taken from a single injection using 1kg in ~1.3 m³/s of flow and shows the inherent uncertainty in a flow measurement with a naturally variable background. The plots in Figure 1 show three interpretations of the same measurement in the Salt Portal and the variance in the Q and Uncertainty. The QiQuac reported this measurement as a Grade B measurement and recommended increasing the salt dosage. Note that the dosage needed to be increased due to the variation in the BG ECT and not the stability of the sensor signal[4], which was actually quite low (0.02%).

a)

b)

c)

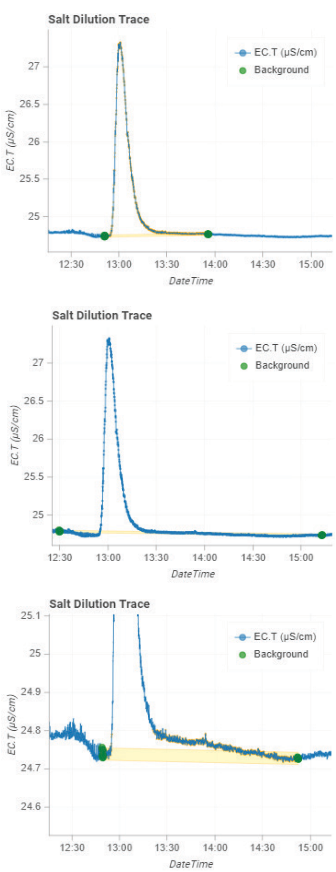

Figure 5. a, b & c

Figure showing the same trace in the Salt Portal with 3 interpretations a) 1.32 m³/s ±4.0% assuming a sloping background. This is probably the most accurate interpretation. Note the rise in EC.T is only 2.5 µS/cm. b) The default interpretation taking the entire trace misses the natural dip in EC.T before the pulse arrives and therefore underestimates the area. With "Assume Sloping BG ECT" OFF, this results in a Q of 1.47 m³/s ±12.5%. c) moving the Pre- BG EC.T sample just before the pulse and extending it out to the start of the rise results in a Q of 1.22 m³/s ±5.3%. In c) we've zoomed in to show the natural BG EC.T variation.

If we tabulate these results and compare them, only interpretation a) and c) are significantly different at 95% confidence. Note that the min Q from b) doesn't include the max Q from c). Note that b) Uncertainty is quite high due to the length of the pulse AND the inherent uncertainty between the Pre- and Post- BG ECT because Assume Sloping BG ECT was OFF.

Case	Q (m^3/s)	Unc. (95%)	Max Q (m^3/s)	Min Q (m^3/s)	Sig Diff from a)	Sig Diff from b)	Sig Diff from c)
a	1.32	4.0%	1.37	1.27		FALSE	FALSE
b	1.47	12.5%	1.65	1.29	FALSE		TRUE
c	1.22	4.9%	1.28	1.16	FALSE	TRUE	

Notes

A] The Uncertainty and Significant Difference calculations are based on 95% confidence.

From this example, the user can see the value of uncertainty analysis, the influence of natural BG ECT variability, and the choices that the user must make in post-processing.

4 The Stability is the standard deviation of the 10 pre and 10 post BG EC.T measurements.

SDIQ Grading

The QQ will attempt to grade your measurement. For this to be possible both channels must have made a measurement so that they can be compared. The Grade thresholds are set in Setup > SDIQ Settings > Grade A Threshold % and Grade B Threshold %. These are set to 7% and 15% by default. These are meant to represent 2 sigma (95% confidence) intervals and represents thresholds from BC RISC guidelines for Grade A and Grade B measurements. Grade A is assigned if QUnc. for Ch0 and for Ch1Ch1 and the percent difference in Q from the two channels (%DQ) are all less than Grade A Thresh%, likewise for Grade B. Grade C is assigned if at least one of these three metrics is greater than Grade B Thresh %.

In our example, the Sensor on the other bank of this trial resulted in a Q of 1.42 m^3/s ±4% which is 8% different than this sensor and therefore a B Grade was assigned with the suggestion to increase the mixing length.

SDIQ Summary File

The QQ produces a Summary File with an Average Q between Ch0 and Ch1Ch1. The uncertainty associated with the Average Q is

$$Q\bar{u}nc = \max(Qun0, Qun1, DQ)$$

This estimate assumes the maximum uncertainty from the 3 estimates should be assigned to the measurement.

SDIQ Uncertainty Summary

Unlike the Infinite Improbability Drive on the Heart of Gold (Adams, D. 1979) there is nothing to be gained from large uncertainty in an SDIQ. You are trying to achieve a Grade A measurement. There are various best practices to achieve this. The QQ tries to capture the significant features of the measurement quantitatively in order to assign a Grade and suggest ways to improve your measurement if a Grade A is not achieved. You can almost always decrease the QUnc. on both channels by injecting more salt to overcome any natural background EC.T variations, although more salt will never overcome a problem with incomplete mixing. In that case, increasing the mixing length with usually overcome this problem. Be careful to avoid local inflows, recirculating pools and eddies, and aeration (bubbles). These will all increase the QUnc and the DQ. It's good practice to make two injections to determine the variability in your method, assuming the stage level is relatively constant. Above all, "Don't Panic."

CHAPTER 3

Operation

In which the QiQuac embarks on a Salt Dilution Instream Flow (SDIQ) measurement.

The QiQuac is on the track of a big flow; even the little T-HRECS know!

