WATER QUALITY SCIENCE

Technical Support

TropWATER

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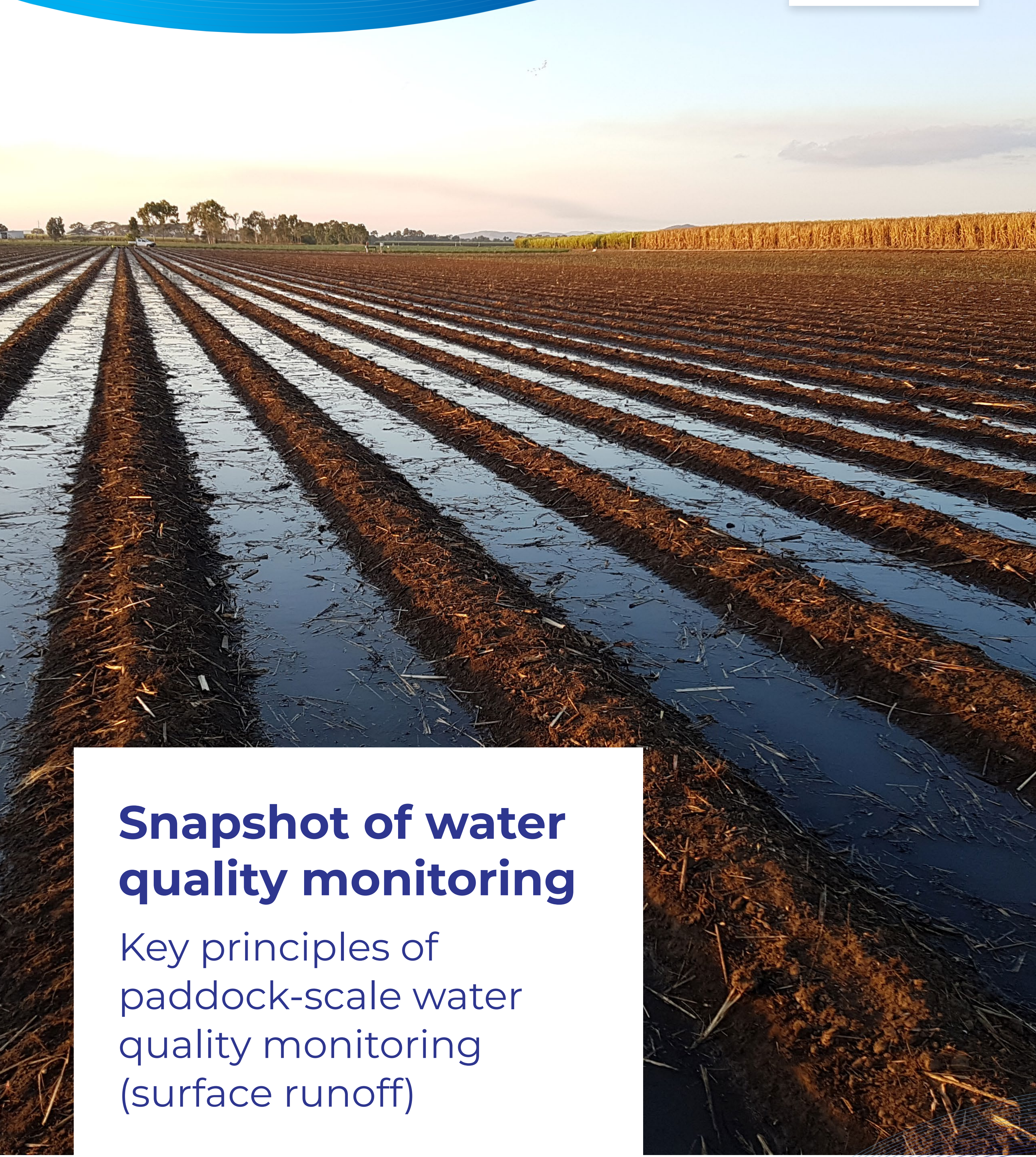

Snapshot of water quality monitoring

Key principles of paddock-scale water quality monitoring (surface runoff)

Australian Government

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Principles of Paddock-scale water quality monitoring (surface runoff) – a technical guide

Paddock-scale water quality monitoring provides targeted data to farmers on fertiliser, pesticide, and sediment losses specific to the farmer's paddock and their management strategies. This monitoring enables farmers to compare different management practices, facilitating a deeper understanding of product losses from their farm and the most effective strategies for minimising these losses.

Conducting water quality monitoring at the paddock scale is a highly complex process. Practitioners must adhere to rigorous technical methods to maintain the scientific integrity of the data collected. Robust data enables accurate analysis and interpretation of the results, thereby ensuring a true representation of the management interventions being compared.

