Interpreting River Health Data

Waterwatch Victoria

waterwatch
VICTORIA
Communities Caring for Catchments

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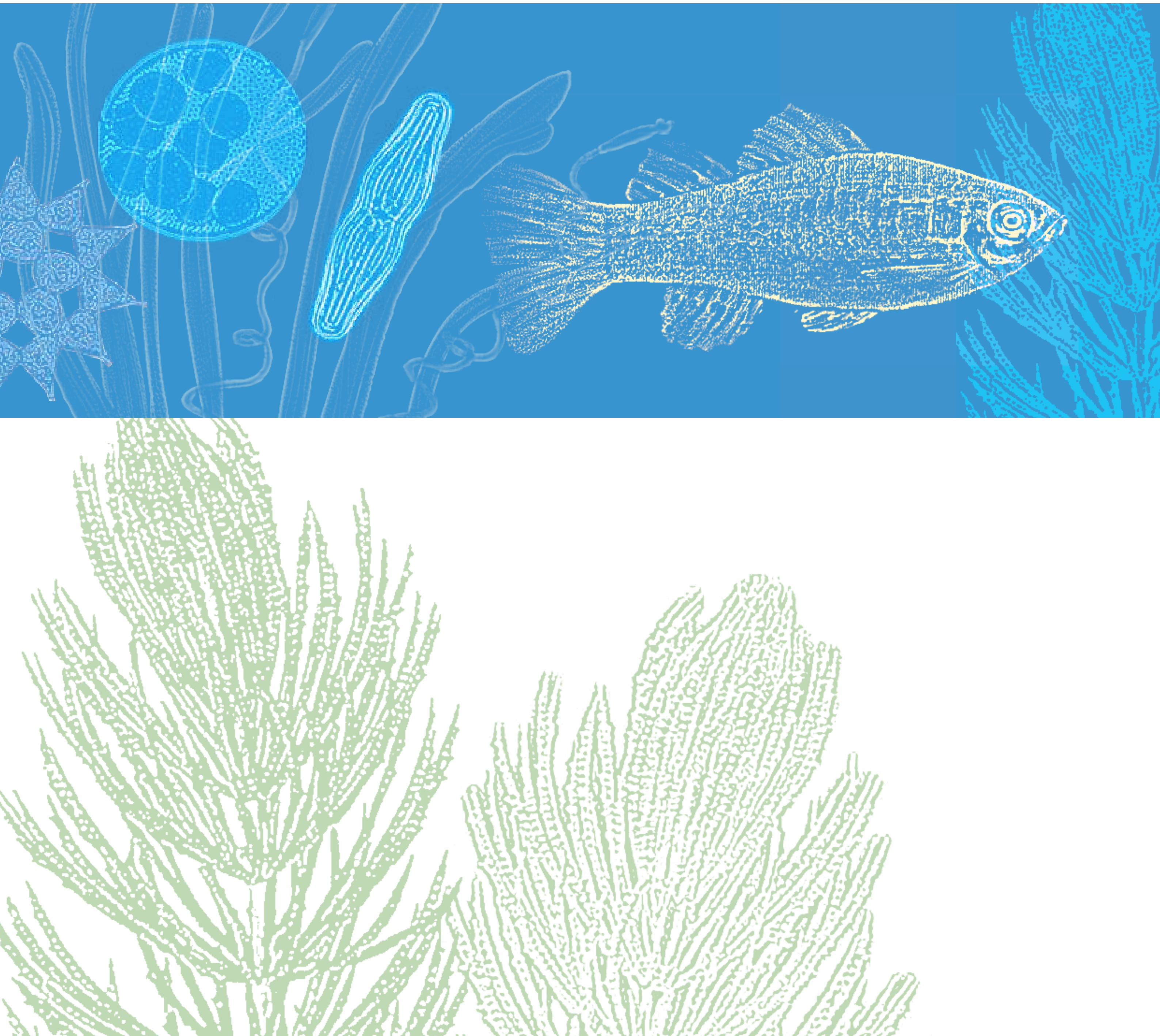
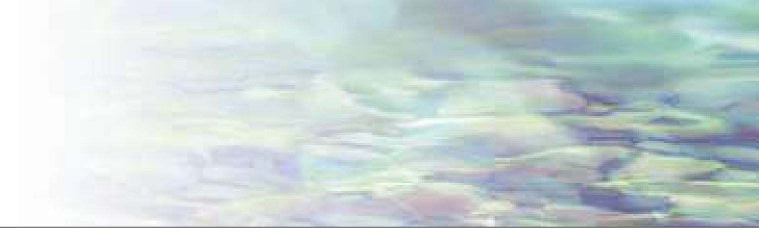




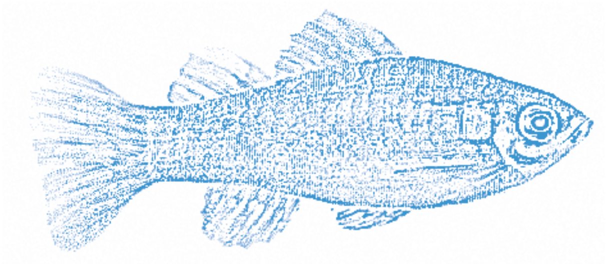
FOREWORD

By Dr. Ian Rutherfurd

Director of Integrated River Health, Department of Sustainability and Environment

Taking a water quality sample is a complicated act. “No”, you rightly say, “surely anybody can look down a tube and estimate turbidity; it’s a bit harder to measure nutrients, but most people can be trained to do it competently. So what is complicated?”

It is what the sample *means*. Taking a water quality sample is to river health, what measuring a person’s temperature is to human health. Parents take a child’s temperature because it provides a surrogate for health. The parent may have only a vague idea why illness seems to lead to increased temperature, but they know that a temperature over 37°C could indicate sickness, perhaps an infection. This example provides some useful analogues for Waterwatch samplers.



- First, there was probably some reason that the parent measured the temperature of the child. They suspected that there was something wrong. They had a question that they wanted answered.
- Second, they were confident that the measure they made was accurate and the thermometer was put in the correct place.
- Third, the measurement was compared against a standard. In this case the average human core temperature.
- Fourth, a parent will continue to measure to look for change or a trend. An upward trend is bad and will trigger further action.
- Fifth, that further action might be to take the child to a doctor, an expert in interpreting what is causing the change in the temperature (the generic surrogate measure).
- Sixth and finally, a parent does not believe that temperature is the only measure of health. Very old people might not have an elevated temperature, but they might also believe that they are no longer as healthy as they were. Human ‘health’ is a complicated idea, just as river health is a complicated idea.

So what is this manual for? To extend the medical analogy, this could be described as a ‘community health centre’ manual for community water quality monitors. Many parents have gone to the community health centre nurse for reassurance, advice or referral. That nurse has to be well educated in basic medicine, but they will also know when to refer to an expert.

This manual is designed, in essence, to help interpret the basic surrogate measures of river health that we use. It is also designed to avoid making basic errors of interpretation, in particular, leaping to unwarranted conclusions and mistaking association for causation when interpreting results.

Following the example, here are the basic questions that this manual will help you to address (although they are not expressed in this order in the manual, you will find the answers throughout):

1. **What is the question?**
   Waterwatch monitors will be involved in the program for many reasons, but it is worth clarifying the questions that they have, so that you can make sure that their monitoring will answer them! For example, monitors may have a suspicion that the water quality in their creek is declining and they want to explore whether it is. Will their routine monitoring tell them? Alternatively, they may care about the condition of a receiving water body (such as a lake), in which case load is much more important than sample concentration.

2. **How good is the measure?**
   The Waterwatch program is underpinned by basic measurement protocols that are becoming more rigorous each year. This is because there is basically no point having water quality samples that we cannot trust. Similarly, our confidence in a measure is increased if that measure is supported by other measures and follow-up sampling.

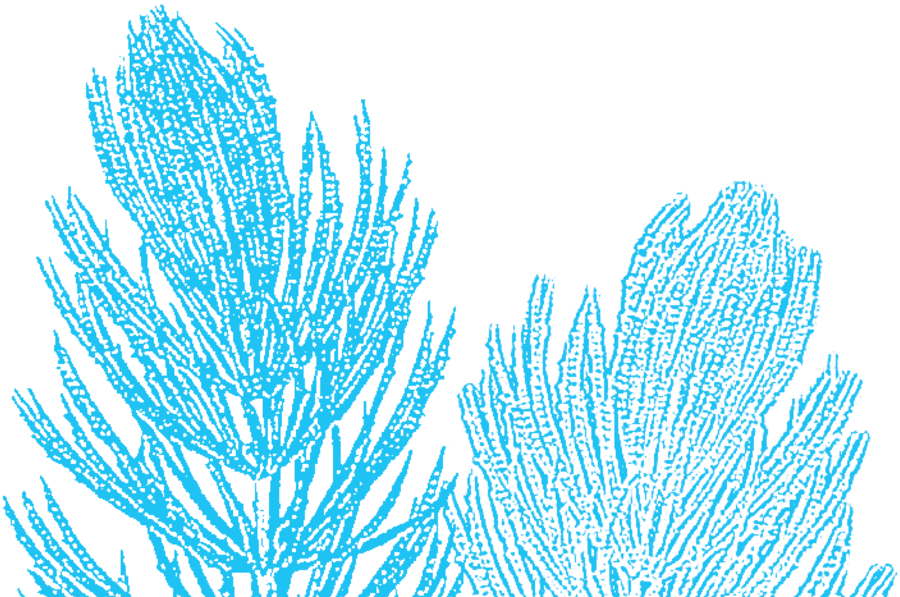
3. **How does a result compare to the 'standard'?**
   Waterwatch monitors should know what the standards are around each class of measure (so many mg/l etc.), and how they were arrived at. Are they, for example, based on toxicity, on potable water standards or on averages from unimpacted areas? What are the error bars around those standards?

4. **What does a change in a value mean from sample to sample?**
   Trend is the hardest thing for a Waterwatch monitor to interpret. The value has changed dramatically over a week, is that normal? We should know the basic processes that influence the variables that we measure (the most important of which is usually simple discharge / rate of water flow). This also relates to basic knowledge about concentration and load. Your load could be increasing dramatically, but your concentration could be going down, simply because discharge is rising. Key to this issue is to understand natural variability as opposed to human influence.

5. **When do we need to act on water quality measures?**
   The Waterwatch network is an important part of the water quality reporting network in Victoria. So what constitutes a problem and when do you report or 'act' on problems? This will relate to standards that are exceeded or to unusual trends. There are formal protocols for when to call in the regulators or the experts. We should know when to seek help.

6. **How do my water quality measures relate to stream health?**
   Water quality is only one aspect of stream health, albeit a critical one. But we should all be aware of where our piece of stream and the water that flows past us day by day, fits into the larger goals of river health. What are the overall plans for this river and how can I help?

Above all, we hope that this manual will help Waterwatch staff and monitors to do more than watch the water – but to question, to measure and to act.



CONTENTS

Courtesy of Goulburn Broken Waterwatch.

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1 INTRODUCTION

Waterwatch Victoria is a community waterway monitoring and engagement program that connects local communities with river health and sustainable water management issues. Waterwatch coordinators and community volunteers have been collecting water quality data across Victoria for over 15 years, with a strong emphasis on data confidence and quality data since 2000.

This manual has been developed to improve and support coordinator feedback to monitors and communities on what their water quality data says about their local sites. The manual will be an initial reference for coordinators wanting to explore and interpret water quality data before producing data reports.

The manual assumes users have some knowledge and skills in *Microsoft Excel* and that the manual is read in conjunction with relevant state and regional documents including the *Waterwatch Victoria Methods Manual (1999)*, *Waterwatch Victoria Data Confidence Guidelines* and regional *Data Confidence Plans and Equipment Manuals*. By using this manual only, coordinators cannot expect to become experts in interpreting water quality data. Coordinators are encouraged to access other resources for assistance in water quality data interpretation, some of which are listed in Section 7, 'Sources of data and expert advice'.

The manual covers water quality indicators regularly measured in the Waterwatch program - the plant nutrients (phosphorus and nitrogen), dissolved oxygen, turbidity, electrical conductivity, pH, temperature and *E. coli*. Macroinvertebrates are not covered in the manual and detailed information on sampling and interpretation can be found in the EPA Victoria publication *Rapid Bioassessment Methodology for Rivers and Streams.* (2003, Publication no. 604.1).

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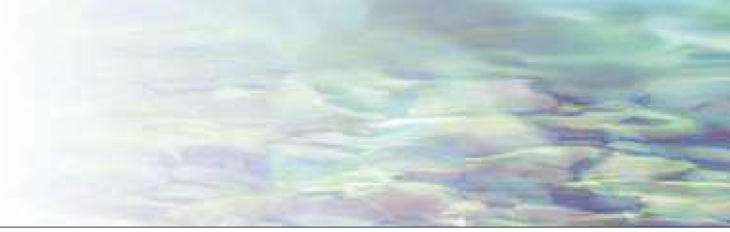


2 WHAT IS RIVER HEALTH?

An ecologically healthy river is a river that retains its major ecological features and functioning similar to that prior to European settlement and which would be able to sustain these characteristics into the future. By this definition, an ecologically healthy river need not be pristine. For example, exotic species may be present or fish passage may be provided by fishways. However, overall, the major natural features, biodiversity and functions of a river are still present and will continue into the future.

Water quality is traditionally measured to assess river health, although in more recent years biological indicators, such as macroinvertebrates, have also been used. Both water quality and biological assemblages vary from year to year, between seasons and from turbulent high mountain streams to large, meandering lowland rivers. Understanding these temporal and spatial differences is important in assessing river health.

Indicators of river health

Various indicators may be used to assess river health. Indicators are the best practical representation of issues impacting river health. For example, phosphorus is used as an indirect measure (indicator) of potential excessive plant growth (the issue). Phosphorus is a major plant nutrient and when there is excess phosphorus there is likely to be greater plant growth. However, a more direct measure would be to assess plant biomass or productivity, but this is time consuming and difficult so is not generally undertaken. Indicators are a tool and must not be the focus of an assessment. The issue must be central to the assessment.

The most regularly used direct measure of river health is the macroinvertebrate community. The macroinvertebrate community is the outcome of environmental conditions, primarily water quality regime, habitat quality and flow regime. Changes in these conditions will change the community.

Another measure sometimes used to assess river health is pollutant load. Pollutant load is the amount of a pollutant that passes a point over a given period of time, usually a year. Regular monthly monitoring is not sufficient to estimate loads. To accurately measure loads, event based monitoring is needed. This requires substantial sampling effort at the time of high flows, in particular floods.

Concentrations provide a measure of immediate availability or effect on biota or ecosystems, whereas loads are more applicable to sinks such as lakes, estuaries and marine environments where pollutants accumulate in sediments to be potentially released when conditions are favourable. Loads are not reported by *Waterwatch* and therefore are not addressed any further in this manual.

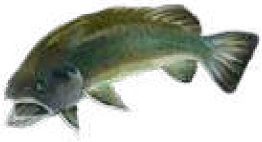
Impacts on river health

Pollution from human activities has impacts on river health. Pollutants may enter rivers continuously, as with a sewage discharge, or intermittently, as with stormwater. Common pollutants entering rivers include plant nutrients (in particular, phosphorus and nitrogen), sediment, salt and oxygen demanding substances and toxicants such as heavy metals and biocides. Changes in water quality may be short or long term depending on the pollutant. For example, oxygen demanding substances such as raw sewage will break down within hours or days whereas heavy metals may remain for decades. While some pollutants are broken down or will pass downstream quickly, others bind to particles of sediment in the water and will settle out, accumulating in the river sediments. Nutrients and many of the toxicants that accumulate in the sediments will remain there and have minimal impact on the aquatic environment. However, under certain environmental conditions they may be released from the sediment to the water column where they can impact river health. Low oxygen levels in the sediment or low pH levels can facilitate this remobilisation.

It is important to note that impacts from pollutants may not be detected by regular monitoring because of the timing of a discharge, the fate of a pollutant and/or where measurements are taken.

Climate change

Climate change will have a substantial impact on aquatic ecosystems including increased water temperatures, decreased stream flows, more extreme events, such as bushfires and a shift from perennial to intermittent stream flows. These are potentially profound changes to aquatic ecosystems. It is possible that the climatic conditions experienced over the last decade are a result of climate change rather than prolonged drought conditions. Water quality and biological data gathered prior to this period are therefore likely to represent different environmental conditions to the current conditions.



3.1 Introduction

This section briefly describes approaches and methods that can be used to explore patterns in data and identify what those patterns may mean. Before looking at the data it is valuable to clearly state the questions you are seeking answers to. Often these questions are best formed through the development of conceptual models. These two aspects of data exploration are examined first. Important features of the data are also discussed, including the use of summary statistics, time series graphs and spatial graphs. The section finishes with an examination of the influences of environmental setting upon water quality indicators.

