NIWA
Taihoro Nukurangi

Water Clarity Monitoring

Te Waikoropupu Springs

Prepared for Tasman District Council

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Contents

Figures

Executive summary

An Envirolink small advice grant was approved for the Tasman District Council (TSDC) to assess current methods and provide guidance on future monitoring of the water clarity of Te Waikoropupu Springs ('Pupu'), near Takaka.

Theoretical estimates of water clarity from transmissometers[1] were compared graphically to horizontal black disk visibility[2] (yBD). This comparison allows the accuracy and sensitivity of the methods to be compared. A site visit was undertaken to assess current methods and test an alternative transmissometer. The opportunity was taken to take samples for coloured dissolved organic matter (CDOM; which, like particles, also attenuates light and therefore influences visual clarity). Measurement protocols are provided in an appendix.

A summary of recommendations:

1. At least two-yearly, undertake factory servicing and calibration of the existing transmissometer (Wetlab-CSTAR).
2. During field measurements record at least 60 readings for robust statistics and to ensure yBD can be estimated with the required precision.
3. An alternative transmissometer (Martek-XMS) should be used (only in Pupu Springs) as it is more sensitive.
4. At Pupu Springs, transmissometer sampling should start early in the morning before oxygen bubbles are produced via photosynthesis by the abundant plant life. Instruments should be deployed from a boat over the central Pupu springs inflow vent to avoid micro-bubbles.
5. At the same time and same sites as the transmissometer measurements, collect triplicate water samples for laboratory spectral absorption analysis of coloured dissolved organic matter (CDOM) as an additional indicator of optical purity.
6. Increase the current 'seasonal' (about every 4 months) sampling to monthly sampling, for a 1 year period, to assess natural variability and to guide the development of a future monitoring plan.
7. Attempt direct visual clarity measurement early in the morning on one occasion (given permissions) to verify transmissometry.
8. Seek, in collaboration with NIWA, an Envirolink medium advice grant ($20 K), to assist in the implementation and analysis of a near-real-time telemetered monitoring study on the temporal changes in Pupu Springs water quality (oxygen, temperature, and optical water quality).

[1] A transmissometer is an electronic instrument which measures the change in intensity ("light transmission") along a light beam. When submerged in water, the transmissometer measures the clarity of the water.
[2] "Horizontal black disk visibility" is the distance from which an observer can distinguish a black target from background. This gives a measure of water clarity.

1 Introduction

Te Waikoropupu Springs (Pupu Springs) is recognised as an iconic feature due to the high flow rate and exceptional water clarity, and has the highest visitor numbers of any location in Golden Bay. The Takaka collaborative governance group, set up under the National Policy Statement for Freshwater Management in 2014, strongly advocates for more data about water clarity from this site. Attempts over the past year, using a 0.25 m pathlength transmissometer (owned and operated by NZ King Salmon), to measure the water clarity have been problematic as regards accuracy and sensitivity. Previously, NIWA had measured black disk visual clarity in-situ with snorkel divers, using a system of mirrors to fold the light path and provide a water background (Davies-Colley and Smith 1995). Cultural issues with having divers in the springs poses difficulties for future monitoring using the black disk method. Tasman District Council (TSDC) sought advice on the applicability of current water clarity measurement method, potential for improvements and alternative solutions to implement a reliable method for monitoring changes in water clarity in this iconic spring.

Accurate and sensitive monthly records of water clarity will provide a reliable assessment of visual clarity, including changes which may be occurring over time. NIWA was contracted to advise on the limitations of current methods and either provide solutions for a more accurate/sensitive application, or propose alternative methods. Advice will also be needed to train staff to implement an updated or alternative method.

2 Background

Visual water clarity in natural waters is best indexed by the horizontal sighting range of a black body (Duntley 1963). Accordingly, the horizontal black disk visibility method was developed by Davies-Colley in the 1980's. The visibility measure is directly related to the green beam attenuation coefficient (c), centred around the mid wavelength sensitivity of the human eye (550 nm) (Davies-Colley 1988):

Equation 2-1: $$yBD = 4.8/c550$$

This 'photopic' beam attenuation coefficient (c550) can be measured using commercially available transmissometers (e.g. WET Labs CSTAR). When the yBD empirical relationship was reviewed against theoretical models, it was proven to be a robust underwater visibility parameter (Zaneveld and Pegau 2003). Instrument monitoring of c550 has advantages over direct measurement of visibility as it is easier to measure and can be monitored continuously if required.

Transmissometers contain their own 'green' light source (or filter only green light at the receiver) and measure the intensity of light at the receiver over a known pathlength (m). This is often measured as the percentage of light transmission, referenced to either air or pure water, which is then converted to an attenuation coefficient (the fraction of light that disappears per metre of path length). Light attenuation is a combination of the absorption coefficient (a) plus the scattering coefficient (b) along this light path.

