4. Designing your study

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Introduction

Overview of this chapter

Chapter 4 assists you to develop a study design appropriate to your monitoring objectives and resources. Study design concepts include study type, as well as what, where, when and how often to monitor.

Specifically, this chapter provides technical information to assist you to:
- define the study type of your monitoring project according to your objectives
- choose indicators relevant to the issue(s) you are investigating
- define the spatial scope of your project and decide where to place monitoring sites
- record all necessary site details
- define the timescale of your project and decide when and how often to monitor to meet your objectives.

Why this chapter is important

Chapter 4 is important because it guides you through the planning stages of your monitoring project. Following the advice given in this chapter will increase your group's potential to meet your monitoring objectives. When designing your study, you must consider:
- your objectives
- your available resources (time, budget, knowledge and skills)
- natural variability of the environment.

Designing your study can sometimes be a difficult process; however, if it is done correctly the first time, only minor changes (if any) will need to be made in the future.

How to use this chapter

This chapter supports questions 5 to 8 in the development of a monitoring plan (see Table 4–1) and therefore assumes that the project objectives have already been defined. Use the information in this chapter to improve your planning and study design skills.

The chapter is separated into four sections:
- defining your study type
- what to monitor
- where to monitor
- when to monitor.

Each of these stages in designing your project involves several steps. For a summary of the steps involved in designing your study, refer to Figure 4–1.

Table 4–1 Steps in developing a monitoring plan

Key steps	Monitoring plan questions
Set monitoring objectives	Q1 Why are you monitoring? Q2 Who will use your data? Q3 How will the data be used? Q4 What data quality do you require?
Develop a study design	Q5 What is your study type? Q6 What will you monitor? Q7 Where will you monitor? Q8 When and how often will you monitor?
Choose monitoring methods and procedures	Q9 What methods will you use?
Plan data management, interpretation, reporting and communication	Q10 Who will be involved and how? Q11 How will the data be managed and reported? Q12 How will you ensure confidence in your data?

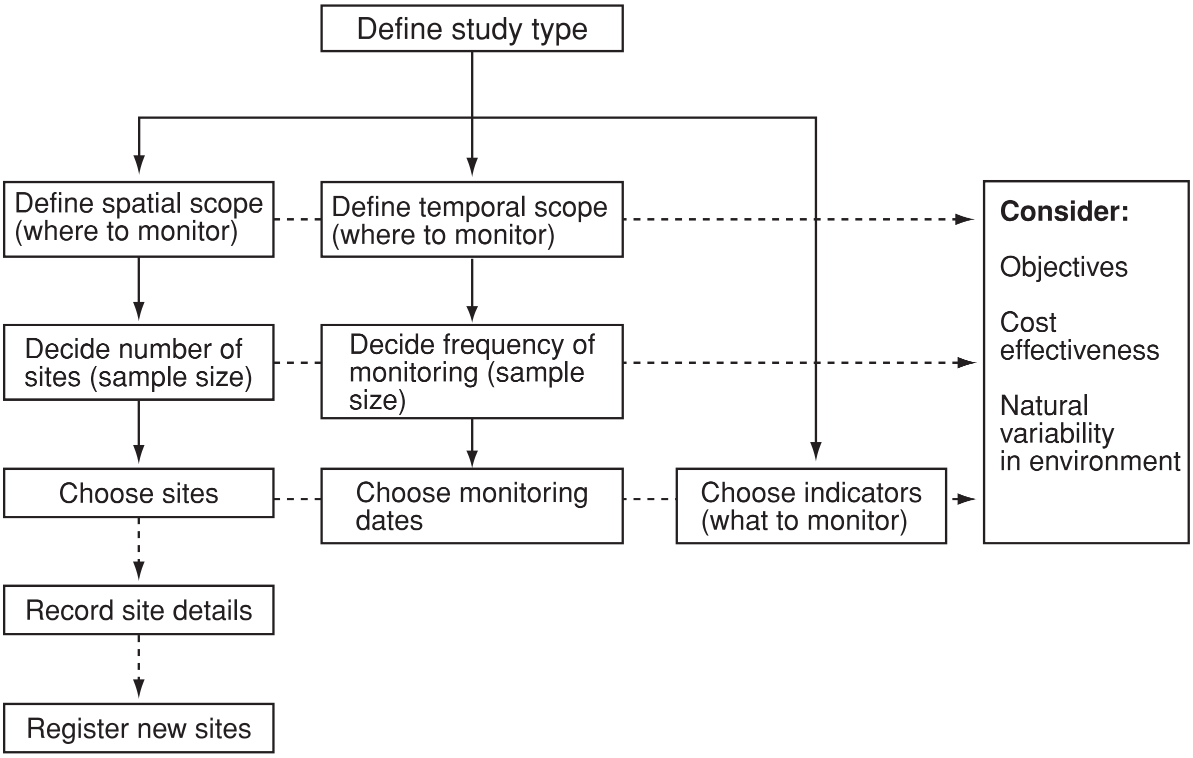

Figure 4–1 Framework for designing a monitoring study

Defining your study type

You need to define your study type in order to develop a study design relevant to your objectives. Each study type will have a different design, particularly in regards to where you place your sites and how often you monitor.

The seven main types of monitoring listed in this section have been devised to direct you to the appropriate advice on how to design your study. While not formal categories, these study types provide a solid framework on which to build your project.

You should select the study type that best relates to your reason(s) for monitoring (identified using Question 1 of the monitoring plan guide). Table 4–2 (overleaf) summarises which types suit different objectives. To use this table, identify your reason(s) for monitoring in the left column, then select from the related monitoring types in the right column. Identifying the correct study type for your project completes Question 8 of the monitoring plan guide. Further information about each study type is provided in the relevant section.

Table 4–2 Suggested study types for specific monitoring objectives

Monitoring objectives	Study type
• Increase community education and awareness • Increase community skills	All types of monitoring
• Assess current condition of waterway	Snapshot assessment
• Establish baseline values for the waterway • Monitor trends through time—both natural and human-driven variation over time • Detect any pollution events or pest species outbreaks • Develop local water quality guidelines • Monitor for compliance indicators	Baseline condition and trend (routine) monitoring
• Estimate sediment and nutrient inputs (loads) during high-flow events • Estimate pollutant inputs (loads) during high-flow events • To estimate pollutant concentrations and distribution during high flow events • Assess pesticide levels (loads) in run-off during high-flow events • Assess pollutant concentration or distribution for a given time period.	Load-based monitoring
• Assess impact of a land use or pollution source	Impact assessment
• Assess effectiveness of a management action	Restoration assessment
• Assess compliance with guidelines for a human use (e.g. animal watering, recreation or irrigation)	Compliance monitoring Note: Baseline condition and trend (routine) monitoring may contain a compliance element
• Investigate causes of a particular water quality or river health problem	Investigative studies

Snapshot assessment

A snapshot assessment is generally performed for educational purposes; however, this type of assessment can also be a useful first step for all monitoring activities. The function of a snapshot assessment is to gain an understanding of the condition of a waterway at a particular moment in time. This can be performed by sampling at one site or sampling at several sites across a catchment simultaneously to get a picture of the catchment. A snapshot assessment can be a tool to quantify waterway issues and processes and to identify major pollutant sources and catchment processes. Results from snapshot assessments can only be used for demonstrative or indicative purposes.

A snapshot survey of a catchment is normally carried out during **stable low-flow conditions** (base flow) to establish the general state of the waterway.

Data from a snapshot survey can be used to:

- identify biological communities at the site
- identify specific sources of pollutants
- estimate pollutant loads and quantify their importance
- design ongoing monitoring programs
- compliance test licensed dischargers—that is, check that they are only discharging what they are supposed to.

Snapshot assessments may also be used for reactive assessments to determine the cause of a sudden change in the system. For example, following a fish kill event, a snapshot assessment may be used to examine the water quality at and downstream from the kill site to identify what parameter may have been responsible.

Snapshot sampling should always be considered in studies of water quality relating to integrated catchment management (Grayson et al. 1997).

Baseline condition and trend (routine) monitoring

Baseline monitoring is typically used to perform descriptive studies—that is, studies that describe the condition of a waterway rather than assessing a particular attribute or impact. It can be used to:

- collect data to assess future trends
- explore natural variability within the waterway over space and time
- work out the best sampling schedules and site placements for future monitoring programs.

Baseline monitoring studies may include those simply assessing water quality as well as those assessing the overall river (ecosystem) health. This study type can also be used for exploratory surveys (initial studies to gain insight into how the waterway is functioning and what sort of condition it is in), reporting on the state of the environment, or assessing conformity with water quality guidelines.

Some long-term monitoring studies also aim to look at whether the condition of the waterway is improving as a result of management actions across the catchment, or declining over time. This study type, known as *trend monitoring*, may be descriptive or more statically orientated. In some cases, baseline monitoring can use statistical tests and analyses to assess whether a change has occurred. See Chapter 3 for further information on statistics.

Monitoring is often conducted to detect the effects of a particular input or disturbance. This involves identifying sites that will not be affected by a disturbance (*reference sites*) and comparing them to those that are affected by a disturbance over time (*test sites*). This technique can also be used to detect pollution events and the outbreak of pest species.

Baseline condition and trend (routine) monitoring can also be used to develop local water quality guidelines. Local guidelines for water quality differ from national, state or regional guidelines as they specifically address the ecological health of your catchment. A key reason for establishing local water quality guidelines is to determine if and how the catchment, waterway or stream section differs from the surrounding waterways, and if and how conditions vary within your area of interest. Individual waterways display natural variation in water quality and biological condition, and a single catchment may differ enough from the surrounding catchments or region to deserve individual guidelines. Similarly, the upland reaches of a waterway may differ enough from the lowland reaches that unique water quality guidelines should be developed for each of the upland and lowland sections. Individual guidelines can be developed for each significantly different zone. Local water quality guidelines incorporate the natural variability of the system (natural changes in water quality and ecosystem condition not influenced by humans) by setting guideline values that take into account this natural variability, whereas existing larger-scale guidelines may be too stringent or too lenient for any individual system.

Load-based monitoring

Load-based monitoring is done to assess the load (total quantity) of pollutants entering a waterway and compare levels between different flow conditions. This type of study can be conducted at any time, depending on your project objectives, and is often used to assess pollution inputs during high-flow events.

Load-based monitoring is usually conducted on an annual, seasonal or event-based scale.

Annual load-based monitoring assesses the total amount (the load) of a pollutant that passes through the system over the duration of a year, although a shorter time period such as a season may also be used. A range of flows including seasonal base-flow and no-flow conditions should be monitored to fully assess loads over time.

Event load-based monitoring is used to measure the amount of a pollutant (the load) that passes into or through the waterway during a flow event (a period of elevated flow levels in the waterway, such as a flood). The events monitored must be those caused by high rainfall, as opposed to releases from large dams. To accurately assess loads over an event, a range of flow conditions must be sampled, including base-flow conditions before and after the event. This allows the change in loads caused by the elevated flow levels to be accurately assessed, as the loads measured during elevated flow can be compared to load conditions before and after the elevated flow period.

Pollutants that most commonly enter waterways during high-flow events are nutrients, sediments and pesticides transported through overland flow from the surrounding catchment.

Load-based monitoring is also used to identify areas or land uses in the catchment that are contributing the largest inputs of pollutants. Furthermore, data generated from load-based monitoring can be used to compare actual loads with those predicted by catchment models such as SedNet and E2 (both available from <www. catchment.crc.org.au>) and EMSS (available from <www.healthywaterways.org>). These models allow the comparison and prioritisation of alternative management strategies that reduce the load of pollutants entering the waterway during storm events, and are therefore very useful tools for natural resource management.

These types of models estimate pollutant loads as:

Pollutant load = surface run-off × event mean concentration (EMC)

+ base flow × dry weather concentration (DWC)

The event mean concentration (EMC) is the flow-weighted average concentration of a load (pollutant) over the duration of an event (rise, plateau and fall). Flow-weighted means that the load measurement is related to the stream flow. The dry weather concentration (DWC) is the pollutant concentration measured during dry weather or base flow (normal, not during a flow event) conditions. The EMC and DWC values are dependent on land use, soil type, slope, climate, and management practices of the catchment, as these are the sources of loads entering the stream.