3.2 Preliminaries

The questions

Before beginning the exploration or interpretation of water quality data, you need to form a clear set of questions that you are seeking answers to. Usually these questions come from management objectives or focus on specific water quality issues at the site or in the reach or catchment. For example, the questions could simply be "What is the condition or health of the site, reach or catchment?". Health or condition can be assessed by comparing the data collected against State Environment Protection Policy (Waters of Victoria (SEP WoV)) water quality and biological objectives. Other questions may include examining the improvements that have arisen from management action taken in the catchment; the changes resulting from drought, flood or climate change; and the assessment of human impacts such as sewage discharges and town and agricultural runoff. Be clear as to why you are looking at the data.

Conceptual models

Conceptual models may help develop the right questions.
A conceptual model is an illustrative representation of an issue and its relationships with other environmental factors. The issue is usually a specific ecosystem value or a threat to that value. For example, a healthy native fish community may be a value you want to manage and protect, whereas an algal bloom may be a threat you want to protect against. A model should represent all relevant details known about the ecosystem, including relationships between the value or threat and factors influencing it. Conceptual models can provide the basis for developing questions on potential cause-effect relationships and for communicating understanding of the issue.

Figure 3.1 provides an example of a conceptual model for causes of increased phosphorus concentrations. The sort of things that may explain increased phosphorus at a site include the loss of native vegetation in the catchment, recent bushfires in the catchment, stock access to the stream, discharges to the stream (e.g. from sewage treatment plants), intensive agricultural activities (e.g. dairying) and poor riparian zone cover. Many of these factors may be exacerbated by storm events in the catchment in the hours or days prior to sampling as storm events wash sediments into streams, increasing phosphorus inputs.

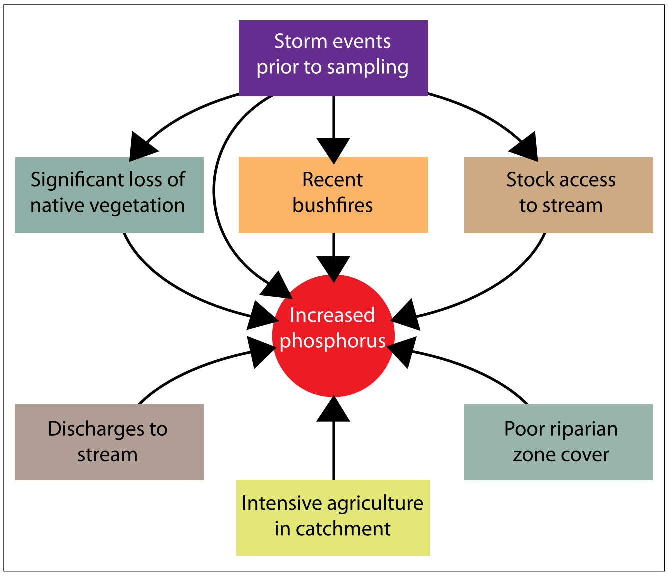


Figure 3.1 Conceptual model for factors causing increased phosphorus concentrations.

Although 'increased phosphorus' may be a trigger for concern, low phosphorus itself is not a value of the stream (i.e. a stream is not 'valued' for its low phosphorus concentrations). It is the impact that increased phosphorus concentrations may have on the stream ecosystem that may affect the stream's value. For example, increased phosphorus concentrations may increase the risk of an algal bloom thereby threatening the recreational and aesthetic values of the stream.

Conceptual models can also be used for problem solving issues and risks to values in natural systems. Figure 3.2 shows an example of an issue-based conceptual model focusing on algal blooms in a lowland reach of river. In this model, increased phosphorus concentrations, warmer waters and reduced water turbulence will increase the risk of an algal bloom. The indirect factors that lead to these conditions include climate change, catchment disturbance and reduced river base flows. Although it is only necessary to monitor the algal levels to identify the growth of a bloom, data needs to be collected for all of the parameters in the conceptual model to understand the drivers of the bloom. This data provides information that can then be used to assist in managing future blooms.

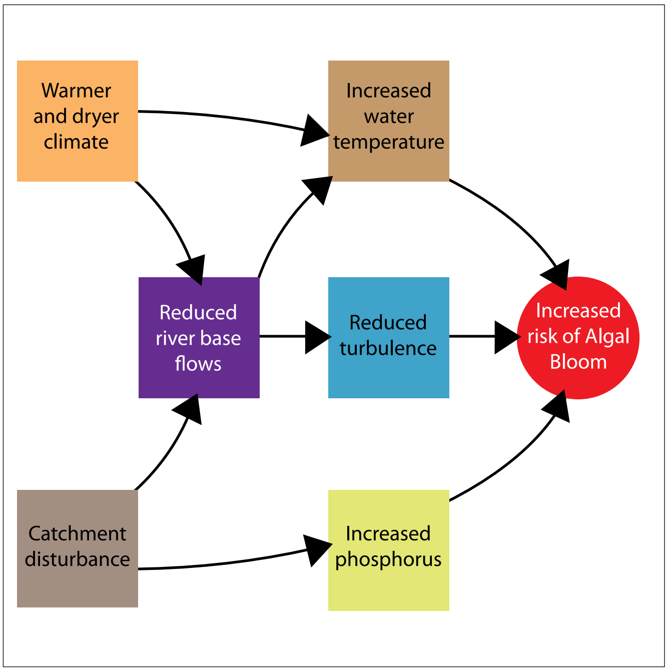


Figure 3.2 Conceptual model for algal bloom risk in a lowland river reach.

The model shown in Figure 3.2 is a simple one and could contain more causal factors and arrows, including factors and arrows related to reducing the risk of algal blooms. The important point is that conceptual models can be used to help you determine the questions that you are asking of your data and to help you visualise the importance of your results within the context of the whole system.

3.3 The Data

To be able to answer your questions about the water body you are sampling, you need to have appropriate measures and sample results. When you take a measurement or a sample from a river, you obtain a single piece of information about that river. That piece of information gives you an indication of the condition of the river at the time of sampling. However, you do not know whether you sampled at a time when the water quality measure was unusually high or unusually low. In other words, you have low confidence in a single measure being an accurate representation of 'typical' conditions.

Some sampling programs use the approach of taking one-off samples of a suite of measures (e.g. nutrients, salinity, dissolved oxygen, suspended solids) at many sites within a region to gain a 'snapshot' of rivers in an area. These programs are useful for gaining some understanding of conditions across a broad region but suffer from having low levels of confidence that any single site has been adequately characterised.

Increased confidence in the information provided by a data set is gained through increased numbers of data points for each site. Once you have a site with many data points, two questions that arise are:

1. What does the data tell me about typical conditions of the site? and
2. What does the data tell me about the range of conditions at the site – i.e. not just the typical conditions.

While data interpretation is best undertaken with a complete or large data set, this is not always possible. Data interpretation should be undertaken with whatever data is available, noting this limitation and any assumptions that are made.

Interpretation of data is helped by using standard, recognised approaches that allow you to compare the data against other sites, objectives or guidelines and data from previous years (to determine trends).

One of the more common ways of defining the typical state of a water body is to use a measure of central tendency, such as the mean or the median.

Calculating the mean

Calculating the mean (sometimes called the 'average') requires adding together all the data points then dividing the total by the number of data points. For example, consider the following 13 results:

5, 5, 6, 6, 4, 6, 97, 6, 5, 5, 45, 88, and 55

The mean value of these results is obtained by adding them all together and dividing by 13:

(5 + 5 + 6 + 6 + 4 + 6 + 97 + 8 + 5 + 6 + 45 + 88 + 5) ÷ 13 = 22

Calculating the median

The median of a set of figures is obtained by arranging them all from the lowest number to the highest and taking the middle value. Using the same 13 results, the median is found to be 6:

4, 5, 5, 5, 5, 6, 6, 6, 6, 8, 45, 88, 97

The median is also known as the '50^{TH} percentile', as it is the half way point in the data array (i.e. 50% of the way from the lowest to the highest data point).

DISTRIBUTION

A graph of the data set presented in the 'Mean' and 'Median' boxes is shown in Figure 3.3. This type of graph is known as a frequency distribution. The frequency distribution of the above data displays a feature that is common in water quality data sets – a 'skew', with most values located at the lower (left) end of the x-axis, and a long 'tail' to the right created by a few, much larger values. As displayed in Figure 3.3, most of the data points (measures) are either 5 or 6 (with a frequency of 4 readings for each). The median of the data set (6) reflects this distribution, whereas the mean value (22) is strongly effected by three high values (45, 88 and 97).

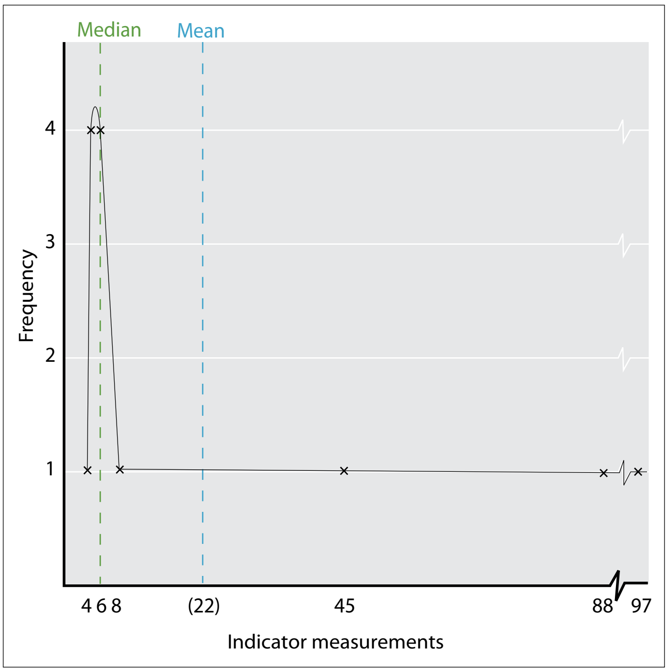


Figure 3.3 Frequency Distribution, Median and Mean Values of a Hypothetical Data Set.

The data presented in Figure 3.3 could represent turbidity measures from a headwater stream in an alpine area. The majority of the time the water is very clear (turbidity between 4 and 8 NTU) but on three occasions – possibly during or following storm events – the turbidity ranged from 45 to 97 NTU. In terms of water quality management, it is more useful to know that the water is generally around 6 NTU than to know that its mean is 22 NTU. If the highest recording (97) had been missed (for example, due to a faulty meter or a lost sample), the median value in the data set would remain 6, whereas the mean value would drop by approximately 30% to 15.75.

In skewed data sets, median values are generally more useful than mean values in reporting the typical water quality at a site. This is why water quality summaries typically use median values rather than the mean. When reporting water quality for Waterwatch, it is recommended that the median be used for summarising central tendency.

SUMMARY STATISTICS

The mean and median are examples of summary statistics. Summary statistics are characteristics of a data set that provide information about the data without needing to reproduce the whole set.

In addition to identifying central tendency, it is often important to summarise the range of conditions that occur within the data set. The highest and lowest values recorded at a site provide the full range, although these may be influenced by extreme events that are rarely encountered. Percentiles are often used to gain some understanding of the range without including extremes. Percentiles are summary statistics that identify the value of a variable within the data set, below which a certain percent of observations fall. For example, the 20th percentile is the value (or score) below which 20 percent of the observations may be found.

EPA Victoria has set many of its SEPP objectives as 75th percentiles (see "Assessing against water quality objectives", p.12). For the data set used in the previous example, the 75th percentile is 8, which is the value that is 75% of the way from the lowest to the highest data point:

median
↓
4, 5, 5, 5, 5, 6, 6, 6, 6, 8, 45, 88, 97
↑ ↑
25th percentile 75th percentile

This data set is indicative of relatively stable water quality conditions (median 6; 75th percentile 8), with infrequent disturbances. If the data set were different, for example -

4, 5, 5, 5, 5, 6, 6, 6, 40, 48, 55, 88, 97;

then the 25th percentile and the median would be unchanged but the 75th percentile would be 48, indicative of more frequent disturbances, probably due to more than just storm events. When reporting against SEPP, you will need to use the 75th percentile for most of the Waterwatch water quality indicators, as well as the 25th percentile for pH and dissolved oxygen.

Many software spreadsheet packages, such as EXCEL, can be used to quickly and easily calculate medians and other percentiles.

USING TIME SERIES

Variability is a natural part of the aquatic environment. Typically with water quality data there is a 10-20% difference between consecutive samples. For example, where salinity is measured at 500 µS/cm, changes of up to 100 µS/cm four weeks later may be due simply to natural variation and not a significant change in the aquatic environment. However, there will be more substantial changes due to floods or after long dry periods. For example, turbidity may go up ten fold during a flood event and salinity can more than double as flows decrease and groundwater becomes the main source of flow.

Displaying the data in a time series provides a picture of change over time. Time series plots are useful to illustrate seasonal patterns, major events or when 'one-off' high or low levels are measured. Figure 3.4 illustrates long term patterns in turbidity in the lower Ovens River. Note the seasonal patterns where turbidity rises during winter/spring and drops in summer/autumn. Also note the occasional high levels in winter, likely to be associated with flood events. Drought in 2002 can be seen in low turbidities during the winter and the effects of fires in 2003 can be seen in the elevated levels post fires.

Trend lines can also be added to determine if there have been substantial increases or decreases over time. For the clearest picture, a long time period is required to show temporal changes. Usually less than five years will not provide a good assessment. Figures 3.5 and 3.6 display five and 14 years of monthly data respectively. The trend lines suggest substantial changes at both sites. Phosphorus levels in Bennison Creek (Figure 3.5) appear to have decreased. Note the lack of very high levels in the later years compared to earlier years, suggesting that drought may have been the cause of this result. In Broken Creek, turbidity levels have increased between 1993 and 2007 (Figure 3.6). Levels gradually increased over time and there is no obvious inflection point, suggesting gradual increases from the catchment rather than a change in activity in the catchment. By 2002, turbidity levels were consistently above 50 NTU and often above 100 NTU. Such levels are likely to be harmful to aquatic life.

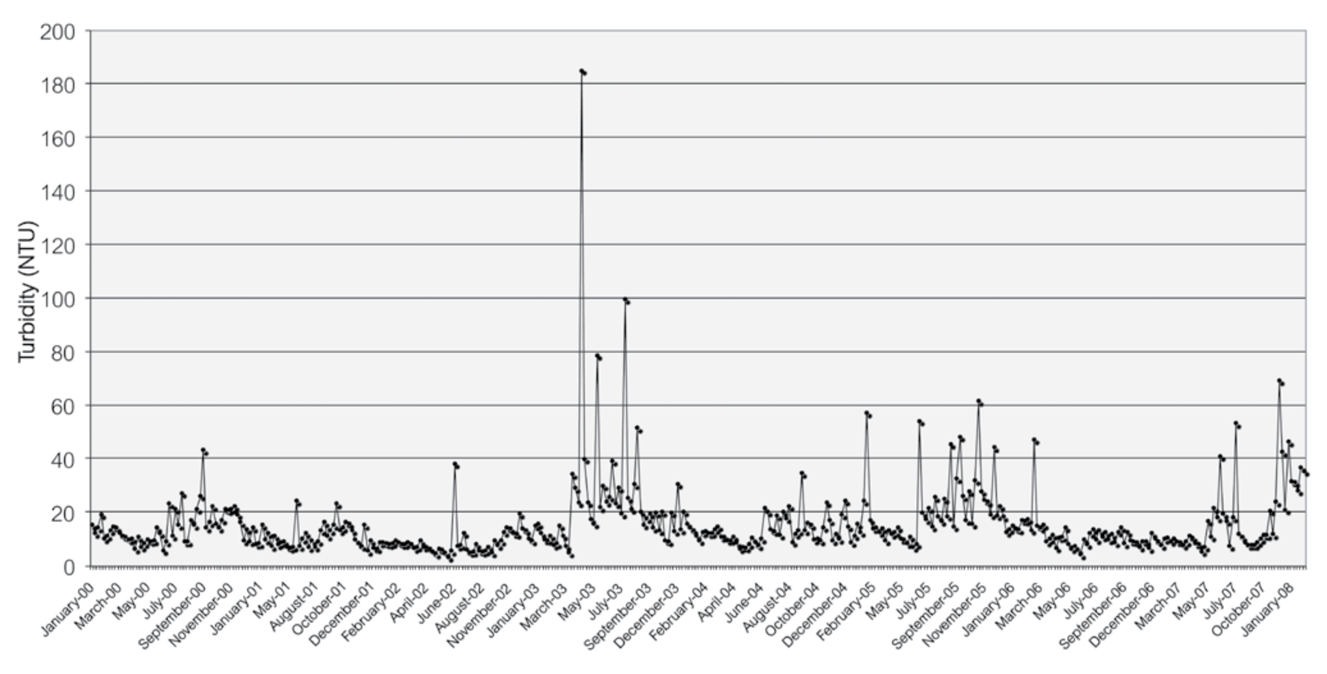
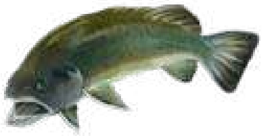


Figure 3.4 Turbidity time series 2000 to 2008 for Ovens River at Peechelba (VWQMN site no. 403241). Source: VWQMN Data Warehouse. Graph generated using Microsoft Excel.