To ensure the collection of reliable, consistent, and accurate data from paddock-scale water quality monitoring, TropWATER have developed two documents to guide practitioners. This Snapshot document provides key information that practitioners can regularly refer to. For more detailed guidance, see the Water Quality Monitoring Guidance Document.

What is in this snapshot?

This snapshot guide is tailored for practitioners considering the monitoring of surface runoff water from cropping paddocks. It outlines overarching principles rather than specific day-to-day operational methods. These fundamental principles provide a framework for practitioners in the planning and establishment of a paddock-scale water quality monitoring program.

During the planning phase, it is crucial to develop Standard Operating Procedures (SOPs) and training packages for all activities to ensure consistent and robust results (e.g., WTMIP SOP007). You will find key guidance in this document. Further detailed information can be found in the Water Quality Monitoring Guidance Document.

This guide is structured linearly, addressing each aspect of a water quality monitoring program in sequence. However, you will need to consider the interconnections between these aspects during the planning stage. A comprehensive understanding of all elements is vital before starting a water quality monitoring program.

Document quick reference

What to consider prior to applying these technical principles

There are several pre-planning considerations for water quality monitoring to ensure the purpose and intent of project is achieved. Key factors include a clear understanding of the objectives of water quality monitoring, as well as determining the specifics of what, where, and when monitoring will take place. You also must consider how the data will be communicated to achieve your project goals.

Purpose of monitoring

The specific purpose for undertaking water quality monitoring should be clearly understood and articulated before considering monitoring methods, location and equipment. The purposes of water quality monitoring can include:

1. Measuring fertiliser and pesticide losses of specific management applications.
2. Model calibration: contribute critical data to the paddock model, to help predict nutrient and pesticide losses over a typical crop cycle.
3. Education and engagement: provide specific examples of losses from management practices back to farmers.

The monitoring program design and equipment needs are different for each of these monitoring purposes. Detailed information on each purpose can be found in the Water Quality Monitoring Guidance Document.

What to sample and why

Choosing what constituents to sample depends on what management practices you are comparing, and typically includes measuring for nutrients (nitrogen and phosphorus), sediment, and pesticides.

There are important considerations around the selection of suitable nutrient species to measure in runoff. For example, nutrients species occur as both dissolved and particulate forms, which can be further classified as organic and inorganic. Monitoring may need to measure some or all of these components to accurately understand losses.

You should also consider the loss pathways you need to monitor to get the best data. Monitoring of surface water runoff only **captures** one loss pathway from a paddock. Other loss pathways depend on the constituent being measured (nutrient, sediment, pesticide) and can include deep drainage, volatilisation, denitrification, crop uptake and degradation. It may be necessary to measure constituents in other loss pathways depending upon the purpose of the monitoring program.

Site selection and DESIGN

Carefully considered site selection is an important component of effective water quality monitoring. Engaging with the landholder is critical. The landholder needs to be fully informed, satisfied with the proposed activities and happy to conduct and share any operations. Health and safety aspects must also be considered.

Checklist for site selection:

- The paddock site selected should have a consistent fall across the cropping area to the measurement site so there is no ponding of runoff water 'up hill' of the sampling location. Water should also continue to drain away from this point so there is no ponding at the sampling site itself.
- Safe access to the sampling point to physically collect samples at times of heavy rain will also be needed.
- To accurately measure water flow from a cropping system, the catchment area needs to be defined. Raised crop rows or bunded banks can be used to define the catchment area within a cropping system. The integrity of these banks must be continually checked and reformed if necessary.
- The paddock should be as uniform as possible across the entire site. Differences in soil type, slope and direction of runoff should be minimised, and crop management (except for the treatment being tested) and paddock management history (how the paddock was managed over the past five to ten years) should also be consistent. Ensuring a uniform treatment area reduces the number of 'other' factors unrelated to the management practices being tested that could influence the results and data interpretation.
- Ensure measured runoff is coming only from the defined treatment area. Choosing the size of the treatment area or plot will depend largely on what is practically available, and includes measuring runoff draining a number of cane rows, with monitoring equipment installed within the paddock. Smaller areas are generally likely to be more consistent in soil type and slope, although as the treatment area decreases small variations in measurement data have a larger impact on results.

Replicating your study

You need to consider replicating your trial. Monitoring two or more sections of the paddock with the same treatment plots will increase the robustness of the monitoring data and provide greater certainty in the effects of the management practices being tested.

Undertaking two replicates will indicate whether there is variability, and three or more replicated plots will allow some basic statistics on the effects of the management treatments being applied to the paddock. When using replication, you need to ensure the replicate plots are as consistent as possible in soil type, slope and current and historical crop management. Good practice also includes the monitoring of 'control' plots (i.e. plots with the existing management practice) to provide comparison water quality data.

