

Standard Operating Procedures for *Stream Metabolism*
Version 1.1

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Introduction

The Standard Operating Procedure (SOP) for Stream Metabolism describes the purpose of stream metabolism monitoring at selected sites in the lower Goulburn River, how the monitoring will be conducted, who is responsible for specific tasks and how the collected data will be analysed and reported. The document is intended to be taken in the field during any stream metabolism monitoring event for the LTIM and should be updated throughout the life of the Long Term Intervention Monitoring Program to reflect any agreed changes to method or procedure.

Objectives and hypotheses

This monitoring protocol for stream metabolism addresses the following Basin scale evaluation questions:

Short-term (one-year) and long-term (five year) questions:

- What did Commonwealth environmental water contribute to patterns and rates of decomposition?
- What did Commonwealth environmental contribute to patterns and rates of primary productivity?

The key objective of the stream metabolism monitoring program is to determine the effects of environmental watering actions on the rates of gross primary production (GPP) and ecosystem respiration (ER) within the Goulburn River. These processes support and sustain aquatic foodwebs hence are directly related to ecosystem health and viable fish populations. Important drivers for these processes, notably nutrient, (water column) chlorophyll-a and organic carbon concentrations and light are collected concurrently to allow flow effects to be distinguished from nutrient variations, phytoplankton effects and daily weather fluctuations.

The Area Specific evaluation questions to consider are:

- How does the timing and magnitude of CEW delivery affect rates of GPP and ER in the lower Goulburn River?
- How do stream metabolism responses to CEW in the lower Goulburn River differ from CEW responses in the Edward Wakool system, which is physically different?

We expect that GPP and ER in the lower Goulburn River will respond to environmental flows in the following ways:

1. Under extended 'cease to flow' conditions of several weeks or more (which are very unlikely in the lower Goulburn River), the responses of GPP and ER will greatly depend on the available nutrient supplies and the time of year. High nutrients and warm conditions may lead to very high rates associated with excessive phytoplankton growth.
2. Under normal 'base' flow, rates of GPP and ER will be constrained to the low-moderate range, typically 1-5 mg O₂/L/Day.
3. With in-stream freshes, rates of GPP and ER will increase slightly to 3-8 mg O₂/L/Day. Larger increases will occur if significant backwater areas are reconnected to the main channel due to enhanced nutrient delivery.
4. Bankfull flows (although unlikely to be delivered through environmental releases) will lead to moderate increases in rate to 6-10 mg O₂/L/Day. Again, larger increases will occur if significant backwater areas are reconnected to the main channel due to enhanced nutrient delivery.
5. Overbank flows will have a much more dramatic effect on rates. Blackwater events arising from extensive ponding of water on the floodplain during hotter months will lead to extremely high ER rates and possible anoxia. Shorter duration inundation will likely cause stimulation of GPP through a large influx of nutrients. Rates of these processes may exceed 20 mg O₂/L/Day.

In all cases, daily rates will vary according to season, weather conditions and nutrient supply.



Indicators

Stream Metabolism is a Category I monitoring indicator for the LTIM Program. It requires continuous measurement of dissolved oxygen, temperature, surface light (PAR) and barometric pressure at a frequency of a reading every 10 minutes. Additionally, water samples for FRP, NO_x, ammonia, TP, TN, Chlorophyll-a and DOC are collected at least monthly during data logger downloads and maintenance. Further adventitious samples will be collected when staff are on-site for other purposes and will especially target flow events.

Stream Metabolism assessments will also require daily discharge measurements at these sites as well as mean water velocity at each discharge level (to enable estimation of upstream distance integrated by each probe). This distance is a function of water velocity and the re-aeration coefficient; the latter is directly determined from the analysis of the diel oxygen curve from the DO logger.

Daily rates of GPP and ER are extracted from the supplied daytime regression model implemented using a Bayesian framework in R and OpenBUGS software. The model provides estimates of uncertainty in these parameters, plus numerical and visual indicators of 'goodness of fit'.

Locations for monitoring

Stream metabolism will be monitored at two sites in each of Zones 1 and 2.