This formula calculates the total pollutant load over time by combining a measure of the load during flow events (surface run-off multiplied by the EMC) with a measure of the load duding normal conditions (base flow multiplied by the DWC).

Impact assessment

An impact assessment of *point-source pollutants* is performed to determine how a single source of pollution affects the condition of a waterway. Point sources of pollution can include stormwater drains, sewer outflow points, septic tank systems, factories, construction sites and livestock feedlots.

An assessment can be done either before or after the impact has occurred. In some cases, the impact may not have occurred yet but some form of impact is anticipated—for example, resulting from the construction of a dam or other development. Data collected before the impact can be compared with post-impact data to determine the severity and mechanism of the impact.

An impact assessment of *diffuse-source pollutants* is performed to determine how pollution from several sources affects the condition of a waterway. When a type of pollution enters the waterway from several points rather than from a single point, it is said to have a diffuse source. A range of catchment land uses upstream of a monitoring point may all be diffuse sources of pollution. Examples of diffuse sources include urban run-off, garden fertilisers, bacteria and micro-organisms from livestock, sediment from poorly managed construction sites, crop and forest lands and eroding stream banks.

This type of study is useful when you want to determine what impact a particular land use (or a variety of land uses) in a subcatchment has on the water downstream.

Restoration assessment

This study type is conducted to evaluate the effectiveness of a particular management action on the condition of a waterway. Management actions are activities that are undertaken to restore a waterway to its original (pre-European) state or at least improve some important aspects of the waterway environment. These actions could include restoring riparian vegetation, fencing off riparian areas from cattle access, stabilising stream banks or re-creating in-stream habitats (for example, re-snagging or re-creating rocky riffles).

It should be noted that although this study type is referred to as restoration assessment, it also includes rehabilitation and remediation assessments. Restoration of a waterway means that the entire stream environment has been restored to its original (pre-European) state. Since this is almost impossible (partly because we simply do not know what the pre-European conditions of our waterways were), normally the aim of this study type is to rehabilitate or remediate the waterway.

The effects of restoration (or rehabilitation or remediation) projects can be difficult to monitor, as gradual changes in ecosystem health following restoration work are often difficult to detect. Some actions, such as revegetation projects, are far simpler to assess than more indirect actions like flow regime restoration, given the current level of scientific understanding and the limits on project resources. In particular, it can be difficult to separate the effects of restoration projects from the natural variability of the system, and from ecosystem responses to climate change.

At present, this type of monitoring is commonly referred to as monitoring and evaluation (M&E). It is often required when developing funding applications to undertake restoration activities.

Compliance monitoring

This study type relates to monitoring conducted to determine whether a waterway or section of waterway complies with certain guidelines and is suitable for particular uses (for example, human uses such as drinking water and recreation, or agricultural uses such as irrigation and stock watering).

Investigative studies

This type of study relates to monitoring that is done to investigate an aspect of the freshwater environment to increase understanding of how the ecological system works. This type of study may aim to explore the relationship between certain measurable aspects of the waterway (variables) or establish a cause-and-effect relationship.

These studies are normally undertaken by research organisations such as universities rather than by community groups; however community groups may be able to assist with data collection. Investigative studies are aimed at finding out more about the complex relationships that exist in aquatic ecosystems.

What to monitor

An important step in developing any monitoring plan is to decide on the indicators or parameters that you will monitor. This step is Question 6 in the monitoring plan guide. A wide range of physico-chemical, biological, and stream condition and habitat measures can be used to provide an indication of waterway condition; however, there is no one single measurement that can completely define it (ANZECC & ARMCANZ 2000). The indicators you use must always be chosen within the context of your monitoring program. Consider what types of methods and levels of data quality you want to use before choosing your indicators.

Selection of indicators will be guided by the issues or problems you seek to address and your understanding of the factors that are important in influencing the waterway system, as identified in your conceptual model. Indicators must be selected only after your project objectives have been properly defined (see Chapter 2 for further details on conceptual models and setting monitoring objectives). For example, if the objective of your monitoring project is to increase public awareness of the effects of run-off on waterway health, then measuring macro-invertebrate diversity would be a suitable indicator because the effects of run-off pollutants on macro-invertebrate diversity are known and understood.

Sometimes indicators are monitored that are not directly related to the conceptual model or project objectives. This is particularly the case when considerable logistical effort is involved in taking such measurements—for example, due to a remote location—or during event monitoring. In such cases, these parameters should be identified as supplementary parameters and excluded from interpretation relating to your objectives. The value of supplementary data is that it often sheds light on other questions and issues that are beyond the scope of your current study. Independent indicators (not closely related) can be chosen to give you a broad coverage of issues when time and cost are limiting factors in your monitoring project. Alternatively, complementary indicators (closely related) may be chosen where necessary to fully explore your monitoring issue. For example, complementary indicators would be temperature and dissolved oxygen, as water temperature affects how much oxygen can dissolve. A change in one indicator would effect a corresponding change in the other.

The main categories of indicator are physico-chemical, biological, and stream condition and habitat (see chapters 5, 6 and 7 respectively for further details). Each of these categories provides effective alternative means of assessing the quality of water within a stream, river or catchment.

Physico-chemical indicators provide measurements of specific contaminants and parameters that may be the source of particular effects or modifiers of them.

Biological indicators are non-specific, responding to the sum of contaminants or conditions within a water body. They can provide a more complete measure of waterway health by indicating the combined effects of contaminants or conditions over time. Certain taxa can provide an early warning system for detecting minute levels of contamination as a result of their susceptibility to particular chemical contaminants. Likewise, certain taxa respond to changes in condition such as altered flow regime or reduction in stream habitat diversity.

Stream condition and habitat indicators can reveal the causes of findings from both physico-chemical and biological indicators, as well as underlying natural limits or drivers of biological or physico-chemical condition. Indicators such as the range of in-stream habitat may explain biological diversity findings where physico-chemical indicators may not.

Which indicator to measure is often determined by your conceptual understanding of the issues of concern. Every issue affects the condition of your waterway via a *pathway*, and the impact of that issue can be measured at different points in the pathway. For example, run-off from farmland often contains excess nutrients that enter the waterway. The waterway will respond to elevated nutrient levels by increasing plant biomass (amount) in the form of algal growth. A rapid increase in the biomass of algae at the site will lead to an increase in oxygen consumption, and this increase in consumption will lead to a crash in dissolved oxygen (DO) levels. A rapid decrease in DO leads to fish and macro-invertebrate kills. Thus, several different indicators can be used to monitor nutrient loads:

- total phosphates and nitrates—a physico-chemical measure of actual nitrate and phosphate levels in water samples. Nutrient levels can be compared to other samples from the subcatchment and to water quality standards
- algal counts—a biological measure of the extent of algal growth, usually conducted by measuring chlorophyll *a* levels in water samples. High algal biomass is indicative of elevated nutrient levels
- macro-invertebrate diversity—a biological measure of the number and types of macro-invertebrates present at the site. The absence of those taxa that are sensitive to low DO levels would show that DO levels have been low at the site.

Each indicator has its strengths and weaknesses, relating to the skill level required to sample it, the strength of relationship between the indicator and the issue it is measuring, the error range in measuring, and the time and money required to measure it. Always consider your data confidence requirements when selecting appropriate indicators. You should choose a combination of indicators to monitor based on your project objectives as well as factors such as costs, location and time.

This manual promotes the concept of integrated assessments to monitor the condition of a waterway. It includes guidelines that provide information on physico-chemical, biological and stream condition and habitat indicators to provide a better understanding of ecosystem condition and function. Some generic recommendations regarding which indicators are relevant to a range of common water quality and stream health issues are provided in Table 4–3. Use this table to assist in the selection of key indicators relevant to the issue that you are interested in.

The Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management publication, *Users' guide for estuarine, coastal and marine indicators for regional NRM monitoring* (Scheltinga et al. 2004), has been transformed into a fully searchable HTML help file system. This is available on the National Action Plan for Salinity and Water Quality's water quality website <www. wqonline.info> and may be useful in deciding what to monitor.

For some of the aquatic ecosystem issues in Table 4–3, it is recommended that indicators from two or three of the different categories be used. It can be important to trial multiple indicators to measure water quality and stream health. The choice of indicators should depend on the values assigned to the waterway, and the project objectives. All three indicator categories can provide important information as part of a combined assessment of environmental health. It is important to decide on whether you wish to measure causal factors, resultant factors or both. Causal factors are those factors that cause a change in condition while resultant factors are the system responses to the change in condition. For example, elevated nitrogen levels in the stream can cause algal blooms due to the excess nutrient in the system. In this case, the high nitrogen levels are the causal factor, and increased algal biomass is the resultant factor. To measure either or both types of factors will require you to use indicators from more than one category. For further information on the methods used to measure each water quality indicator, refer to chapters 5, 6 and 7 of the manual.

Once you have short-listed the indicators for monitoring, ANZECC and ARMCANZ (2000) recommend consideration of the following attributes to determine a definitive list:

- **relevance**—does the indicator reflect directly on the issue of concern?
- **validity**—does the indicator respond to changes in the environment and have some explanatory power?
- **diagnostic value**—is the indicator able to detect changes or trends in conditions for the specified monitoring period? Can the amount of change be assessed quantitatively or qualitatively?
- **responsiveness**—can the indicator detect changes early enough to permit a management response, and will it reflect changes due to the management response?
- **reliability**—is the indicator measurable in a reliable, reproducible and cost-effective way?
- **appropriateness**—is the measurement parameter appropriate for the time and spatial scales of the project?

Further guidance on selecting indicators around project objectives can be found in the case studies outlined in Chapter 11. One case study example used in this manual is the *Community water quality monitoring report for the Maroochy River, January 2003 to June 2004* (Fawns et al. 2004). For this particular project, the major water quality issues identified included urban stormwater run-off, unvegetated and eroding water courses, rural run-off from agriculture and grazing land, and water from sewage treatment plants. With these issues taken into consideration, a series of project objectives were established that involved increasing public involvement in and knowledge of water quality within the catchment. Valuable data was collected over time, which signalled a possible need for management intervention. In order to investigate the identified issues and address the established objectives, the selection of indicators from two categories was required. Level one physico-chemical testing was conducted, along with biological monitoring using macro-invertebrates as bio-indicators to discover the effects of the physico-chemical findings on stream health.

Other resources to support indicator selection include:

- the *Land manager's monitoring guide* indicators web page <www.nrw.qld.gov.au/monitoring_guide/indicators/index.html> (Department of Natural Resources and Water 2006b)
- Appendix 2 of 'Development of conceptual pressure-vector-response models for Queensland's riverine ecosystems' (Department of Natural Resources, Mines and Water 2006)
- the *Users' guide for estuarine, coastal and marine indicators for regional NRM monitoring*, downloadable from <www.coastal.crc.org.au/Publications/indicators.html> (Scheltinga et al. 2004)
- Table 6 of *Aquatic biodiversity assessment and mapping method (AquaBAMM): a conservation values assessment tool for wetlands with trial application in the Burnett, River catchment*, downloadable from <www.epa.qld.gov.au/nature_conservation/habitats/wetlands/wetland_assessment/aquatic_conservation_assessments_aquabamm> (Clayton et al. 2006).

Table 4–3 Guide to choosing indicators

Issue		Description	Potential key indicators to test or survey			Notes
			Physico-chemical	Biological	Stream condition and habitat	
General water quality and stream condition	No specific water quality or stream condition issue known as yet. No pollution sources yet identified. Basic information on water quality and stream condition required.		Flow Temperature Electrical conductivity pH Dissolved oxygen Turbidity/transparency Nutrients Suspended sediments	Macro-invertebrates Fish Other waterway fauna (e.g. turtles, waterbirds)	Stream habitat diversity Riparian zone disturbance Bank and bed stability	Monitoring undertaken to assess general condition of waterway
Specific water quality and stream condition problemsw	Algal blooms	Algal blooms occur during periods of low flow, warm temperatures and high nutrients. Can affect parameters such as dissolved oxygen, pH and transparency.	Dissolved oxygen Temperature pH Turbidity Nutrients	Algal counts		Monitoring undertaken to assess the risk of, or impacts of, algal blooms. Key periods are during summer months. Certain strains of blue-green algae may be toxic.
	Nuisance aquatic plant growth	Can alter flow, and increase nutrients and eutrophic conditions as they break down.	Dissolved oxygen Nutrients pH Flow Turbidity	Exotic macrophytes	Stream habitat diversity	Monitoring undertaken to assess the impacts associated with nuisance plant growth, identify weed species, and manage the risk of transporting weeds to unaffected areas.
	Stagnant (eutrophic) water	Eutrophic conditions are characterised by elevated nutrients and low oxygen levels. Often, water appears murky.	Temperature pH Dissolved oxygen Turbidity Nutrients Flow	Algal counts		Monitoring undertaken to determine the risks associated with stagnant water. High algae levels can contribute to eutrophication through decomposition.
	Fish kills	Caused by a range of pressures including biological and chemical impacts, such as blackwater, eutrophic conditions and chemical pollution.	Temperature pH Dissolved oxygen Turbidity Nutrients Pesticides Flow			Monitoring undertaken to determine the potential causes of fish kills.