Data capture and analysis

There are two main types of water quality data generated from paddock-scale water quality monitoring programs. Data can be communicated as concentrations of constituents, or as a constituent load. Concentration data show how much constituent is in a sample per unit volume and is typically the raw data provided in a laboratory report. Concentration data are expressed in the form of weight or mass of constituent per volume of sample, such as milligrams per litre.

Constituent load data are calculated from concentration data, and the volume of water lost from a given area in the surface runoff. It is expressed in the form of mass per area, such as kg/ha. Loads are a more meaningful unit for farmers and extension officers and allow a more robust comparison between trials.

The veracity of the concentration or load data is dependent on representative samples being collected over individual flow events as well as throughout the season.

Load Calculation

Calculation of a load lost in runoff from a paddock requires three steps:

- Determine the amount of water leaving the paddock.
- Flumes (equipment) (Section 1)
- Water height (equipment, sampling frequency) (Section 1)
- Plot rain gauge or irrigation volumes (Section 1)
- Catchment area and management (plot area, planning, row hill height) (Section 3)
- Determine the amount of constituent as a concentration in the runoff water.
- Sample across the event (discrete, composite) (Section 4)
- Sample preservation (constituent dependent) (Section 2)
- Sample analysis (constituent dependent) (Section 2)
- Multiply the volume of water by the amount of constituent.
- Event mean concentration (discrete vs composite sample) (Section 4)
- Total flow (flume, water height, plot area) (Sections 1& 4)

Data Interpretation and communication

The results from paddock-scale monitoring should be carefully evaluated in light of the limitations in the monitoring design and implementation. It is crucial to acknowledge and document any constraints in the monitoring process. This enables the audience to assess the validity of the results and the extent to which they can be applied to other paddock or farm situations.

It's important to note that the strength of the findings is enhanced when paddock setups are replicated or multiple trials are conducted over time, reflecting consistent results. If the monitoring aims to reinforce established scientific knowledge or promote the adoption of best practices, you should review the results in comparison with previous studies to ensure they align with the current understanding.

If the monitoring results appear to contradict the existing knowledge, they should not be disseminated to the broader industry until further trials can provide a comprehensive understanding. You should also seek additional technical advice at this stage. On the other hand, if the purpose of the monitoring is to validate a paddock model, the (raw) data set should be interpreted by the modeling team before communicating the findings to the intended audience.

1. Sampling equipment for paddock-scale water quality monitoring (surface runoff)

This section provides a summary of the different sampling equipment available for surface runoff water quality monitoring at the paddock-scale, and their associated benefits and limitations.

If the monitoring objective is to quantify losses in paddock-scale surface water runoff (e.g. to calculate a nitrate or pesticide load), minimum standards for water quality monitoring equipment include a reliable measure of paddock water runoff volume and a representative measurement of concentration for each runoff event.

Equipment for monitoring water volume leaving a paddock

To determine runoff volume from a paddock monitoring equipment is used to measure the instantaneous flow (litres per second) at numerous times across the runoff event. Instantaneous flow can be plotted over time to generate a hydrograph (Section 4). There are several approaches and equipment available for monitoring of paddock runoff. A summary of the benefits and limitations for common equipment used at the paddock scale are provided in Table 1.

To measure water volume the installation of a flume coupled with a pressure transducer is usually employed. A flume is a specific shape where runoff water flows through. The height of water in the flume is used to calculate instantaneous flow, and a pressure transducer is used to remotely measure water height. There are many types and sizes of flumes, and a number of different pressure transducers available for use. The accuracy of pressure transducers can vary significantly. (add flume image near this section)

Runoff flow volumes can also be taken manually if there is a box-weir type setup or using a bucket and stopwatch technique, although these manual measurements will need to be regularly (i.e. every ~ 15 mins) collected throughout the entire runoff event. Manual runoff monitoring is suitable to irrigation monitoring as timing is known.

Key message

Suitable equipment to ensure robust water quality monitoring needs to be carefully considered and align with the purpose of the work conducted. Equipment needs to be installed and subjected to regular maintenance following standard operating procedures.

Equipment for taking samples of water

Taking a sample of water is used to enable laboratory analysis of the water for constituent concentration. To calculate runoff load, the water sample must be representative of the whole runoff event. Constituent concentrations typically vary at different points of the event, and how they vary across an event may vary too.

The cost of sampling equipment are highly variable and it is important to understand the limitations of each device against the purpose of the monitoring program before a suitable design can be implemented (Table 1).