Get Started: Capturing a Q

1. To begin a measurement, select "Start Logging" from the main menu.
2. If Setup>Site Settings is set to "from txt list" or "from csv db", you will be asked to select a station[5],or the generic "SDIQ". Select the station by pushing the button.
    a. If either file is chosen, this text of the chosen station will be pre-pended to the file name, and
    b. If "from csv list" station information such as site and project ID will be stored with the QQ file, and the last CFT values recalled into RAM. Wait for the station information to leave the screen.
3. QQ will begin listening on the channels for transmissions. Ch0 is always the RS232 connected serial device and Ch1 and Ch2 are from the radio channel[6]. When a transmission arrives, it will be displayed. Every transmission will be logged to the SDCard from this time until the measurement is canceled or finished. You can now either leave QQ recording to process the measurement at a later time, or push the button to begin an SDIQ. The rest of the instructions assume you have pushed the button to start an SDIQ.
4. Enter the Mass of salt to be injected when prompted. Enter the significant digits first, then change the decimal place after pushing the button to accept the digits. Turning the knob faster will result in larger changes. Set the default Mass in settings. You can change the mass during a measurement.
5. Next, you will be asked to set the CF.T, or "Hold to Calibrate". The CF.T should be ~0.486±.02 (mg/l)/(μS/cm) for NaCl in freshwater. However, this will depend on the unit's current calibration and also to some degree (±3%) on the stream chemistry. If the "csv db" option was set in Site Settings, then the last saved CF.T will be displayed for each channel. If the CF.T is known to be otherwise, turn the rotary encoder to set. To start a CF.T calibration, push and hold the button for >1 second then release. The calibration procedure will begin with the next received serial transmission[7].

Calibration (5-10 mins)

6. If Calibration mode was selected, you will be asked to inject 1 ml of 5 g/l standard into 1000 ml of stream sample[8]. Before doing this, you should prepare the stream sample. Place the probe(s) in the stream to reach equilibrium.

5 Site names are stored in the station_list.txt or station_list.csv file. Edit this file in any wordprocessor or excel.

6 It's important that the Setup>Device Settings>Set Ch1 SN is set to the text string arriving from T-HRECS for it to be recognized. Otherwise an "Unknown Device" alarm with trigger and data will default to Ch0.

7 Performing a calibration each SDIQ, or site visit, is not necessary according to RISC 2018 (BC Provincial Guidelines), The calibration error is on the same order as natural variability, but having a repository of historical CF.T values for a site makes choosing a historical value more defensible.

8 These parameters can be changed in the Setup menu.

7. If using QuickFlask, there are 3 methods to verify that it contains 1000+/10ml: scale, meniscus-lines, and drain port:
   a. Place the provided kitchen scale on a flat surface. A level note-book computer is ideal, but not so much in the rain. The top of the DuckBox has enough flat surface to use, but care must be taken when positioning the feet to ensure that nothing is touching any of the box ridges. After the scale is powered on, place the QuickFlask on the scale and tare it. You have a limited amount of time before the scale automatically powers down, which can be extended by pressing the scale surface.
   b. Open the port and dunk the flask in the stream. While holding the handle such that the flask is plumb, allow the sample to drain out . The QuickFlask has a calibrated handle. Hold the handle at the approximate water temperature. Water is most dense at 4oC, as shown in Figure 4 above, until the meniscus is below the black lines[9]. Close the port.
   c. Place the flask on the scale. Water at room temperature (20˚C) will weigh 997g. Water below 10˚C will weigh 1000g. We aim to have the weight within 5g (0.5% error). This error is taken into account in the derived SDIQ Uncertainty and can be set in Setup>Meta Settings>Uncert CF.T%. The total CF.T% is set at 2.0% as default for plasticware. If lower uncertainty is required, the user must go to volumetric glassware, which can achieve 1.4% uncertainty.
8. Note the EC.T[10] when the probes are in the stream. Now put the EC.T probes into QuickFlask and note the EC.T. It may increase by a few µS/cm. In theory, a slightly higher (i.e. <1%) ECT should not affect the CFT. But residual salt in the flask for example, can contaminate the results and if the ECT increases by more than 1%, step 7 should be repeated. Push the button to set the first EC.T in the calibration. As calibration points are collected, they are displayed. Often, the first injection results in an unacceptably high or low CFT. If it is less than 0.44 or higher than 0.55, press and hold the button to remove the last point and start again. If you miss pressing a button after an injection, you can press and hold multiple times to restart the CF.T calibration. Only a few ml have been injected, after all, and can either be removed with the pipettor or ignored if you just start the CF.T again without refilling the flask.
9. Inject 1 ml of standard and mix until the EC.T stabilizes (about 50 vigorous up & down motions). Push the button to accept this value. Repeat for 3 more injections. After the last button push, QiQuac will calculate and display the final CF.T for each active channel. Nothing needs to be done with these numbers, they will be saved to RAM, but you may wish to write them down, or take a photo, for your field notes.

---

9 The accuracy of the stream sample volume will depend on this step and the user should try several test runs with QuickFlask and a scale to determine the volume and uncertainty of the sample.

10 EC.T is Electrical Conductivity.Temperature Compensated in µS/cm at 25°C using NLF (Non-Linear Function based on EU standard 27888).