Table 4–3 Guide to choosing indicators (cont.)

Issue		Description	Potential key indicators to test or survey			Notes
			Physico-chemical	Biological	Stream condition and habitat	
Specific water quality and stream condition problems (continued)	Altered flows	Can be caused by a range of activities including extraction and irrigation, vegetation clearing and interference to channel and bed. Also caused by structures such as dams and weirs.	Flow Temperature Conductivity pH Dissolved oxygen Turbidity Nutrients Suspended sediments	Macro-invertebrates Fish Other waterway fauna	Stream habitat diversity Riparian zone disturbance (particularly native vegetation regeneration)	This issue may impact on all aspects of water quality, biological function (such as fish spawning) and stream health.
	Animal pest species	Various pests have differing impacts. Fish may impact on water quality and habitat. Other pests may alter habitat or native species composition.	Dissolved oxygen Turbidity Nutrients Suspended sediments	Macro-invertebrates Fish	Stream habitat diversity	Check specific impacts associated with particular species of interest. For example, carp increase turbidity levels and reduce macrophyte abundance.
	Riparian weeds	Can alter flow, water quality, biology and habitat.	Flow Temperature Dissolved oxygen Turbidity Nutrients	Macro-invertebrates Fish	Stream habitat diversity Riparian zone disturbance	The leaves of some introduced plants, like the camphor laurel, can be toxic to native fauna. Check specific impacts associated with particular species of interest.
	Erosion and bank stability	Contributes sediments, chemicals and pathogens, and alters habitat.	Flow Conductivity Dissolved oxygen Turbidity Nutrients Suspended sediments		Stream habitat diversity Riparian zone disturbance Bank and bed stability	Monitoring to determine causes and direct impacts of issue. May also reduce abundance or diversity of waterway fauna.

Table 4–3 Guide to choosing indicators (cont.)

Issue		Description	Potential key indicators to test or survey			Notes
			Physico-chemical	Biological	Stream condition and habitat	
Specific water quality and stream condition problems (continued)	Pollution (slicks and scums)	Includes biological and chemical pollution. Can affect water quality, biology and habitat.	Temperature pH Dissolved oxygen Nutrients Pesticides/herbicides Other industrial chemicals	Macro-invertebrates Fish Other waterway fauna		Monitoring to determine the cause and impacts of pollution events. Exercise caution when dealing with pollution events. Laboratory testing of pollutant samples is recommended.
	Murky (turbid) water	Result of sediments, biological impacts or chemical pollution.	pH Dissolved oxygen Turbidity Nutrients Total suspended sediments		Bank and bed stability	Monitoring to determine causes and direct impacts of issue. May also reduce abundance or diversity of waterway fauna. Monitoring should be conducted during base-flow and high-flow events.
	Blackwater	Caused by tannins entering the water in billabongs and wallum swamps.	Temperature pH Dissolved oxygen Nutrients			
	Degraded riparian zone	Removal of riparian vegetation, introduction of non-native plants, changes to structure of riparian vegetation.	Flow Temperature Conductivity pH Dissolved oxygen Turbidity Nutrients Suspended sediments		Stream habitat diversity Riparian zone disturbance Bank and bed stability	May contribute to a wide range of quality, biological and habitat impact issues.

Table 4–3 Guide to choosing indicators (cont.)

Issue		Description	Potential key indicators to test or survey			Notes
			Physico-chemical	**Biological**	**Stream condition and habitat**	
Catchment land uses and pollution sources	Aquaculture	Farming of aquatic fauna or flora under controlled or semi-controlled conditions. Examples are oysters, crocodiles and prawns.	Dissolved oxygen Salinity pH Phosphates Nitrates Temperature	Macro-invertebrates Fish Other waterway fauna Exotic fauna Algal counts		Impacts can differ between ponded and in-channel aquaculture. Can also lead to introduction of antibiotics and diseases into waterways.
	Dairy farming	Can be both an intensive animal production system and an intensive grazing system. Common along the coast or in the hinterlands where rainfall is high.	Dissolved oxygen Salinity pH Phosphates Nitrates Turbidity Faecal coliforms	Macro-invertebrates Fish Other waterway fauna Exotic fauna Algal counts	Stream habitat diversity Riparian zone disturbance Bank and bed stability	
	Extensive grazing	Occurs on larger properties where pastures are generally unimproved (mainly beef cattle grazing).	Phosphate Nitrates Salinity Turbidity Faecal coliforms	Macro-invertebrates Fish Other waterway fauna	Stream habitat diversity Riparian zone disturbance Bank and bed stability	
	Farm forestry	The establishment or management of any forest type on a farm in combination with other farming activities.	Dissolved oxygen pH Nitrates Phosphates Temperature Salinity Pesticides/herbicides	Macro-invertebrates Fish Other waterway fauna Exotic fauna	Stream habitat diversity Riparian zone disturbance Bank and bed stability	
	Field cropping	Dryland and irrigated production of crops (e.g. barley, chickpeas and cotton).	Dissolved oxygen pH Phosphates Nitrates Salinity Pesticides/herbicides Total suspended sediments	Macro-invertebrates Fish Other waterway fauna Exotic fauna	Stream habitat diversity Riparian zone disturbance Bank and bed stability	

Table 4–3 Guide to choosing indicators (cont.)

Issue		Description	Potential key indicators to test or survey			Notes
			Physico-chemical	Biological	Stream condition and habitat	
Catchment land uses and pollution sources (continued)	Horticulture	Cultivation of flowers, fruits, nuts, vegetables, etc.	Flow Dissolved oxygen Phosphate Nitrates Salinity Temperature Pesticides/herbicides Total suspended sediments	Macro-invertebrates Fish Other waterway fauna Micro-algae	Stream habitat diversity Riparian zone disturbance Bank and bed stability	
	Intensive animal production	Includes cattle feedlots, piggeries and poultry farming.	Dissolved oxygen Salinity pH Phosphates Nitrates Pesticides Total suspended sediments Faecal coliforms	Macro-invertebrates Fish Other waterway fauna	Stream habitat diversity Riparian zone disturbance	
	Intensive grazing	Smaller properties where pastures are generally improved (e.g. grazing of beef cattle or goats).	Dissolved oxygen Temperature Salinity Phosphates Nitrates Total suspended sediments Faecal coliforms	Macro-invertebrates Fish Other waterway fauna Micro-algae	Stream habitat diversity Riparian zone disturbance Bank and bed stability	
	Plantation forestry	Cultivation of tree species for the commercial production of timber and fibre products to support high-volume uses.	Salinity Nitrates Phosphate Dissolved oxygen Temperature Pesticides/herbicides Total suspended sediments	Macro-invertebrates Fish Micro-algae Other waterway fauna Macrophytes	Stream habitat diversity Riparian zone disturbance Bank and bed stability	

Table 4–3 Guide to choosing indicators (cont.)

Issue		Description	Potential key indicators to test or survey			Notes
			Physico-chemical	**Biological**	**Stream condition and habitat**	
Assessing and evaluating management actions	Riparian fencing and management	Aims to reduce stream bank and paddock erosion and increase habitat value.	Flow Temperature Electrical conductivity pH Dissolved oxygen Turbidity/transparency Nutrients Suspended sediments Faecal coliforms		Stream habitat diversity Riparian zone disturbance Bank and bed stability	
	Riparian planting	Aims to reduce stream bank and paddock erosion and increase habitat value.	Flow Temperature Electrical conductivity pH Dissolved oxygen Turbidity/transparency Nutrients Suspended sediments		Stream habitat diversity Riparian zone disturbance Bank and bed stability	
	Stream bank stabilisation	Aims to reduce stream bank erosion.	Flow Turbidity/transparency Nutrients Suspended sediments		Stream habitat diversity Riparian zone disturbance Bank and bed stability	
	Increased perennial pastures in catchments	Increases vegetation cover through catchment, reducing run-off and erosion.	Flow Temperature Electrical conductivity Dissolved oxygen Turbidity/transparency Nutrients Suspended sediments		Stream habitat diversity Bank and bed stability	Likely to lead to long-term changes.

Table 4–3 Guide to choosing indicators (cont.)

Issue		Description	Potential key indicators to test or survey			Notes
			Physico-chemical	Biological	Stream condition and habitat	
Assessing and evaluating management actions (continued)	Rubbish removal		Flow Nutrients Pesticides Metals		Stream habitat diversity	Some rubbish can act as in-stream habitat.
	Re-snagging	Adding natural timber (snags) to the stream to replace historically removed material	Flow Temperature	Macro-invertebrates Fish	Stream habitat diversity	Some macro-invertebrate and fish species prefer or require timbered habitats.
Determining suitability for particular uses	Protection of aquatic ecosystems	Ecosystems are affected by many pollutants and clearing of riparian vegetation	Flow Temperature Electrical conductivity pH Dissolved oxygen Turbidity/transparency Nutrients Suspended sediments Pesticides/herbicides Metals Faecal coliforms	Macro-invertebrates Fish Algal counts Other waterway fauna Macrophytes	Stream habitat diversity Riparian zone disturbance Bank and bed stability	Confirm selections against the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC & ARMCANZ 2000).
	Recreation	Bacteria and aesthetics are main problems	Temperature pH Turbidity/transparency Pesticides/herbicides Metals Faecal coliforms	Faecal coliforms Algal counts	Stream habitat diversity Riparian zone disturbance Bank and bed stability	Confirm selections against the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC & ARMCANZ 2000).
	Agriculture	Farm productivity may be affected by poor water quality	Electrical conductivity pH Nutrients Suspended sediments Pesticides/herbicides Metals	Algal counts		Confirm selections against the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC & ARMCANZ 2000).

Where to monitor

After identifying your study type and deciding what to monitor, the next critical step is to decide where to monitor. This is Question 7 in your monitoring plan. Where your sites are located in the catchment is one of the most important factors in determining how well your data answers your monitoring questions and objectives. A good site will lead to good data and an increase in data quality, providing that the right parameters are monitored at the right time. See Chapter 3 for further information on data quality.

Before choosing individual monitoring sites, you should consider the monitoring program as a whole and define the spatial scope of your project (geographic boundaries and scale). You will also need to think about any universal requirements for your sites, such as whether they need to be in certain water body types. If you are planning to compare sites, they need to be as similar as possible to one another. Refer to Figure 4–1 for an overview of a monitoring program and where site selection fits in.

Once you have defined the spatial scope of your project, you can then consider where sites should be placed within your area to meet your objectives. Your objectives and corresponding study type directly influence the pattern of site placement in your study area because representativeness and comparability are key aspects of good data quality. For example, if you want to measure an impact of a discharge from a drain (impact assessment) you will need to place sites upstream and downstream of the impact, whereas if you want to determine the general condition of waterways in your catchment you should place sites at a variety of locations that represent the full range of conditions (land uses) in the catchment.

Viewing your study area as a whole can also allow you to consider issues of resourcing including cost, time and people—that is, how many sites you can afford the money and time to monitor or that you have people willing to monitor. Ideally, you would always want to monitor as many sites as possible to take into account the full range of variability in environmental conditions across the study area. However, since you are often restricted by resources, there may have to be a trade-off between resources and number of sites. It is important that the sites that are chosen are appropriate for and representative of the conditions you are seeking to investigate.

Once you have a general idea of where you want your sites to be, begin to work out the exact locations and check to see whether they suit all of your other criteria including safety, accessibility and other site attributes.

Geographic boundaries

It is important to clearly define the geographic boundaries of your project. You would have outlined the general location of your monitoring project (for example, the Brown River) when you developed your objectives, but you will also need to decide on more specific details, such as whether you will be monitoring just the main stem of the Brown River or the tributaries flowing into it as well (that is, the entire catchment).