Considerations:

- Samples may be collected using discrete sampling (collection of individual samples at specified times during an event) or a composite sample in which multiple sub-samples collected over a specified period of time or set of flow conditions are pooled as one sample (i.e. autosampler set to collect flow-weighted specific volumes into the one bottle). Discrete samples (e.g. captured manually or using an autosampler with 10+ bottle configuration) provide the advantage of capturing how the constituent concentration changes throughout a runoff event. Composite samples, on the other hand, are less costly by the nature of having fewer samples to analyse but changes in constituent concentrations over a flow event cannot be explored.

- Importantly, each water sampling device will record different temporal components of the paddock runoff profile representing different flow stages. For example, rising stage and Pitfall samplers capture the 'first flush' or rising stages of runoff from a paddock. Other samplers are designed to capture the entire runoff event. These can include time-based sampling (the collection of a sample at specified time intervals) or flow-weighted sampling (the collection of samples triggered at certain runoff volumes or flow rates) approaches.

- All monitoring equipment require careful installation and regular maintenance. Reliable data loggers are also required for specific equipment data recording and sample triggering.

Additional data as a minimum standard

- Installation of a site rain gauge to provide rainfall water input when interpreting water runoff amounts (i.e. rainfall:runoff ratio) as well as to provide context when intepreting constituent concentrations. Comparisons of the rainfall:runoff water balance can also provide additional verification of the measured runoff area.

- Relevant farm management (fertiliser, pesticide, soil conditioner application timing and rates, crop cycle, etc.) and site characteristics (soil type, slope) of the monitored paddock should be thoroughly documented to assist with data interpretation (Section 3).

Specific equipment recommendations for calculation of loads

- The calculation of a load requires measurements of both the concentration (preferably flow-weighted) of the water quality constituent coupled with the water flow/water volumes. This requires the installation of a suitable device to measure runoff volumes.

- The accuracy of the load is dependent on reliable measurements of flow and concentration that are representative of the flow event (Section 4). As the concentration of constituents can vary considerably over a runoff event, we strongly recommend a flow-weighted sampling approach. Ideally flow-weighted discrete sampling is preferred for capturing the range of concentrations and calculating an event mean concentration (EMC). An alternative approach is time-based discrete sampling. This can be a reliable approach if the time intervals capture the main variation in the constituent (i.e. rise, peak, fall) and has accompanying flow data.

- We caution the use of time-based composite sampling and first flush devices as these are not suited to the calculation of loads. The resulting samples can be biased to conditions that occur the majority of the time; and hence often underestimate loads if peaks in concentrations are relatively short lived. The first flush samplers (Pitfalls and rising stage samplers) will likely capture the highest concentrations that are often associated with the start of a flow event resulting in an overestimation of loads.

- Where manual grab sampling is used, at a minimum, samples should capture the rise, peak and fall of the constituent of interest, and be implemented over the entire runoff event. Grab samples should be prioritised across the early stages of the runoff event to capture the rapid change in concentrations that often occur during the rise and peak flow stages.

Table 1. Benefits and limitations of common sampling equipment utilised in monitoring of paddock-scale surface runoff water quality.

Benefits	Limitations
Autosampler (refrigerated and non- refrigerated options)	
Refrigerated autosamplers are generally considered the 'gold star' of monitoring. Has ability to collect high temporal resolution samples over the rise, peak and fall of the runoff event in remote locations where the integrity of the sample can be maintained for a longer period due to refrigeration (up to 48hrs); can be set to target set time intervals or flow-weighted discrete or composite samples; can collect multiple water quality constituents (e.g., glass bottle for pesticides etc). Sample start time, duration, collection and preservation timings are all recorded. Non-refrigerated option is cheaper and can be used as trailer set up for short-term/mobile use.	High purchase and installation costs; requires regular maintenance and an experienced operator to install and set the sampler. Requires careful site selection (i.e. flood heights, security). Quite bulky and can be an obstacle to daily farm operations. Solar panel/battery requirements. Can fail due to false activations, system malfunctions and insect infestations. Non-refrigerated option requires earlier sample retrieval to ensure sample integrity (refer to section 3).
Manual sampling	
Cheap method of obtaining grab samples from individual flow events. Useful tool for landholder engagement if samples are collected across a runoff event; highly suitable for irrigation trials (i.e., with known flood/furrow timing). Immediate on-site processing (filtering, placement on ice) ensures water sample integrity is maintained.	Not always suitable at small-scales where rainfall-runoff is very flashy over short time periods. Requires 'people power' to respond to sampling and spend time at a location to collect an adequate number of samples over a surface runoff event.
Time-based composite sampler (e.g. KP sampler)	
Relatively cheap and effective for capturing water quality runoff samples from a paddock. Suitable engagement tool to show landholders that nutrients/pesticides are lost from the paddock.	Can only provide a composite sample for the specific component of runoff captured. Requires installation as per guidelines and regular maintenance; pump can fail or tubes can block resulting in incomplete sampling of an event. Requires immediate sample retrieval to ensure integrity as non-refrigerated. Load calculations are not advised and not suited to examine water quality outcomes of changed management practice.
Paddock rising stage samplers (e.g. Pitfall samplers)	
Relatively cheap and effective for capturing water quality runoff samples from a paddock. Suitable engagement tool to show landholders that nutrients/pesticides are lost from the paddock. Generally captures first flush/rising stage runoff when highest losses commonly occur. Can provide sampling redundancy when other samplers fail.	Can only provide a composite sample for the specific component of runoff captured (usually from the rising stage). Requires installation as per guidelines and regular maintenance; tubes can block resulting in incomplete sampling of an event. Requires immediate sample retrieval to ensure integrity. As not flow-weighted, load calculations are not advised (low reliability). Load calculations are not advised and not suited to examine water quality outcomes of changed management practice.