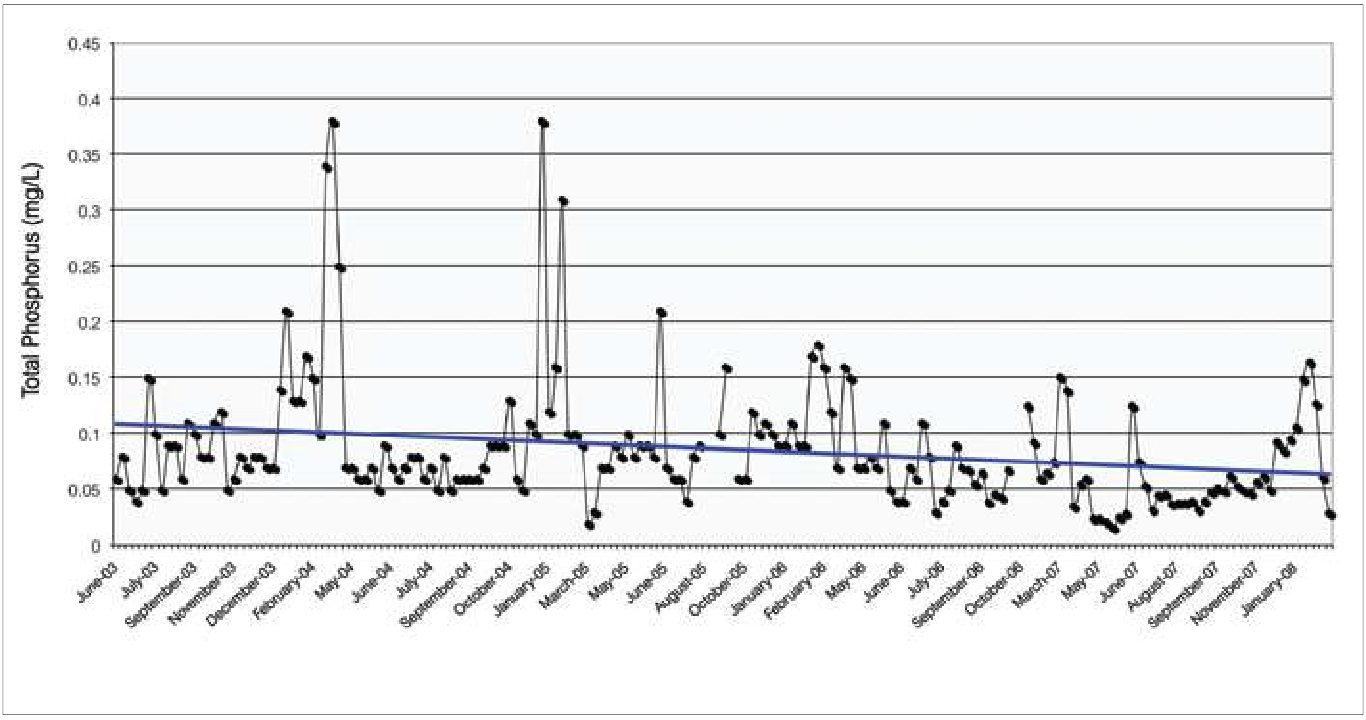


Figure 3.5 Total phosphorus time series and trend line for Bennison Creek at south Gippsland Highway (site no. BNN020). Source: West Gippsland CMA. Graph generated using Microsoft Excel.

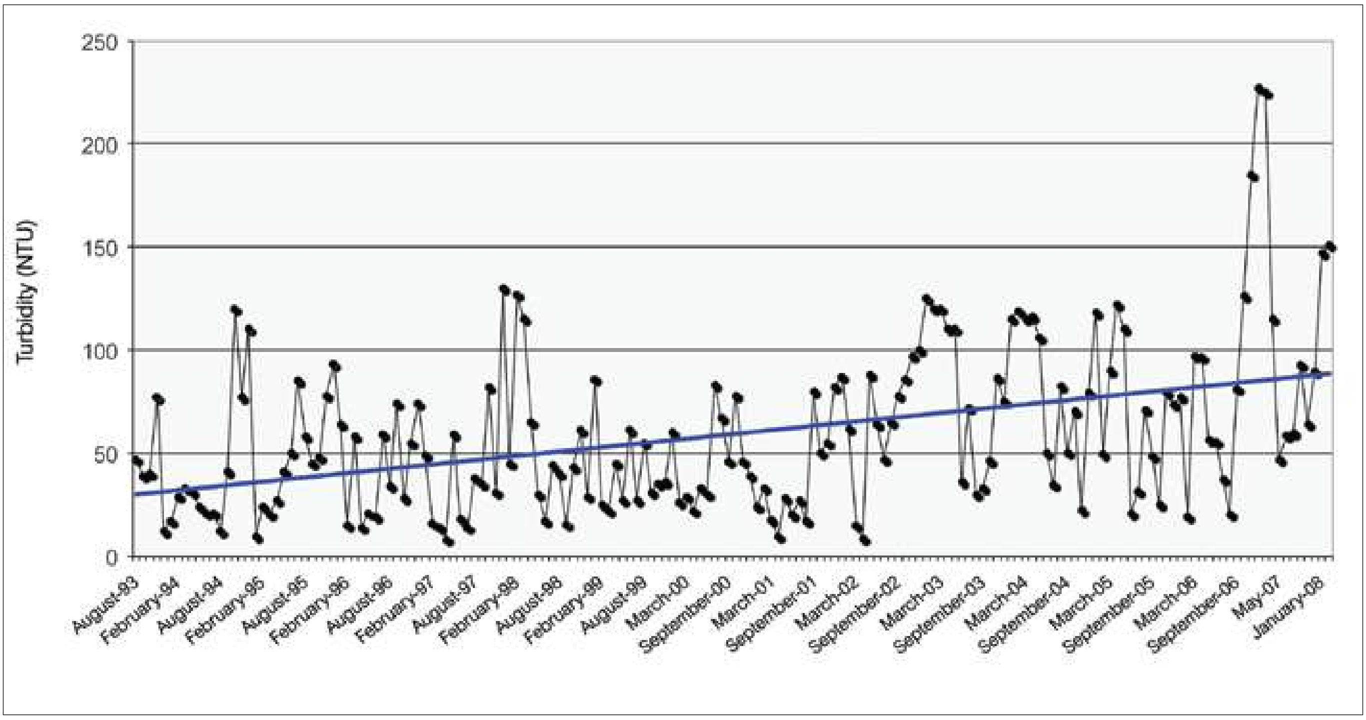


Figure 3.6 Turbidity time series and trend line for Broken River at Gownagardie (site no. BAR010). Source: Goulburn-Broken Waterwatch. Graph generated using Microsoft Excel.

Assessing water quality against objectives

The majority of assessments using water quality data collected for Waterwatch will be against the objectives provided in the SEPP (WoV). There are some important points to note about the SEPP (WoV) objectives:

1. They are ambient objectives and are not designed for use in single or short-term sampling programs. The objectives are designed to indicate low-risk conditions within a region or segment over an extended period of time (months to years). However, single sampling or a few samples from a site can still be used to provide some indication of condition and may suggest that further sampling is warranted
2. They are typically provided as 75th percentiles (e.g. total phosphorus, total nitrogen, turbidity, electrical conductivity, pH-high) or 25th percentiles for indicators that should not fall below particular values (e.g. pH-low, dissolved oxygen-low). The use of 75th and 25th percentiles requires a minimum of 11 samples for adequate confidence. Therefore, an annual monthly monitoring program should be sufficient for assessment against SEPP objectives
3. They are 'trigger' values. It is important to recognise the difference between trigger values and pass/fail objectives. If a pass/fail objective is not met, the site is deemed to have failed an assessment of its ecological condition. Although this is useful for auditing or catchment condition reporting, it does not necessarily trigger follow-up action. In contrast, if a trigger value objective is not met, then this should 'trigger' some action. The action that is triggered may range from spending a few hours to identify possible reasons (such as natural disturbances like storms, droughts or bushfires), through to undertaking ecological risk assessments or target-setting programs.
4. The objectives have been derived for regions based on ecological condition (Figure 3.7).

A data set collected from monthly sampling at a site can be compared to the SEPP (WoV) objectives for the segment (waterway section) to determine whether any results trigger further action. The SEPP (WoV) and its background documents provide important information for the assessment of data against objectives.

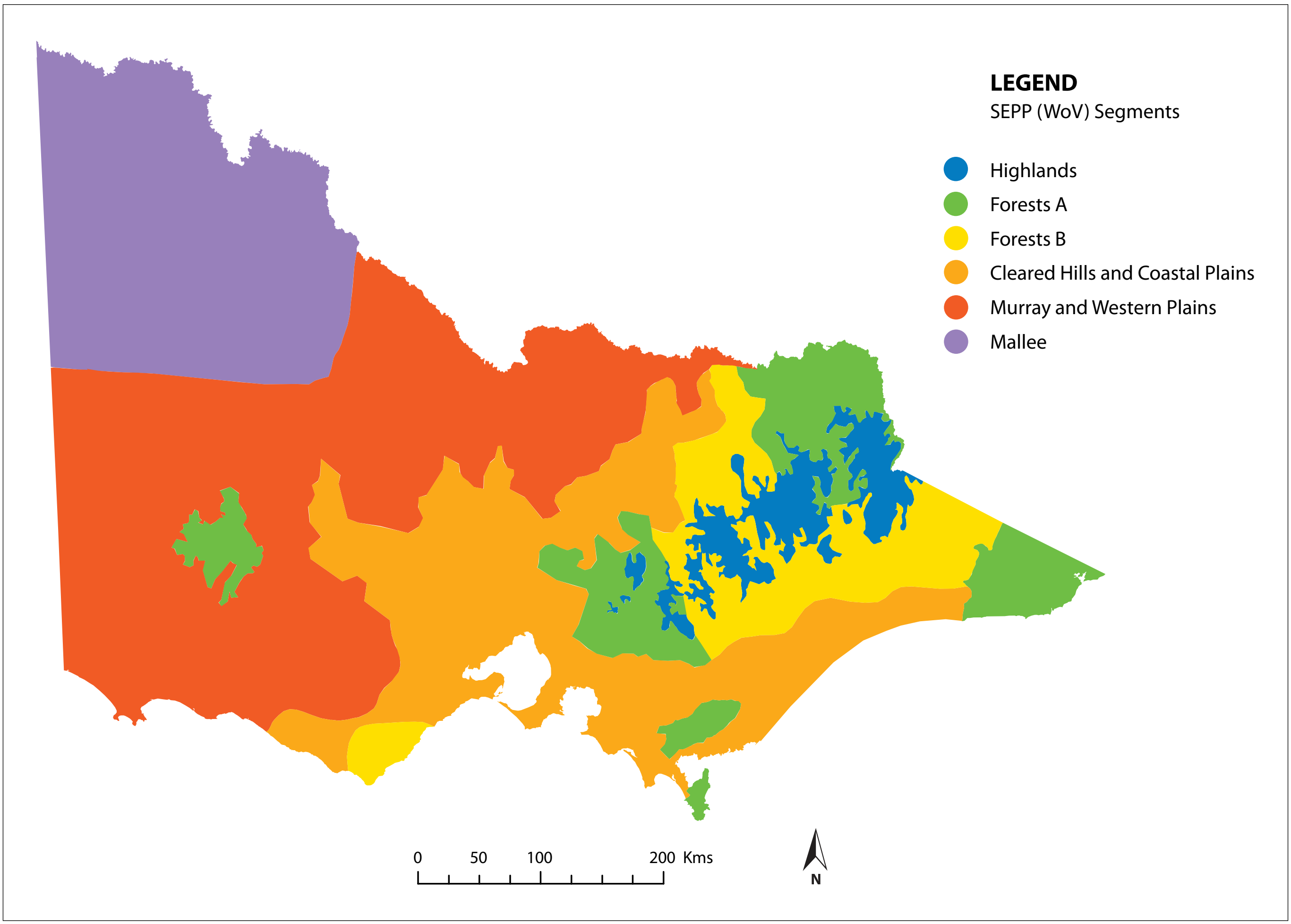


Figure 3.7 State Environment Protection Policy (Waters of Victoria) segments.

A single indicator triggering by a small amount for the first time (i.e. it hasn't triggered previously), may be considered a result worthy of 'watch' status. In contrast, a suite of indicators (e.g. total phosphorus, total nitrogen and dissolved oxygen) that continually trigger by a substantial amount and/or are increasing in their magnitude of triggering may warrant a full risk assessment. Between these two scenarios, further assessment by waterway managers or an aquatic ecologist may be warranted. Further details on the SEPP (WoV) approach can be found in *Risk-based assessment of ecosystem protection in ambient waters* (EPA Victoria 2004).

An example of assessing site data against SEPP objectives is provided for Bennison Creek (Table 3.1). In this example, only pH and turbidity meet the SEPP objectives for the Cleared Hills and Coastal Plain segment. Although not likely to be a risk to the ecosystem, the results are an alert that there may be an issue at the site. Electrical conductivity is over the objective, although not substantially and no single measurement is above potential toxic levels (greater than 1,000 µS/cm). While total phosphorus is also just over the objective, some of the measurements were particularly high and if sustained could result in excessive plant growth. Further investigation of total phosphorus is likely to be warranted. With this process there is a need to look at past results and see if a pattern is emerging or whether the events are one off and are unlikely to occur again or occur infrequently.

The SEPP (WoV) objectives do not provide a scale of outcomes (e.g. very good condition, good condition, poor condition, etc.). However, they do indicate if a site is good (i.e. the site meets the trigger value), or possibly bad (the site does not meet the trigger value). The distinction is not always clear when results are close to the trigger values, as demonstrated in the Bennison Creek example.

Table 3.1 Water quality data and annual percentiles for 2007 for Bennison Creek at South Gippsland Highway. SEPP (WoV) Cleared Hills and Coastal Plain segment. (site no. BNN020) Source: West Gippsland CMA

Date	Electrical Conductivity (µS/cm)	pH (pH Units)	Total Phosphorus (mg/LP)	Turbidity (NTU)
2 Mar	777	6.99	0.151	8
6 Apr	591	6.72	0.035	3
4 May	625	6.9	0.06	11
25 May	680	7.16	0.021	6
15 Jun	492	6.73	0.029	10
6 Jul	290	6.68	0.053	25
27 Jul	310	6.85	0.046	8
17 Aug	253	6.9	0.038	12
7 Sep	325	7.02	0.04	5
28 Sep	304	7.06	0.049	8
19 Oct	263	7.15	0.049	9
2 Nov	328	7.1	0.057	5
23 Nov	325	7.12	0.092	10
Annual 75th percentile	591	7.1	0.057	10
Annual 25th percentile	-	6.85	-	-
WoV Objective (annual percentile)	75th ≤ 500	75th ≤ 7.7 25th ≥ 6.4	75th ≤ 0.045	75th ≤ 10

3.4 Interpreting the Data in terms of Environmental Setting

RELATIONSHIPS BETWEEN INDICATORS AND OTHER ECOLOGICAL COMPONENTS

The results obtained from any sampling event or program will reflect a variety of physical and biological features that may be affecting water quality at each site. These include:

- the nature of the surrounding catchment (steepness, soil type, vegetation cover);
- site location within the catchment (headwater/upland, lowland plains);
- weather conditions during or prior to sampling (storms, droughts);
- land use within the catchment, particularly close to the sampling site (urban/industrial, agricultural, nature reserve); and
- in-stream inputs and actions (stock access, waste discharges, water removal, storages).

Similarly, the water quality at a site affects other components of the water body, including other aspects of water quality and the biota that the water body supports. A few of the more common relationships between water quality indicators and other ecological components are presented in this section. Greater discussion of the most sampled indicators is provided in section five.

THE SURROUNDING CATCHMENT

One of the most important natural features of the surrounding catchment is soil erodibility (which itself is a function of vegetation cover, slope steepness and length and soil type). In particular, catchments that have steep slopes and/or sparse vegetation cover are particularly susceptible to soil erosion, with potentially serious implications for water quality.

Soil that is eroded from the catchment and subsequently deposited in streams can directly and indirectly impact on the condition of the receiving water bodies. One direct impact is physical, with coarser grained sediments (sand, fine gravel) filling in deep pools required by fish and filling in interstices (gaps) between rocks and stones that are vital habitat for some macroinvertebrate species. The deposition of finer sediments derived from soil (such as silts and clays) can smother habitat and clog the gills of fish and invertebrates.