Previous studies in 'exceptionally' clear waters of Pupu Springs (Davies-Colley and Smith 1995 – yBD about 63 m) and Blue Lake (Gall, Davies-Colley et al. 2013 – about 80 m), support the empirical relationship. However, there are logistical and technical challenges in measurements in these extremely clear conditions. For the black disk method in very clear waters (such as Pupu Spring), a large (of order 1 m diameter) black disk is required, and mirrors are needed to fold the light path as the distance across the spring is less than the visual water clarity distance. As black disk measurements are onerous and constrained in Pupu Springs, there is interest in alternative methods, such as monitoring with transmissometers. However, the accuracy and sensitivity required for measurements of water clarity by transmissometers in exceptionally clear water requires high quality instruments with particular attention to specified calibration protocols.

3 Comparison of transmissometer performance

To provide context and guidance to results in these exceptionally clear conditions (high light transmission, low beam attenuation coefficients – close to pure water), the empirical relationship was used to compute expected transmittance readings from two different types of transmissometer: That presently being used for monitoring, a WET Labs-CSTAR-G (green - 530 nm), 0.25 m pathlength instrument; and an alternative, the Martek-XMS (green, - 530 nm), 1 m pathlength instrument.

The WET Labs CSTAR has a straight 0.25 m pathlength, uses a 'collimated optical system', and calibrated to pure water, giving a 100 % transmittance reading (i.e. pure water attenuation subtracted from values). Calibration drift is monitored and adjusted by measuring in air with the light path unobstructed, and blocked. WET Labs state a precision of about 0.02 % and accuracy of beam attenuation of about 0.003 m^{-1}. This equates to about 0.1 % transmission at 100 %, decreasing as a percentage as the attenuation rises (transmission lowers). Expected horizontal visibility distances with a black disk versus expected percentage transmission values are shown in Figure 3-1. Note that a shift from an 83 m visibility in pure water (100 % Tr) to 50 m, equates to only a 1 % reduction in signal (about 10 times the accuracy of the instrument). This shows that 0.25 m path transmissometers do not have the resolution to detect anything other than gross changes in visual clarity.

As the human eye (peak photopic sensitivity of about 550 nm) and the green light of the transmissometer (about 530 nm) are slightly different 'greens', there is a difference in responses due to the type of optically active material in the water. Coloured dissolved organic matter (CDOM - yellow colour), is highly absorbing, with more absorption at shorter (blue) wavelengths. It therefore has more influence on wavelengths between 530 > 550 nm. Consequently, if yellow substance dominates attenuation in a water body, the attenuation measured by a 530 nm transmissometer must be adjusted to estimate the absorption at 550 nm (about 35 % less) for the purposes of estimating black disk visibility (Figure 3-1 – orange line). In contrast, suspended particles are likely to have the same attenuation (absorption plus scattering) within this green region (530 ~ 550 nm). If particles dominate attenuation, measurements at 530 nm will be similar to those at 550 nm (Figure 3-1 – blue line). Both conditions represent the boundaries in expected readings, whereas the reality is likely to be intermediate (Figure 3-1 – black line).