Benefits	Limitations
Continuous monitoring probes/sensors	
High resolution continuous measurements of water quality changes.	High purchase and installation costs; requires regular calibration and maintenance. Generally, only applies to specific constituents e.g., nitrate, turbidity; needs to be installed in a secure area; biofouling issues.
Stage/pressure transducer (in flume/weir)	
Provides a measure of water height in a weir/flume to calculate discharge volume to calculate loads. In the absence of a flume, flow volume can be estimated by coupling a velocity sensor with cross-sectional area.	Needs a setup where flow channels through a defined measuring point. Pressure transducers range in quality. Maintenance and zero reset required prior to rainfall events.
Tipping bucket rain gauge	
Provides measure of total rainfall coupled with rainfall intensity. Rainfall intensity can be a critical constituent to help explain variability in water quality data. Some designs can be relatively cheap.	Requires regular maintenance and cleaning. Some set ups can be expensive.
Standard rain gauge	
Cheap to purchase and install. Provides measure of total rainfall over an event at the site.	Does not provide rainfall intensity. Requires manual reading and regular presence at site to record daily volumes.

2. Sample collection, preservation and analysis

This section focuses on the collection and storage of water quality samples obtained from paddock-scale monitoring. Selecting which water quality constituents to measure will depend on the monitoring intent and the treatments being applied to the paddock. Nutrients are typically measured as total nitrogen and total phosphorus and also as its component fractions. These include dissolved species (nitrate, nitrite, ammonia, urea, phosphate) and particulate forms (particulate nitrogen, particulate phosphorus). Pesticides typically measured include herbicides and insecticides.

Key message

The integrity of water quality results relies on the timely collection, processing, and preservation of water samples. It is crucial to carefully follow recommended protocols. Detailed sampling record sheets should be maintained to document the duration between sample collection and retrieval, and the speed at which samples are processed and preserved.

Retrieving samples and sample containers

- After a sampling device has been triggered and holds a water sample in a paddock, it is crucial to promptly retrieve the sample (refer to Table 2), process where necessary and store in appropriate containers. Typically, nutrient samples are stored in sterile plastic containers, while glass containers are used for pesticides. Dissolved nutrient samples require filtration at 0.45 µm using sterile syringes and disposable filters as soon as possible after collection. The sampler must follow clear sampling principles, such as maintaining clean hands, wearing gloves and not smoking. Nutrient samples should be cooled and frozen as soon as possible, while pesticide samples need to be stored in the fridge. Some nitrogen species are particularly unstable in the environment, especially at temperatures above 4°C or with exposure to sunlight. If samples are not quickly retrieved, processed, and preserved, rapid transformations (changes in the chemical state of the nutrient) can occur, which will compromise sample integrity.

Holding conditions

- The recommended holding times (the time between sample collection and laboratory analysis) for nutrients and pesticides are specified in Table 2. Holding times for nutrients vary depending on the nutrient form. For highly transformative or bioavailable nutrient forms, holding times are extended when samples are immediately filtered and cooled on-site. According to the Australian Standard (AS/NZS 5667.1), freezing of nutrient samples is most effective if applied immediately after collection.
- It is important to record the holding times and the general conditions the sample has been subject to. This information can aid in data interpretation and may help explain anomalous results.
- Even if sample retrieval times, timely preservation, and storage of samples are exceeded, the sample may still have value. In such cases, we recommend focusing on analysing more stable constituents (e.g., total nitrogen instead of all nitrogen species) and documenting the sampling, retrieval, and preservation times.

Table 2. Australian Standard collection, preservation and holding times for nutrients and pesticides.

