Water quality fact sheets for production nurseries

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Supported by

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Supporting publications

Ralph, T.J., Graves, B.P., Gomes, M., 2025. Framework to identify and mitigate water storage contamination concerns at NSW and ACT production nurseries. Macquarie University. https://doi.org/10.25949/AS0X-VX91

Gomes, M., Ralph, T., Humphries, M., Graves, B., Kobayashi, T., Gore, D. 2025. Waterborne contaminants in high intensity agriculture and plant production: A review of on-site and downstream impacts. Science of the Total Environment, 958. 178084. https://doi.org/10.1016/j.scitotenv.2024.178084

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Disclaimer

Water Quality Fact Sheets

OVERVIEW

Fact sheets provide clear and concise summaries of key concepts and are an accessible way to understand water quality. This series of fact sheets is designed to support informed decision-making and promote best practices across the production nursery and horticultural industries.

The Nursery and Garden Industry NSW and ACT (NGINA), with Macquarie University, led a government-funded project to investigate water quality concerns related to storm and flood events at production nurseries (**Figure 1**).

A literature review identified important catchment conditions, water quality parameters, and other relevant issues. Catchment and nursery lot mapping, flow path and inundation modelling, and water and sediment monitoring was undertaken. An adaptive framework was developed to understand and help manage water quality and contamination concerns at production nurseries.

Read and download the literature review online:

Gomes, M., Ralph, T., Humphries, M., Graves, B., Kobayashi, T., Gore, D. 2025. Waterborne contaminants in high intensity agriculture and plant production: A review of on-site and downstream impacts. Science of the Total Environment, 958. 178084. https://doi.org/10.1016/j.scitotenv.2024.178084

FACT SHEET TOPICS

The fact sheets cover the following topics:

1. Water Quality Overview
2. Catchments and Waterways
3. Storms and Floods
4. Water Sampling
5. pH and Alkalinity
6. Salinity
7. Water Hardness
8. Heavy Metals
9. Nutrients
10. Turbidity
11. Sediment
12. Pathogens
13. Aquatic Biota
14. Weeds
15. Adaptive Management

Read and download the adaptive framework online:

Ralph, T.J., Graves, B.P., Gomes, M., 2025. Framework to identify and mitigate water storage contamination concerns at NSW and ACT production nurseries. Macquarie University. https://doi.org/10.25949/AS0X-VX91

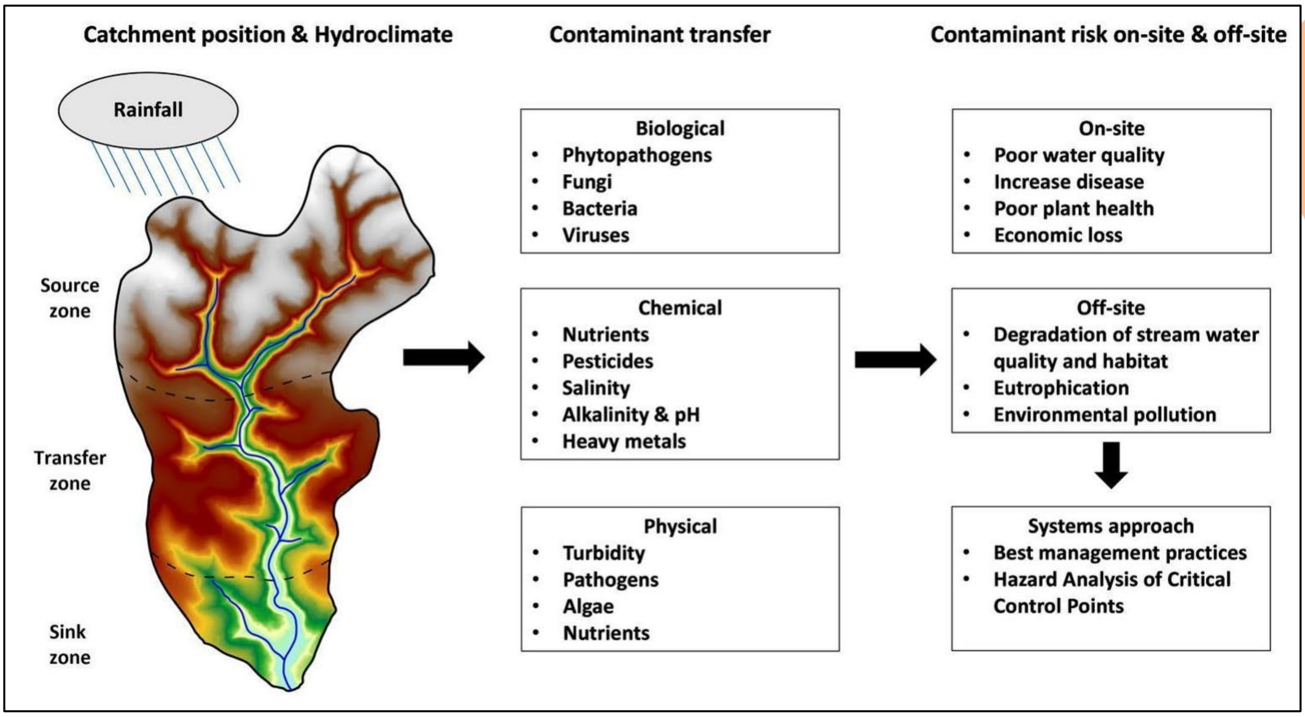

Figure 1. Summary of physical and biogeochemical factors contributing to water-borne contaminant risk at production nurseries.

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The following documents and websites were consulted during the preparation of these fact sheets. For a full list of papers included in the literature review, see the references in Gomes et al. (2025).