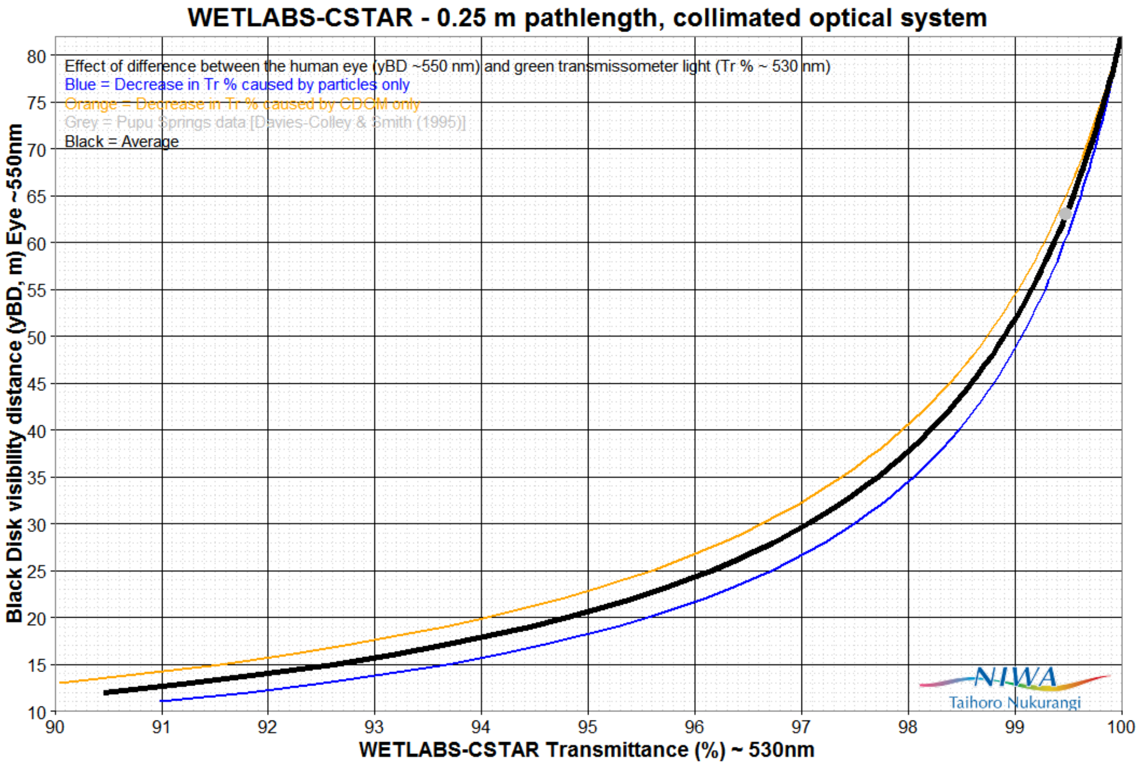

Figure 3-1: Black disk visibility distance against WET Labs-CSTAR green transmittance values. The two outer lines are the effects of different types of material in the water, CDOM (coloured dissolved organic matter – orange) and particles (blue line). The black line is the average of CDOM and particle effects.

The Martek-XMS has a water light path folded with a mirror (1 m - 2 x 0.5 m), uses a 'cylindrical optical system', and is calibrated to its theoretical value of 85.5 % transmittance with the light path unobstructed in air. Theory suggests a beam transmission in pure water of 95.5 %. The instrument has been demonstrated to have a precision of about 0.06 % transmission and accuracy to within 0.004 m^{-1} (Gashler 1996). This is similar to the WET Labs-CSTAR, equating to about 0.1 % transmission accuracy. Expected horizontal visibility distances with a black disk versus expected Martek (1 m path) transmission values are shown in Figure 3-2. This instrument was the same used to develop the original relationship, and measurements in Pupu Springs (displayed in Figure 3-2) and Blue Lake. Compared to the WET Labs-CSTAR, the increased pathlength offers 4 times the sensitivity.

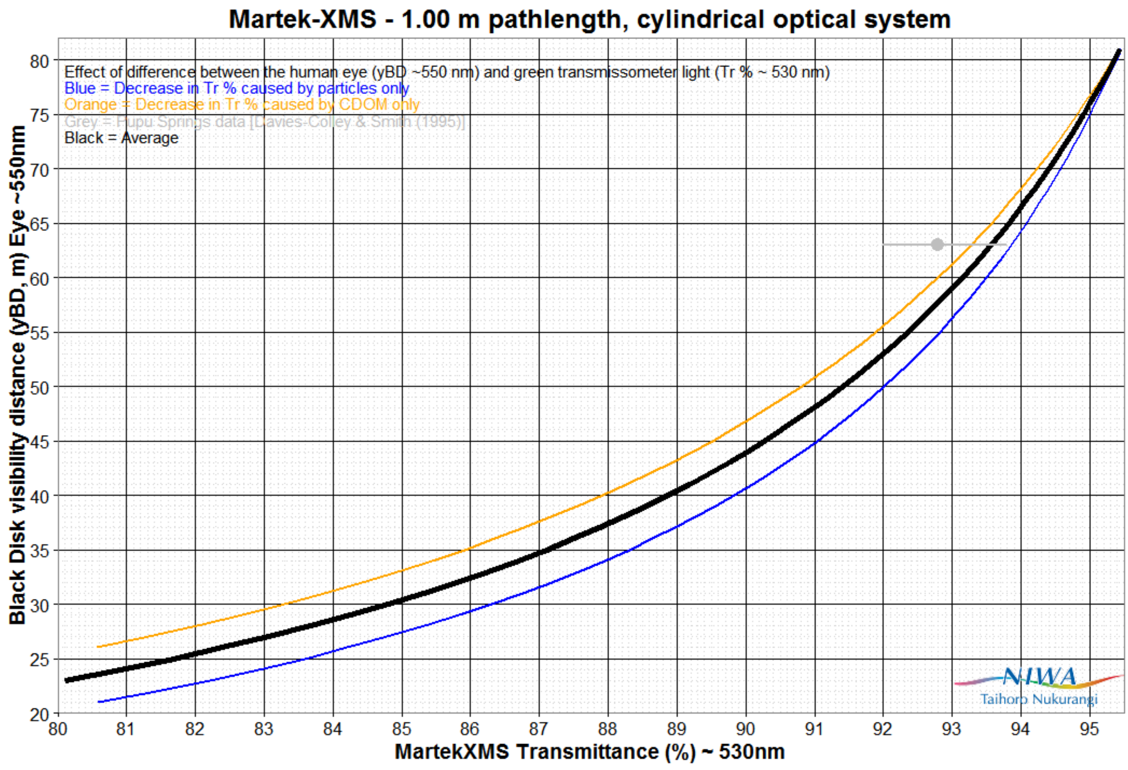

Figure 3-2: Black disk visibility distance against Martek-XMS transmittance values. The two outer lines are the effects of different types of material in the water, CDOM (coloured dissolved organic matter – orange) and particles (blue). The black line is a combination of CDOM and particle effects. Note that the original Pupu Springs measurements are illustrated as the grey point and line (Davies-Colley 1988).