A measure of the extent to which finer particles are present in the water column is provided by an analysis of suspended particulate matter (SPM) concentration in the water (often also called suspended solids (SS), total suspended solids (TSS), or non filterable residue (NFR)). Finer particles can also act to reduce light transmission through the water column, inhibiting growth potential for aquatic macrophytes and algae and impacting on fish species that are visual predators. Turbidity is a surrogate measure of light transmission through the water. High turbidities are often an indication of poor land use management within the catchment, including the riparian zone. Elevated turbidity and SPM are often correlated with increased total nutrient concentrations (total nitrogen and total phosphorus), as soil particles often have nutrients attached to them.

SITE LOCATION WITHIN THE CATCHMENT

Sites that are high within catchments are often more prone to marked swings in water quality, as they have little buffering from rainfall events. This is because headwater streams are often small and drain a small catchment area, so any rain event within that catchment has the potential to cause substantial fluctuations in water quality. In contrast, large rivers in the lower reaches typically have many tributaries feeding into them and at any time may be receiving waters from some tributaries that have experienced storms, and others that have not. Therefore, water quality changes are often only small. Of course, changes in water quality from a major catchment-wide storm event will be readily observable even at lowland sites.

WEATHER CONDITIONS PRIOR TO SAMPLING

Under typical flow conditions, a perennial stream within a given catchment will be expected to have a reasonably predictable set of water quality measurements and variability. However, unusual weather conditions prior to sampling can lead to large changes in water quality. For example, during droughts the gradual reduction in flows leads to an increased proportion of groundwater contributing to streamflow. Large parts of Victoria have groundwater with substantially higher salt and nitrate concentrations than typically found in flowing surface waters. Concurrently, the reduced inputs of water from overland flow and throughflow result in less sediment being washed into the stream and therefore less associated nutrients.

As a result, prolonged drought conditions are often reflected by reduced stream flows with greater electrical conductivities (EC), increased nitrate concentrations and reduced turbidities, SPM and total nutrient concentrations.

In contrast, high flows following storm events or substantial rainfalls are typically associated with greater dilution of groundwater and increased sediment loads being washed into the stream (Figure 3.8). Typical impacts on water quality are therefore reduced EC and nitrate concentration, accompanied by higher turbidities and associated increased concentrations of SPM, total nitrogen (TN) and total phosphorus (TP) (Figure 3.8). Increases in nutrient concentrations can lead to further problems associated with eutrophication (see sections on nutrients and oxygen).

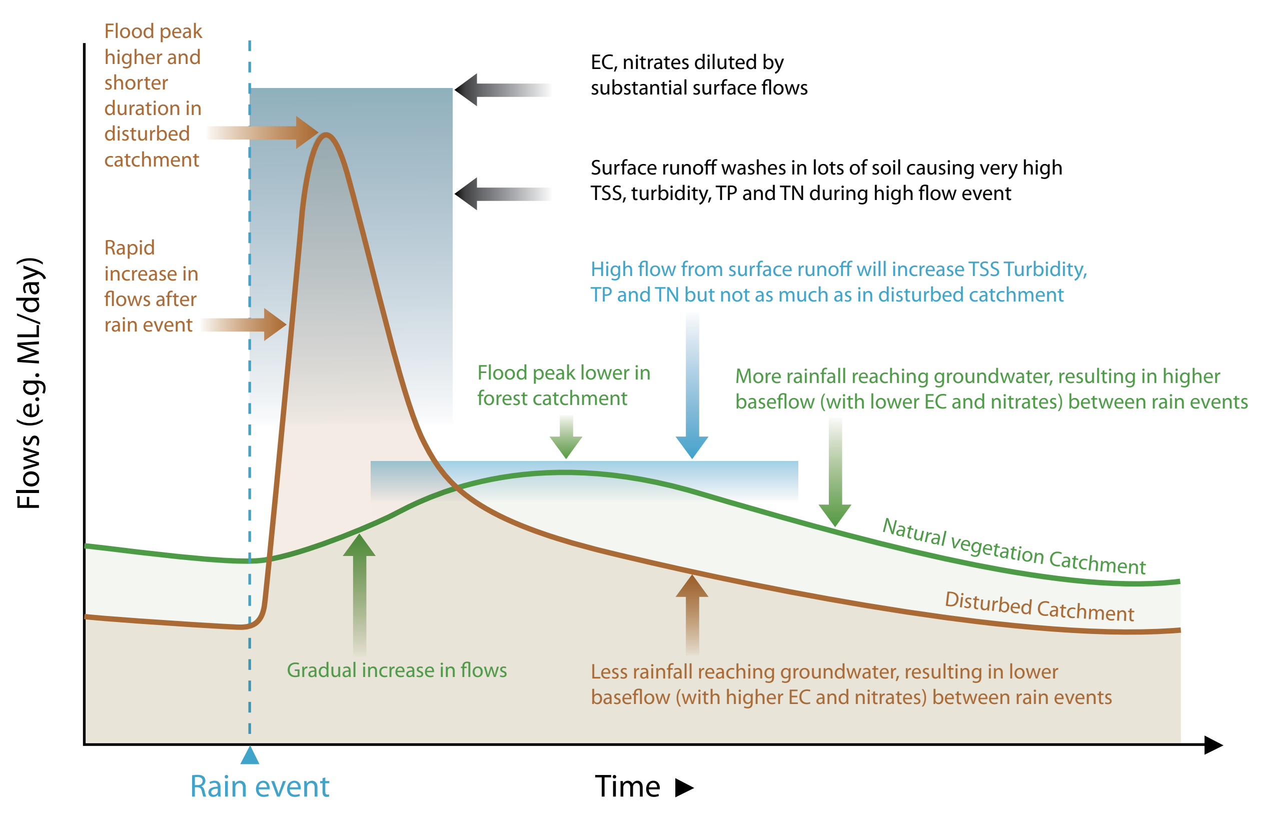


Figure 3.8 Typical flow hydrograph after rainfall in a forested and a disturbed catchment.

Catchment land use

Land use within a catchment can have a major influence on the water quality of stream systems. Catchments that have a large proportion of native vegetation, nature reserves and national parks will have lower rates of erosion and therefore less inputs of sediment into streams. In pristine or near pristine catchments, a large percentage of water from rainfall events tends to soak into the ground, recharging groundwater and gradually contributing to stream base flow over an extended period of time.

In contrast, catchments with a large degree of disturbance (such as urbanisation, large scale vegetation clearance or poor agricultural practices) tend to have higher surface runoff during rainfall events. The surface runoff will pick up pollutants (from urban areas) and soil particles (particularly in agricultural areas) and deposit them into the receiving waterways. Another feature of increased overland flow in disturbed catchments is that the rainwater is delivered more quickly to the streams, resulting in a higher flood peak that passes quickly through the system (Figure 3.8). The higher flood peak results in increased washing away erosion of streambeds and banks, in turn contributing more sediment to the stream system. The rapid draining of catchments also leads to reduced groundwater recharge and once the flood peak has passed, there is less groundwater to contribute to base flow, resulting in a greater potential for streams to dry during low rainfall periods.

Therefore, streams that drain catchments disturbed by land uses such as urbanisation, intensive agriculture and large-scale clearing can be expected to have higher concentrations of contaminants, sediments and associated total nutrients, particularly during and soon after large rainfall events.

Closer to the stream channel, removal of riparian vegetation can intensify these impacts and also add to temperature fluctuations, particularly through reduced stream shading in summer. The warmer waters can directly stress in-stream biota, as well as lead to reduced dissolved oxygen concentrations (see oxygen section), further stressing the biota.

In-stream inputs and actions

Other common influences on water quality that may be reflected in routine sampling include direct discharges to streams (e.g. from sewage treatment plants, dairy effluent or stormwater), stock access to streams and flow regulation or extraction. The effects of discharges will vary according to the discharge and its make-up.

Sewage discharges will often have high nutrients (including reactive phosphorus, ammonia/ammonium and nitrates), high oxygen-demanding substances (which may lead to low dissolved oxygen further downstream), high salts (reflected in EC readings) and miscellaneous organic and metal contaminants (depending on the sources to the sewage treatment plant).

Howqua River upstream of Running Creek Campground (looking downstream).

Stormwater may also contain contaminants such as metals from industry and from roads, as well as particulates with nutrients and high oxygen demand. Dairy effluent discharging to streams will often have very high oxygen demand from the organic matter, as well as high nutrients (including reactive phosphorus, ammonia/ammonium and nitrates).

Direct stock access into waterways typically results in increased bed and bank erosion, which contributes to increased turbidity, SPM and associated TN and TP. Faecal matter from stock also contributes to oxygen demand and high nutrients (including reactive phosphorus, ammonia/ammonium and nitrates).

Stream flow regulation can lead to greater temperature fluctuations. This can be attributed to cold water discharges from deep storages and reduced flow having less thermal mass and therefore heating up and cooling down more rapidly with the ambient air temperatures. Rapid fluctuations in flows associated with some regulation can also create bank instability, leading to bank failure and increased sediment input.

Looking for spatial patterns

Water quality changes as you go downstream. Small, shallow headwater streams change to bigger, deeper lowland rivers. Water clarity decreases naturally and nutrient and salinity levels increase naturally. The magnitude of changes will depend on the catchment. Forested catchments with little land disturbance change gradually, while more disturbed catchments will have rapidly changing water quality. Human activities including agriculture and urbanisation can have substantial effects on water quality.

Assessing downstream water quality is a valuable tool to determine point source discharges, such as sewage or stormwater discharges, and diffuse sources, such as from agriculture. To give a good spatial representation of changes and good differentiation of likely sources, sites need to be relatively close together. In addition, using longer term data (at least twelve months) will give a more effective and accurate assessment.

An example of spatial patterns is given in Figure 3.9 for the Broken River/Broken Creek catchment. In this catchment, turbidity levels are low in the forested reaches of the catchment upstream of Lake Nillahcootie (around the SEPP WoV objective of 5 NTU). Downstream of the lake, turbidity levels increased to more than five times the upstream levels. However, the increase at Caseys Weir is far greater, to more than twice the SEPP WoV objective of 30 NTU for this lowland segment. The increase is almost certainly due to the very turbid waters entering from an off-line storage (Lake Mokoan). Surprisingly, even greater increases were measured further downstream of Caseys Weir, even though obvious sources have not been identified. The continued increase is likely to come from one or more sources, most probably from the bed and banks, irrigation return waters or surface runoff.

In this example, sites are relatively close together which gives a good spatial representation of changes and good differentiation of reach changes, however it has not identified sources. Sources could be investigated by undertaking site inspections, discussions with local landholders and/or further sampling designed specifically to identify potential sources.

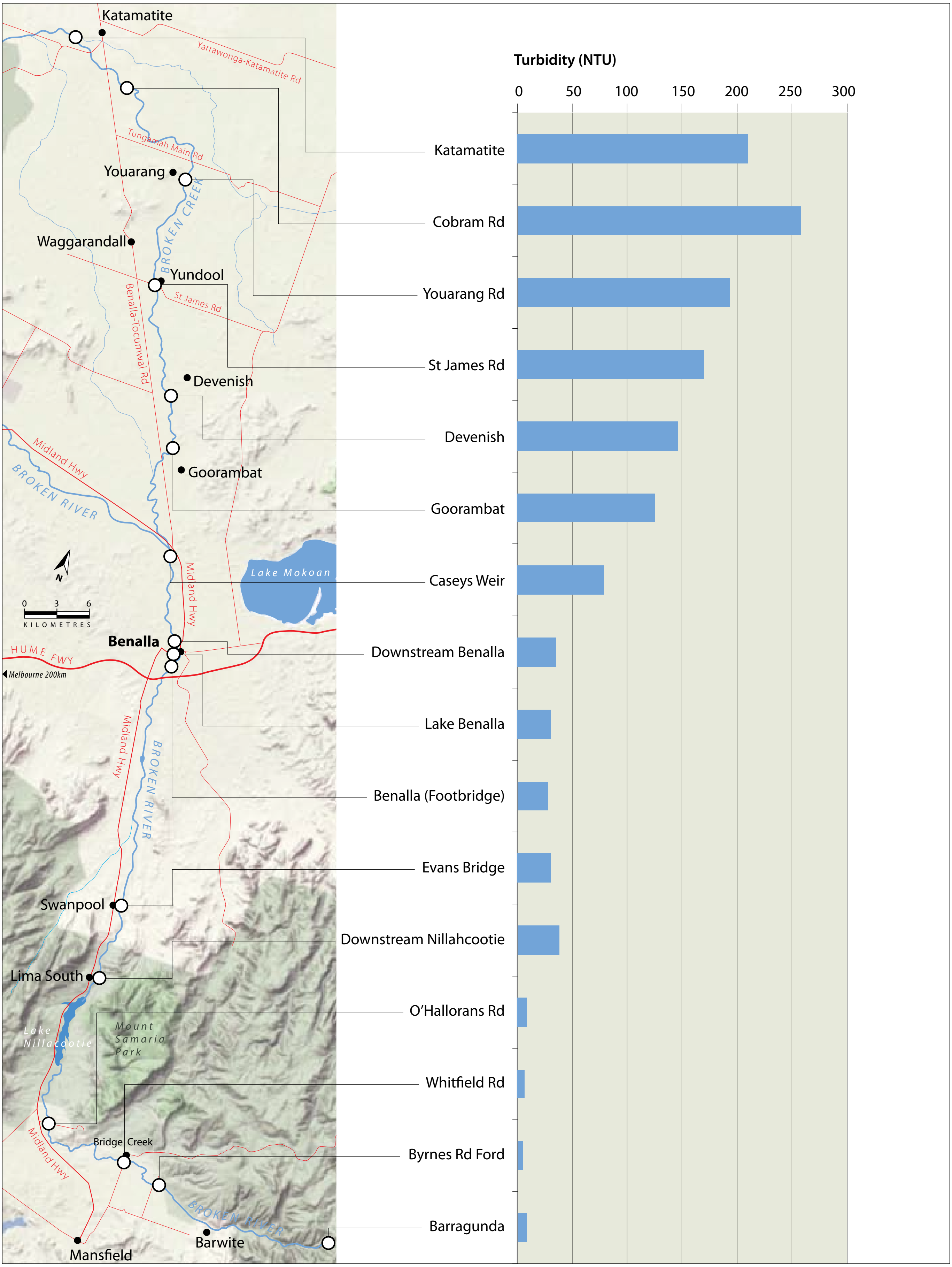


Figure 3.9 Turbidity in Broken River and Broken Creek. Long term 75th percentiles (1996-2008). Data Source: Goulburn-Broken Waterwatch.

4.1 Phosphorus

WHAT IS IT?

Phosphorus is a naturally occurring element originating from minerals in rocks and is essential for animal and plant life. In natural circumstances, phosphorus usually enters waterways from the weathering of rocks (inorganic phosphorus) and the decomposition of plant and animal material (organic phosphorus).

Although phosphorus is one of many nutrients required by plants and animals, in freshwater systems it is often the nutrient limiting plant growth (i.e. it is the nutrient in shortest supply). This places a special importance on the monitoring and management of phosphorus.

Phosphorus is rarely found in its elemental form (P). It usually occurs in waterways as a form of phosphate (PO_4^{3-}). Different forms of phosphate are categorised as either chemically based forms or analytical methods-based forms. Chemically based forms of phosphate include:

- **Orthophosphates** These are the forms most readily available to plants and include the simple inorganic forms of phosphates, such as PO_4^{3-}, $HPO4^{2-}$, $H_2PO_4^-$, and H_3PO_4.
- **Condensed Phosphates** These are complex, tightly-bound, inorganic phosphate compounds sometimes referred to as 'polyphosphates'.
- **Organic phosphorus** This refers to a phosphate molecule associated with a carbon-based molecule, as in plant or animal tissue.

Organic and inorganic phosphate can be dissolved in the water or suspended (attached to particles in the water column).

The three most commonly used analytical methods for measuring phosphorus concentrations are:

- **Reactive Phosphorus (RP)** This measures any form of phosphorus that reacts with reagents in a colorimetric test without prior filtering or digestion (acid and heating). This method is also known as 'total reactive phosphorus' and is largely a measure of orthophosphates. However, the procedure isn't 100 per cent accurate and so results will include a small fraction of some other forms of organic and inorganic phosphorus that are easily broken down in water.
- **Filterable Reactive Phosphorus (FRP)** This is the fraction of the total reactive phosphorus that is in solution in the water (as opposed to being attached to suspended particles). It is determined by first filtering the sample, then analysing the filtered sample for reactive phosphorus.
- **Total Phosphorus (TP)** This is the sum of organic and inorganic forms of phosphorus in unfiltered water samples. The procedure uses sample digestion (acid and heating) and measures both dissolved and suspended orthophosphate.

A simple conceptual model of the different measured forms of phosphorus is presented in Figure 4.1. A measurement of filterable reactive phosphorus (FRP) is a component of measuring reactive phosphorus (TRP or, more usually, RP), which itself is a component of total phosphorus (TP).