Site Name	Zone	Zone	Easting	Northing
Day's Rd	1	55	338896	5938441
Darcy's Track-Gardiner Swamp	1	55	351770	5965722
Loch Gary	2	55	345976	5987892
McCoy's Bridge	2	55	330771	5994884

The Day's Rd site was added in 2015 after the original site at Moss Rd proved unsuitable because of its proximity to Goulburn Weir, resulting in the loss of data for that site from the first year's monitoring

All sites are at existing stream gauging stations. Stream metabolism monitoring using the mandated single-station approach for the LTIM requires a single dissolved oxygen logger per site. Hence daily metabolic parameters will be calculated from these two locations.

The distance upstream integrated by the daily metabolism measurements will be calculated from measurements of mean water velocity and the re-aeration coefficient from the metabolism modelling. This distance is discharge dependent, but is likely to range between 2 and 10 km in the Goulburn River. The selected monitoring sites were in part chosen because there are no major tributaries in the 10 km distance upstream from each probe.

Timing and frequency of sampling

Loggers are deployed at the Day's Rd, Darcy's Track, and Loch Gary sites for ~9 months per year, from approximately the beginning of September to the end of May. The colder water temperatures during Jun-Aug reduce metabolic activity substantially, and the investment required to maintain the loggers year around is not justified during these cold months. However, to test and confirm this, the logger at McCoy's bridge will be deployed continuously.

During deployments, stream metabolism will be monitored continuously at each site over the five year period, thus providing daily estimates of the metabolic parameters. Measurement of dissolved oxygen, temperature, surface light (PAR) and barometric pressure will be recorded every 10 minutes. Additionally, water samples for nutrient analysis (FRP, NO_x, ammonia, chlorophyll-a, TP, TN and DOC) will be collected at least monthly during data logger downloads and maintenance. In addition, as noted above, water samples for these analyses will be collected when staff visit the monitoring sites for other activities, especially during



flow events. The need for a strict maintenance, calibration check and possible recalibration means that one day's data is lost per month as the probe is removed from the stream for these activities.

Responsibilities – identifying key staff

Field program

Data downloading, calibration checks, probe maintenance and water sample collection will be conducted every 4-6 weeks by two people from WaterWatch, under the direction of David Hodgkins from Goulburn Valley Water. We will use our own DO logger at McCoy's Bridge but it will be housed within the long PVC pipe used by Thiess. Coordination with Thiess (Jac Farrow) will ensure access to keys to the lock on the PVC pipe and maintenance schedules.

Laboratory requirements (if any)

All chemical analyses apart from chlorophyll-a will be performed by the Water Studies Centre's Analytical Laboratory at Monash University. The laboratory is NATA-accredited for each of the required analyses. The Officer in Charge of the laboratory (and NATA signatory) is Mrs Tina Hines. As the WSC laboratory does not have accreditation for chlorophyll-a analysis, chlorophyll-a samples (filter papers wrapped in aluminium foil) will be sent to the Eastern Melbourne Laboratory's chemical analysis unit. Grace Boonthakanon is the EML officer in charge. The WSC and EML have over ten years of highly successful co-operation in chemical analyses for a range of clients.

All samples collected will be immediately packed on dry ice in an esky and transported overnight (or sooner) to the two laboratories.

The field sheets designated by the LTIM SOP will provide sample identification and will be provided to each laboratory with the samples. The chain of custody within each lab is part of the NATA accreditation process, so standard laboratory data handling and security procedures through LIMS (Laboratory Information Management System) are already in place. NATA accreditation also mandates analysis-specific QA/QC procedures (e.g. blanks, spike recoveries, duplicates, standard reference materials) and these will all be performed as a matter of standard laboratory operation.

Procedure for transferring knowledge to new team members

No formal qualification or accreditation is required to collect data for determining rates of stream metabolism. However, it is important that the people collecting the data are instructed in correct techniques. Training on probe maintenance, downloading, calibration checking and recalibration will be provided by Associate Professor Mike Grace. A senior field technical officer will be identified from the field team. This person will liaise regularly with A/Prof Grace and will train any new staff required throughout the duration of the project. The procedures for downloading data, checking calibration and recalibration are all very straight forward.