4 Site visit and assessment

Pupu Springs was visited on Friday 30th September 2016, with TSDC (Trevor James) and Envirolink Ltd. staff (Tony Hewitt and Mark Hahn).

4.1 WET Labs-CSTAR method (existing)

Current methodology involves the use of a 0.25 m green (530 nm) transmissometer. This was initially cleaned and calibrated dry in air, and blocked (to measure zero digital counts), before placing in a sample contained within a white tube bath (about 200 mm diameter). Stable readings for each measure are observed through the supplied WetView software, and when readings are consistent (typically three in a row), the value (digital counts) documented. Values are entered into an EXCEL spreadsheet, containing the appropriate calculations to obtain transmittance %.

From inspection of data collected so far (Nov-15, Jan-16 and May-16), Pupu Springs samples are often > 100 %, and variable. There are no statistical metrics on variability. This indicates either incorrect air calibrations, calculations, or other faults. As shown in Figure 3-1, for Pupu Springs accurate and stable readings are required to be confident in < 1 % transmittance differences.

The current collection methodology was not useful for providing statistical details or diagnosing transmissometer performance. Manufacturer assessment and re-calibrated is recommended. Instructions for use of this transmissometer are detailed in the Appendix (Section 9.1).

4.2 Martek-XMS method (alternative)

The Marek-XMS was calibrated to air, then allowed to warm up for 10 min, and calibrated to air again (Tr = 85.5 %) prior to deployment following the instructions outlined in the Appendix, section 9.2. In-situ values appeared much lower (about 86.3 % - yBD ~ 30 m) than expected (93.0 % - yBD ~ 60 m) (see Figure 4-1 but refer to Figure 3-2 for expected values). It made no difference to the measurements whether readings were taken closer to the platform (nearer aquatic vegetation) or father out (about 3 m) into the main flow.

Transmissometers can suffer from condensation build-up within the instrument housing, when sampling cold water due to moist air inside the housing. This is usually observable with the naked eye as a frosty appearance due to light scattering. Although the Martek instrument was checked for this at a NIWA laboratory prior to the field work, it cannot be ruled out with measurements in-situ. Another tell-tale sign is that as condensation builds, transmittance decreases and stabilizes to a lower value. This is not apparent in the in-situ measurements data trace (Figure 4-1.).

It was not possible to bracket calibrations with an end value after measurements were completed due to the wet conditions of the day. As the transmissometer was cold (about 12^{o}C), moisture instantly condensed on the optical faces exposed to air.

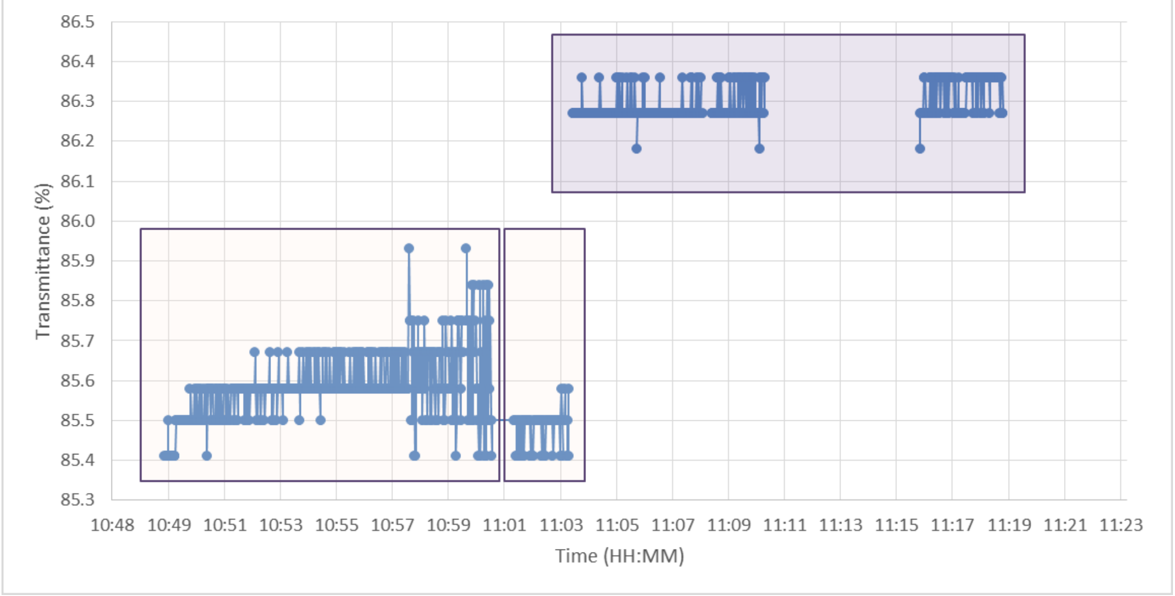

Figure 4-1: Martek-XMS deployment in Pupu Springs Transmittance (%) vs time. Initial period (yellow box) was an air calibration, followed by a 10 min warm-up period. The instrument was re-calibrated to air (85.5 %) @ 11:01 (second yellow box). Pupu Springs in-situ sampling began at about 11:04 (purple box). Gap in middle was removing from water, inspecting and redeploying to note any obvious causes for lower than expected transmittance values.