10. The QiQuac will present several options for the derived CFT depending on the situation. Do not push the button to select your choice until the probes are placed in calm flow in the channel. Rotate the dial clockwise to change the option, rotate counterclockwise to change the channel:
    a. If the CFT is out side of the range 0.4 to 0.6, "CFT:Bad->Default" will be displayed and it will not be possible to choose another option. The default values, either derived from the SD Card or Settings, will be used for the measurement
    b. If a site was chosen from "csv db" file, you will be given the option to either save to the SD card for this site, "CFT->SD Card" or save to both the default settings and the SD card "CFT->SD & Sett."
11. If no site was chosen from the "csv db" file, then you can either save to Settings (which can be changed from the main menu via Setup> SDIQ Settings>CFT0) or to RAM. RAM is what is used for this SDIQ measurement. Once the correct Save CFT option is chosen AND the probes are placed in the channel, push the button to start the SDIQ.
12. If the button was pushed too soon, Don't Panic, put the probes in the stream, the QiQuac may complain about anomalies but push on, then push the button again to bring up the context menu, and select Hold to Restart. Hold >1 sec and release to restart the SDIQ.

Salt Dilution Measurement (10-60 mins)

At this point, you must decide whether to use the 3rd probe (Ch2) as an Upstream or Downstream probe. The QiQuac is currently designed to only Grade an SDIQ based on Ch0 and Ch1, but the user can chose to measure the Q with Ch2 as well. If you are gauging in a channel with an active BGECT, ie changing more than 1% over the course of the measurement, then we recommend using Ch2 as an U/S probe. This is often the case in urban or agricultural runoff scenarios, and can also be the case on the falling or rising limb of a hydrograph. The QiQuac will always consider the Pre- and Post-BGECT when calculating the area under the curve, but if the Ch2 probe is not used as the 3rd U/S probe, then a linear interpolation is used, which is sufficient most of the time.

Many of the context menu options discussed below are only available after the Pre-BG ECT count has reached Zero, i.e. the QiQuac has at least BG ECT N points recorded for each channel.

13. Ensure the shroud is on all EC Probes. Place the probes in the stream in moving, but not turbulent or aerated, water. Ideally place the Ch0 and Ch1 probes on opposite banks, 10-20 channel widths downstream of the point of injection. If not possible, then place one probe in the center of the channel and the other on the near shore. If not possible, place one probe near shore and the second probe 2-3 channel widths downstream.
    a. If using Ch2 as the 3rd U/S Probe (this is the default if Ch2 is active), then place it in moving, but not turbulent or aerated water upstream of the point of injection and ensure it has >1min to stabilize its temperature[11].
14. Wait for the EC.T and temperature to stabilize. It may be necessary to lightly knock the shroud to release any entrapped air. Ensure there are no upstream water inflows. This will show up as noise in the EC and likely only on one channel. It may be due to unseen groundwater inflows. Push the button to begin calculating the background EC.T[12]. By default, QiQuac uses a 15-point Pre- and Post- average for BG EC.T[13]. The Post-BG EC.T is a moving average of the last N points, thus the QiQuac will begin calculating the Post-BG EC.T immediately after the Pre-BG EC.T. The area under the curve is calculated by either
    a. The difference between the ECT trace and the line between Pre-BG ECT and Post-BG ECT or
    b. The difference between the ECT trace and the estimated BGECT derived from the 3rd U/S Probe.
15. Inject the required amount of salt[14] a sufficient distance upstream[15] in sufficiently turbulent flow[16].

11 If not using Ch2 at all, then no changes are necessary if it was turned off or not present. The QiQuac will handle the SDIQ as a 2 probe scenario. If using Ch2 as a 3rd D/S probe, after starting the measurement and Pre-BG N has reached zero, push the button again, select "Use 3rd U/S BG" from the context menu. This will change the setting for the Displayed (either D or S) channel. If Ch2 is selected, the wording changes to "Use Ch2 AS 3U/S?"

12 Note that if 2-3 EC.T probes are being used, turning the dial counter-clockwise will toggle the values between the channels. The currently displayed channel is indicated by Ch0D, or Ch1D, or Ch2D for multi-plot display or Ch0S, Ch1S, or Ch2S for Solo display.

13 The number of BG points can be changed in settings or from the context menu. More BG points should reduce the associated uncertainty, but will require more time. Use 15-30 points if relying on the regression line, use 5-10 point is using the 3rd U/S sensor.

14 The rule of thumb dosing guideline is 1 kg per m^3/s and should not exceed ~5 kg per m^3/s. There are more detailed dosing guidelines in the references. The required amount can be reduced for lower BG EC.T values, or for shorter transit times. We built the QiQuac with the aim to reduce the dosing to 0.1 kg per m^3/s but often 0.2 kg per m^3/s results in a Grade A measurement.

15 A sufficient distance is typically 10-20x the channel width. This can be reduced for very turbulent reaches or where there is a constriction. The mixing distance must be increased for less turbulent flow and may not work at all for calm flow. Placing one of the two EC.T probes in the channel center and the other on the bank should help determine if complete mixing did not occur. Averaging the two derived Q's should be more accurate than if both probes are placed near the same bank.

16 The salt should be injected in very turbulent flow. Ensure there is no salt left on the bottom of the channel. The salt can be injected slowly over time or spread out over the channel width to assist in mixing. The salt can also be pre-dissolved in stream water before injection. In cold water (<5°C) this is recommended.