A/Prof Mike Grace will convene (either face to face or by teleconference) regular debriefs with the field team after field trips to identify any issues of concern. Scheduled debriefings will occur after the first three trips and then at six months after commencement and every six months thereafter for the duration of the project. Any significant matters will be dealt with immediately rather than waiting for a scheduled debrief.

Monitoring methods

This protocol uses the single station open water method as described in the LTIM Standard Operating Procedures Manual and comprises:

- Water level and stream characteristics (available from an established gauging station at each site)
- Discrete water quality samples (chlorophyll-a, total nitrogen, NO_x, NH₄⁺, total phosphorus, FRP, dissolved organic carbon)
- *In situ* logging within the water column (dissolved oxygen, temperature) at every stream metabolism site



- Logging of photosynthetically active radiation (PAR) and barometric pressure in a nearby terrestrial location, with the potential for a single PAR / barometric pressure station to capture all stream metabolism sites within 100 km.

This protocol is based on the single station open water stream metabolism method as detailed in Grace, M. and Imberger, S. (2006) Stream Metabolism: Performing and Interpreting Measurements, Monash University (available to read online at: <http://www.yumpu.com/en/document/view/5585275/stream-metabolism-faculty-of-science-monash-university>).

Field methods (Water quality measurements)

Water quality variables are important for interpreting the stream metabolism results and are an input to the ecological response model for Basin scale evaluation. Water samples are collected for: chlorophyll-a, total nitrogen (TN), total phosphorus (TP), nitrate-nitrite (NO_x), ammonium (NH₄), filterable reactive phosphorus (FRP) and dissolved organic carbon (DOC). In-situ spot measurements are taken for pH, turbidity and electrical conductivity (EC). As a minimum, these water quality samples and measures are collected when sensors are deployed and at each time the station is serviced and calibrated (≤ 6 week intervals). Further samples can be collected during site visits for other purposes.

Equipment

Sample containers and appropriate preservatives (sourced from laboratory)
 0.2 μ m filters and suitable filtering device (e.g. syringe filter) for dissolved nutrients and carbon
 47 mm glass fibre (GFC) filters and suitable filtering device for chlorophyll-a
 Pre-calibrated Water quality meter (e.g. Horiba U10) with pH, turbidity and electrical conductivity probes
 Deionised water for sample blanks
 Eskies and ice for sample preservation and storage; dry ice for sample transport to the laboratories.
 Datasheets and/or field computer
 Chain of custody sheets
 Copy of this protocol

Protocol

1. Samples and measurements are collected mid stream and mid depth, provided it is safe to do so. Samples must be collected in the main flow path, carefully avoiding backwaters and stratified pools.
2. Ensure that sampler stands downstream of sample collection point.
3. Avoid surface films, but if present, a description should be entered onto the field sheet.
4. Filtering for dissolved nutrients (NO_x, NH₄⁺, FRP, DOC) and chlorophyll-a must take place on site as samples are collected.
 - 4.1 The syringe, filter and receiving bottle should all first be rinsed with a small volume (e.g. 5 mL) of the water sample. This filtered washing is then discarded. The filtered sample for analysis is then collected. The NATA-accredited laboratory will advise on the volume they require for analysis.
 - 4.2 If the water is extremely turbid, a prefilter (e.g. GFC) may be used.
5. Samples must be stored on dry ice for transport to laboratories.

Field methods (Stream metabolism)

Stream metabolism measures for temperature, dissolved oxygen, light (PAR) and barometric pressure are logged at ten-minute intervals. Loggers are deployed continuously, or in the case of non-permanent river sites, for the period that the river is flowing. Consideration must be given to maintenance, cleaning and battery life and details of the length of deployment provided in Monitoring and Evaluation Plans.

Equipment

Dissolved oxygen and temperature sensors with an integrated logger (e.g. ZebraTech DOpto) using optical (fluorescence) DO measurement. One spare logger is taken into the field to replace a malfunctioning unit if required. This minimises loss of data.