4.3 Coloured Dissolved Organic Matter (CDOM) absorption

To augment visual clarity estimates, water samples for laboratory measurement of CDOM were taken at Pupu Springs and a site on Springs River 600m downstream of Pupu's main spring. This downstream site is also influenced by Fish Creek which drains a catchment of about 216 ha. It was assumed that particle effects on green light attenuation at these sites was negligible, being dominated by pure water attenuation and CDOM absorption, allowing estimates of visual clarity based on c550 from pure water and CDOM alone.

Clean CDOM bottles were rinsed three times with sample water prior to collection in triplicate. Water samples were stored refrigerated in the dark, before spectral absorption analysis at the NIWA, Wellington campus. In brief, the absorption spectra from 300 to 850 nm was determined using a UV/VIS light source and spectrophotometer (Ocean Optics Inc.), through a 1 m long liquid waveguide capillary cell (LWCC - Precision Instruments Inc.) following methods reported for similarly optically pure Blue Lake (Gall, Davies-Colley et al. 2013). The sample was pre-filtered (< 0.45 um cartridge) prior to determination against referenced laboratory fresh nanopure water (Figure 4-2).

The absorption coefficient of CDOM (or gilvin – ag m^{-1}) in the stream at 550 nm (ag550 - 0.136 m^{-1}) was about 42 times higher than Pupu Springs (ag550 ~ 0.003 m^{-1}). The CDOM absorption in the Spring water was barely detectable versus nanopure water. By adding the attenuation coefficient of pure water at this wavelength (cw550 ~ 0.0584 m^{-1}) to the measured CDOM absorption, we calculated a black disk visibility (yBD) of 25 m for the stream site and 77 m for Pupu Springs. Stream site yBD observation by two staff ranged between 23 and 27 m, underscoring the usefulness of measuring CDOM as an estimate of visibility at that site. The higher visibility of Pupu Springs (about

77 m) compared to that estimated by the Martek-XMS, highlights the difficulty in attaining "accurate" estimates in such a clear water.

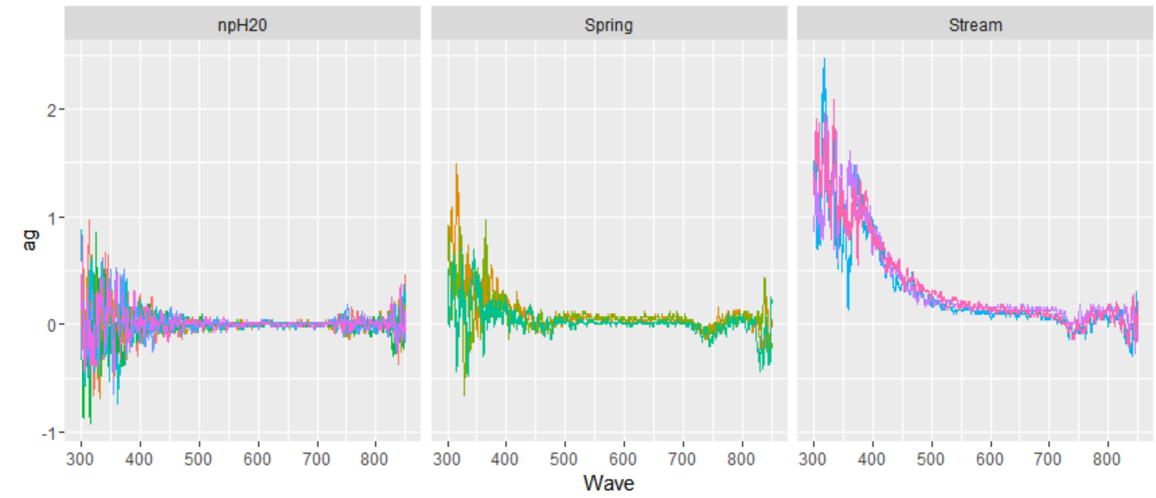

Figure 4-2: Coloured Dissolved Organic Matter (CDOM) absorption spectra The absorption coefficient of CDOM or gilvin (ag m^{-1}) against wavelength (nm) for nanopure water, Pupu Springs and the Stream. Non-linear statistical curve fitting (exponential) was used to determine the exponential slope and intercept value of interest (in this case ag550 nm).