16. As the salt wave travels past the EC.T probe(s), observe the EC.T trace rise and fall[17]. The derived Q will change as the EC.T changes. The EC.T may take a very long time (>1hr) to reach BG EC.T, when the derived Q does not change much with time. QiQuac shows the change in the derived Q for each new measurement of EC.T. When this value alternates about zero, it can be assumed to have reached BG EC.T. If time constraints (helicopter for example) prevent this, there will be more uncertainty in the derived Q. You can also zoom in on the Y-axis so better see trends.

17. Push the button at any time to access the context menu, which has 8 options. Push and hold at most options to return to the SDIQ (except Adj Pre-BG_ECT)

    a. Finish SDIQ: Select this to finish the SDIQ and bring up the SDIQ Summary card. Data will continue to log until you leave the summary card. When you Finish an SDIQ, a line is written to the SDIQ_Summary file in the directory. You can back out of the Summary Card by pushing and holding the button.

    b. Adj Pre-BG_ECT: You can almost always achieve a lower Uncertainty by selecting Adj Pre-BG_ECT. Two vertical bars will appear indicating the period being averaged for the Pre-BG_ECT. Move these closer to the start of the Breakthrough Curve and watch the Uncertainty and Q change. Turning slowly will change the bars by BG_N/10 records and turning quickly will change by BG_N. Push the button to accept the new Pre-BG_ECT period. This function adjusts the Pre-BG_ECT for the Displayed channel. After finishing with one channel, turn the dial counter-clockwise to change the displayed channel and repeat. The difference between the pre- and post-wave BG EC.T will be taken into account in the derived Q and associated uncertainty[18].

        i. If Ch2 is currently Displayed, and if Use Ch2 AS 3U/S is "1" then a single thick bar appears. This is the point of injection. Adjust this to the approximate time of injection.

        ii. If Auto Adj. Pre-BGECT is set to a non-zero integer in Setup>Meta Settings, then the Pre-BGECT may already be at the base of the Breakthrough Curve.

    c. Adj Mass: Use this to adjust the mass in realtime. This is often the case if you weigh the mass after starting the SDIQ.

    d. Enter Stage: This value is currently not used for anything in the SDIQ (we hope to integrate Rating Curves in future firmware) but you can enter the stage here as a way to record it on the SDIQ. It is written to the end of the Summary file record.

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17 If "Auto Adj. Pre-BGECT" is set to a non-zero integer, the QiQuac will Quack and adjust the Pre-BGECT to the start of the pulse. The EC.T label will change from "ECT:" to "ECT="

18 The Q%Unc uses the Standard Deviation of the entire BG EC.T sample. If the Pre- and Post-samples vary significantly (i.e. incomplete trace) this will be reflected in the diagnotic.

e. Use 3rd U/S BG: This setting will apply to whichever channel is currently displayed. If Ch2 is active, this will be set to 1 for both Ch0 and Ch1 and the Ch2 trace will be adjusted by transit time and delta ECT to estimate the BG ECT over the course of the measurement. If Ch2 is displayed, the text will become "Use Ch2 AS 3U/S?" and the user can chose to use Ch2 as the 3rd U/S probe or the 3rd D/S probe. At the current time, it's not possible to set Ch2 as the second measurement for purposes of Grading, but that will be available in the future. If the user wishes to use the probe currently set to Ch2 as Ch1, that change can be made in Setup>Device Settings>Set Ch1 SN. Ensure that no two Channels have the same SN.

f. Hold to Restart: Push and hold to restart all the calculations associated with the SDIQ, and also reset the display. There are two useful situations for this: 1. If you accidentally leave the probes in the calibration flask when you hit the button to start an SDIQ, you can move the probes to their appropriate place, then Restart SDIQ, or 2. If you are performing multiple injections and would like to process all measurements within a single file, you can record the SDIQ values during the measurement, then select Restart SDIQ to begin the next measurement.

g. Adj Y-Axis: Turn the dial to adjust the Y-Axis Max, push the button to accept, then adjust the Y-Axis Min and push to accept. Use this feature to zoom in on the BG_ECT near the end of an SDIQ.

h. Return to SDIQ: Select to return to the SDIQ with no changes.

i. Hold to Cancel: Push and hold to stop logging without writing the summary SDIQ stats to the Summary file or displaying a Summary card. All data is still logged to the SD Card and can be post-processed.

18. After the measurement is finished the Q+/-Uncertainty for each channel is displayed. These will be written to the SD card with a timestamp. The displayed uncertainty is the 95%Confidence Interval. The measurement is graded by both the individual QUnc. and the %DQ[19]. Feedback on the measurement is also offered. Push the button to return to the main menu.

Determining the BG ECT for Low Dosing

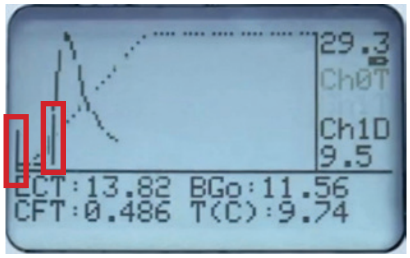
There are 3 methods by which the QiQuac can determine the BG ECT during a measurement, equally, there are 3 methods by which the uncertainty on the measurement can be determined. These are

1. Average of Pre- and Post- BGECT,
2. The regression line determined by the Pre-BGECT (or Pre- and Post- together if uncertainty falls below the Snap Tolerance) and
3. the transposed 3rd U/S Probe (CH2).