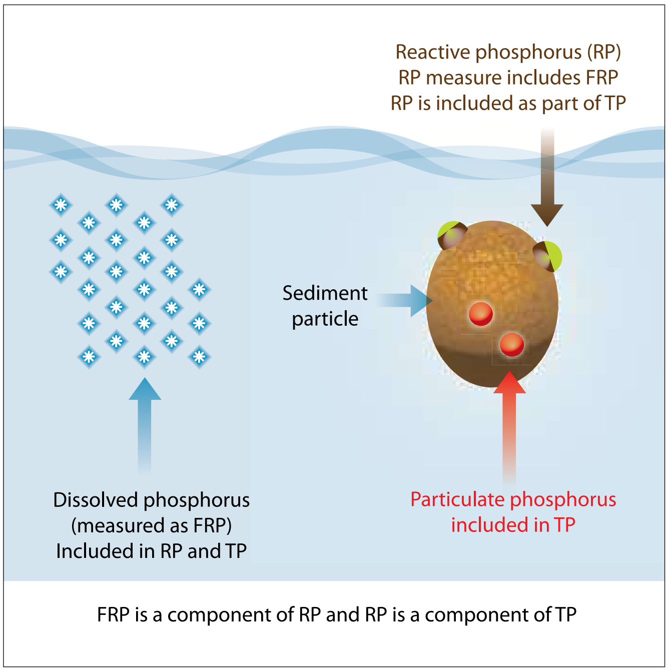


Figure 4.1 Conceptual model of common forms of phosphorus in water.

HOW IS IT MEASURED?

As described above, the three most common ways to measure phosphorus are RP, FRP and TP. Within Victoria, the SEPP (WoV) objectives for phosphorus use TP. Although TP is likely to be an overestimate of the biologically available phosphorus in a water sample, biochemical processes such as remineralisation of organic phosphorus and conversions between the various forms, mean that measures of TP give a reasonable indication of the amount of phosphorus ultimately available.

The SEPP (WoV) objectives are presented as 75th percentiles and vary between segments of each waterway.

The different measures of phosphorus cannot be substituted. However, if a measure of FRP or RP was approaching or greater than the SEPP (WoV) objective for TP, this would be a strong indication of excessive phosphorus concentrations.

Why monitor phosphorus?

Phosphorus is often the limiting nutrient in freshwater systems. This means that increased concentrations of phosphorus provide increased opportunity for growth of algae and other plants. If phosphorus concentrations are high enough, they can contribute to algal blooms and infestations of aquatic macrophytes. Excessive algal and macrophyte growth can lead to smothering of habitat, clogging of waterways and overnight 'oxygen troughs'. Oxygen troughs occur when plants respire during the night (consuming oxygen) but are not photosynthesising (and therefore not producing oxygen). Under normal circumstances, a cycle of oxygen peaks during the day and troughs during the night (Figure 4.5, p.31). However, in eutrophic waters this cycle becomes exaggerated, with oxygen concentrations reaching very high levels during the mid afternoon and then dropping to very low levels just before sunrise (Figure 4.5, p.31). Levels can be low enough to severely stress, or even kill, the fauna of the stream.

At the end of an algal bloom, when the plant material is decaying (oxidising), the micro-organisms that break down the plant material consume large amounts of oxygen during the process, also adding oxygen stress to the ecosystem (Figure 4.4, p.23).

Sources

Natural sources of phosphorus in waterways include: inorganic phosphates dissolved from weathered rocks; organic material from plants that have taken up the inorganic phosphate; organic material from animals (including wastes and decaying tissues); and remineralised phosphate that has been converted by bacteria from organic particulate phosphorus into dissolved inorganic phosphate (Figure 4.3, p.22).

Human derived or accelerated inputs of phosphorus to waterways can include those associated with eroded soil that is deposited as sediment (including particles with phosphate fertiliser attached), discharges from sewage treatment plants, stormwater runoff, discharges from intensive agriculture/dairying, stock access to streams and poor land management (Figure 4.4, p.23).

Courtesy of Corangamite Waterwatch.

Natural Variations

Phosphorus concentrations can vary over time in relation to seasonal phenomena and episodic events. For example, higher flows (whether seasonal or episodic) are typically associated with increased inputs of suspended particulate matter, which carry attached TP. If storms follow bushfires within a catchment, extremely high levels of TP may be measured, associated with ash deposition and massive sediment inputs.

Concentrations of phosphorus also vary spatially across the State and this has formed the basis of the nutrient regions defined within SEPP (WoV). Objectives for TP range from 20 µg L^{-1} in the highlands, up to 45 µg L^{-1} in lowland plains. Typically, concentrations of most nutrients increase from headwaters to lowlands and this is the case for phosphorus.

Total phosphorus concentrations greater than 50 µg L^{-1} in upland rivers and streams are likely to lead to excessive plant growth while in lowland reaches, concentrations greater than 100 µg L^{-1} may lead to algal blooms if light is high (turbidity low).

4.2 Nitrogen

WHAT IS IT?

Nitrogen is a naturally occurring element (chemical symbol 'N'), originating from the atmosphere (chiefly as N_2) and from minerals in rocks. Nitrogen is essential for all animal and plant life and is continually cycled through ecosystems. Few living things can use atmospheric nitrogen, and instead rely on compounds of nitrogen.

However, there are forms of bacteria that turn atmospheric N_2 into nitrogen compounds that can be taken up by plants. This process is termed 'nitrogen fixing' and the bacteria are called 'nitrogen fixers'. Some nitrogen fixing bacteria live within the roots of land plants such as wattles and legumes or within the roots of aquatic plants, such as the fern Azolla, common in many of Victoria's waterbodies. Other forms of nitrogen fixing bacteria are found within soils and waterbodies, including cyanobacteria (often called 'blue-green algae').

In natural circumstances, nitrogen typically enters water bodies from the weathering of rocks (inorganic nitrogen) and the decomposition of plant and animal material (organic nitrogen) (Figure 4.3, p.22). Unlike phosphorus, which is readily adsorbed to soil and sediment particles, nitrogen compounds dissolved in water can be easily transported through groundwater to receiving waterbodies. Therefore, human inputs of nitrogen to the groundwater (e.g. through fertilisers, septic systems or animal waste, see Figure 4.4, p.23), are typically much more likely to reach waterbodies than human inputs of phosphorus (Although in some landscapes where the soil is very sandy, phosphorus can also be transported readily through the groundwater to surface waterbodies. This is because sand grains are more inert than other soil particles and therefore less able to adsorb nutrients. Also, very sandy soils are often more porous, leading to more rapid throughflow of groundwater).

Nitrogen is one of many nutrients required by plants and animals in freshwater systems. However, along with phosphorus it can be a limiting nutrient, with low concentrations restricting plant growth and high concentrations contributing to excessive growths of algae and other plants. Therefore, similar to phosphorus, the monitoring and management of nitrogen is important in the protection of waterbodies.

The most common forms of nitrogen found in waterbodies are:

- the oxides of nitrogen - nitrate (NO_3^-) and nitrite (NO_2^-), together often written as NO_x ;
- ammonia (NH_3)/ammonium (NH_4^+); and
- organic nitrogen (particulate and dissolved) derived from the breakdown of plant and animal tissue within the water body.

Oxides of nitrogen and ammonia/ammonium are the most available forms of nitrogen for uptake by plants, although organic nitrogen can be broken down by bacteria and converted into a more readily available form. Ammonia, in the form of un-ionised ammonia (NH_3) is toxic to aquatic life.

Laboratory measurement of nitrogen in water samples is undertaken through a variety of means which focus on different forms of nitrogen. The measurements of most interest to Waterwatch are:

- oxides of nitrogen (NO_x) – typically measured using a colorimetric method;
- ammonia/ammonium (NH_3/NH_4^+) – typically measured using an ammonia probe;
- Total Kjeldahl Nitrogen (TKN) – uses heat and acid to digest the sample and extract the nitrogen. This method loses the NO_x from the sample and therefore only measures the organic nitrogen (ON) and the NH_3/NH_4^+; and
- Total nitrogen (TN) – usually derived by adding results of NO_x and TKN analyses.

Water quality reporting usually includes TN, and often NO_x and NH_3/NH_4^+. As a general rule, the following equations are useful in assessing and describing the various nitrogen forms and combinations:

$$\mathrm{NO_x = NO_3{-} + NO_2{-}}$$

$$\mathrm{TKN = ON + NH3/NH_4^+}$$

$$\mathrm{TN = TKN + NO_x}$$

Nitrogen can be converted between forms, depending on the concentration of each form and also the environmental conditions within the river. For example, Figure 4.2 shows that a higher ratio of NO_3^- to NO_2^- is typically indicative of greater oxygen availability, where as higher proportions of NH_3/NH_4^+ are indicative of very low oxygen availability. Similarly, higher pH levels will tend to result in more NH_4^+ being converted to NH_3.

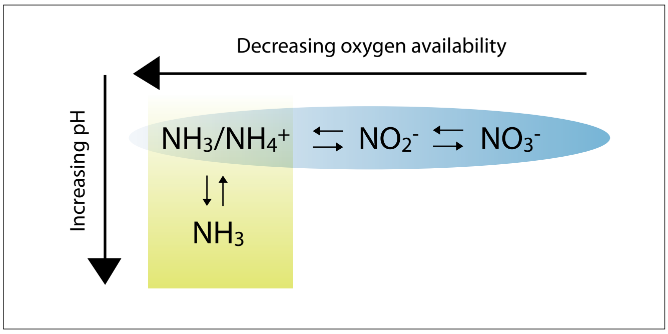


Figure 4.2 Forms of nitrogen in response to environmental conditions.

How is it measured?

Water quality reporting usually includes measures of TN and often NO_x and NH_3/NH_4^+. Within Victoria, the SEPP (WoV) objectives for nitrogen use TN. Similar to TP, TN is likely to be an overestimate of the biologically available form of the nutrient in a water sample. However, biochemical processes such as nitrification and other conversions between the various forms, mean that measures of the total nitrogen give a reasonable indication of the amount ultimately available.

The SEPP (WoV) objectives are presented as 75th percentiles and vary between segments of each waterway.

The different measures of nitrogen cannot be substituted. However, if a measure of NO_x was approaching or greater than the SEPP (WoV) objective for TN, this would be a strong indication of excessive nitrogen concentrations. If the concentration of NH_3/NH_4^+ was approaching the TN objective, this would also be a strong indication of excessive nitrogen concentrations as well as organic wastes, a chemical spill and/or low oxygen conditions.

Why monitor nitrogen?

Nitrogen is a key nutrient in freshwater systems. This means that increased concentrations of nitrogen provide increased opportunity for growth of algae and other plants. Nitrogen can act as a limiting nutrient if phosphorus concentrations are high. However, if both nitrogen and phosphorus concentrations are high, they can contribute to algal blooms and infestations of aquatic macrophytes. Excessive algal and macrophyte growths can lead to clogging of waterways, overnight 'oxygen troughs' and massive oxygen demand at the end of a bloom when the plant material is decaying (oxidising). These conditions result in the deaths of aquatic biota such as aquatic macroinvertebrates and fish. Ammonia (NH_3) is also toxic to aquatic life.

Sources

Natural sources of nitrogen in waterways include inorganic dissolved forms from weathered rocks, organic material from plants that have taken up inorganic nitrogen, organic material from animals (including wastes and decaying tissues), organic nitrogen that has been converted to nitrate by bacteria and nitrogen that has been fixed within the river (Figure 4.3). The source pathways are many and often overlap. For example, nitrogen contributed through the groundwater may have come from:

- mineral nitrates dissolved from rocks,
- gaseous N_2 fixed by bacteria in the roots of wattles,
- organic nitrogen that has been converted to nitrate by other bacteria,
- organic nitrogen that has been converted to ammonia by other bacteria,
- dissolved organic nitrogen.

Human derived or accelerated inputs of nitrogen to waterways can include: organic nitrogen associated with eroded soil that is deposited as sediment; NO_x and NH_3/NH_4^+ from fertiliser that has reached the groundwater; discharges from sewage treatment plants (mostly NO_x and NH_3/NH_4^+); stormwater runoff (ON/TKN); discharges from intensive agriculture/dairying (ON, NO_x and NH_3/NH_4^+); stock access to streams and poor land management (Figure 4.4).

Natural Variations

Concentrations of nitrogen vary across the State and this has formed the basis of the nutrient regions defined within the SEPP (WoV). Nitrogen is usually present in higher concentrations than phosphorus in freshwater environments. In catchments where there is a high percent coverage of wattles (*Acacia* sp.) there are indications that high levels of nitrogen fixation are contributing to elevated nitrogen concentrations in the groundwaters, which are ultimately reflected in the waterbodies that receive the groundwaters. This is likely to occur in catchments where substantial wattle regrowth is occurring after disturbances such as bushfires or vegetation clearance.

Reduced flows caused by drought or climate change result in a smaller proportion of streamflow being derived from surface runoff and therefore, a greater proportion of streamflow being sourced from groundwater. In many areas of Victoria the groundwater has high concentrations of NO_x. As a consequence, substantial flow reductions are often accompanied by large increases in NO_x concentrations, with NO_x often constituting almost all the TN at a site.

Nitrogen concentrations can also vary over time in relation to seasonal phenomena and with episodic events. For example, higher flows (whether seasonal or episodic) are typically associated with increased inputs of suspended particulate matter, which carry attached TN. If storms follow bushfires within a catchment, extremely high measures of TN may be measured, associated with ash deposition and massive sediment inputs.

SEPP (WoV) objectives for TN range from 0.15 mg L^{-1} (150 µg L^{-1}) in the highlands, to 0.9 mg L^{-1} (900 µg L^{-1}) in lowland plains. Similar to phosphorus, concentrations of nitrogen typically increase from headwaters to lowlands.

Total nitrogen concentrations greater than 0.25 mg L^{-1} (250 µg L^{-1}) in upland rivers and streams are likely to contribute to excessive plant growth while in lowland reaches, concentrations greater than 1.2 mg L^{-1} (1200 µg L^{-1}) may contribute to algal blooms if light is high (turbidity low).

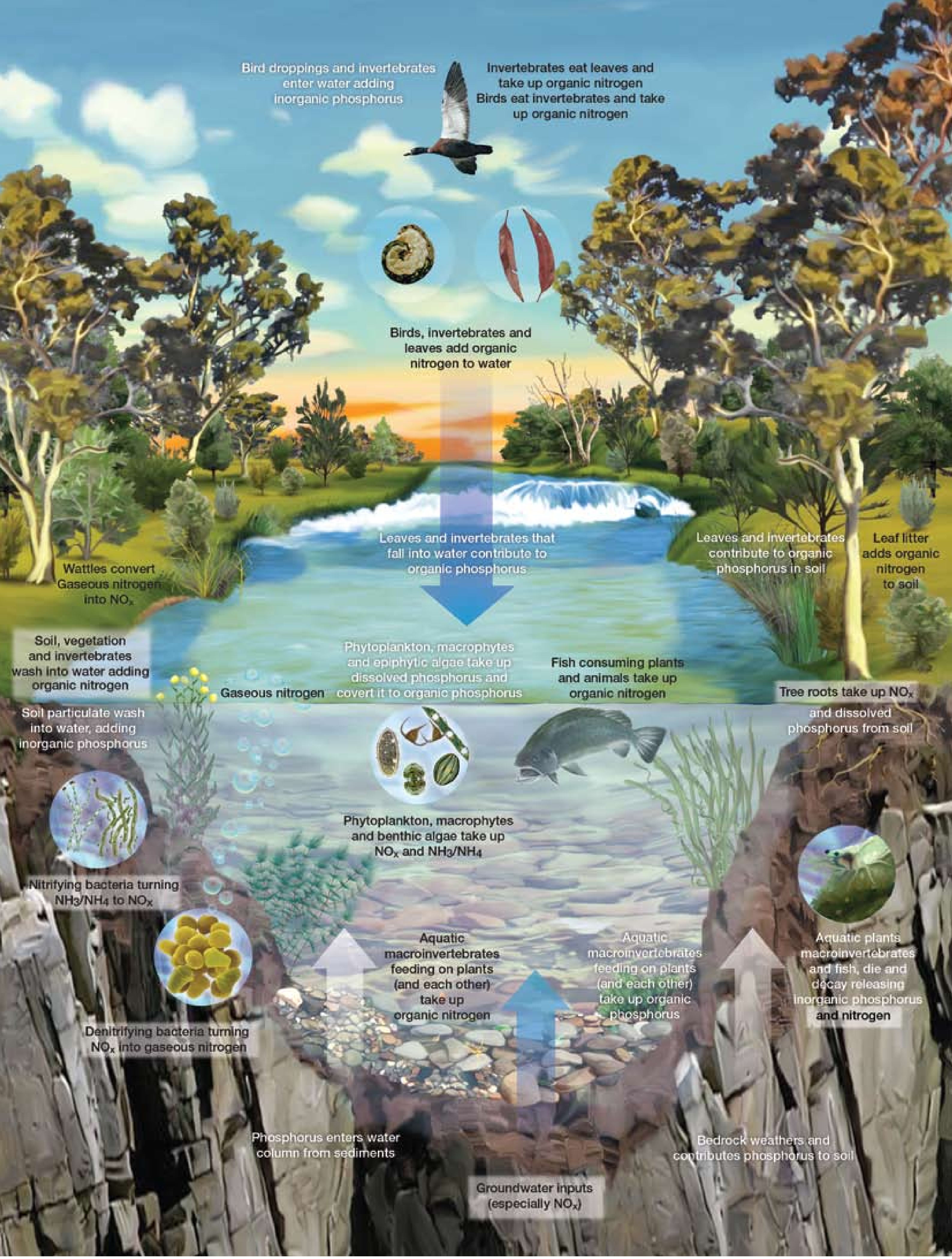


Figure 4.3 A phosphorus and nitrogen conceptual model for a healthy catchment.