5 Discussion

Pupu Springs, like Blue Lake, is recognised to have 'exceptional' water clarity (Davies-Colley and Smith 1995, and Gall, Davies-Colley et al. 2013). These extremely clear waters approach pure water, challenging the sensitivity of measurements, their precision and accuracy. In clear waters, Gall, Davies-Colley et al. (2013) reasoned that the precision of human observations of visibility (using the horizontal black disk method) is better (about 5 % CV) than that of standard oceanographic instrumentation, such as the Martek-XMS beam transmissometer (about 10 % CV). This supports the use of the black disk method, where practical in clear water conditions.

For Pupu Springs, black disk observations are rather impractical as there are restrictions in the use of divers and/or boats, and a mirror is required to fold the light path, as the spring basin is too small for direct sighting (Davies-Colley and Smith 1995). This favours the use of a beam transmissometer to monitor estimates of water clarity (from the well-known empirical relationship of Davies-Colley 1988). However, previous attempts over the past year, using a WET Labs CSTAR 0.25 m instrument, have been imprecise and inaccurate. Theoretical estimates of water clarity (yBD) from an alternative longer pathlength (1 m) transmissometer (Martek), illustrates the potential for about 4 times the sensitivity.

The site visit demonstrated the requirements for accurate readings and the careful protocols needed for calibration. The current transmissometer (WET Labs-CSTAR CST-1511PG) requires factory-servicing and calibration, prior to further use, as its last calibration was dated 10-July-2012. Cleaning and calibration protocols outlined on the WET Labs website, and the general instructions in method application will improve the accuracy and reliability of observations with this instrument. However, even with such attention to detail this sensor (0.25 m pathlength) is intrinsically too limited in sensitivity for detecting change in optical quality in such a clear water.

The site visit also demonstrated the use of an alternative transmissometer (Martek-XMS). This deployment highlighted challenges in measurements from surface waters near the observation platform and to the interpretation of readings, with lower transmittance values (about 86 %) than expected (about 95 %). Fine microbubbles in the water may have contributed to reduced transmittance values (Zhang, Lewis et al. 2002). This was noted in the original 1998 study and speculated to be due to increased oxygen bubble formation due to primary production from aquatic plants during the day-time (Davies-Colley pers. comm.).

Long pathlength (1 m) spectral absorption analysis of the collected CDOM samples provided a useful alternative method, and provided an upper bound estimate of visibility (about 77 m). The method reasonably assumes negligible concentrations of light-attenuating particulates, as these have not been detectable in the Pupu springs in the past, and are unlikely due to efficient particle filtration through groundwater aquifers of long (years to decades) residence time. CDOM results support the potential influence of micro-bubbles with in-situ measures, highlighting the difficulty of spot measurements at one time of day. Future transmissometry should be done early in the day (say, before 9:00 am) before oxygen evolution from the abundant plant life in the springs basin becomes problematic.

Access to the middle of the springs with a small boat, would be ideal in order to sample directly above the main inflow vent. A near-realtime telemetered monitoring study on temporal changes (daily, weekly, monthly, and seasonally) in Pupu Springs water quality (oxygen, temperature and water clarity) would address the unknowns of microbubble influence within the water column. Monthly, in-situ sampling and calibrations for a 1 year period, is needed to assess natural variability and to guide the development of a future monitoring plan.

6 Recommendations

1. The existing transmissometer (WET Labs-CSTAR CST-1511PG) should be factory-serviced and calibrated, prior to further use, as its last calibration was dated 10-July-2012.

2. Field cleaning and calibration protocols outlined on the WET Labs website should be followed, with raw value recording for at least 60 readings at 1 second intervals. Statistics (mean and standard deviation) should be calculated to allow yBD to be estimated with the required precision. This degree of rigour is necessary for Pupu Springs sampling because of its exceptional clarity. A protocol is outlined in the Appendix.

3. An alternative transmissometer (Martek-XMS) should be used (only in Pupu Springs) as it is more sensitive, and deployed following protocols outline in the Appendix.

4. For monitoring water clarity, Pupu Springs should be sampled at the same time of day on each occasion, ideally early in the morning before oxygen bubbles are produced via photosynthesis by the abundant plant life. Ideally instruments should be deployed from a boat over the central Pupu springs inflow vent to avoid micro-bubbles.

5. Triplicate coloured dissolved organic matter (CDOM) water samples should be collected at the same time and same sites as the transmissometer measurements. These samples should be analysed for spectral absorption analysis at NIWA, Wellington, as an additional indicator of optical purity.

6. The present 'seasonal' (about 4 monthly) sampling should be increased to monthly sampling for a 1 year period, to assess natural variability and to guide the development of a future monitoring plan.

7. Direct visual clarity measurement should be attempted on one occasion (given permissions) using mirrors to fold the light path as in the original work by Davies-Colley and Smith (1995) – in order to verify transmissometry. In such clear water (as noted for Blue Lake by Gall et al. 2013) visual clarity measurement is actually more accurate than transmissometry.