Ideally, your study boundaries should be decided based on your issues of concern rather than convenience or budget. For example, if you are investigating a certain impact, think about where the impact is likely to be occurring. For projects investigating the general condition of a waterway and how this relates to human activities occurring in the catchment, catchment boundaries are normally most appropriate. Thinking carefully about the most appropriate boundaries for your project will ensure that you do not focus the study away from important causes or effects.

Your decision is likely to be based on both your issue of concern and availability of resources (budget, time and people). Whatever you decide, make sure that you can explain why your boundaries were chosen.

Scale

You will need to define whether you are monitoring at the regional, subregional, catchment, subcatchment or tributary scale. Some community monitoring projects are also undertaken at the paddock or reach (single site) scale.

Ideally, your decision should again be based on your issue of concern. Different processes and impacts occur at different scales. Toxicant effects, including heavy metals discharged from a drain, typically occur at a local scale such as the reach or tributary scale. The effects of nutrient enrichment can be apparent over much larger scales such as the subcatchment or catchment scale.

You will also need to think about your available resources when considering your spatial scope. Keep in mind that if you choose a larger scale over which to monitor, limited resources may require your sites to be spread further apart across the area. This may mean that your study is less representative of the conditions you are investigating, as you may miss certain 'hot spots' or areas that are displaying very different conditions from the rest of your study area. This is an important consideration for those conducting trend or baseline studies.

Type of water body

Before you start selecting sites, it is also important to define what type(s) of water body you will be monitoring—for example, upland streams, lowland streams, estuaries, wetlands, lakes, reservoirs, farm dams, groundwater bores, or coastal inlets and bays.

Consider whether you want your study to just cover one water body type or multiple water body types. This decision will depend on your objectives. If you want to compare sites to one another or combine results from multiple sites to get a picture of your study area as a whole, you will need to ensure that your sites are as similar as possible to one another. Choosing to monitor just one water body type is a good way of doing this. See 'Steps in choosing sites' on page 4–20 for further information on where to place sites to meet objectives.

Different types of water bodies are often treated separately because they require different study designs or sampling schedules. It would be impractical to combine and compare the results for different types of water bodies such as those of a large lake and a small flowing stream. This is because they have different patterns of variability, so sites should be placed differently and monitoring should be done at different frequencies for these water bodies. For example, sampling of lakes for baseline studies often requires that you sample in locations that represent typical conditions. The best sites would generally be in the deepest part of the lake. However, because stratification occurs in lakes, affecting the water temperature at varying depths, samples should be taken at various depths.

Some community monitoring programs will not be seeking to compare sites to one another. Some will only be seeking to assess individual sites by comparing the data to available water quality guidelines. In those cases, including different types of water bodies in the monitoring program would be acceptable because each site would be assessed independently.

This manual only provides study design advice for projects monitoring rivers and streams. For advice on study design for other water bodies, refer to the 'Further reading' section at the back of this chapter.

Number of sites (sample size)

The number of sites that you choose to monitor should be determined by your objectives, the level of data quality you want to achieve and the completeness of the account you want to tell about your catchment or study area.

Streams are highly variable in their natural characteristics both between one another and within themselves. For example, concentrations of dissolved oxygen can vary greatly along a waterway; higher levels are often found in upstream sections of the waterway and during the day, and lower levels are found downstream and at night. Characteristics can also vary markedly at a single site depending on the depth, distance from the bank and degree of turbulence in the water; a turbulent riffle section will be very different from a stagnant pool at the same site.

Ideally, you would want to monitor at every section of waterway in the catchment and at every point along the waterway to be able to paint the complete picture. This is generally not possible. Instead, samples of the area are taken by selecting a limited number of sites that represent what is going on.

Try to ensure that you have at least enough sites to capture most of the variability in your parameter(s) of interest across your study area. For example, if you are undertaking baseline monitoring to reveal the condition of your catchment, try to sample enough sites to cover the full range of land uses and different branches of the waterway (tributaries) in the catchment.

Remember to consider your resources (budget, time, knowledge and skills) and the trade-off between monitoring a few sites to a high degree of accuracy and precision (low completeness and representativeness) or monitoring many sites to a lower degree of accuracy and precision (higher completeness and representativeness). The first option will ensure confidence in the quality of the data collected for each site; however, you will cover less of your study area and so may miss some important information. The latter option means that you will obtain a more complete picture of your study area; however, you will not be as confident in each individual piece of data.

Replication is an important element of monitoring projects that are aiming to statistically test a hypothesis and develop analytical data (data that can be used to perform statistical analyses). For all types of monitoring, replication is a way of ensuring that the intrusions of chance events (for example, if playing children collect macro-invertebrates from your site before you monitor it) do not greatly influence your results. Replication involves choosing two or more sites that are as similar as possible to monitor. Similar sites should produce similar results so, by deliberately selecting sites that are as similar as possible, any unusual results can be detected and explained.

Replication is often used for selecting multiple reference (control) sites unaffected by human activity, to compare with test sites that have been affected by human activity. By replicating sites, you can gain a higher level of certainty that the observed changes were caused by either management actions or identified impact sources.

Remember, monitoring few sites very well is usually better than monitoring many sites less thoroughly. Monitoring the optimum number of sites will give you the highest possible data quality for your project resources.

The Ecosystem Health Monitoring Program (EHMP 2006) selected 127 sites across South East Queensland. Sites were chosen to provide good geographical coverage and to be representative of the waterway form and major land uses so that the results would exemplify the health of the streams within the catchment. Sites (100 m reaches) were chosen on waterways ranging from small (first order) headwater streams, to large (fourth and fifth order) lowland rivers, each representative of its area. A case study of the EHMP is presented in Chapter 11 of this manual.

Steps in choosing sites

The way in which you choose monitoring sites will reflect the waterway and your project objectives. You must have a good understanding of your study area prior to selecting sites. Catchment conditions upstream from your site can compromise the quality of your data, particularly for impact and restoration assessments. Ensure that the upstream conditions are suitable by conducting a field inspection prior to finalising site selection.

Follow the steps below to short-list potential monitoring sites:

1. Access a map of your study area (for example, a catchment map).
2. Divide your study area into a grid of smaller units—for example, reaches or subreaches. For baseline monitoring projects at the catchment scale, the most appropriate size of the units is often reach size. Reaches can be defined as sections of the stream that are 10–100 m in length and are uniform in physical structure and condition; however, defining the exact boundaries of each section is subjective.
3. Cross out areas or reaches that you already know are not suitable—for example, areas in the headwaters of the catchment that are in steep, inaccessible terrain, or (for loads-based monitoring) those that do not have gauging stations nearby.

4. Using your best judgment, select the best areas or reaches to sample in to meet your monitoring objectives and study type requirements. Use the guidance provided for each study type in the sections below, but do not consider specific sites yet.
5. In each area or reach, highlight sections that are most representative and would be best to sample in.
6. In these highlighted areas, pinpoint some possible monitoring sites.
7. Visit each site to check whether it is suitable. Use the 'Site placement' checklist on page 4–22. Choose one site in each of the areas or reaches that you highlighted.
8. After you have your list of representative sites, consider any additional special interest sites and back-up sites (extra sites that can serve to replace any sites in case of changes in suitability) that may be added.

Special interest sites could include those that are adjacent to on-ground works, sites in areas of rare or endangered species or sites that are known to display a specific waterway condition problem ('hot spots'). Alternatively, special interest sites could be those that a community volunteer is keen to monitor simply out of personal interest or handiness. Selecting sites of personal interest to volunteers can be very important for education purposes, but may mean that you have more than one site in a reach. This is acceptable in most cases, as it will simply provide more information. However, as far as possible you should ensure that these sites are also representative and not adjacent to any impeding features such as drains or road crossings, and that including this non-essential site is viable within your available resources. If a volunteer is keen to monitor an unrepresentative site due to personal interest or convenience, analyse the results from this site separately from the rest of the project results. Alternatively, develop a separate project that can look at the issue of concern in more detail. If you cannot completely justify including a special interest site, do not include it.

The method of choosing sites outlined above has a major limitation that is worth noting: it can lead to bias in your results. Bias in your results means that your results have been influenced in a certain way by you (often subconsciously) and thus, they may not reflect the true picture of what is going on. This can often happen when short-listing sites. For example, if you want to find out the health of your catchment and you suspect that its condition is quite bad, you may end up choosing sites that support your belief—that is, those in bad shape—without meaning to. Being aware of the potential for bias can help to minimise its impact on site selection.

The main way to prevent bias in your results is to select your sites randomly. At Step 4 above when short-listing potential monitoring sites, instead of choosing the areas or reaches that you will sample in, select them randomly. You can do this by giving all the suitable reaches a number, and then use a random number table (available in basic statistics textbooks) or the random function in Microsoft Excel or on a calculator to select your sites. This method is known as simple random sampling and works well if you have a large number of possible areas or reaches to choose from.

Information on other, more complicated ways of selecting sites randomly can be found in the ANZECC and ARMCANZ guidelines (2000) as well as a number of statistical textbooks. Alternatively, advice can be sought from someone with knowledge of statistics. If you are conducting a monitoring project that is seeking to test a specific hypothesis and conduct statistical analysis on your results, it is strongly recommended that you seek out these resources and advice.

Choosing sites is much easier if you have done an initial catchment survey and understand your catchment.

Site placement

After you have plotted all possible sites on a map, refine your site selection by visiting each site and considering any relevant scientific and practical issues.

Scientific considerations include:

- suitability for monitoring objectives
  - o representativeness of the conditions for investigation
  - o distance from any interfering factors such as drains or bridges
  - o proximity to a flow gauge board or possibility of installing a gauge board
- appropriateness for measuring chosen parameters. For example, some sites may be too deep for macro-invertebrate sampling. Also, the methods for stream condition assessment mentioned in this manual have some site requirements. Refer to the relevant methods chapter for more information
- proximity to sites monitored by others, such as government agencies. Locating your site close to one that is monitored by a government agency may be a good idea, as it will allow to you to compare results to check the quality of your data (shadow testing). If a nearby site is being monitored by another local group, however, you may want to consider moving your site elsewhere to prevent duplication of data and effort
- possibility of monitoring the site at all required times of year using the same method
  - o whether the site will contain sufficient water on all planned monitoring dates (for in-stream monitoring)
  - o whether the site is likely to change significantly during flood events
  - o whether the site can be accessed at all times, including after heavy rainfall and in high flows. It can be useful to discuss access conditions with local residents
  - o whether water at the site is permanent. Examine aerial photographs and consult local residents to help determine water permanence.

Practical considerations include:

- accessibility of the site
  - o whether the site is on private property and, if so, whether permission is required to enter the property
  - o whether a four-wheel drive vehicle is required
  - o whether the site will be accessible after wet conditions or (for event monitoring projects) during wet conditions
- your ability to easily identify and revisit the site
- creation of enough interest in the site to maintain volunteer enthusiasm
- safety of the site including access during wet conditions. To assist you to determine whether the site is safe, refer to the *Health and safety guidelines for community-based waterway monitoring* (Department of Natural Resources and Water 2006a).

Even if a potential monitoring site seems ideal, you must always evaluate it against health and safety considerations. A risk assessment process must be completed for each new site or for every change in activities taking place (see the *Health and safety guidelines for community-based waterway monitoring* for a sample risk assessment form and further details on this procedure). No site should pose an unmanageable risk to those undertaking monitoring. If the risk cannot be managed, the site must be classified as unsuitable.

For information on where to conduct monitoring at each site, refer to the monitoring methods chapters within this manual (chapters 5, 6 and 7). The best location will depend on what you are monitoring (physico-chemical, biological or stream condition and habitat parameters) so be sure to refer to the relevant section. Ensure that you monitor in the same place at the site each time to allow proper comparison between your results. Additionally, make sure that you sample in a representative section of the stream. For example, if most of the stream is flowing rather than stagnant (non-flowing), take your sample in the flowing section each time.

The placement of your sites across the study area will depend on your specific objectives. Table 4–4 provides some general guidance on where to place sites for common study types. Site location information for each of these is explained in greater detail in the sections below.