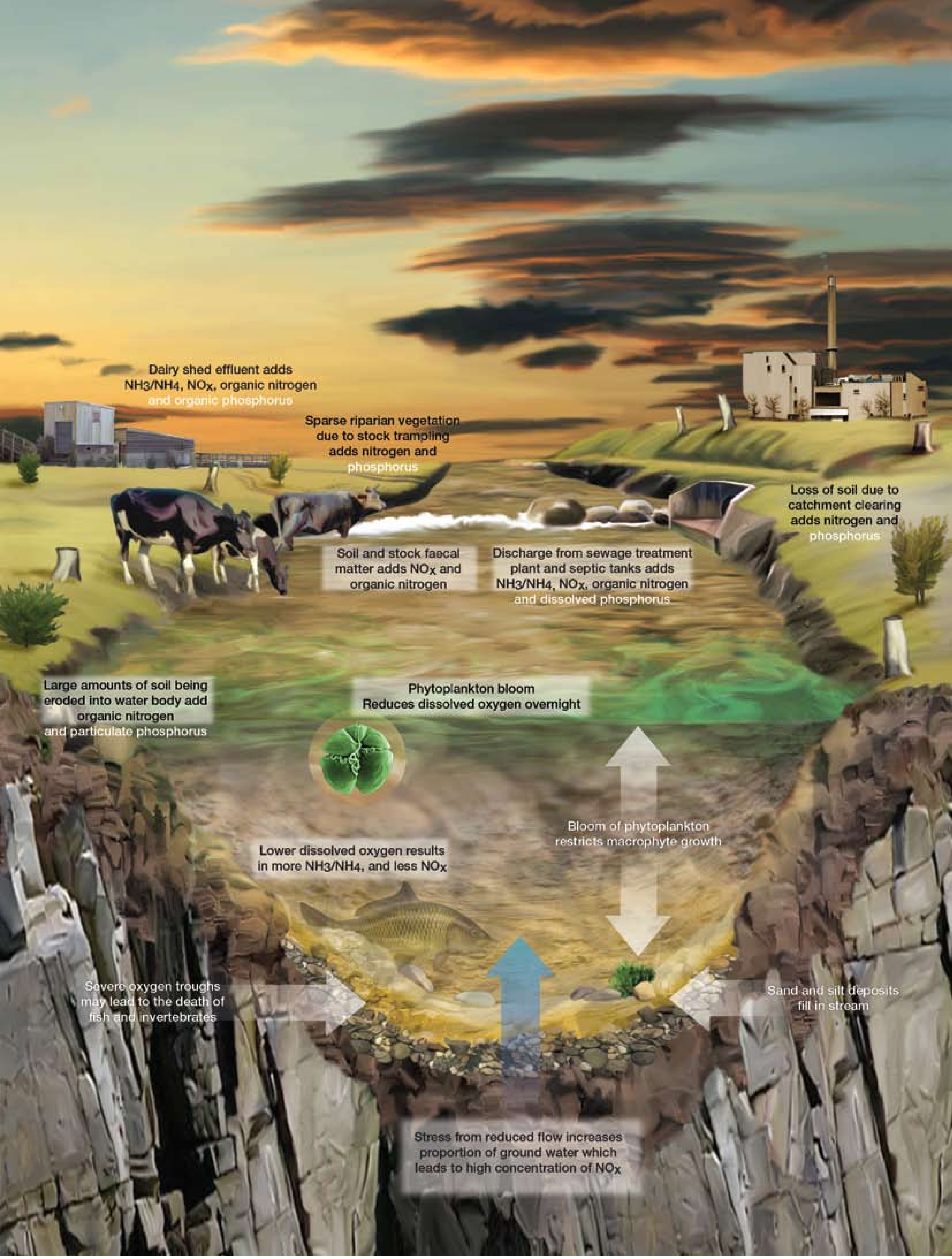


Figure 4.4 A nitrogen and phosphorus conceptual model for an unhealthy catchment.

4.3 Electrical conductivity

WHAT IS IT?

Electrical conductivity (EC) measures the flow of electricity in a solution. Conductivity in a solution increases as the amount of salts dissolved in the water increases. The relationship between conductivity and dissolved salt concentrations is used as a measure of salinity. The units of EC in water are usually expressed as micro Siemens per centimetre (µS/cm).

WHY MONITOR ELECTRICAL CONDUCTIVITY?

While some dissolved salts are needed for metabolic processes by aquatic organisms, excessive amounts may be toxic. Freshwater aquatic organisms have different tolerances to salinity with a few, such as the emergent macrophyte *Phragmites sp*. and many of the micro-crustaceans, tolerating levels higher than seawater (around 53,000 µS/cm). Nonetheless, most freshwater aquatic organisms will not survive in high levels of salinity. Unfortunately, salinity levels in many places have been increasing substantially and have impacted on the condition of aquatic ecosystems.

HOW IS IT MEASURED?

The direct measure of salinity involves measuring the mass of dissolved salts in the water. This is done by first filtering a known volume of river water to remove the suspended matter. This filtrate is then dried and weighed, giving a mass per volume result. Units are usually mg/L. Because there is a relationship between EC and salinity, EC can be converted to salinity by multiplying the EC by the conversion factor of 0.64 (although some meters may be different so check the meter's manual).

An electrode is placed in the water and the flow of electricity is measured. Units are usually µS/cm, but some meters may read it as mS/cm and this should be converted to µS/cm for consistency (one milli Siemen is 1000 micro Siemens).

EC varies with temperature. The higher the temperature, the higher the EC for a given salt concentration. EC meters will measure either at ambient temperature or will standardise at 25°C. It is important to standardise to 25°C as SEPP (WoV) objectives are measured at 25°C. If data have been collected at ambient temperature they can be converted to 25°C using the formula:

$$K_{25} = \frac{Kt}{1+C(t-25)}$$

Where:

C (constant) = 0.0191

K_{25} = EC at 25 °C

Kt = EC at ambient

t = ambient temp in °C

Courtesy of Corangamite Waterwatch.

SOURCES

Salinity levels will vary due to the influences of geology, proximity to the coast, urban and agricultural runoff, sewage and industrial effluent and, most importantly, groundwater (Figure 4.6, p.33). Groundwater can have very high salt concentrations, and rising groundwater tables have elevated salinity levels in many rivers in Victoria.

NATURAL VARIATION

Salinity levels vary substantially across Victoria (Table 4.1). In general, levels below 1,500 µS/cm are considered to have minimal short-term effect on aquatic biota. Toxicity studies suggest a step-wise impact on biota, with more and more taxa being removed from the aquatic community as salinity rises. Some very tolerant taxa are not affected until levels are above 30,000 µS/cm.

In the alps, highlands and forested catchments salinity is unlikely to reach levels that would be toxic to aquatic life. On the other hand, after prolonged dry periods in western Victoria, salinity may reach critical levels even after a short period of no flow, resulting in substantial changes to the aquatic ecosystem. In these systems groundwater is the major contributor of water to rivers, lakes and wetlands and much of the groundwater is high in salt. There is a natural cycle of high salinity water during a dry period followed by lower levels when runoff contributes to flows. In these catchments water harvesting has reduced runoff so groundwater contributions are now higher and base level salinities are therefore higher. In addition, evaporation in pools concentrates salts to even higher levels, especially after long periods of zero inflows.

Courtesy of Goulburn Broken Waterwatch.

Table 4.1 SEPP (WoV) objectives and typical levels in late summer and after a prolonged dry period (µS/cm @ 25°C).

Segment/region	SEPP (WoV) objective	Late summer levels	Extreme levels after prolonged dry period
Highlands (including the alps)	100	200	500
Forests	100	400	700
Cleared hills	500	1,000	3,000
Coastal plains	500 – 1,500	1,500	5,000
Murray plains	500	1,000 – 3,000	1,000 – 10,000
Western Victoria	1,500	2,000 – 10,000	6,000 – 40,000

4.4 pH

What is it?

The pH of water is a measure of its acidity or alkalinity. The actual component of the water being measured is its concentration of hydrogen ions (H^+). In water, some of the H_2O molecules will dissociate into H^+ ions (also called protons) and OH^- ions (hydroxide). These ions will be taken up differentially by other molecules through chemical and biochemical reactions. When there are more H^+ ions than OH^- ions the water will have a pH below 7 and is said to be 'acidic'. Conversely, when there are more OH^- ions than H^+ ions the water will have a pH greater than 7 and is said to be 'alkaline'. When the pH of a water body is 7, the H^+ concentration is the same as the concentration of hydroxide (OH^-) ions and the water is said to be 'neutral'. When the water is approximately neutral, it is called 'circum-neutral'.

The pH scale is logarithmic, which means that a change of two units (e.g. from 7 to 5) is ten times the change of one unit (e.g. from 7 to 6). In other words, lowering pH from 7 to 6 represents a ten-fold increase in H^+ ions, whereas a reduction from 7 to 5 represents a hundred-fold increase, and a reduction from 7 to 4 represents a thousand-fold increase. As a consequence, the further the pH is from neutral (7), the greater the impact of any further movement from 7. Therefore, although changes in pH from 7 to 6 are generally not considered a problem, changes from 6 to 5 will usually require explanation or investigation as they represent substantially greater increases in H^+ ions. Similarly, changes from 8 to 9 represent a substantially greater change in water quality conditions than changes from 7 to 8.

Note that although waters with high pH values are said to be 'alkaline', this is not the same as the water quality indicator 'alkalinity'. Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH. The alkalinity of a river is a measure of its buffering capacity, or its capacity to neutralize acids, including acidic pollution. Waters with high pH but low alkalinity are likely to be unstable and could change quickly from high pH to low pH.

Why monitor pH?

The pH of a water body can have serious direct and indirect impacts on the organisms living within the water and on the potential uses of the water. Changes to pH may directly affect the physiological functioning of aquatic biota, including enzyme functioning and membrane processes. Low pH has been reported to have adverse effects on fish and aquatic macroinvertebrates, including physiological functioning, spawning failure and diminished egg hatching. Changes to pH also have indirect impacts. For example, increased pH raises toxicity of ammonia, while decreased pH can increase the toxicity of some metals. Low pH levels can also increase the solubility of toxic metals that would otherwise be bound to sediments.

How is it measured?

The best way to measure pH for water quality monitoring is *in situ*, with a pH probe and meter. In situ measurement is preferred over laboratory measurement, as the pH of a water sample can change once removed from the waterway.

A probe with a meter is preferred over pH paper (pH strips), as the probe and meter provide greater accuracy. However, in the absence of a pH probe and meter, use of pH paper is better than no measurement.

Influences on pH

The pH of a water body is naturally influenced by geology, soils, salinity, algal and other plant photosynthesis and respiration, and rainfall (Figure 4.5, p.31).

The geology of the catchment can influence pH through the bedrock (Figure 4.6, p.33). For example, granitice rocks typically contribute to a lowering of groundwater pH, whereas basaltic rocks and rocks with carbonates tend to increase pH. Soil characteristics also influence pH, with soils high in organic acids typically reducing the groundwater pH and soils high in salts typically increasing the pH of groundwater.

The photosynthesis and respiration of algae and other plants within a water body can have a marked effect on pH, through altering the concentration of dissolved carbon dioxide (CO_2) in the water (Figure 4.6, p.33). Dissolved CO_2 forms a weak acid (carbonic acid). During daylight, photosynthesis results in the uptake of CO_2, thereby reducing the concentration of CO_2 in the water body and in turn reducing the acidity (therefore increasing pH). In contrast, during the night (when respiration is the dominant process), dissolved CO_2 concentrations can increase markedly thereby creating more acidic conditions (low pH). In water bodies where there is high algal biomass, these diurnal (day-night) fluctuations can be clearly identified and are usually accompanied by significant diurnal fluctuations in dissolved oxygen.

Similarly, rain typically dissolves some atmospheric CO_2 as it falls and consequently, rainfall often contributes to a minor reduction in the pH of water bodies. However, this reduction may be overridden by inputs of dissolved salts washed in from the catchment, which typically raises pH.

Human-induced changes to pH in water bodies can include agricultural land practices (leading to soil acidification), waste discharges, and air pollution (Figure 4.6, p.33). Soil acidification typically occurs through leaching from the upper soil horizons, leaving an excess of H^+ ions. Water flowing through the acidic soils enters the receiving water body with low pH.

Agricultural practices can also lead to increased nutrients, which increases algal growth and consequently leads to the greater diurnal fluctuation of pH as described previously.

Changes to the hydrology of rivers and wetlands can also lead to acidification. Sulphides naturally form in anaerobic (oxygen free) river and wetland sediments where sulphates from groundwater or seawater accumulate and where iron oxides and organic matter levels are high. Bacteria are responsible for the conversion of sulphate to sulphide in anaerobic conditions. Left covered with water, these sediments are stable and the sulphides remain bound in the sediments. However, if the water level drops due to drought or drainage, the sediments become exposed to oxygen and sulphuric acid is formed. When the sediment is re-wetted, acid can be mobilised from the sediments.

Discharges from factories, mine sites and other industrial locations can often contain liquids with high or low pH. Urban and industrial land uses should be investigated as potential causes to rapid or large changes to pH and for anomalous sites within a region.

Emissions from car exhausts and coal-burning power plants increase the concentrations of nitrogen oxides (NO_2, NO_3) and sulphur dioxide (SO_2) in the air. These pollutants can react in the atmosphere to form nitric acid (HNO_3) and sulphuric acid (H_2SO_4). These acids can affect the pH of streams by combining with moisture in the air and falling to the earth as acid rain.

Courtesy of Goulburn Broken Waterwatch.

Natural variation

Most natural freshwaters within Victoria have a pH in the range 6.5 to 8.0. The more saline areas in western and north-western Victoria generally have higher pH. This is reflected in the SEPP(WoV) objectives for the State, which are:

- 6.4 (25th percentile) to 7.7 (75th percentile) for the eastern half of state (SEPP obj) plus the Grampians and Otways Ranges; and
- 6.5 (25th percentile) to 8.3 (75th percentile) for the western half of state.

At pH levels less than 6 and greater than 9 harmful effects may occur. At pH levels less than 5 and greater than 10 harmful effects are almost certain.

4.5 Turbidity

What is it?

Turbidity is a measure of the clarity of water. As suspended particulate matter including clay, silt, detritus and plankton in the water increases, the clarity decreases and the water takes on a muddy appearance. Turbidity does not measure the quantity of suspended matter in the water. This is measured as suspended particulate matter (SPM), also called suspended solids (SS). While turbidity is not a direct measure SPM, they are highly correlated and turbidity can be used to indicate the likely effects of suspended matter.

Why monitor Turbidity?

Turbidity reduces the amount of light entering the water, which will reduce the growth of submerged aquatic plants including most phytoplankton. Cyanobacteria ('blue-green algae'), however, may be favoured as they can float to the surface to find light, ultimately covering the surface with a thick layer of cells reducing light almost completely. Lack of light also makes it difficult for predators like fish and birds to hunt successfully.

Turbid waters absorb more heat. Increasing water temperatures may affect plant growth, the behaviour and breeding of animals and if extreme levels are reached, kill biota.

Although not a direct measure of SPM, turbidity is indicative of SPM levels. High SPM levels interfere with the uptake of oxygen by fish and invertebrates and when particulate matter settles, causes sedimentation.

The greatest impact of sediment entering waterways is on habitat. Sediment will smother rocky bottoms, coat snags and fill deep pools, reducing the available habitat and affect the feeding and breeding of fish and aquatic invertebrates.

Nutrient and toxicants can bind to suspended particles. SPM is therefore important in the transport and fate of nutrients and toxicants in rivers.

How is it measured?

There are several ways turbidity can be measured but all relate to nephelometry, which is a measurement of the size and concentration of particles in water by analysis of light scattered by the water. The greater the scattering of light by suspended particles the greater the turbidity. The measurement unit for turbidity is the nephelomeric turbidity unit (NTU).