Constituent	Preservation procedure	Maximum time recommended	Collection bottle type	Reference
Total Nitrogen/ Total Phosphorus	Refrigerate (cool to <°4)	24 h to 48[a] h	Sterile plastic or glass –washed with Decon 90 or similar and Milli-Q rinsed	AS/NZS 5667.1:1998
	Freeze	1 month		
Nitrate	Refrigerate	24 h		
	Filter[b] on site, freeze	1 month		
Nitrite	Immediate analysis			
	Filter[b] on site, freeze	2 days		
Ammonia	Refrigerate	6 h		
	Filter[b] on site, refrigerate	24 h		
	Filter[b] on site, freeze	1 month		
Phosphate	Filter[b] on site, refrigerate	24 h		
	Filter[b] on site, freeze	1 month		
Herbicides	Refrigerate	7 days until extraction	Borosilicate glass – solvent washed with PTFE cap liner	AS/NZS 5667.1:1998
Phenoxy-acid herbicides/ glyphosate				US EPA SW-846

[a] Some testing in Queensland waterway to support extension to 48 hours at 4C for TN only, needs further validation data at paddock-scale.

[b] 0.45 μm cellulose acetate membrane filter

Laboratory analysis

- Follow laboratory protocols on sample collection and preservation.
- Confirm chosen analytical laboratory has the capacity to analyse constituents to a detection level relevant to the study purpose.
- As a minimum QA/QC requirement, consider occasional submission of duplicate or split samples to an alternative laboratory for comparison.

3. Essential paddock-scale information requirements

Key message

Water quality data can be influenced by a number of geographic and on-farm management factors. These factors need to be carefully recorded so that the water quality results can be interpreted in context with the highest level of confidence.

This section outlines the contextual information required to interpret water quality data from paddock-scale monitoring.

We note there are additional requirements if the data from the study may be used for water quality model development and validation. These can be found in Department of Resources, 2022 (see Useful Resources).

Site Selection

- A suitable paddock site should be carefully selected to carry out surface water quality monitoring. Optimal paddock sites include features such as adequate fall (≥ 1%) at the bottom of the paddock so that water doesn't pool and/or backflow; blocks with relatively high hill profiles so there is limited chance for water to break over the rows (and limited potential for cross-fall for lateral movement of water); and blocks that are accessible during wetter periods for timely retrieval of samples.

Essential information

- Site location (latitude and longitude) and key objectives/ purpose of study.
- Site description including paddock soil type(s) and slope. Paddock area captured by the sample runoff equipment, including a site map (i.e. number of rows, length of rows and approximate area).
- Reliable collection of flow and concentration data and record sheets of sampling dates/times, retrieval timing and conditions, sample preservation/storage etc.
- Total daily rainfall at the site is critical. Rainfall intensity (mm.hr-1) is also highly desirable. A rain gauge should be installed at the sampling site location.
- Crop watering management (i.e. rainfed; rainfed with supplemental irrigation; furrow-irrigated; centre-pivot irrigated).
- If irrigated, what is the water volume applied and source of water (i.e. bore, channel or scheme water, river, on-farm water storage). As much detail as possible should be recorded about irrigation events (application method, volume or estimate rate by time, timing). It is essential that samples of the source irrigation water are collected and analysed on multiple occasions so that constituent inputs can be accurately estimated.
- Paddock management data specifically related to the purpose of the trial. A nutrient trial will need to document fertiliser application type and rates, timing and placement. Pesticide trials will need to document active ingredient rates applied and method of application (i.e. broadcast/banded/spot spray). Any other additions to the paddock such as soil conditioners or mill mud also need recording, as these products influence the absorption and decay rates of both fertilisers and pesticides.
- Paddock management data related to crop cycle (when planted/last harvested, was there a fallow crop grown; trash blanket thickness) and practices such as controlled traffic (i.e. knowing which rows are preferentially compacted by wheel tracks) and all tillage operations as these can influence trash and soil pesticide/nutrient concentrations.
- Block yields/productivity for current crop (tonnes/Ha, CCS content). Historical crop yield data is also desirable.
- Antecedent conditions for the paddock such as last rainfall-runoff or irrigation event.
- Any relevant previous results from similar studies.

Desirable information

- Soil composition and bulk density (i.e. particle size analysis, organic carbon content, pH, carbon:nitrogen ratios, pesticide concentration in soil after application).
- Soil moisture prior to runoff event (and general soil moisture throughout season).
- Cane variety (for sugarcane studies).
- Crop condition over the growing season.
- Fallow periods.
- All prior applications of fertilisers and pesticides for last crop cycle.
- Photographs of site setup and crop.

4. Water quality load calculations and understanding data limitations

This section describes key concepts that practitioners should be aware of when undertaking paddock-scale water quality monitoring. This will allow the reliable quantification of constituent loads leaving the paddock and foster an improved understanding of the confidence/limitations of the collected data.

Key messages

Water quality load calculations provide a powerful means to quantify the percentage losses of applied fertiliser and pesticides from a paddock.