Table 4–4 Advice on site placement for common study types

Common study types	Reference and test	Sample in paired catchments	Representative of study area	Other sites	Comments
Snapshot assessment			X		Every confluence and discharge point in the river system
Baseline condition and trend (routine) monitoring			X	Close to flow gauging stations where possible	At least 100 m upstream of drains, bridges, etc.
Load-based monitoring			X	At run-off points, near flow gauging stations, or at the end of the system or subcatchment	
Impact assessment	X	X	X	Close to flow gauging stations where possible	Sites need to be located both upstream and downstream of an impact
Restoration assessment	X	X	X	Close to flow gauging stations where possible	Similar to impact assessment
Compliance monitoring			X	At particular sites of interest	
Investigative studies			X	Dependent on where the subject of the investigation occurs	

Baseline condition and trend (routine) monitoring

Establishing a baseline or identifying current condition

For baseline monitoring projects, most community groups will be aiming to establish an overall picture of the health of their catchment. Sites should be selected to allow comparisons between sites and to allow inferences to be made about the whole catchment. To do this, choose a group of sites that represents the range of conditions across the catchment. A group of sites that are representative of the catchment would include:

- sites across the full range of land uses occurring in the catchment
- sites in the upper, middle and lower parts of the catchment
- sites in both the small and large branches of the river system
- sites in both natural and modified areas of the catchment
- sites that display all typical physical features of the waterway—for example, sites in freshwater upland streams should display both pool and riffle sections as this is typical of these types of streams.

Sites located throughout the catchment will generate data that can indicate where a stream begins to deteriorate. Locating sites at the base of the catchment is especially important; what is occurring at this site will give you a good indication of the health of the entire catchment, because the site will be influenced by all the impacts occurring upstream.

To avoid choosing sites that are unrepresentative of the catchment, do not locate sites:

- near drains (not relevant if only monitoring stream structure and habitat)
- near bridges, fords or road and track crossings
- near dams or weirs.

Be aware that if sites are located near a *point source* of pollution (such as a drain), your data will only be relevant to that particular site. You will not be able to use the data to make inferences about the condition of that stretch of waterway.

If you are worried about a particular point source of pollution, it is best to do a separate assessment of this. Refer to the 'Measuring point source solution' section in this chapter for information on how to design a study to measure the impact of a point source.

In practice, many of your sites may be near bridges or roads because this makes them easily accessible. If this is the case, try to place your site at least 100 m upstream (far enough away to neutralise the impact) of these structures.

Additionally, if you are sampling immediately downstream of a tributary, make sure that you are far enough downstream to allow for mixing of the waters (at least 100 m). Otherwise, you will be taking a sample of the tributary rather than the stream.

Monitoring trends

If you want to simply observe trends through time, no further study design requirements apply. However, in many cases, you will want to be able to attribute any trends to a particular human cause. For example, if you observe a positive change in your waterway, you may wish to know whether it is due to the extensive restoration works that have occurred throughout the catchment over recent years. To do this effectively, you will need reference (or control) sites. Reference sites are locations within the catchment that are in undisturbed or near-natural condition.

Reference sites have the same physical characteristics as your normal (test) sites but are not subject to the factors that you are interested in, such as the restoration works. You will be able to attribute any differences in parameters resulting from the restoration works by comparing the data from these sites to that of your test sites. In many cases, you will not be able to find sites that have exactly the same physical characteristics as your treatment sites. Instead, you will have to select sites that are as similar as possible. Reference sites for this sort of study should be located in neighbouring streams where possible, or at least within the same catchment, and should be as comparable as possible.

Developing local water quality guidelines

If you are developing local water quality guidelines, you will need to select both reference and test sites. The results from reference sites can be used to determine the strength of an impact (pollutant, land use or waterway modification) at a test site. Guidelines on what constitutes a reference site can be found in Appendix C of the Environmental Protection Agency publication *Queensland water quality guidelines* (2006). The Queensland guidelines recommend that a minimum of two reference sites be used to develop local water quality guidelines, and, if the data from these two sites noticeably differs, more sites must be used.

Load-based monitoring

Where to place your sites for a load-based monitoring program will depend on your specific objectives for monitoring.

If you are trying to work out the loads coming in from certain land uses in your catchment, monitoring should take place upstream and downstream of each land use. If possible, this type of load-based monitoring should be undertaken by selecting a small subcatchment (preferable less than 200 hectares) in which the type of land use you are investigating accounts for the majority (preferably at least 80%) of land area in the subcatchment.

Although more difficult, the same procedure can be used when looking at a pollutant load from a point source. Monitoring of a pollutant load is undertaken by placing sites upstream and downstream of an industrial point source of pollution as illustrated in Figure 4–2. The Department of Environment and Resource Management is currently trialling this type of

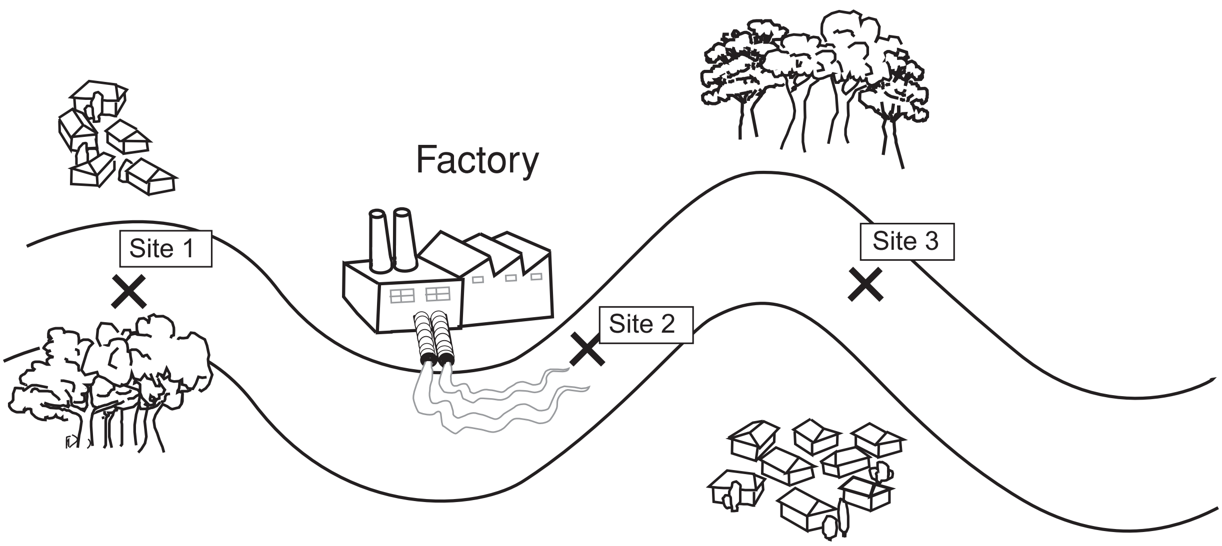

Figure 4–2 Model of site placement upstream and downstream of a pollutant load from a point source (modified from Foster 1994)

approach.

For load-based snapshot assessments, a sample is taken at every confluence and discharge point. Because base-flow conditions exist for long periods, the water quality during this time has a major effect on stream ecosystem health.

To determine the total loads emanating from a particular part of the catchment or compare this to other parts of the catchment, place your monitoring sites at the end of each subcatchment just before the stream joins with the main branch of the waterway. Refer to Figure 4–3 for where to place the sites when you want to compare total loads coming out of different parts of a catchment.

If you are using the data to calibrate models, there may be other requirements. Seek further advice from the modeller.

No matter what your specific objectives are, you should always try to place sites near a gauging station. This will allow you to access flow data from the gauge—a requirement for calculating loads. If this is not possible, you will need to collect flow data yourself.

The water flow at a site at the time of monitoring can greatly influence your results. As such, it is useful to measure the flow at the time of sampling, especially for sites known to experience wide fluctuations in stream flow. This is easily done by having a gauge board installed at the site.

A gauge board is essentially a ruler that measures flow—a vertical strip or stick with clearly marked numbers corresponding to increments of flow. You have probably seen them around bridges and areas prone to flooding. The measurements on the gauge board measure flow by relating the water height to the stream volume. Each board needs to be calibrated for the stream cross-section it is placed in. This is done by hydrographers, who relate the stream cross-section and water height to known flow conditions. To have a gauge board installed at a site, contact your local Department of Environment and Resource Management office and ask to speak to a hydrographer.

The flow information provided by a gauge board can assist you to interpret your indicator data. For example, if a result for nitrate levels at one site is unusually high and the gauge board shows that flow at that site was unusually high, it would suggest that there had been recent heavy rainfall (or a dam release if the site is close downstream) influencing conditions at that site. The unusually high result, coupled with the elevated flow reading, suggests that recent rainfall increased nutrient run-off into the stream.

For more detailed instruction on selecting sampling sites see the *Events Monitoring Methods Manual* (Department of Natural Resources and Water 2007).

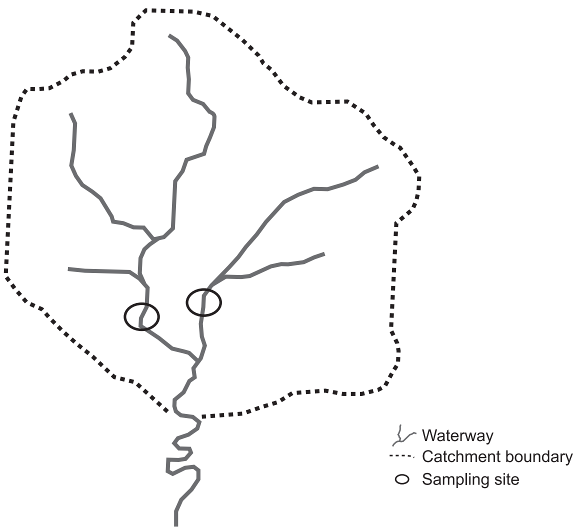

Figure 4–3 Model of monitoring site placement when comparing subcatchments (modified from Cassidy 2003)

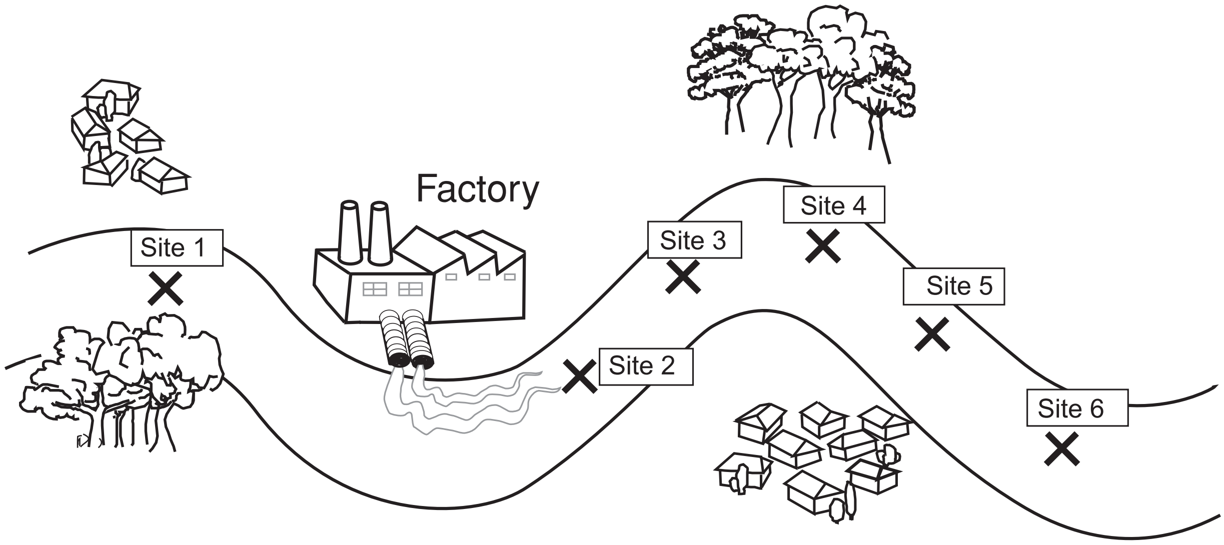

Figure 4–4 Model of monitoring site placement for assessing point source impacts
(modified from Foster 1994)

Impact assessment

Selecting sites with a gauge board installed may be useful for conducting impact assessments. Having a gauge board at the site allows you to easily and effectively measure the amount of water flowing through your site at the time of monitoring (the discharge). Knowing the discharge and the concentration (amount per volume) of pollutant present allows you to accurately estimate the distribution of a pollutant at given flow levels.