19 Grade A is assigned if QUnc. for CH0 and for CH1 and %DQ are all less than Grade A Thresh%, likewise for Grade B. Grade C is at least one of these three metrics is greater than Grade B Thresh %. These Thresh values can be changed in SDIQ Settings.

1. The default Q is determined by dividing the Mass by the area between a line drawn between Pre- and Post- BG-ECT area between the break-through curve and the line drawn between Pre- and Post- BG-ECT. The Uncertainty is the standard deviation of Pre- and Post- BG ECT points multiplied by the elapsed time, divided by the Area.

A)



B)

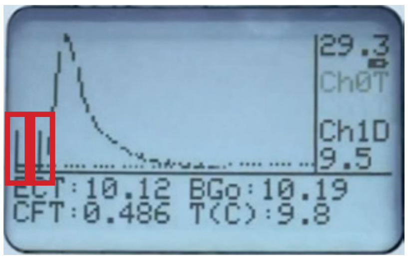


Figure 6. A & B

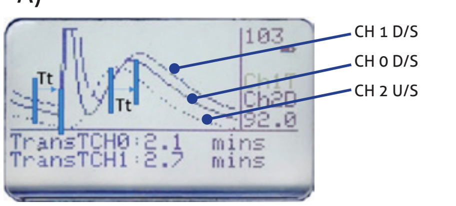
Figure A) shows the BG ECT Regression line with too many BG N points (15) which captures some of the rise in BGECT for CH1. After reducing the BG N (by Push-holding on the Adj. Pre- BG ECT selection) to 5 points, the regression line is more reasonable and "snaps" on to the Post- BG ECT sample, thereby greatly reducing the Unc on Ch1. When this Snapping event happens, the QiQuac will double "Quack" and the "Un1:" will change to "Un1="

2. The setting for Setup>Meta Settings>Show BGECT Line will determine if the regression line will be shown. The setting for "Use Regression Line" will determine if the regression line is used for determination of Uncertainty. When using the regression line for uncertainty, the uncertainty is determine as the standard error about the displayed regression line. When the uncertainty for a channel drops below the setting for "BGECT Reg.Snap Tol%" the regression line will switch from just using the Pre-BGECT to using both Pre- and Post- BGECT. This will cause the regression line to always pass through the Pre- and Post- samples. This will have a tendency to underestimate the uncertainty.

3. If Use 3rd U/S Probe is set for a given channel, then Ch2 will be transposed to the that channel by x (determined by Transit Time) and y (determined by the difference between the time shifted 3rd U/S probe and the channel Pre-BG ECT. This means the 3rd U/S Probe BGECT will always start at the end of the Pre-BGECT sample period, as shown in Figure B) The raw data for this plot is shown in Figure A)

   The 3rd U/S Probe has the potential to greatly reduce the amount of salt required to achieve Grade A measurements (default is <7% uncertainty). However, it can be complicated to properly shift the Ch2 data to downstream sites. This current beta version of the system is promising and further refinement of the system will be coming shortly. We've tested the system as a simple 2 probe system, and give the user the option of switching out the 3rd U/S probe during a measurement to see the difference.

A)



B)

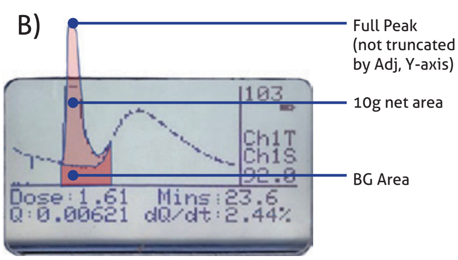


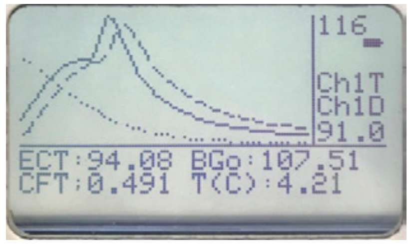
Figure 7: 3rd U/S Probe

In A) we see the unprocessed data from 3 channels, with Ch2 being further upstream above the point of injection. In order to simulate a changing BGECT, we injected an unknown amount of salt much further upstream. We then injected a known amount of salt downstream of the 3rd U/S Probe. The Ch2 probe is always dotted and does not show the smaller pulse. The user must first set the Pre-BGECT for both Ch0 and Ch1 as close to the rise of the pulse as possible. They must then set the thick bar on the Ch2 to the injection time. If two people are making the measurement, the downstream hydrographer can push the button to start, or restart, the measurement when the injection is made. If this happens, it's not necessary to set the injection bar. Alternately, if one person is injecting, then can count the seconds after making the injection, and set the thick injection bar to the number of records back from the head of the trace. For example, if using a 5 second interval and 30 seconds elapse between the time of injection and when the bar is set, set it 6 pixels back from the head of the measurement. We intend to make this procedure more intuitive in future iterations of the firmware.

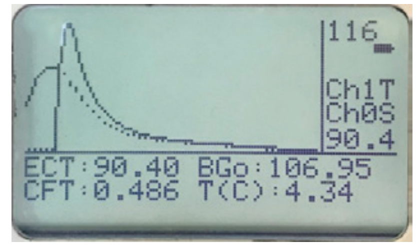
Figure 8. A & B

Figure showing another example where the 3rd U/S Probe is recording a larger slower pulse than a second injection made afterwards. A) shows the raw data and B) the transposed data for Ch0.