Estimating loads is not a trivial exercise and has significant planning and implementation requirements including study/trial design, site selection, equipment choice and installation, sampling strategy including timely sample collection, preservation and laboratory analysis, runoff volume measurements as well as data processing and interpretation.

Practitioners need to be clear about the limitations of the approach used, and all assumptions should be documented. All load estimations contain uncertainty, even with the most sophisticated approaches.

Loads cannot be determined accurately from time-based composite or rising stage/Pitfall samplers.

Loads

The ability to calculate surface runoff loads of various water quality constituents provides a powerful means to quantify the percentage losses of applied fertiliser and pesticides on the paddock and to directly compare the efficacy and environmental outcomes of various management practices.

Constituent concentrations and loads provide different information on water quality. For example, a small runoff event may have a highly concentrated constituent, but the total amount of constituent lost may be small. On the other hand, a large intense rain event may lead to a more diluted constituent concentration in runoff but a much larger overall load.

The calculation of a load is defined as the concentration (generally measured as micrograms (µg) or milligrams (mg) per litre) multiplied by the corresponding runoff volume (in litres). This simple multiplication produces a load in the mass of the concentration data (i.e. µg or mg) which can then be converted to a more useful mass/flux unit (e.g. kg/ha) that is more relevant to a grower.

If a flow-weighted concentration (either discrete or composite) has been measured for an event, each sample is assumed to represent the average pollutant concentration for that flow increment and the determination of the load is relatively straightforward (multiply the concentration by the runoff volume). The determination of the optimal volume/flow increments to sample is dependent on a number of factors, such as the event size and duration, and will involve some uncertainty. Complimentary grab sampling of events (coupled with flow data) can help inform these optimal increments.

If the constituent has been collected at set time intervals (either from an autosampler or manual grab sampling), then the samples must be collected and analysed as discrete samples. This is because the samples do not represent constant runoff amounts and hence each sample must be weighted by the corresponding runoff volume. The determination of a load is thus more complicated and a more sophisticated load calculation method (e.g. linear interpolation) is required. The determination of optimal time increments is dependent on a number of factors such as the event size and duration and it will be important to ensure that the increments capture the rise, peak and fall of the constituent of interest and be sampled over the entire runoff event.

Recognising variability in paddock runoff across space and time

- The concentration of a water quality constituent of interest can change by orders of magnitude over a single runoff event and constituents can display vastly different relationships to flow stage (Figure 1). Rainfall frequency and intensity also influence the runoff profile.
- The concentration of water quality constituents will generally decline considerably over successive runoff events, unless product reapplication occurs. This is particularly so for constituents associated with fertiliser applications (i.e. nitrogen and phosphorus) and insect/weed control measures (herbicides/insecticides). Potential exceptions to this trend could include slow-release fertiliser/pesticide breakdown, mill mud products where nitrogen may initially be immobilised before being mineralised, or the slow wetting of "stranded" fertiliser under some furrow irrigation scenarios. Capturing all runoff events over the season is critical to document this decline in paddock losses.
- The chemical form of nitrogen in paddock runoff changes greatly across a wet season. Changes can occur depending on the length of time between nitrogen fertiliser application and the runoff event; the type of nitrogen fertiliser applied; recent fallow legume crop type and management; mill mud application and composition and the nature and composition of the soil. Hence these paddock management activities need thorough documentation (Section 3).