Measuring point-source pollution

To measure the impact of pollution, you need to have both reference and test sites. As outlined previously, reference sites are sites that are not affected by the treatment or impact. Test sites are sites where you anticipate that an impact is occurring. By comparing the results from your reference sites and your test sites, you will be able to assess whether the impact has occurred, as well as its magnitude.

Sites located sufficiently upstream of the point source (or impact) can act as reference sites. For most types of impacts, placing your sites approximately 50 m upstream is considered sufficient.

Sites located downstream of the point source can act as test sites because, in flowing waterways, this is where the impact is likely to be occurring. As a general rule, sites should be located at least 100 m downstream of the point source, where the pollutant is completely mixed in with the water. Having a number of test sites downstream of the point source allows you to see how far the impact has extended. Be aware that, in some cases, impacts could be occurring as far as 2 km downstream.

You should have at least one site upstream and one downstream of your main test site to allow for comparisons. Having more than one reference site upstream is recommended, however, because this enables background variability to be taken into consideration. If the goal of the group is to determine how far downstream the impact reaches, monitoring will need to take place at numerous established test sites downstream (as illustrated in Figure 4–4).

Reference sites and test sites should be as similar as possible to one another in their physical characteristics, as this allows any differences in your results to be ascribed to the impact of the point source rather than other factors. Unwanted factors that influence your results are called *confounding variables.* All scientific studies should try to avoid these, but it is not always easy.

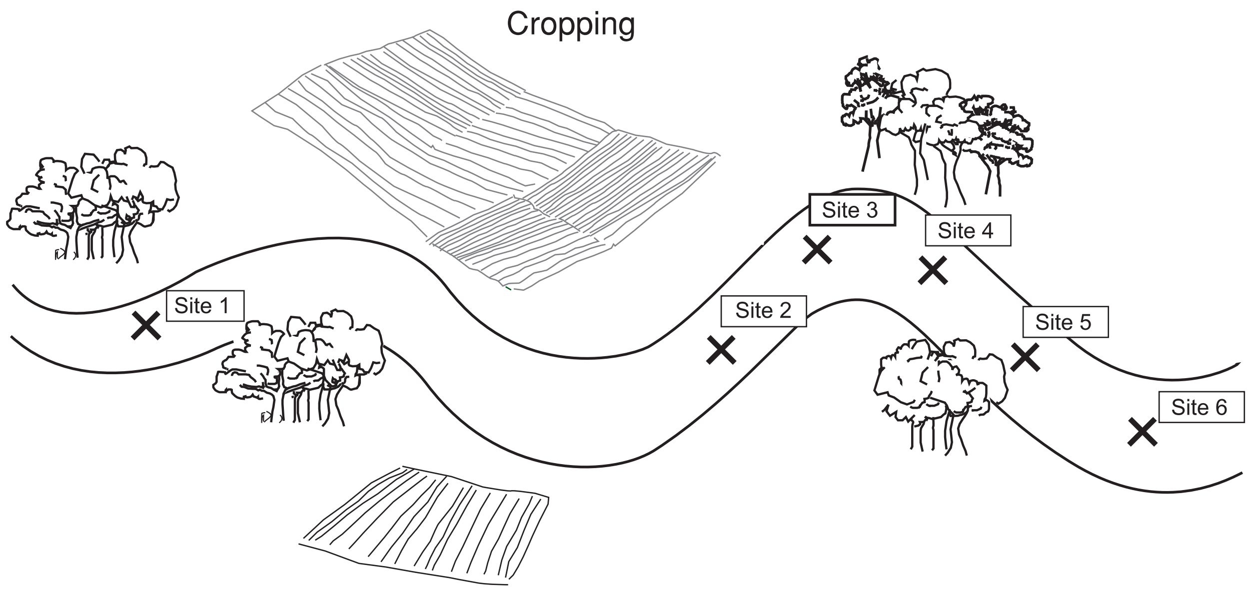

Figure 4–5 Model of monitoring site placement for assessing the impact of a land use (modified from Foster 1994)

If the impact has not yet occurred, place sites based on where you anticipate the impact to occur.

In some cases, you will be unable to find a suitable reference site. This could be because you are unable to find a site upstream that is sufficiently similar (in physical characteristics) to the test sites, or maybe other point sources are located just upstream. If this is the case and the impact hasn't occurred yet, you will still be able to get some useful results. By monitoring your test sites(s) both before and after the impact, you will be able to detect any changes; however, you will not be able to tell whether changes are due to the impact of the point source or just natural variation in the waterway over time. If you cannot find a suitable reference site and the impact has already occurred, then obtaining any useful results will be extremely difficult. In such cases, it may be beneficial to establish reference sites in a neighbouring catchment at locations that exhibit similar physical characteristics to those of your test site(s).

Monitoring at your reference and test sites both before and after the impact is known as a BACI (before–after control–impact) design (Green 1979). BACI designs are the best design for measuring impacts. For more information on BACI designs, refer to the *Australian guidelines for water quality monitoring and reporting* (ANZECC & ARMCANZ 2000).

Measuring diffuse-source pollution

Choosing where to place monitoring sites to study of the impact of a diffuse source is very similar to assessing point sources. Reference and test sites are needed as described for point source impact assessment above.

If the study is on the impact of a single land use, reference sites can be located upstream of the land use (pollution source) and test sites can be placed downstream. This is the same design as described above for point source impact assessment. The only difference is that the reference and test sites are further apart because the pollution source occurs over a larger area. Refer to Figure 4–5 for an example of where to place monitoring sites when assessing the impact of a diffuse pollution source from surrounding agricultural land use.

However, if a study looks at the effects of an impact on the whole catchment, locating reference sites upstream may not be possible. For example, if an entire small subcatchment is converted into grazing lands while a neighbouring subcatchment is left untouched—and both of these subcatchments exhibit the same rainfall, geology and other waterway characteristics—the only difference between the two catchments should be the impact. Therefore, sites in one subcatchment can be used as reference sites, while sites in the other subcatchment can be used to measure the impact, as illustrated in Figure 4–6.

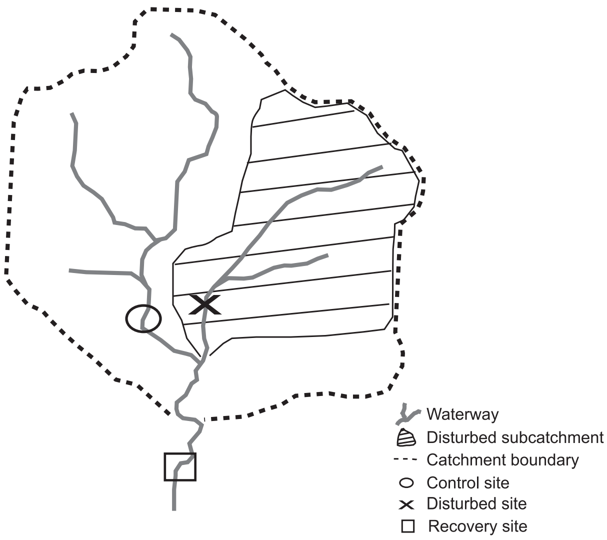

Figure 4–6 Model of site placement for assessing the impact of pollution from a whole subcatchment
(modified from Cassidy 2003)

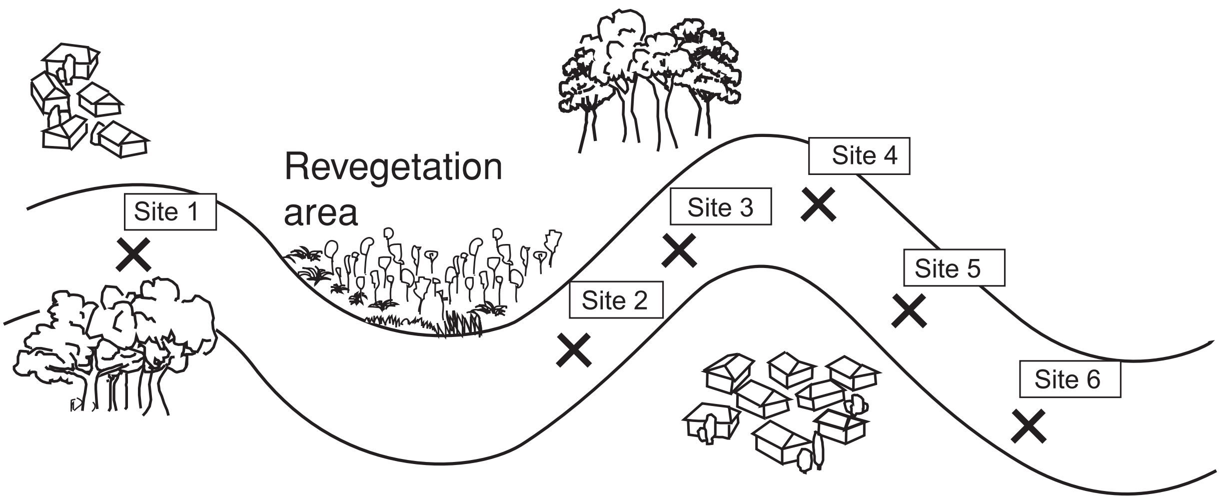

Figure 4–7 Model of monitoring site placement for assessing restoration actions
(modified from the Foster 1994)

Restoration assessment

Where to place sites for restoration assessments is the same as for impact assessments. This is because the only difference between these two study types is that an impact assessment anticipates a negative change while a restoration assessment anticipates a positive change. Sites should be situated within the area connected to the management actions (for example, revegetation of riparian zone as shown by Site 2 in Figure 4–7), as well as upstream (Site 1 in Figure 4–7) and downstream of the area (sites 3 to 7 in Figure 4–7). This enables comparisons to be made between sites where restoration actions have and have not taken place. Monitoring at numerous sites downstream can allow the spatial extent of the restoration actions to be determined. If the management action was performed at a number of sites in the catchment, then the study design for a diffuse source should be followed.

Compliance monitoring

Where to place your sites in the catchment for compliance monitoring depends on the area and water body use you are interested in. For example, if you are trying to assess whether your local stream is safe to swim in, sites should be located in those areas where the community are keen to swim. Unlike other types of monitoring projects, one site rather than multiple sites throughout the catchment can be sufficient to answer your question of interest. To prevent any legal complications, you should seek advice from local authorities prior to conducting sampling. This may involve following strict guidelines outlined in various pieces of legislation, such as the *Environmental Protection Act 1994.* A good starting point prior to commencing monitoring is to consult your local council.

Investigative studies

This type of study relates to monitoring that is done to investigate an aspect of the freshwater environment to increase understanding of how the ecological system works. Where you place sites depends on what you are investigating. Most community groups will not undertake this type of study; however, if they choose to do so, they should seek scientific advice from research organisations such as universities who normally undertake these types of studies.

Recording site details

Once you have chosen your sites, you will need to record all relevant details of the site locations in your project monitoring plan. In addition to site description information, it is recommended that you undertake an assessment of the stream condition and habitat (including bed and bank stability, riparian vegetation and stream habitat) at that site if you are not already doing so. This approach provides the information to understand the natural processes occurring at your site, which in turn assists you to identify human impacts. Use the basic method outlined in Chapter 7 as a bare minimum. This assessment should be repeated and updated regularly (once a year) no matter what sort of monitoring you are doing. The more site description information you collect, the easier it will be to interpret any monitoring results collected at that site. The following sections describe the site location information that should be recorded.

Site name

A site name should be unique and give a rough indication of where the site is. The best way of naming a site is to combine the name of the waterway with the location of the site on that waterway or a landmark. For example: Brown River at Smiths Bridge, or Emu Creek at end of South Road.

Site code

Giving your site a code is a handy way of referring to it in a succinct manner. This can be useful when storing data in a spreadsheet or labelling sample bottles when out in the field. Having both a site name and a site code can also function as a double check for field sampling sheets when writing is illegible or either the site code or name is omitted from the sheet. A site code should also be unique and give a rough indication of the location of the site, as per a site name; however, it should be much shorter than a site name. The Waterwatch Australia Steering Committee (2003) recommends using a three-letter, three-number format. The three letters refer to the name of your waterway and the three numbers refer to the location of the site on the waterway (such as relative distance of the site from the headwaters). For example, a site located at the headwaters of Emu Creek could be EMU-000. A site located about halfway along Brown River could be BRO-500. Alternatively, if you are planning to integrate your data with others, you may want to check whether your project partners or stakeholders have any site coding requirements.