Correlations between turbidity and SPM are difficult because differences in size, shape and composition of the suspended particles will affect reflective and absorbance characteristics and hence the scattering of light. Therefore, SPM and turbidity measures within a single site may show a reasonable correlation (as long as the sediment sources are consistent) but this correlation is unlikely to be transferrable to other sites.

Turbidity should be measured as soon as a sample is taken, as suspended matter may stick to the walls of the container or bind together through physical and chemical processes (e.g. temperature).

Turbidity tubes measure the absorbance of light rather than the scattering of light. While they will at times overestimate or underestimate turbidity and do not measure very low levels accurately, they are generally a good estimate of the true turbidity.

The Secchi disk has been used extensively in the past to measure water clarity, particularly in deep water environments such as lakes. Secchi disks are not recommended for monitoring turbidity as there are no related water quality guidelines.

Sources of turbidity

Most of the sediment in rivers and streams comes from catchment and stream bank erosion (Figure 4.6, p.33). Sediment entering waterways is a natural process but human land use can result in excessive quantities entering waterways. Agriculture, forestry and housing developments can all lead to extensive soil disturbance, erosion and sediment runoff to rivers and streams. Unsealed roads can also contribute substantial quantities of sediment to waterways. Carp, an introduced pest fish species, can increase the mobilisation of sediment due to its habit of digging in stream sediments and dislodging macrophytes, resulting in unstable stream beds.

Other sources of sediment include sewage effluent discharges, industrial discharges, septic tank discharges and destabilisation of bed and banks after the removal of snags and macrophytes.

Natural variation

Levels of turbidity in water will vary depending on the physical and chemical activities in the river. Typically, turbidity levels increase from headwaters to lowlands (Figure 3.9, p.17). The old geology and associated high levels of clays result in naturally higher levels of turbidity in our rivers and streams compared to those overseas. Extensive clearing has made Australian soils more prone to erosion, increasing sediment loads and turbidity.

Turbidity levels vary over time. High flows (whether seasonal or episodic) are typically associated with increased inputs of sediment. If storms follow bushfires, even higher sediment loads can be expected. SEPP (WoV) objectives for turbidity and typical levels in healthy and disturbed catchments are detailed in Table 4.2.

Courtesy of Goulburn Broken Waterwatch.

Table 4.2 SEPP (WoV) objectives - typical levels in healthy waterbodies and levels that may result in ecosystem damage.

Segment/region	SEPP (WoV) objective (75th percentiles) (NTU)	Typical range in healthy waterbodies (NTU)	Level which may cause ecosystem damage (NTU)
Highlands (including the alps)	≤ 5	≤ 5 – 10	≥ 20
Forests	≤ 5	≤ 5 – 10	≥ 25
Cleared hills	≤ 10	≤ 10 – 20	≥ 100
Coastal plains	≤ 10	≤ 10 – 20	≥ 100
Murray plains	≤ 30	≤ 30 – 100	≥ 200
Western Victoria	≤ 10	≤ 10 – 20	≥ 100
South western Victoria	≤ 10	≤ 10 – 20	≥ 100

4.6 Dissolved oxygen

What is it?

Dissolved oxygen (DO) is a measure of the concentration of oxygen dissolved in water.

Why monitor dissolved oxygen?

Oxygen is essential for respiration by all aquatic plants and animals. Without it they will die. Oxygen in water comes primarily from the atmosphere. Diffusion across the water-air interface transfers oxygen to the water and this is substantially increased by turbulent mixing of water with air. In a standing water body the transfer process is slow, whereas in a fast flowing, turbulent upland stream, oxygen uptake is considerably higher. Oxygen in water can also come from plants as it is produced during photosynthesis. The contribution of plants and in particular algae, is generally relatively small in a healthy river but may be substantial in highly eutrophic (nutrient enriched) waterbodies where plant productivity is high.

Oxygen is used by not only plants and animals but also bacteria and other micro-organisms. The breakdown or decay of organic matter by micro-organisms is an important process in the carbon and nutrient cycles of a river. As the amount of organic matter increases the amount of oxygen used also increases. This is called oxygen demand. If the demand exceeds the ability of the system to take up oxygen then levels may fall dramatically.

Organic matter often builds up on the bottom of a river where much of the breakdown by micro-organisms occurs, thereby consuming available oxygen. If oxygen levels at the sediment-water interface become low enough, this could result in the sediments releasing molecules that are bound to the individual sediment particles. Nutrients and toxicants are among the molecules that the sediment particles could release, potentially creating high nutrient or toxic conditions in the stream.

How is it measured?

There are two common methods of measuring oxygen in waters; the Winkler or iodometric method and electrometric methods.

The Winkler method is a titrimetric procedure based on the oxidising properties of oxygen. The Winkler method is the most accurate way of measuring oxygen concentrations in water, however, the water must be tested immediately after a sample has been taken as water can lose or gain oxygen very quickly due to mixing or a change in temperature. Adding a preservative can extend analysis by up to eight hours.

Electrometric methods use the principle that oxygen will generate a current on metal electrodes and this current is proportional to the concentration of molecular oxygen. The current is converted to oxygen concentration, usually in mg/L, and most meters can calculate percent saturation. Calibration of the meter is critical and correction for temperature and high salinity is essential. While not as accurate as the Winkler method, portable meters have the advantage of undertaking instantaneous readings, depth readings and can be deployed for continuous monitoring.

Dissolved oxygen can be expressed as either a concentration, usually milligrams of O_2 per litre of water (mg/L), or as percent saturation. At a given water temperature, salinity level, air pressure (altitude), and with sufficient mixing, oxygen will reach an equilibrium in water. That is, a stable concentration where oxygen entering and leaving the water is equal. This is called saturation and the water is said to contain 100% of the oxygen it should be able to hold.

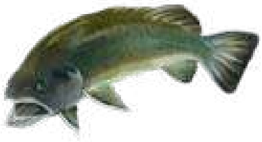
Because of the temporal and spatial variability, single measurements may not provide the complete picture of the oxygen regime. Monthly sampling and an assessment against the SEPP (WoV) objective will provide a good assessment of condition. If the objective is not met then an investigation of spatial and temporal differences is needed to gain a better understanding. A more complete picture of the oxygen regime can be acquired through continuous diurnal monitoring, particularly during likely critical periods, such as during low flow. In deeper rivers and in pools depth profiles can be undertaken.

Sources of oxygen demand

Major sources of oxygen demanding substances include:

- Sewage effluent discharges
- Industrial discharges
- Septics tank discharges
- Leaf litter from the floodplain, river banks and dry waterways
- Instream plant material (Macrophytes and algae)
- Blackwater events – low oxygen, organically rich waters entering a river from floodplain wetlands, backwaters and tributaries.

Where low oxygen concentrations are believed to be due to oxygen demand, the biochemical oxygen demand (BOD) or chemical oxygen demand (COD) of the river can be investigated. However, these measures have been developed primarily for sewage and industrial wastes which quickly use up oxygen in waters. Therefore, they may not be useful for assessing the demand from natural organic matter such as terrestrial leaves or aquatic plant material which break down much more slowly.



Natural variation

Concentrations of oxygen in water will vary depending on the physical, chemical and biochemical activities in the river. Under most natural conditions a water body will be at least 80% of saturation. Oxygen concentrations will vary over a 24 hour (diurnal) cycle, even in pristine waterbodies. Plant respiration at night will reduce oxygen levels over night while during the day, photosynthesis will produce oxygen and raise oxygen levels (Figures 4.5 and 4.6). In eutrophic conditions where there are blooms of algae or other aquatic plants, there are more plant cells respiring (which consumes oxygen), creating very low oxygen concentrations overnight. Conversely, the high number of plant cells photosynthesising during daylight hours can result in very high dissolved oxygen concentrations (called 'supersaturation'). Dissolved oxygen levels above 110% saturation are indicative of eutrophic conditions and levels of 130% or more are almost certainly due to blooms of algae or other aquatic plants.

Oxygen demanding substances will reduce oxygen levels, sometimes to very low levels. Often the demand originates from the sediments, where large quantities of organic matter accumulate and bacterial activity removes much of the oxygen from the bottom waters (Figure 4.6). If the demand is substantial then the de-oxygenation may reach the surface.

The process of de-oxygenation is a natural part of most lowland rivers and billabongs where organic matter accumulates after runoff. However, in these healthy waterbodies the period of low oxygen will be relatively short as the river quickly processes the organic matter. The biota are likely to be tolerant of these short periods of low oxygen. For example, most native fish in lowland rivers can tolerate levels down to 50% saturation (or around 5mg/L) for extended periods of time and short term levels even lower. However, complete de-oxygenation will kill most lowland aquatic organisms. Very low oxygen levels may also cause the formation of hydrogen sulphide (H2S), which is highly toxic to most native fish species.

Oxygen demanding substances can also originate from human sources such as ongoing discharges of sewage and industrial effluent, which may result in long periods of moderate to low oxygen levels, particularly during low flow periods in rivers and streams. Raw sewage and chemical spills can result in massive oxygen demand, although usually only for short periods of time.

In standing water bodies, primarily lakes but also large pools in rivers, stratification can occur where the bottom waters are cut off from the surface. This occurs due to either the warming of a surface layer of water or a saline intrusion into the bottom waters. The result is that the bottom waters are cut-off from oxygen from the surface. If there is an oxygen demand from the sediments then oxygen concentrations will decrease (Figure 4.5). If prolonged, conditions may become almost anoxic and will not support aquatic plants or animals. In addition, when the bottom waters turn over and mix with the surface, oxygen levels in the surface may also drop substantially.

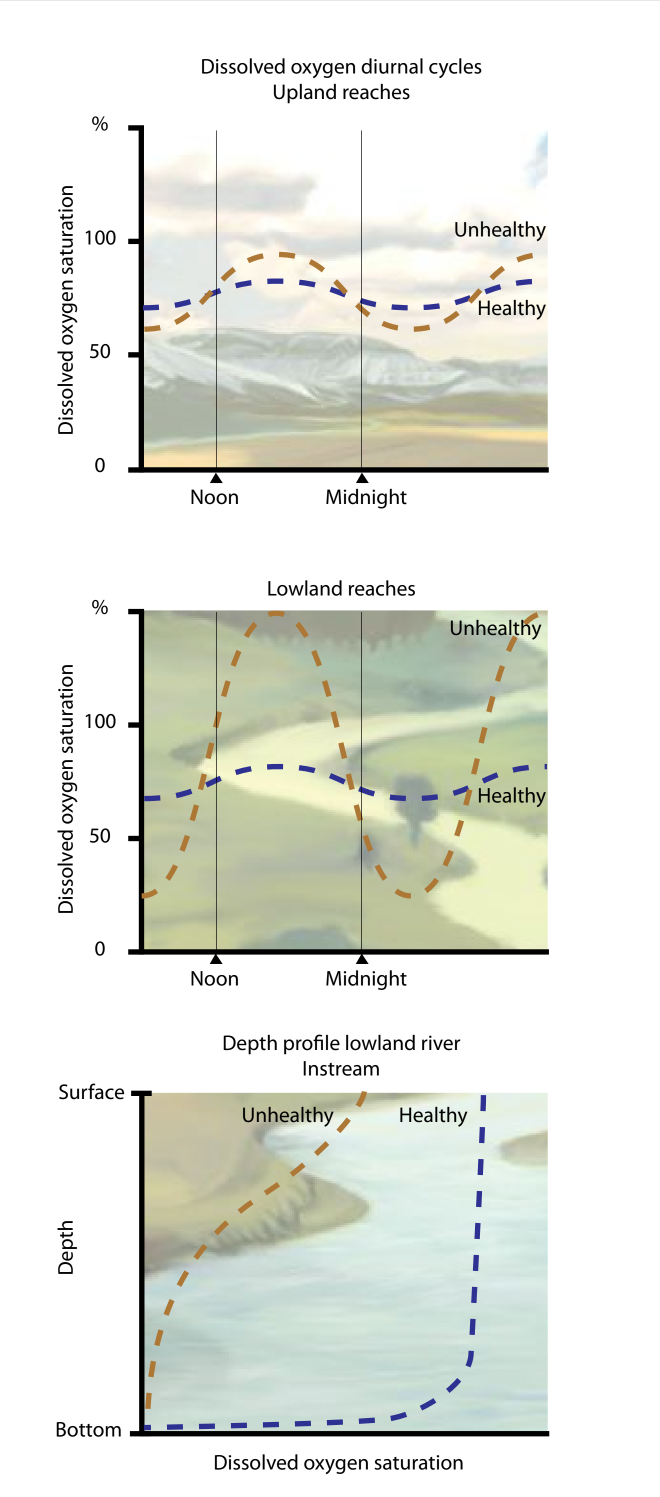


Figure 4.5 Dissolved oxygen diurnal cycles and depth profiles.

Oxygen in excess of 100% saturation is called supersaturation. As with low oxygen saturation, supersaturation may be harmful to aquatic life. For example, fish may suffer 'gas bubble disease' where bubbles of oxygen can form in the blood. Mountain streams and waterfalls may naturally have oxygen levels above 100% saturation, but generally not above 110% saturation.

Most aquatic species will tolerate some variation in dissolved oxygen, particularly lowland species where variation is greatest. More is known about fish species tolerances than invertebrates and very little known about plant species tolerances. SEPP (WoV) objectives for dissolved oxygen (Table 4.3) reflect not only regional differences but also the health of aquatic biota.

Table 4.3 SEPP (WoV) objectives - typical levels in healthy waterbodies and levels that may result in ecosystem damage.

Segment/region	SEPP (WoV) objective (% saturation*)	Typical range in healthy waterbodies (% saturation**)	Level which may cause ecosystem damage (% saturation**)
Highlands (including the alps)	≥ 95 ≤ 110	80 – 110	≤ 60
Forests	≥ 90 ≤ 110	70 – 110	≤ 60
Cleared hills	≥ 85 ≤ 110	60 – 110	≤ 60
Coastal plains	≥ 85 ≤ 110	60 – 110	≤ 50
Murray plains	≥ 85 ≤ 110	50 – 110	≤ 40
Western Victoria	≥ 80 ≤ 110	50 – 110	≤ 40
South western Victoria	≥ 85 ≤ 110	60 – 110	≤ 40

* SEPP WoV Objective is both a 25th percentile of annual data and a maximum level, that is from any reading
** From any single reading

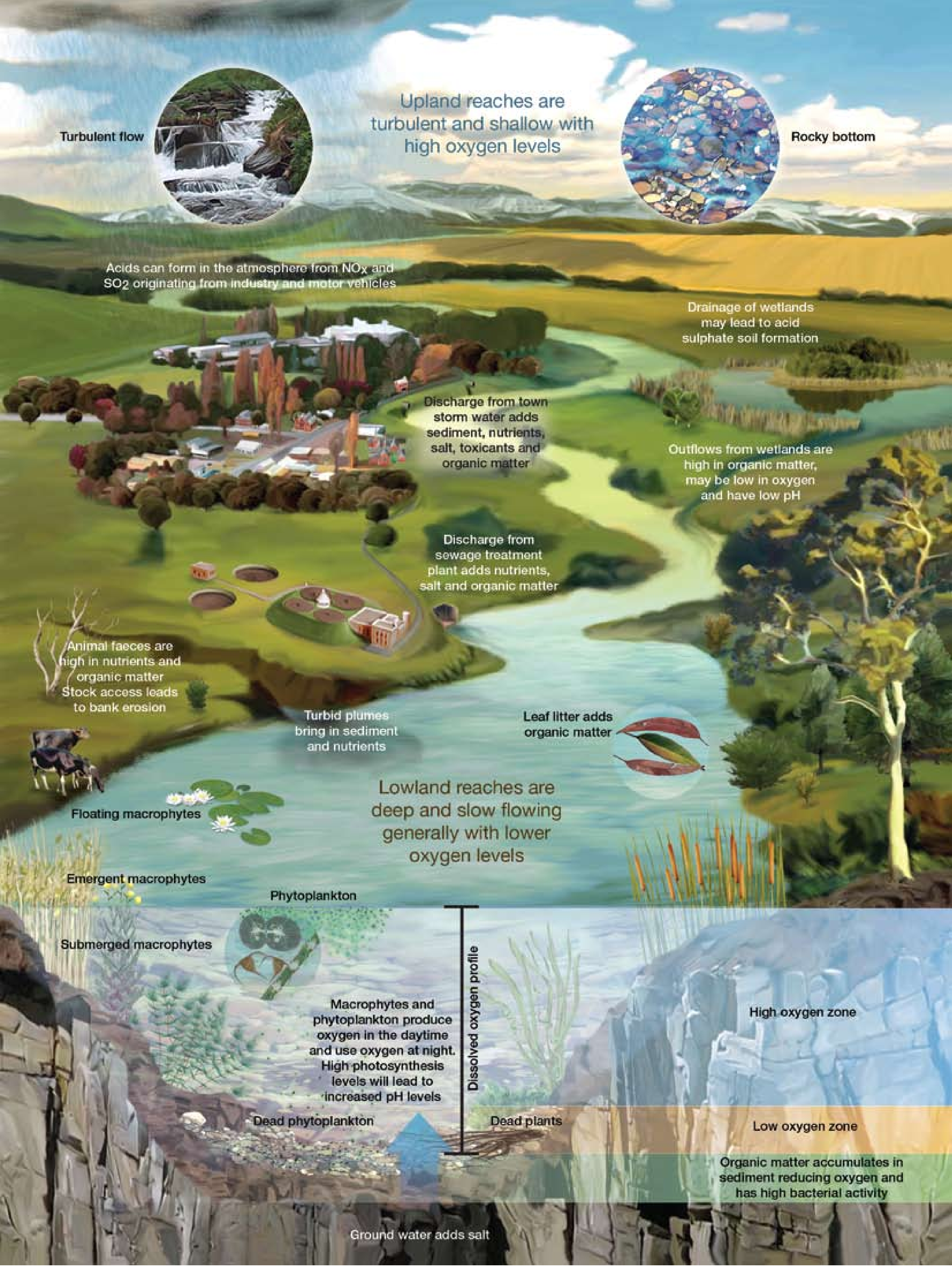


Figure 4.6 Salinity, pH, turbidity and dissolved oxygen conceptual model.