A)



B)



Unloading the Data from the QiQuac and Post-Processing

Data is stored as csv files on an internal SD Card. We can access the data with the USB-Mini cables supplied with the kit. These cables have been modified to have a longer plug required by the USB-Mini waterproof port. Using a standard USB Mini cable will not work.

To download the data, the QiQuac must be turned off to begin. Plug in the USB cable to the QiQuac and the computer (Windows, Mac, or Linux will be the same). The QiQuac should wake up and display SD Card info if it recognized the USB Host. The computer should mount the QiQuac as an external storage device. Access it like you would any external storage device.

To Post-Process the data, log into the Salt Portal or use the Field Access Salt Portal. Instructions on Post-Processing can be found at https://www.fathomscientific.com/enter-yon-salt-portal/.

CHAPTER 4

QiQuac Menu System

In which the QiQuac is exposed to show
several layers of sophistication,
much like an onion.

The QiQuac hides his true feelings behind his tools; even though, properly polished, they could be jewels!

There are several menus within QiQuac (QQ) to set various parameters and start operations. This guide will explain the various parameters. To change the selection, rotate the dial. To select, push the dial. The dial has debouncing circuitry; if the dial is rotated too quickly the value will not change as quickly. In general, holding the dial down for longer than 1 second will cancel an operation, or go back. Nothing will change after 1 sec, but releasing the dial will execute the Hold command.

Main Menu

The Main Menu consists of 4 options:

Start Logging

If you've chosen to use a Station_list.csv or .txt file under Setup>Station Settings, you will be prompted to select the station before logging begins. Once the station, or the generic SDIQ, is chosen, the QQ will wait for serial data to appear at either channel. When data appears, the Salt Dilution Instream Q (SDIQ) screen will appear. Push the dial and Hold to cancel the Start Logging operation. Two types of files are recorded on the internal SD Card: "*.csv" is a formatted file with format "Date:Time,EC,Temp,EC.T", and "*.raw" is the unprocessed serial data. Step-by-step instructions to Start Logging are detailed on pg 13, "Get Started: Capturing a Q"

Setup

Select this to access secondary settings menus. For further detail see "Setup" below.

Replay

This function will Replay the files on the SD card named "Demo_Ch_0.raw" and "Demo_Ch_1.raw" and the corollary _CFT files, if they exist. This menu item will not be available if these files are not present on the SD Card. This function also serves as a demo, or test, simulation. All functionality of the SDIQ screen will be available, except that the data will be processed much faster than the original dataset.

Power Down

Select to Power Down. The QQ will automatically Power Down after 5 minutes of inactivity, except in Logging mode or Serial Term mode.

Setup Menu

The Setup Menu consists of 8 options:

1. Device Settings
2. Station Settings
3. Set Time
4. Set Date
5. SDIQ Settings
6. Meta Settings
7. Serial Term
8. Back

1. **Device Settings**

This will take the user to submenu with 4 options.

a. Set Locations:
b. Set Ch0 SN
c. Set Ch1 SN
d. Set Ch2 SN

1.a. Set Locations is not yet implemented, but will allow the user to set any Ch ID to a location. Currently only the RS232 Serial unit can be Ch0.

1.b. Set Ch0 SN: Use this to set the Serial Number of the T-HRECS device on Ch0.

1.c. Ch0 SN: Use this to set the Serial Number of the T-HRECS device on Ch1.

1.d. Set Ch2 SN: Use this to set the Serial Number of the T-HRECS device on Ch2.

2. **Station Settings**

Select From txt list to read the "station_list.txt" file from the SD Card and pre-pend a station name to each file before each SDIQ.

Select From csv db to read the "station_list.csv" file from the SD Card and pre-pend a station name to each file before each SDIQ, and also read the station and project ID, and Ch0, Ch1, and Ch2 CFT values from the SD Card.

3. **Set Time**

Rotate the dial to set the time.

4. **Set Date**

Rotate the dial to set the date.

5. **SDIQ Settings**

Select to access secondary menu related to the SDIQ.

The SDIQ Settings Menu consists of 13 options:

a. Mass (kg)
b. CFT0(mg/l)/(uS/cm)
c. CFT1 (mg/l)/(uS/cm)
d. CFT2 (mg/l)/(uS/cm)
e. Inj. Conc. [mg/l]
f. Inj. Volume (l)
g. Stream Sample (l)
h. BG EC.T N
i. Set Interval
j. Grade A Thresh %
k. Grade B Thresh %
l. Log Interval (sec)
m. Restore Defaults
n. Back

5.a. Mass (kg): The default mass for each SDIQ. Factory Default is 2kg.

5.b. CFT0(mg/l)/(uS/cm): The default CF.T. Factory Default is 0.486(mg/l)/(uS/cm).

5.c. CFT1(mg/l)/(uS/cm): The default CF.T. Factory Default is 0.486(mg/l)/(uS/cm).

5.d. CFT1(mg/l)/(uS/cm): The default CF.T. Factory Default is 0.486(mg/l)/(uS/cm).

5.e. Solute EC.T (uS/cm): This value is used to correct the CF.T if a standard solution is used for CF.T derivation. Factory default is 5µS/cm.

5.f. Inj. Conc. [mg/l]: This is the concentration of the added NaCl to the solute to make the standard. Factory default is 5000 mg/l.

5.g. Inj. Volume (l): This is the volume of injection for the CF.T derivation. Factory default is 0.001lt.