Australian Map Grid (AMG) references

This vital information gives an exact location of the site in a format that is universally recognised. AMG references should be recorded as the zone, the eastings and the northings. For example, Zone 55 E 0505851.334 N 7869375.326 is the AMG reference for the Townsville Global Positioning System (GPS) Station. This information can be obtained from a GPS reading taken while at the site or from a topographic map. Taking a GPS reading and double-checking it against a map is a good idea.

Latitude and longitude references

This information also gives an exact location of the site. Recording the latitude and longitude (lat/long) of a site as well as the AMG provides a means of double-checking a location. Making a mistake and writing down one incorrect digit is easy to do. In some cases, groups will prefer to use lat/long references if they are located on an AMG zone boundary. Lat/long references can be obtained from a topographic map by recording the values on the *x* and *y* axes where they intersect at your site.

In addition to basic site location details, other information about your site should be collected before monitoring commences. This information can be recorded in your monitoring plan or be recorded on a separate record sheet containing information about each monitoring site. The site description record sheet (see Chapter 10 for record sheet templates) contains all relevant information about a site, including photographs and sketches. A site description record sheet should be completed once for each monitoring site. It should be taken out in the field to locate the correct site and monitoring location each time monitoring is undertaken.

Catchment

Record the name of the catchment in which the site is located.

Access instructions and sketch map

Provide written instructions on how to get to the site. Sometimes a roughly sketched map is also useful. A street directory reference can also be handy. Access instructions mean that the site can still be easily found even if the people responsible for monitoring a site change.

Photographs of site

Taking photographs of the site is a good way of recording the site location and ensuring that the same site is visited each time. Photographs can also assist you to interpret monitoring results, as they provide an indication of the site condition and factors that may be affecting the stream. It is recommended that you take photographs of:

- the bank looking upstream and downstream—the bare minimum
- streamside vegetation, woody debris in the stream, erosion or stock in water
- a bend in the stream
- a view from a distance overlooking the waterway and surrounding areas—choose an elevated position if possible, such as the top of a bank or bridge.

Record the photograph number from your camera for each shot to help you identify the photographs later on.

Location description and sketch map

Describe the specific location of where you are monitoring at the site so that future monitoring can be performed at exactly the same location. For example, you may refer to a specific landmark, or mark the places on a site sketch. This will mean that your results are more comparable to one another.

Method used to obtain location references

Recording the latitude and longitude of a site allows that site to be accurately located again by any person and places the site at a set global location. Latitude and longitude data can also be used to create accurate maps of your site using geographic information system (GIS) software—for example, ArcGIS. Where the latitude and longitude cannot be identified (by using a GPS unit) or the available maps do not list them, you may use the grid references from a topographic map. You should record the method used to obtain your location references—that is, were they found using a GPS unit, a topographic map, or both? These records will give you an idea of how confident you can be about the spatial location of your site. For example, if you have only used a GPS unit, your references could be wrong if the equipment was faulty, whereas if you have used both a GPS unit and a map to check the references and both sets of figures agree, you can be very sure that the references are correct.

Details of GPS unit and map

If you have used a GPS unit to obtain your grid references, it is a good idea to record the make and model details of the equipment used and the datum it uses. If you have access to a topographic map to obtain or check your grid references, note down the map name, number and scale. If you are unsure of where to find this information on your topographic map, Geoscience Australia (2005) provides an excellent guide, available on their website <www.ga.gov.au> (search for 'map reading guide').

Reason for choosing site

Provide a brief explanation of why you chose the site. For example, if you are conducting a baseline monitoring project you may simply note that the site was chosen because it was a representative of that stretch of the waterway as well as having sufficient and safe access. If you are conducting an impact assessment, you may note that the site is a control or reference site (if it is located upstream of the impact). Stating your reasons for choosing each site can demonstrate to others that the sites have been chosen carefully, and thus provide increased confidence in the data generated from your monitoring project.

Health and safety issues at the site

You should note anything at the site that may pose a health and safety risk to people monitoring at that site. Such issues could include an electric fence, a steep slippery river bank or even a bull in the adjacent paddock. You should also note any advice that you can offer on how the risk can be avoided. This will ensure that every person monitoring at that site is aware of the risk and can take steps to minimise the chance of getting hurt. If a significant health and safety risk is posed at a site, an alternative site should be chosen. A risk assessment should be performed at every site before the monitoring project commences. Identified hazards need to be pointed out to each team member and all risk control measures explained and documented on a project risk assessment form. For information on how to do this, refer to the *Health and safety guidelines for community-based waterway monitoring* (Department of Natural Resources and Water 2006a).

Type of water body

If your monitoring project covers multiple water bodies, record the type of water body in which each site is located. If your project only involves monitoring in one type of water body (as for most projects), you will not need to provide this information for every site.

Altitude

Record the altitude of your site location. This can be obtained from a GPS unit or a topographic map. As well as assisting with data interpretation, this information is relevant when calibrating a dissolved oxygen meter.

Surrounding land use

Note the surrounding land use(s) at the site up to a distance of 400 m away from the waterway. Land-use categories could include industrial, commercial and urban uses, or be even be as specific as aquaculture, dairy farming or field cropping.

Upstream land use

Identify the land uses occurring throughout the catchment upstream of your site. Upstream land uses can have significant effects on a site, even for a site in the lower reaches. For example, land clearing and forestry upstream can release sediments and nutrients that travel far downstream. Important land-use categories at this scale include mining, forestry, irrigation and water extraction, as well as any other land uses with long-ranging impacts.

Conditions affecting stream

Note down the general conditions that may be affecting the health of the stream. These could include stock access, a drain pipe, a quarry or a sewage treatment plant. Look for evidence of these at your site as well as up to 200 m upstream.

When to monitor

Once you have identified your study type and determined what and where you are going to monitor, the next key step is to decide when and how often you are going to monitor. Your responses will form the basis of Question 8 in the monitoring plan (Table 4–1). Your monitoring objectives are the key to determining when and at what frequency you are going to monitor. You could monitor on a weekly, monthly, seasonal, annual or once-off basis depending on the objectives you wish to achieve. When and how often you monitor will also affect your data quality, so think about the data quality requirements of your project before finalising when to monitor.

Regardless of the type of monitoring being conducted, the sampling frequency needs to be decided prior to beginning work in the field. Once again, this is determined by the questions that your project aims to answer. If, for example, you were trying to gain a broad understanding of seasonal trends in macro-invertebrate populations, conducting sampling on a quarterly basis would be sufficient.

Other factors that need to be considered are the dates and time of the day when monitoring will occur. Time of the day can affect the results of certain physico-chemical parameters such as temperature and dissolved oxygen, so you must record the time of day and ensure that future monitoring occurs at the same time whenever possible. Dates are also an important consideration, as the selected dates need to coincide with the availability of group members and facilitators. If the desired numbers of people are unable to attend a monitoring session, it is highly unlikely that the required data will be collected. Ensuring that the required number of people will be available on each planned monitoring date is an important element in designing your study.

The resources available for your project may also limit the frequency of monitoring. Consider your project resources in terms of people, equipment and time, before finalising the monitoring frequency.

Timescale of project (duration)

The duration of your monitoring project—that is, how long you will need to monitor in order to answer your monitoring objectives—needs to be defined.

Start and end dates for monitoring must be defined prior to sampling. In some cases, monitoring projects may not have a designated end date, but review dates should be set to ensure that the project is on track and is meeting all monitoring objectives.

In other cases, such as event-based monitoring, the start date will not be definable. In these cases, you need to define the event that will trigger the start of monitoring and when you will finish monitoring.

According to the ANZECC and ARMCANZ guidelines (2000), timescale decisions should be based on:

- the characteristics of the parameter being measured
- the purpose of the data collection
- the statistical or other tools that will be used to interpret the data
- the characteristics of the response of interest
- recognition that a process cannot be measured if it takes longer to happen than the period over which the measurements are made.

Frequency of monitoring (sample size)

Determine if your monitoring project is going to be once-off, routine or event-based monitoring.

Once-off or snapshot—Once-off monitoring is really a form of event-based monitoring but without the need for frequency considerations, as the data is only collected once.

Routine—Routine or periodic monitoring strategies are based on predictable natural systemic changes, such as daily, weekly or monthly cycles.

Event-based—When the likelihood and frequency of an event occurring cannot be predicted, you may need to adopt an event-based monitoring strategy.

If you will be undertaking routine or event-based monitoring, you need to think about how often you will take a sample. For event-based monitoring, the frequency of monitoring will depend on when the event occurs and on how many samples you need to take. You will need to ensure that you take enough samples to capture the full range of variability in the parameter(s) of interest.

Figure 4–8 illustrates the importance of selecting the appropriate monitoring frequency. Each graph represents four values, collected over time, of a single water quality parameter (i). The dotted line represents the level above which the parameter fails its water quality criteria. Given the data collected, a line of the probable parameter concentration can be plotted (ii). However, when compared to data collected on a finer timescale (iii) it is evident that insufficient data was collected over the time period to accurately represent this parameter. Therefore a finer timescale (more frequent sampling) should be used to accurately perform such an assessment.

In some cases, it is possible to monitor too frequently. If monitoring macro-invertebrates, for example, you need to be careful not to over-sample as this can have devastating effects on the macro-invertebrate community. This could result in misrepresented results in the future, along with unnecessary environmental damage.

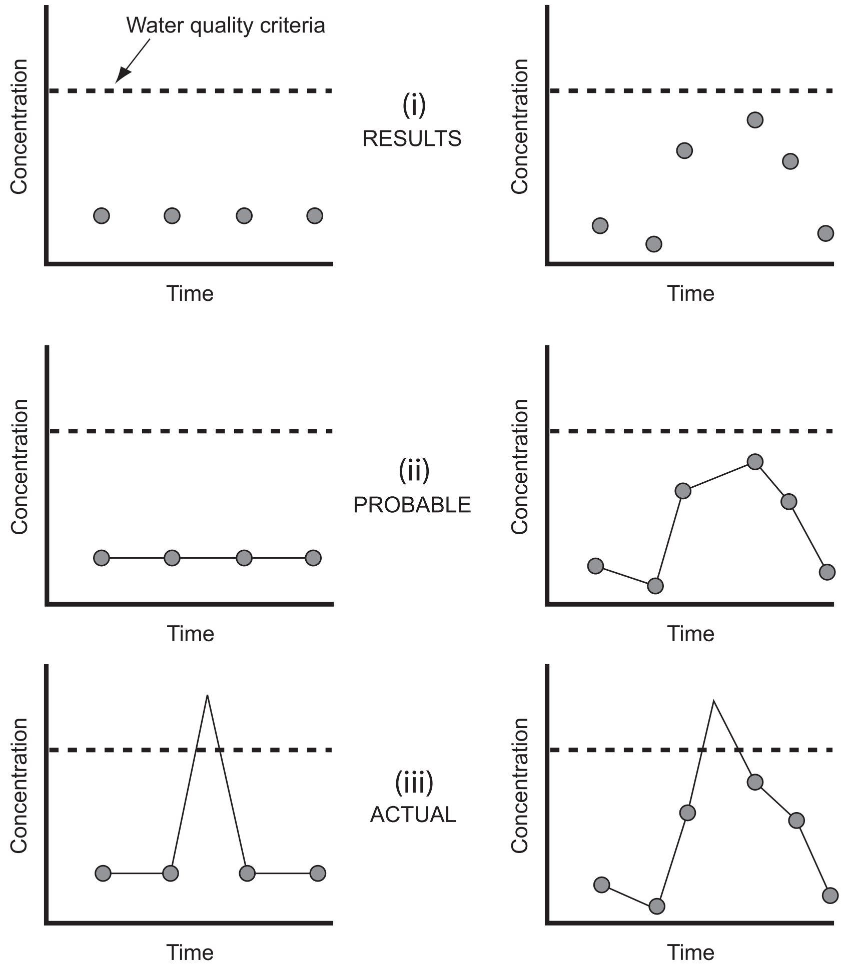

Figure 4–8 Model of the effects of monitoring frequency (ANZECC & ARMCANZ 2000; modified from Maher, Cullen & Norris 1994)

Table 4–5 provides general guidance on monitoring frequency for perennial streams.