4.7 Temperature

What is it?

Temperature is a measure of the amount of heat in the water, that is, how hot or cold a river is. It is measured as degrees Celsius, (°C).

Why measure it?

The temperature of water influences and regulates many chemical, physical and biological processes. When water temperatures are very low (less than 4ºC) many biological processes slow down, for example, bacterial breakdown of organic matter. As water warms up processes generally speed up, including the metabolic rates of plants and animals. However, at very high temperatures metabolic rate drops off and at extreme levels plants and animals may die. Plants and animals usually have a temperature range that they best grow, feed and reproduce in. When temperatures move outside the range of one species it is likely to be replaced by a species that can tolerate the new temperature range. Climate change is likely to increase water temperature causing many species which cannot tolerate the higher temperature to be removed from an ecosystem. Importantly, temperature regulates oxygen solubility in water and as temperature increases solubility decreases (section 4.6).

How is it measured?

Temperature is measured with either a glass thermometer or a thermistor (digital thermometer).

Sources

Water absorbs heat from the air, from sunlight falling directly on the water or from the surface or groundwater water inflows. Water may also heat up as a result of bacterial breakdown of organic matter, although usually by only a very small amount.

The greatest human induced changes arise from hot water discharges from industrial and power generation and cold water discharges from the bottom waters (hypolimnion) of large dams. The removal of shading and increased turbidity arising from human activities will also increase water temperatures due to the increased heat absorption by the water.

Natural variation

While water temperatures can vary from 0ºC to 100ºC (frozen to boiling) in rivers and streams, temperatures are more likely to be between 2ºC and 35ºC. Alpine streams will be at the low end of this scale whereas small pools in ephemeral streams will be at the top end of the scale and may even exceed 35ºC. Temperatures will vary during the day and by seasons, just as air temperatures vary. The clarity and colour of water will affect temperature as darker, more turbulent waters adsorb more sunlight and therefore heat up more. Due to the substantial temporal and spatial variation in water temperatures there are no specific objectives or guidelines. In general, substantial deviations from background levels due to hot or cold water discharges are likely to affect the behaviour or survival of native biota. Smaller deviations due to atmospheric warming, decreased flow or increased turbidity are likely to result in the removal of temperature sensitive species and changes in the structure of the ecosystem.

Courtesy of West Gippsland Waterwatch.

4.8 *E. coli*

What is it?

Escherichia coli (E. coli) is one of a group of coliforms called faecal coliform bacteria which is natural bacteria found in the gut of warm blooded animals. There are both pathogenic and non-pathogenic strains of *E. coli*. A non-pathogenic strain of *E. coli* is used as an indicator of human and animal faecal contamination in waterbodies. The presence of faecal contamination is indicated by the number of *E. coli* cells (measured as colonies) per 100 mL.

Why measure it?

Faecal contamination of water bodies may lead to potential human health risks from disease-causing pathogens. Pathogens include bacteria such as *Vibrio cholerae* and *Salmonella*, viruses such as hepatitis A and parasites such as *Giardia* and *Cryptosporidium*. *E. coli* is an indicator of the potential presence of these and other human pathogens.

How is it measured?

E. coli has traditionally been used as an indicator to assess potential faecal contamination of waterways. It is not a measure of the abundance or even presence of human pathogens. Methods for determining *E. coli* counts require the plating and culturing of the bacteria. Sterile conditions are needed or contamination of the plates will occur. To measure, a water sample is applied to an *E. coli* specific nutrient rich agar gel in a petri dish which is then placed into an incubator for a period of time (usually more than 24 hours). After this time the colonies of bacteria are counted.

Sources

Potential sources of human faecal contamination include:

- Sewage overflows
- Poorly treated sewage
- Leaking sewerage systems
- Illegal sewerage connections to stormwater
- Septic tanks
- Untreated sullage or grey water discharges
- Runoff from contaminated areas

Natural variation

E. coli do not survive in water and will die off. Persistence will depend on factors including exposure to UV light, grazing by microorganisms, turbidity and water temperature. Unfortunately, the die off of *E. coli* is not related to the die off of human pathogens, which may live much longer than *E. coli*. In near pristine catchments, *E. coli* counts may be high due to runoff of native animal faecal material.

E. coli counts should be less than 200 cells per 100ml for primary contact such as swimming (SEPP (WoV)). In drinking water there should be no faecal contamination and *E. coli* should not be detected in a sample of drinking water (see the *Australian Drinking Water Guidelines* from the National Health and Medical Research Council, 2008).

Courtesy of Corangamite Waterwatch.

DRAWING CONCLUSIONS

Drawing conclusions can be difficult. Data can be highly variable and changes transient, making interpretation complicated or even not possible. The limitations of the data must be recognised and not exceeded. Nonetheless, developing suggestions that may explain patterns in the data or causes of change are important as these form the questions that will drive further investigation. The need for more data is usually identified and either collected over a greater period of time or at a greater number of sites. The assessment and interpretation of the data will help define how much more information is required, the key indicators and spatial and temporal needs. It is not scientifically correct to make assumptions or guesses and present these as support for the conclusions. The data must support your conclusions.

When reporting monitoring data it is important to answer the study aims and questions (see section 3.2). If the questions are clearly stated this process is straightforward. As stated previously, conceptual models may assist in not only the development of questions but in answering them as well.

Reports on catchment and pollution monitoring and catchment management strategies from Government agencies and universities are important sources of information that will assist in drawing conclusions. In addition, Government agencies and universities have experts that can provide advice on analysis and interpretation.

Courtesy of West Gippsland Waterwatch.

Courtesy of West Gippsland Waterwatch.

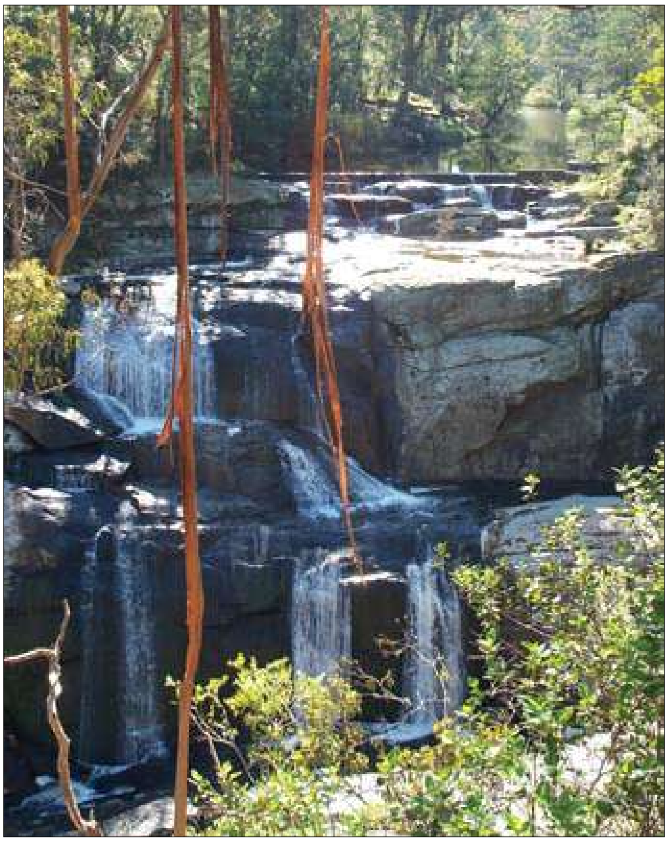
6 PRESENTING THE DATA

The two most important considerations when presenting data are to be confident that the presentation relates to the questions being addressed and to keep within the limitations of the data.

For example, if your question is "Has this site met SEPP (WoV) water quality objectives?" then you first need to have enough data to assess against SEPP (WoV) water quality objectives. Secondly, you should present the data in a table, possibly with values that trigger SEPP (WoV) highlighted, so the reader can see the results. You could also present results from previous years as a comparison. In this example it is not appropriate to use time series graphs to work out whether the site meets the objectives, as you can only determine approximate percentile values from a graph.

When an issue is identified, it is best to state the issue first then assess possible causes. For example, summary statistics indicate that total phosphorus exceeds the water quality objective and therefore a risk of excessive algal growth exists. Once stated, an investigation into the magnitude of the problem, the likelihood that a risk exists and potential sources can be undertaken.

An important point when presenting data is to keep it as simple as possible. Complicated graphs or tables may confuse readers, especially when too much data or information is included in one figure or table.



Courtesy of West Gippsland Waterwatch.

In general, three major forms of data presentation are most appropriate for the purposes of community monitoring. These are:

1. **Assessment against SEPP (WoV)** - a *table* of objectives and results for sites or catchments. The results of previous years can be added for comparison with results of the current year. For example, Table 3.1 in section 3.3.
2. **Temporal changes** - time series for looking at changes at a site over time and for identifying specific events such as drought and floods. Be wary of 'joining the dots.' By drawing a line between two data points an assumption may be made that the line represents what would have been measured between the points, whereas this is not necessarily the situation. 'Joining the dots' helps to see the trajectory and patterns in the data, however, if there are only a few data points, it may be misleading. For example, Figure 3.6 in section 3.3.
3. **Spatial changes** - column graphs for downstream changes. Conveying the spatial context can be assisted by mapping the sampling sites, data and sources or potential sources of contamination. Column graphs are a useful way to present spatial changes. For example, Figure 3.9 in section 3.3.

Avoid the use of statistical terms such as 'average', 'significant', or 'correlated' unless you have undertaken these analyses. For substitution of the above statistical terms, you can use non-statistical terms such as 'typical', 'marked', or 'indicative of a positive relationship' to indicate these sorts of relationships.

7 SOURCES OF DATA AND EXPERT ADVICE

The Department of Sustainability and Environment (DSE) manages the Victorian Water Quality Monitoring Network (VWQMN). Data stored on the Victorian Water Resources Data Warehouse can be accessed through: http://www.vicwaterdata.net/vicwaterdata/home.aspx

Within DSE, Waterwatch can provide water quality and biological interpretation and reporting advice. Contact Waterwatch coordinators via the Waterwatch Victoria website http://www.vic.waterwatch.org.au/

Also within DSE is the Freshwater Ecology Research group at the Arthur Rylah Institute (ARI), who can provide aquatic ecology advice, particularly on fish ecology. For information on current Freshwater Ecology projects at ARI and contact details visit http://www.dse.vic.gov.au/DSE/nrenari.nsf/fid/0D9706C5D8D06EFECA2574EB001D582D

The Environment Protection Authority (EPA), Victoria has an extensive database of water quality and biological information for Victorian rivers. The EPA also has a significant number of publications on regional water quality, assessment methods and guidelines. The EPA has experts in water quality and biology who can be contacted for advice. Contact the EPA by phone on (03) 9695 2722 or request information through the web at: https://epanote2.epa.vic.gov.au/4A2565E60021FA61/requestinfogeneral?openform

Catchment Management Authorities (CMAs) also have substantial data resources and water quality and environmental reports. Contact your local CMA.

North Central CMA	Phone (03) 5448 7124
Mallee CMA	Phone (03) 5051 4377
Wimmera CMA	Phone (03) 5384 1544
Port Phillip & Western Port CMA	Phone (03) 8781 7900
Corangamite CMA	Phone (03) 5232 9100
Glenelg Hopkins CMA	Phone (03) 5571 2526
West Gippsland CMA	Phone 1300 094 262
East Gippsland CMA	Phone (03) 5152 0600
North East CMA	Phone (02) 6043 7600
Goulburn Broken CMA	Phone (03) 5820 1100

Courtesy of West Gippsland Waterwatch.

Courtesy of West Gippsland Waterwatch.

8 FURTHER READING

Water sampling and quality assurance

Waterwatch Victoria Methods Manual http://www.vic.waterwatch.org.au/file/inform/Methods%20Manual%20June99.pdf

Waterwatch Victoria Equipment Manual http://www.vic.waterwatch.org.au/file/inform/Equipment%20Manual%20April%2099.pdf

Waterwatch Victoria Data Confidence Guidelines

http://www.vic.waterwatch.org.au/file/inform/dc_guidelines.pdf

Waterwatch Victoria annual QAQC program reports

http://www.vic.waterwatch.org.au/monitoring-&-data/204/

Contact the relevant Regional Waterwatch Coordinator for Regional Data Confidence Plans and Regional Methods Manuals

Water quality guidelines

ANZECC & ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council, Canberra.

Environment Protection Authority Victoria (2004). *Risk based assessment of ecosystem protection in ambient waters*. Publication no. 961. EPA Victoria, Melbourne.

Government of Victoria (2003). Variation to State Environment Protection Policy (Waters of Victoria). Victorian Government Printer, Australia.

Freshwater ecology and pollution impacts

Boulton A.J. and Brock M.A. (1999). *Australian freshwater ecology processes and management*. Gleneagles Publishing, Adelaide.

Hellawell, J.M. (1986). *Biological indicators of freshwater pollution and environmental management*. Elsevier Applied Science Publications, London.

Water chemistry

Manahan, S.E. (2004). *Environmental chemistry*. 8th Edition. CRC Press, Boca Raton, Florida USA.

Wetzel, R.G. (1983). *Limnology: Lake and river ecosystems*. Academic Press, London.

Macroinvertebrates

Environment Protection Authority Victoria (2003). *Rapid bioassessment methodology for rivers and streams*. Publication no. 604.1. EPA Victoria, Melbourne.

Human health including E. coli:

Government of Victoria (2003). Variation to State Environment Protection Policy (Waters of Victoria). Victorian Government Printer, Australia.

National Health and Medical Research Council (2004). Australian drinking water guidelines. NH&MRC, Canberra.

National Health and Medical Research Council (2008). *Australian Drinking Water Guidelines*, NH&MRC, Canberra.

9 GLOSSARY

Alkaline – pH greater than 7.

Alkalinity – the ability of water to resist change in pH.

Blackwater event – when low oxygen, organically rich waters enter a river from floodplain wetlands, backwaters or tributaries.

Biochemical oxygen demand (BOD) – The oxygen demand associated with the microbial decomposition of organic material.

Circum-neutral – when water has an approximately neutral pH i.e.7.

Condensed phosphates – complex, tightly-bound inorganic phosphate compounds. Sometimes referred to as 'polyphosphates'.

Dissolved oxygen –oxygen dissolved in water. Usually measured in milligrams per litre (mg/L) but can also be presented as percent saturation (%sat).

Eutrophication – the process in which a body of water becomes enriched in dissolved nutrients.

Nitrogen fixing – The process whereby bacteria turn atmospheric nitrogen into nitrogen compounds that can be taken up by plants.

Organic phosphorus – Phosphorus molecules associated with a carbon-based molecule, as in plant or animal tissue.

Orthophosphates – simple inorganic forms of phosphates that are the most readily available to plants.

Oxygen trough – when the consumption of dissolved oxygen by the aquatic biota exceeds the input of dissolved oxygen, leading to a lowering of oxygen concentrations.

Pass/ Fail objectives – objectives derived to assess whether a site meets a required standard.

Saturation – The point at which the amount of oxygen entering and leaving water is equal. The water contains 100% of the oxygen it should be able to hold.

Snapshot monitoring – taking one-off samples of a water quality parameter at many sites within a region to gain a 'snapshot' of river condition in the area.

Step-wise impact – An impact which occurs in discrete, punctuated steps rather than causing a steady gradual decline in condition.

Suspended particulate matter (SPM) – The quantity of matter, for example clay, silt, detritus and plankton, in the water.

Suspended solids (SS) - The quantity of matter, for example clay, silt, detritus and plankton in the water.

Trigger values – a value or objective that, when met, triggers or prompts further action.

Turbidity – visible pollution due to suspended material in water causing a reduction in the transmission of light.

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