5.h. Stream Sample (l): This is the volume of the stream sample. Factory default is 1lt.

5.i. BG EC.T N: This is the number of points, pre and post trace, to use in the calculation of the BG EC.T. Factory default is 10.

5.j. Grade A Thresh %: This is the user defined threshold for Grade A measurements. Factory default is 7%.

5.k. Grade B Thresh %: This is the user defined threshold for Grade A measurements. Factory default is 15%.

5.l. Log Interval (sec) This option will allow you to set both the T-HRECS interval without accessing the T-HRECS menu from the Serial Terminal.

5.m. Restore Defaults: Select to restore factory defaults.

6. Meta Settings

Select to access secondary menu related to metadata.

The Meta Settings Menu consists of 6 options:

a. Uncert. in CF.T %
b. Uncert. in Mass %
c. Moving Circ. BGEC.T
d. Apply SINE Unc
e. Anomaly Detect
f. Sound Volume %
g. LCD Contract
h. B-Light Bright %
i. Extrapolate SDIQ
j. Show BGECT Line
k. BGECT Reg.Snap Tol%
l. Trans.Min.Size
m. Auto Adj. Pre-BGECT"
n. Restore Defaults
o. Back

6.a. Uncert. in CF.T%: The estimated 95% confidence limits on the CF.T. The factory default is 2.0%, which corresponds to the uncertainty using plasticware (and QuickFlask). Glassware could yield an uncertainty of 1.4%.

6.b. Uncert. In Mass %: The estimated 95% confidence limits on the Mass. The factory default is 0.5% which corresponds to a scale accuracy of 10g and a mass of 2 kg.

6.c. Moving Circ.BGEC.T: Set this to 1 to have QQ calculate the Post-Pulse average BG EC.T based on the last measurements. This will result in a very large, or non-sensical (i.e. -1) uncertainty estimated until the pulse nears the original BG EC.T. Set to 0 to have QQ calculate the Post- Pulse BG EC.T only after the dial is pushed to finish the measurement. The Factory default is 1.

6.d. Apply SINE Unc: This is the SINE multiplier of the Standard Deviation in BGECT. It was an attempt to convey the uncertainty in the BGECT in the regression line by applying a SINE wave to the BGECT Line. However, this adds noise to an already busy graph so it is set to Zero as default.

6.e. Anomaly Detect: Sometimes an EC measurement device will produce an anomalous value, like zero, for no known reason. This erroneous measurement can corrupt a calculated Q, the associated uncertainty, and also the plot. Set parameter to a non-zero value to instruct QQ to set recorded EC.T values less than this anomaly value to the previous measurement. Set to zero to disable this feature. The factory default is 1 uS/cm.

6.f. Sound Volume %: Adjust to change "Quack" volume.

6.g. LCD Contract: Adjust to improve contrast.

6.h. B-Light Bright %: Adjust to change Background Light. Factory Default is 50%.

6.i. Extrapolate SDIQ: This should be named Use SDIQ Regression. This will determine if the regression line is used to calculate Uncertainty for a given channel. Factory default is 1.

6.j. Show BGECT Line: Set to display the BGECT Regression Line. Factory default is 1.

6.k. BGECT Reg.Snap Tol%: The uncertainty obtained from the chosen Uncertainty method before the regression line will snap to both Pre- and Post- BGECT Samples. Before this occurs, only the Pre-BGECT is used in the regression line equation.

6.l. Trans.Min.Size: The minimum number of characters to be considered a valid transmission. Factory Default is 23.

6.m. Auto Adj. Pre-BGECT: Enter a number between 1 and 30 to indicate the number of points before 5σ (5 standard devations) from the Pre-BGECT the trace is exceeded in order to reset the Pre-BGECT endpoint. During a measurement, the QiQuac will record the mean and σ of the Pre-BGECT. When the current ECT value exceeds 5σ, we can be 99.9999% confident that it is significantly larger than the Pre-BGECT and the Pre-BGECT end will move N values back from this time. When this occurs, the QiQuac with Quack and the EC.T label will change from "ECT:" to "ECT=". Enter 0 to turn off this feature. Default is 5 points.

6.n. Restore Defaults: Select to restore factory defaults.

6.o. Back Select to return to the setup menu.

7. Serial Term

Select to access a serial terminal program (baud 9600, 8,N,1)

The Serial Terminal program is a basic serial terminal operating at 9600 baud, 8,N,1. After selecting this option, you will be prompted to choose the Channel to access. The terminal screen should be blank except at the bottom it will read SEND and a "0". Rotating the dial will change this character. Pushing the dial will select the displayed character and move to the next. Selecting the ¶ symbol (5 characters down from A), by turning the dial counter-clockwise from "0", will invert the "SEND" label. The ¶ symbol represents a Carriage Return (CR) and will send the character string to the port. After selecting the ¶ symbol, the character string will be the same as what was sent, but the selected character will be the left most. To exit the Serial Terminal, push, hold and release the dial after more than 1 second.

There are only two UART channels to access, Ch0 on the rs232 port and Ch1 for the radio.

Power Management & SD Card Access

To charge the QQ, plug the provided mini-USB cable into the QQ and a power source such as a laptop. The QQ will power up. If the QQ detects a USB data port, it will remain on the SD Card information screen and attempt to mount as an external storage device on the laptop. If this is not desired, push the button to skip this function to get to the main menu. The charge status can be monitored from the main menu. The voltage will increase when the USB is plugged in and drop when unplugged.