You need to account for the natural variability in the parameters being measured in order to ensure that the data you collect provides a true indication of the health or water quality of the waterway.

To develop an understanding of natural variability, you should first conduct baseline or pilot monitoring. You could start off monitoring more frequently and then cut back to a lower frequency once you have an idea of the variability of your parameters.

An idea of the natural variability of waterways over time has been established in some areas of Australia. As a result, precedent has been set and many monitoring programs now stick to roughly the same frequency of monitoring. Some general guidance based on the most common practices in Queensland is listed below. However, it is important to keep in mind that your areas may be different, particularly if you are monitoring where little previous research has been conducted.

For examples of the timing for different types of monitoring, refer to the case studies outlined in Chapter 11.

Monitoring dates

Table 4–6 (overleaf) provides advice on when to monitor to meet your project objectives, taking your study type and monitoring method into consideration.

Table 4–5 Advice on monitoring frequency

Study type	Monitoring methods		
	Physico-chemical	**Biological**	**Stream condition and habitat**
Snapshot	Once-off	Once-off	Once-off
Baseline condition and trend (routine) monitoring	Routine: monthly Leave time after high-flow events for conditions to stabilise.	Routine: every 1–5 years Data must be collected from two seasons to make an accurate assessment. Leave 4–6 weeks after high-flow events for communities to re-establish.	Routine: every 1–5 years Leave time after high-flow events for conditions to stabilise
Load-based monitoring	Base flow: monthly Event-based: 5 to 20 times over the event duration (depends on knowledge of flow dynamics)	N/A	N/A
Impact assessment	Event-based: before and after the impact, at weekly to monthly intervals	Once before and once after the impact	Before and after the impact
Restoration assessment	Before and after the restoration at monthly intervals	Once before and once after the restoration activity	Before and after the restoration activity
Compliance monitoring	Monthly to weekly intervals for certain indicators during periods of high use (e.g. faecal coliforms)	N/A	N/A
Investigative studies	Depends on particular question or objective	Depends on particular question or objective	Depends on particular question or objective

Table 4–6 Advice on when to monitor

Study type	Monitoring methods		
	Physico-chemical	**Biological**	**Stream condition and habitat**
Snapshot	Any time of year	Autumn or spring	Dry season
Baseline condition and trend (routine) monitoring	Throughout the year	Autumn and spring	Dry season
Load-based monitoring	During flood events (in Qld usually Nov. to Apr.), or a seasonal cycle	N/A	N/A
Impact assessment	Before and after	Before and after	Dry season
Restoration assessment	Before and after	Before and after	Before and after, dry season
Compliance monitoring	Any time of year	N/A	N/A
Investigative studies	Depends on particular question/objective	Depends on particular question/objective	Depends on particular question/objective

Snapshot assessment

For macro-invertebrate monitoring, autumn or spring is the best time for monitoring due to the life cycle of water bugs, which tend not to be active or present in streams during winter and summer. For physico-chemical monitoring, the time of the year is irrelevant when conducting snapshot monitoring.

Stream condition and habitat assessment surveys should be conducted once a year, in the dry season, to avoid problems with bad weather and access difficulties. It is best done when the water levels are low and water clarity is highest.

Baseline condition and trend (routine) monitoring

The rules for snapshot monitoring also apply to baseline condition and trend (routine) monitoring. Macro-invertebrate monitoring should be conducted during autumn or spring to coincide with the active stages of water bug life cycles. Macro-invertebrate monitoring should not be carried out too regularly at a particular site due to the harmful effects this may have on the populations.

The time of the year is again irrelevant when conducting physico-chemical monitoring.

Monitoring should take place at regular intervals (weekly, monthly, etc.), particularly in the early stages when baseline data is being developed.

As for snapshot monitoring, baseline monitoring is best done once a year, in the dry season. This avoids bad weather and access difficulties, and ensures that water levels are low and water clarity is high.

Monitoring to establish local water quality guidelines should be performed under a range of flow conditions; this allows you to capture the full natural variability of your water quality indicators. Monitoring should be conducted in both wet and dry seasons and in both low- and high-flow conditions at a bare minimum. It is a good idea to establish an approximate measure of the variability of each indicator before determining how often you will need to monitor that parameter. For example, while pH is fairly stable over time, dissolved oxygen (DO) levels fluctuate over a twenty-four hour period; therefore, you would monitor DO more frequently than pH over the same time period.

The *Queensland water quality guidelines* (Environmental Protection Agency 2006) recommend that monitoring occur at a minimum of two reference sites and that monitoring be conducted seven or more times over a twelve-month period.

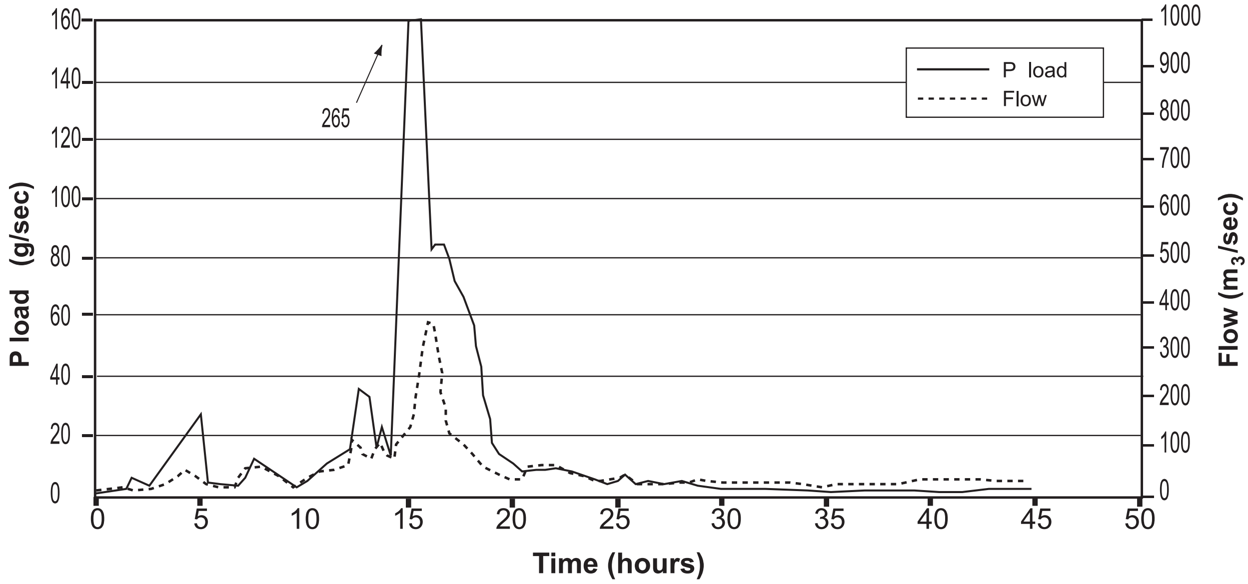

Figure 4–9 Hydrograph showing flow rates and phosphorus loads during an event (modified from Rayment & Poplawski 1992)

Load-based monitoring

Load-based monitoring is carried out over a pre-defined period—for example, during a flow event, during base-flow conditions, or on a seasonal cycle—and applies only to physico-chemical parameters.

An event is any increase in flow caused by rainfall—for example, a flash flood, cyclone or storm. In Queensland, most events occur during the wet season, from November to April. As monitoring is conducted whenever events occur, the frequency of monitoring efforts could be erratic.

Base flow refers to any water flowing into or through the waterway that does not come from rainfall at or upstream of the site. Examples include groundwater entering the waterway, and designated dam releases. Monitoring is generally conducted at a fixed frequency, when conditions are stable.

During the planning stages of your project, you need to work out what flow conditions you need to monitor. If you need to monitor loads during an event, you must define what an event is before monitoring commences—for example, if you are assessing loads during floods, you must specify how high the river has to be before it is classified as a flood event and monitoring is triggered. You will also need to state the conditions (such as water level) at which the event is considered finished and monitoring should cease. These limits should be defined in Question 8 of your monitoring plan.

To produce high-quality data, the frequency of sampling needs to reflect the rate of change in load concentration at your site. Select the highest frequency to answer your reasons for monitoring within your available resources (there will always be a trade-off between data quality and resources) to meet your required level of data confidence. Lower monitoring frequencies reduce the certainty of data associated with your load estimates.

To assess loads under base flow (dry weather) conditions, The Department of Natural Resources and Water (2007) recommends taking a minimum of one sample per month under stable conditions. Monitoring should be conducted at least three weeks after any event to ensure that you are measuring only base-flow conditions.

To assess event loads (event mean concentration) and understand how loads fluctuate during an event, water quality sampling should be undertaken over the entire event duration. To produce the highest possible data quality, monitoring should be conducted at hourly or even half-hourly intervals during events because the concentration of pollutant can change very rapidly during the peak of an event (refer to Figure 4–9). This ensures that fluctuations in load concentration are adequately detected. At least one sample per day should be taken in larger catchments, and the frequency of monitoring should increase with decreasing catchment size or increasing stream flow velocity.

The Department of Natural Resources and Water (2007) states that the ideal number of samples to collect will depend on your understanding of the relationship between the rise and fall in water height and the associated change in load concentrations. However, in reality the frequency of sampling will be constrained by your available resources. The following sampling frequencies are recommended:

- If a relationship has not yet been established, collect fifteen to twenty samples, evenly distributed throughout the entire event duration.
- If a relationship has been established, collect a minimum of five samples over an event
  - two as the hydrograph rises—that is, as flow increases from base flow but before the maximum flow volume and velocity is reached
  - one as flow peaks—that is, as the flow reaches its maximum volume and velocity
  - two as the hydrograph falls—that is, as the flow recedes from the maximum but before it returns to base-flow levels.

Impact assessment

Monitoring should occur at regular intervals before, after and during an impact whenever possible. This allows data from each of these times to be compared and the level of impact determined. Time your monitoring to coincide with the suspected impact. For example, if you wish to determine the impact of sewage on aquatic ecosystem health, you may choose to monitor dissolved oxygen at sunrise when levels are at their lowest.

Restoration assessment

The monitoring pattern for restoration assessment should mirror that of impact assessment. The only difference between the two study types is that restoration assessment anticipates a positive change, while impact assessment anticipates a negative change. Therefore, monitoring should occur prior to and after restoration actions such as restoring riparian vegetation, fencing off riparian areas from cattle access, stabilising stream banks or re-creating in-stream habitat (for example, resnagging or re-creating rocky riffles). Monitoring should be performed at regular intervals.

Compliance monitoring

As this study type is conducted to determine whether a waterway complies with certain guidelines and is suitable for a particular use, when to monitor varies depending on the water use in question.

For **drinking water**, monitoring should occur on a weekly to monthly basis due to the importance of changed conditions on animal health. Drinking water monitoring for human health is measured at the tap, as that is where the water is consumed from. Monitoring frequency should be increased in summer months when bacteria are more active, or in response to an event.

To determine whether a water body is suitable for **recreation activities** (such as swimming) monitoring needs to be conducted frequently, particularly in summer when bacteria are more active and so are more variable. Monitoring can be an ongoing process or conducted in irregular intervals in response to an event, particularly if there is reason to believe that the area is at an increased risk of contamination.

For **agriculture**, monitoring should occur on a weekly to monthly basis depending on the time of the year, with an increase in monitoring possibly needed during the summer months.

Investigative studies

When to monitor will be highly variable, depending on the question or objective being investigated. These types of studies are normally undertaken by research organisations such as universities, so advice from experts is recommended.

Time of day to monitor

When monitoring physico-chemical parameters, each sampling session should take place at approximately the same time of the day because some parameters such as temperature, pH, and dissolved oxygen can vary greatly throughout a 24-hour period. Monitoring at roughly the same time for each session helps ensure comparability of data over time.

When monitoring macro-invertebrates and other biological parameters, it is still a good idea to monitor at the same time of day whenever possible due to the behaviour of certain aquatic species in response to the physico-chemical parameters mentioned above. This helps to increase comparability of data over time by removing other factors that can influence data.

Stream condition and habitat assessment can be undertaken at any time of day because the time will have little, if any, effect on the comparability of the data.

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