8. In collaboration with NIWA, an Envirolink medium advice grant ($20 K) should be sought. The grant would assist in the implementation and analysis of a near-real-time telemetered monitoring study on the temporal changes (daily, weekly, monthly, and seasonally) in Pupu Springs water quality (oxygen, temperature, and optical water quality). It would align with the monthly calibrations/servicing recommended above.

7 Acknowledgements

Thanks to Matt Pinkerton and Rob Davies-Colley for reviewing this report and Juliet Milne for overseeing the Envirolink advice grant. John Nagels and Richard Yates tested out the old Martek transmissometer and readout instrument for the current field campaign. Thanks also to Tony Hewett and Mark Hahn (Envirolink Ltd.) for field work assistance.

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9 Appendix

9.1 WET Labs-CSTAR transmissometer protocol

Wetlab supplies several documents which outline the calculations, procedures for use and functional checks and cleaning methodologies on their website (http://WET Labs.com/CSTAR). Users of this instrument should be familiar with these documents and follow recommended protocols. This is especially important when the water is very clear and the instrument is operating close to its limit of sensitivity. In particular, should the transmissometer fall outside these functional checks after careful cleaning, it should be returned to the factory for diagnostics and re-calibration. WET Labs recommends annual factory servicing, particularly to check seals and ensure there is no moisture inside the instrument housing which causes condensation behind optical lenses. If this is not apparent, the instrument should be factory calibrated every two years (its warranty period).

There are a number of recommendations to ensure high precision (low variability around reading) and accuracy (high confidence in value of readings) using the C-Star with its supplied WETView software:

1. Adjust the settings of instrument to output data at 1 second intervals.
2. Collect at least 60 seconds worth of ‘good’ data for each measurement (air, blocked, sample). This can be done within the same file (noting time ranges for each measurement) or as separate files, naming appropriately. An air and dark sample should only be needed at the beginning of day’s sampling. We suggest using a reverse date file naming (e.g. YYYYMMDD_Type.raw: For example, 20161005_Air.raw). This ensures files will sort in order of date.
3. If possible, measure with the instrument directly in the water (in-situ), ensuring optical surfaces are free of air and bubbles. Visualise the data trace using the plot tab on WETview and once stable, record a raw file for at least 60 samples. This should minimise any contamination and provide a stable reading. If the instrument track is not stable over the 60 seconds, inspect the instrument, clean the optical surfaces and repeat the measurement procedure.
4. If an in-situ measurement is not possible, collect a sample using a ‘very clean’ container (rinse several times with sample water) and dispense into a black pipe with endcap just larger than C-Star – or use the black pipe to fill with sample. Place C-Star in the pipe and move up and down to assist in mixing. Note if the data trace is stable and record a raw file for at least 60 samples. If the trace decreases or increases over this period, bubbles are forming on the optical faces or particles are settling out. Repeat until the most stable trace possible is recorded. Take readings as soon as practical and before water warms to air temperature as this will cause degassing of water.
5. Import the saved raw files into EXCEL. Undertake quality control and calculate statistics (e.g. mean, median, standard deviation; standard error, etc.). Use these values for further calculations.

Recording at least 60 samples ensures statistical robustness and enables diagnostics to be compared against published noise and expected deviations of air and dark calibrations over time. It also ensures confidence in an accurate representation of the sampling and if measurements are being affected by drift over the sampling period. It should provide a true statistic of natural variability of the calibrations and sampling.

9.2 Martek-XMS trnsmissometer protocol

9.2.1 Overview

This modified transmissometer system displays and logs water attenuation (related to turbidity) readings. The values are in percent green light transmission (Tr %). The time stamped values are stored to a removable PC readable SD card. Any recently manufactured SD card up to several gigabytes in size can be used. Data can be written to the SD card in several different user selectable time intervals from 1 second to several minutes. The data on the SD card can be easily imported into any spreadsheet program if required.

This type of transmissometer uses a cylindrical optical system, which is different than other collimated optical systems such as WET Labs-CSTAR transmissometers. The former's maximum value is for that of pure water (Tr ~ 85.5 %), as opposed to the latter where pure water has been subtracted from the signal (Tr ~ 100 %). The Martek-XMS uses an incandescent bulb as the light source and pass filters that only allow light at a bandwidth of about 528nm (green) to be measured.

9.2.2 Inventory

1. Control and display box.
2. SD card (this needs to be set up with the folder "TRANS" in the root directory). Note this is supplied.
3. 1 meter folded path length transmissometer (for reasonably clear water).
4. Power connector for 12 v battery.
5. 12 volt battery.
6. Control and display box cabling.
7. Deployment rope.
8. Towels and tissues for cleaning and drying.
9. Small bottle of detergent and ethanol or cleaning.
10. Hydro-frame for deployment.
11. Extendable bottle sampling pole to push away from weed obstructions.

9.2.3 Control and display box summary

The control box is an IP67 rated, latchable enclosure that houses the display, control electronics and the SD card control board. The exterior of the box includes a viewable area for the display, IP65 power switch. It display transmittance to the nearest decimal place (e.g. 81.1 %) but is recorded to the SD card to two decimal places.