PAR sensor and logger (e.g. DataFlow Odyssey). The sensor will be calibrated against a laboratory-based sensor reading in $\mu\text{Es}/\text{m}^2/\text{s}$ across the full range of PAR expected throughout a bright summer's day.

Barometric pressure sensor and logger (weather station).

Tool kit and spare parts for the multi-parameter probe; including spare batteries

Metal star pickets and star picket driver or mallet

Anodized chain with padlock, plus cable ties to attach probe to a star picket or permanent structure

GPS

Probe calibration log

Field sheets

Laptop and data cables for connecting to probes / logger

Air bubbler with battery (e.g. one suitable for a large fish tank) and a large bucket (e.g. 20 L), for probe calibration.

Protocol

Preparation

1. Prior to deployment in the field, the probe(s) will be calibrated, using a two point (100% & 0% DO saturation) according to manufacturer's instructions and results of calibration entered into a calibration log.
2. Before leaving the office / laboratory the following should be checked for all electronic equipment (probes, loggers, GPS):

Batteries are charged and properly inserted
 Previous data downloaded and memory cleared
 Check cable and cable connections
 Check for any obvious/minor faults on sensors including growth or dirt on the probes or tubing
 Check contents and condition of probe toolkit
 All equipment listed above is present and in functional order

Field method – PAR, barometric pressure

1. Establish a suitable location, above the area likely to be inundated and in a clear open (unshaded) area. This could be a nearby paddock. Note that on private property locations a fence post near gate access may be suitable.
2. Secure PAR logger to existing structure or if necessary, a newly placed star picket.
3. Set loggers to read at 10 minute intervals.

Field method – water column measures

1. Record the following on the field sheet:
 - River name and ANAE Streamid
 - Date and time
 - GPS coordinates (latitude and longitude; GDA94)
 - Name(s) of survey team
2. Record site characteristics:
 - Substrate type
 - Width of channel
 - Presence of any geomorphic features
 - Percent canopy cover
 - Land use immediately adjacent to site
3. Collect water quality samples and spot measures as described above.
4. Calibrate dissolved oxygen sensor on site:
 - Calibrate according to manufacturer's instructions for both oxygen free water (e.g. 1% sodium sulfite Na_2SO_3 solution) and 100% saturation (air saturated water). The easiest way to obtain a reliable on-site calibration of 100% saturation is to place the probe in a bucket of stream water which itself is sitting in the stream to ensure thermal control. Air is bubbled through the water in the bucket for at least 45-60 minutes. This should result in a stable reading from the probe. It is important that the probe is not in the direct line of air bubbles. The reading at this stage should be 100% saturation at the on-site barometric pressure and EC. If not, adjust the calibration according to manufacturer's instructions.
5. Set the dissolved oxygen, temperature, PAR and barometric pressure loggers to record at ten minute intervals. Synchronise loggers so as to obtain corresponding readings.
6. Select appropriate place for deployment of sensors and loggers noting:



- Dissolved oxygen and temperature sensors must be placed in open water, mid stream and at a depth that will not expose sensors for the entire deployment period. Sensors should not be placed in eddies, stratified zones, backwaters or where flow is influenced by structures.
 - Sensors can be deployed on suitable existing structures or on star pickets embedded mid-stream. The latter option should consider possible washaway of the star picket during higher flows.
 - Safe access to install loggers and then subsequent access for maintenance, data downloads, calibration check and recalibration
 - As far as possible, consider security of loggers to minimize theft/vandalism.
7. Deploy loggers.
 8. Leave loggers deployed for between four and six weeks.
 9. Perform servicing, cleaning and calibration of loggers at each repeat visit.
 - 9.1 Repeat 100% saturation value check (air-saturated water) and record the % DO saturation value after one hour (to enable post hoc drift correction) *before* recalibrating.
 - 9.2 Upload data onto laptop following manufacturer's instructions.
 - 9.3 Calibrate all sensors and loggers and perform routine maintenance / cleaning as necessary. This will likely include changing battery/batteries.
 - 9.4 If a probe is malfunctioning and cannot be fixed on-site, it should be replaced with the spare probe, which in turn will need the full on-site calibration.
 10. Repeat water quality samples and spot measures at each repeat visit.
 11. Record any relevant information, such as changes in site characteristics since deployment.