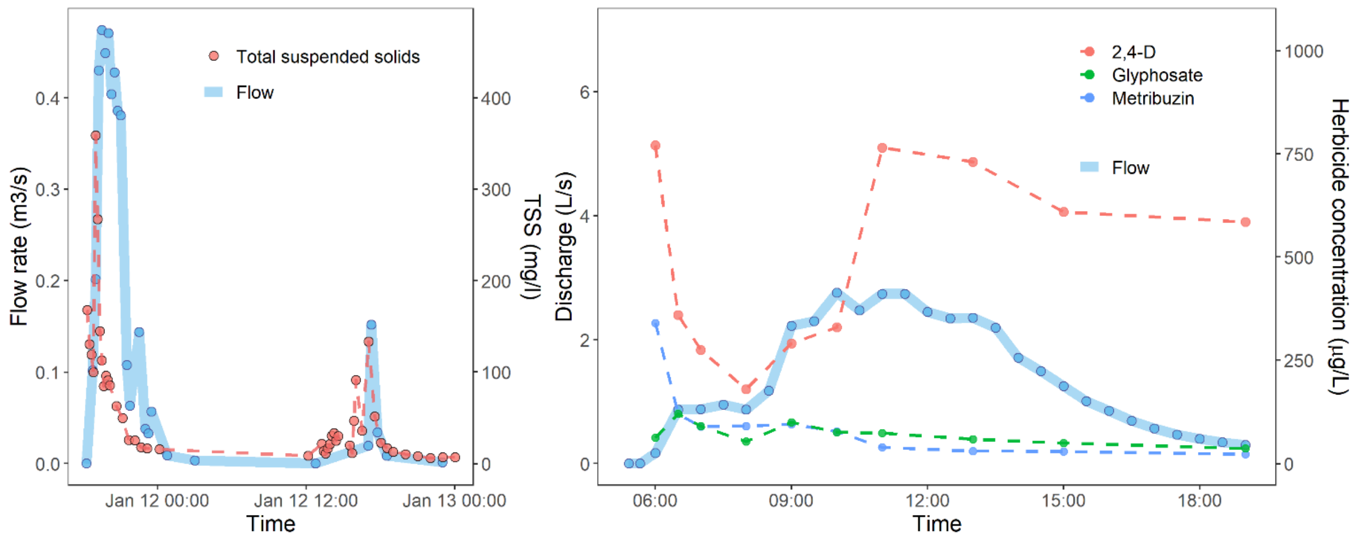

Figure 1. Examples of varying flow and concentration relationships for different constituents. Some constituents (e.g. total suspended solids, metribuzin) exhibit the highest concentrations during the first flush, while other constituents can vary throughout the hydrograph (e.g. 2,4-D) or remain relatively stable during the event (e.g. glyphosate).

Acknowledging/quantifying uncertainty in paddock runoff load calculations

- There are many sources of uncertainty within water quality monitoring data including natural fine-scale spatial variability (e.g., variability in application rates of fertilisers and pesticides, soil condition/compaction), runoff volume measurement uncertainty, the frequency and method of collection of water samples over the event, laboratory measurements and the method choice in the calculation of a load. These sources of uncertainty should all be considered when calculating paddock losses. In general, the most sophisticated water quality monitoring program would have uncertainties of the reported data within ± 10 to 20%. This inherent uncertainty can hinder the ability of studies to produce a statistically significant result when comparing one practice with another.
- Care needs to be taken when dealing with analytical data that are reported as below the laboratory detection limit. Incorporating such data into load calculations can result in load inaccuracies and advice should be sought prior to calculation.
- Figure 2 illustrates the high variability in flow and total suspended solids (TSS) concentration over a single runoff event and the range in load calculations generated using different sampling strategies. The flow-weighted TSS Event Mean Concentration (EMC) using linear interpolation (162 mg/L) is the approach that provides a value closest to the true value. In comparison, the average TSS concentration (115 mg/L) without reference to flow underestimates this paddock load by around 30%. A rising-stage sampler approach or a single grab sample that captures any part of the event could potentially over - or under-estimate the total event load by > 100%.

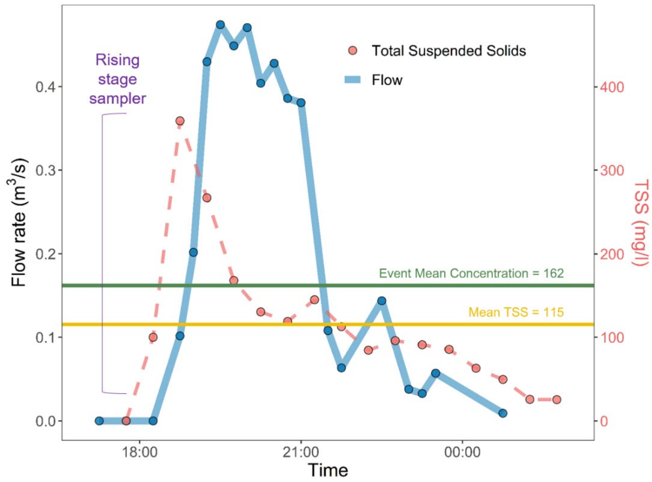

Figure 2. Differences in constituent "load" calculations (total suspended solids used in this example) that could be generated under various sampling strategies.

Pesticide concentration data at the paddock-scale

Monitoring of pesticide concentrations in paddock runoff can be used to:

1. Show pesticides are lost from the paddock for engagement purposes;
2. Benchmark relative losses (i.e. mobility) of various chemicals with each other and;
3. Evaluate the relative risk of the offsite pesticide losses as either an individual or as a cumulative (i.e. multi-pesticide) risk.

Importantly, the same principles outlined for concentration monitoring apply including adequate sample (or flow-weighted) coverage over the entire runoff event and monitoring of all events over the wet season.

Useful Resources

- TropWATER Water Quality Monitoring Guidance Document (2023). Add link
- Department of Resources. 2022. Monitoring an agricultural field trial for water quality modelling. Version 1. Queensland Department of Resources, Queensland.
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