9.2.4 Power supply

The requirement is a 12v battery – current draw: ~800 – 1000 mA (depending on bulb used).

9.2.5 Software and firmware

The firmware for the microprocessor is contained in the program transmissometer(3).bas. The software for resetting the internal clock (if required) is the python file pit_log_date(6).py. There is also an executable file pit_log_date(6).exe for windows systems that do not have the python programming environment.

To set the internal clock: (you will need a serial cable and access to the program pit_log_date(6).exe).
1. Run the program pit_log_date(6).exe.
2. Follow the onscreen instructions (the serial cable is connected to a serial port jack inside the control box).
3. Either watch the on-screen display or the display on the control box;
   On-screen display: after a few seconds you will see data appear indicating what is being transferred to the chip. This will be followed by a message to indicate that the transfer has finished and a message to close the program.
   Control box display: when the setup gets to the point "set clock" you will see dots appear indicating the progress of data transfer.
4. When finished disconnect serial cable from serial port.

9.2.6 Setup procedure

1. Turn on main power switch (setup and boot information will appear on the display).

2. Watch information on the display until "set path" appears. At this point press the control button (and **hold down**) and two options will be presented, after the correct option that you require has appeared, **release the control button** – the message "confirmed" will appear. Note that if you forget to set the path length, execution will halt and you will have to switch off, restart the unit and repeat the above. It is important that correct path is set for the unit being used as each transmissometer has a separate configurable amplifier to amplify that unit's signal to the correct level for that unit.

3. Watch information on the display until "set rec length" appears (this is the interval between data being written to the card). At this point press the control button and several options will be presented. After the correct option has appeared, release the control button – the message "confirmed" will appear. Note that if you forget to set the record length a default of 1 second will be used.

4. If everything has been completed correctly you will receive the message "Ready" followed by the message "MAX VOLT NOT SET" and under this the current amplified voltage from the instrument. Allow the unit to settle for at least 5-15 minutes. Make sure the voltage is somewhere between 4.7 and 4.9 volts, if not open up the control box, locate the correct amplifier trim pot for the unit in use and trim the voltage to within the correct range. When complete, make sure that the amplification setting will still allow the indicated voltage to fluctuate slightly.

5. Once the unit is fully "warmed up" and the output voltage is in the correct range, place some form of blanking disk into the units light path to "blank" the unit. At this point you should see the voltage go to zero. Remove the blanking disk and the voltage should return to its previous maximum value. Now press the control button until a message "setting max" appears, then release the button. At this point the control electronics will go through an automatic max voltage setting procedure. Once this has completed the 85% value (for air) will appear. Now re-blank the unit and 0% should appear. The unit is now ready to be deployed.

Note: for initial testing prior to full deployment, use the one second interval option, if this is fine then change to required time interval and be aware that the unit will only update the LCD display when data is written to the SD which is dependant on the user selected logging interval.

9.2.7 Operational measurements

It is ideal to 'bracket' reading in air, before and after deployment measurements, to calibrate and adjust for instrument temperature differences or changes should they occur. However, at times where there is moisture in the air, the cold instrument will condense water on the optical faces, making it impossible to reliably do this procedure until the instrument has warmed up. However, if it is a dry day it should also be possible to undertake a calibration check at the end of sampling. Do both if possible.

1. Ensure the unit is clean and dry. Clean windows with tissues and inspect.
2. Supply power and go through setup procedure above. Allow about 10 minutes for the instrument to warm-up and stabilise. It will be logging internally. Note time difference on control/display box.
3. Turn the power supply on and off again to reapply setup procedure and recalibrate to maximum voltage. It should read 85.5 %. Note this number. Allow it to record at least 1 min worth of data onto the SD card. Note any changes.
4. Block the path without touching the optical windows. It should read 0 %. Note this number. Allow it to record at least 1 min worth of data onto the SD card.
5. Deploy the instrument. Make sure there are no bubbles or air trapped near optical windows. Note time in the water.
6. Allow it to record for at least 5 min worth of data onto the SD card. This will ensure the instrument has equilibrated in temperature to its environment. Note readings during this period. If decreasing, bubbles will be forming on windows. Pull out and put back in water, which helps remove bubbles sticking to faces. Note times any changes are made to anything during deployment.
7. Remove instrument from water. Note time. Dry with towels. Clean optical faces with tissues, ensure dry, and allow it to record for at least another minute.
8. Backup datafile once back in office.

The datafile will contain a continuous recording during above procedure. Good time-keeping and records are essential for QA/QC. The dataset will need cleaning to remove spurious data prior to data-processing and statistical analysis.

9.2.8 Data format example

An example of the format of the data on the SD card is shown below:

```
07/31/2047---15:22:40---1.00m
15:22:40,85.13,%
15:22:40,85.12,%
15:22:40,85.12,%
15:22:40,85.14,%
```