Laboratory methods

The NATA accredited laboratories will perform the requisite chemical analyses using their standard methods with all appropriate QA/QC.

Data analysis

This method adopts the approach of determining gross primary production (GPP), ecosystem respiration (ER) and reaeration rate (K_{O_2}) from the diel dissolved oxygen curves using the daytime regression model reviewed by Kosinski (1984). A program to evaluate these parameters for the diel dissolved oxygen curve has been developed by Mike Grace, Darren Giling and Ralph MacNally at Monash University using Bayesian analysis implemented in OPenBUGS with an interface in 'R'. This freeware package and is available for the LTIM project via the Govdex website.

The model requires data for dissolved oxygen in mg O_2 /L, temperature, PAR and barometric pressure (in atmospheres) at 10 minute intervals. The salinity also needs to be entered. This will be approximated as 0 unless the electrical conductivity increases above 500 μ S/cm, in which case salinity = $6 \times 10^{-4} \times EC$ (Based on conversion factor of 1 μ S/cm = 0.6 mg/L TDS). The program provides estimates of GPP and ER in mg O_2 /L/Day with uncertainties for each and goodness of fit parameters.

Subsequent data analysis involves correlating the daily estimates for the two metabolic parameters with the collected explanatory variables (nutrients, DOC, chlorophyll-a, light) as well as daily discharge and season.

Reporting

Reporting will involve compilation of metabolic rates (primary production and respiration), reaeration coefficients, discharge and PAR on a daily basis and water quality and nutrient concentrations when collected. Diel profiles of water temperature, PAR and dissolved oxygen concentrations will be added to the LTIM database as a primary data resource.

Data will be uploaded into the LTIM central database in the format specified in the LTIM Data Standard (Brooks & Wealands 2013) and provided in Attachment 1 of this SOP.



References

Brooks, S. and Wealands, S. (2013) LTIM Data Standard v0.2. Draft Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre, MDFRC Publication 29.3/2013 November, 29pp.

Kosinski, R.J., 1984. A comparison of the accuracy and precision of several open-water oxygen productivity techniques. *Hydrobiologia* 119:139-148.

Attachment 1 LTIM Data Standard requirements for Stream Metabolism

Attachment 1.1 LTIM requirements for discrete data

Variable	Description	Type	Req	Range
assessmentUnitId	The approximate point along the stream at which the measures were collectively taken	string	Y	
dateStart	Start date (inclusive) that these measures were observed	dateTime	Y	
dateEnd	End date (exclusive) that these measures were observed	dateTime	Y	
discharge	ML / day	number	N	[0,+]
ecosystemRespiration Volumetric	mg / L / day	number	N	[0,+]
grossPrimaryProductivity Volumetric	mg / L / day	number	N	[0,+]
velocity	Mean velocity (m / s)	number	N	[0,+]
chlorophyllA	µg / L	number	N	[0,+] < LoR
totalNitrogen	mg / L	number	N	[0,+] < LoR
nitrateNitrite	µg / L	number	N	[0,+] < LoR
ammonium	µg / L	number	N	[0,+] < LoR
totalPhosphorus	mg / L	number	N	[0,+] < LoR



Variable	Description	Type	Req	Range
filterableReactivePhosphorus	µg / L	number	N	[0,+] < LoR
dissolvedOrganicCarbon	µg / L	number	N	[0,+] < LoR

Attachment 1.2 LTIM requirements for logger data at regular 10-minute intervals

Variable	Description	Type	Req	Range
assessmentUnitId	The approximate point along the stream at which the measures were collectively taken	string	Y	
dateStart	Start date/time (inclusive) that these measures were observed	dateTime	Y	
dateEnd	End date/time (exclusive) that these measures were observed	dateTime	Y	
dissolvedOxygen	mg / L	number	N	[0,16]
temperature	degrees Celsius	number	N	[0,+]