You can monitor the battery voltage on the Main Menu. A fully charged battery will read >4V and a depleted battery will read <3.5V. The QQ will sound a "Quack" when the voltage drops below 3.5V when logging. When the USB is plugged in and the battery is charging, the battery icon will show rising gradations.

To access the data on the QQ, the unit must first be turned off to begin with. Plug the unit into a PC or Laptop and it should power up. The PC should install the necessary drivers and the QQ should appear as an external mass storage device. You can now access the files as you would any external hard drive.

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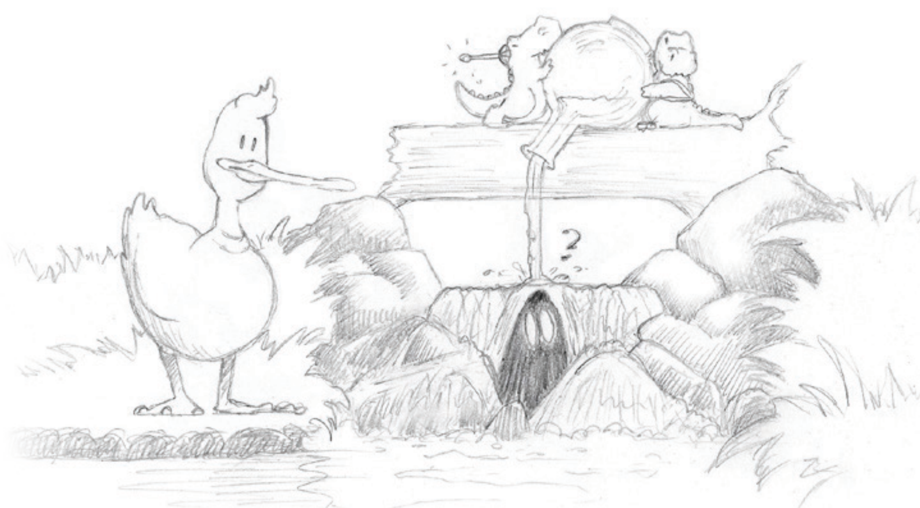
CHAPTER 5: EPILOGUE

Frequently Asked Questions (FAQs)

In which several humorous questions
are posed and answered.



The Q is released back into the wild but has a few Qs of his own to repine,
like what were the motives and who was that duck, and why do I now taste like brine?

Q: *My QiQuac is on fire, is that normal?*

A: It's perfectly normal for the QiQuac to catch fire from time to time. Simply remove all flammable material from its perimeter, grab a guitar, and roast some marshmallows.

Q: *I get shocked every time I touch the QiQuac, am I doing something wrong?*

A: The QiQuac generates a powerful EMF or Electromagnetic Field. Keep cell phones, laptops, pacemakers, radios, or any other electronic device at least 20ft away. Ensure you are well grounded before operating the QiQuac as it can build up >10,000V over the course of a measurement. Do NOT use the QiQuac around water.

Q: *My QiQuac just told me to Quack off!, should I be concerned?*

A: Absolutely not. Each QiQuac has a "Drunken Sailor Processor" or DSP which randomly generates cuss phrases and slurs when the mood arises. Consider it character!

Q: *The QiQuac Manual makes no sense and appears to be randomly organized. Who wrote this sh**?!?*

A: We get this one a lot. The Manual was actually written in English by Fathom Scientific Ltd, then passed through 5 language translations: Nepalese, German, French, Spanish and Dutch before retranslating to English. And yes, you nailed it, the organization IS random. P.S. Please refrain from profanity.

Q: *The QiQuac asked me for my credit card number, and I just found out my card has been drained. What gives?*

A: Hah, that little trickster. This is to be expected. The QiQuac has a history of this kind of shenanigans. Best to just leave it be and hope he gives the money back.

Q: *Why are there no real Questions in this FAQ?*

A: We've often found, in this manual as well as in life, that taking time to laugh is more valuable than getting actual work done. We think that QiQuac customers will feel the same way. If not, maybe they should buy a Sommer.

Q: *I just fell in the river with the QiQuac and my lunch, I'm soaking wet and waiting for the helicopter.*

A: Sorry, is there a question there? Sounds like you're feeling pretty low. Cheer up! The QiQuac is IP67 waterproof so that's not a problem. You live and work in the most beautiful place in the world, and food ALWAYS tastes better if you have to wait for it.

Q: *This QiQuac is pretty tricky to use, why not just make a tablet or phone app?*

A: I was going to say something about "craftsmanship" and "tactile interaction" and "good ol' days", but you're probably right. We'll work on it.

Q: *Wow, this manual is a real tome. Don't you just throw salt in and measure the conductivity? Why all the mumbo-jumbo*

A: Wow, ok, so we're using words like tome. Ok. To answer your question, "Yes" you could just throw in a tonne of salt, but the little critters you're throwing it on and the ecosystem you're accumulating the salt in wouldn't appreciate it. We've found careful consideration of sources of error and Signal to Noise Ratio the best approach to reduce environmental load AND reduce uncertainty. So put that in your tome and smoke it.

Q: *That doesn't make any sense, I can't smoke something in a tome.*

A: (Security, we have a situation in the Q&A section) Next Question.

Q: *I love these Fathom T-Shirts, where can I get one?*

A: Buy a QiQuac! Or AutoSalt!