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Ralph et al. (2025). Water quality fact sheets for production nurseries. https://doi.org/10.25949/JH43-4N56

Water Quality Overview

OVERVIEW

- This factsheet introduces key aspects of water quality, monitoring, and management in plant production nurseries.
- Water quality refers to the physical, chemical, and biological characteristics of water used for irrigation.
- Good water quality is essential for plant growth, efficient nutrient uptake, and disease prevention.
- Regular water testing helps detect problems early and supports proactive water and nursery management.

HIGHLIGHTS

- Water quality is critical for healthy, productive nursery plants.
- Poor water quality can reduce plant growth, increase disease risk, and damage equipment.
- Key factors include water source, environment, nursery practices, and specific water quality parameters.
- Regular testing and monitoring are essential for early detection and effective management.
- Management actions should be guided by test results and followed up with ongoing monitoring.

KEY FACTORS

- The sources of water (e.g., surface, groundwater, municipal, or recycled) used for irrigation and any treatments can greatly influence water quality.
- Land use and activities upstream or nearby (e.g. agriculture, urban development) affect water via runoff, nutrients, sediments, or contaminants.
- Fertiliser and pesticide use, as well as farm layout and runoff management, impact water quality.
- Important water quality indicators include pH, electrical conductivity (salinity), nutrients (e.g. nitrogen, phosphorus), turbidity, and pathogens.
- Water quality changes with seasons, after rainfall, drought, or flooding, and as local and catchment land use and development change over time.

MANAGEMENT

- Understand the specific attributes of your water by testing for key parameters relevant to plant health and nursery operations (**Figure 1**).
- Consider and select management strategies based on water test results; these might include filtration, disinfection, nutrient management, or changes to irrigation practices or nursery layout.
- Monitor water quality to evaluate the success of management actions and to identify new issues.
- Use a combination of strategies for best results and keep good records of water quality conditions and management actions to enable adaptation.

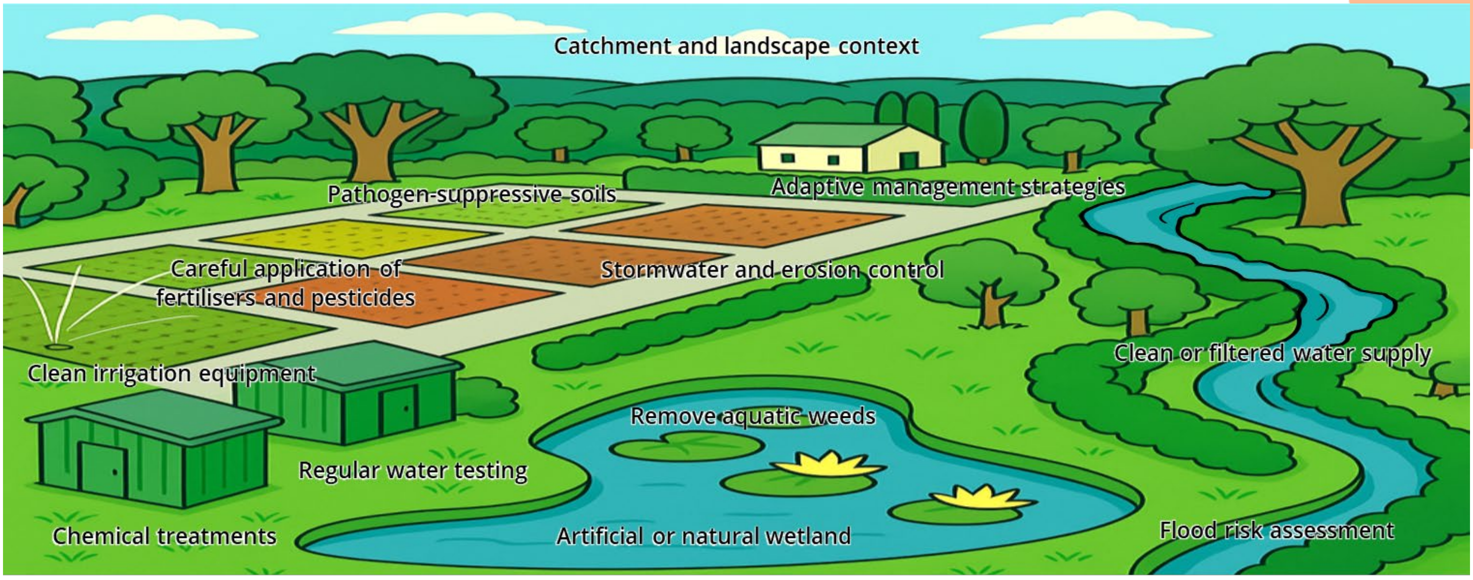

Figure 1. Examples of management considerations to maintain and improve water quality in a plant production nursery setting.

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Catchments and Waterways

OVERVIEW

- A catchment is an area of land where all surface water, or runoff, drains towards a common outlet.
- Catchment characteristics such as topography, land use, storms and floods, droughts, and connections between waterways from the headwaters to the outlet influence runoff, river flow, sediment transport, and contaminant movement.
- The position of a nursery within a catchment, such as near the headwaters or outlet, affects water quality and likely storm and flood impacts (**Figure 1**).

HIGHLIGHTS

- The position of a production nursery in a catchment influences storm and flood hazards.
- Upper catchment sites tend to have water quality issues due to local erosion and storm runoff.
- Middle catchment sites may receive water and contaminants from upstream and yield them to downstream areas.
- Lower catchment sites may have long floods and can receive contaminated water from upstream.

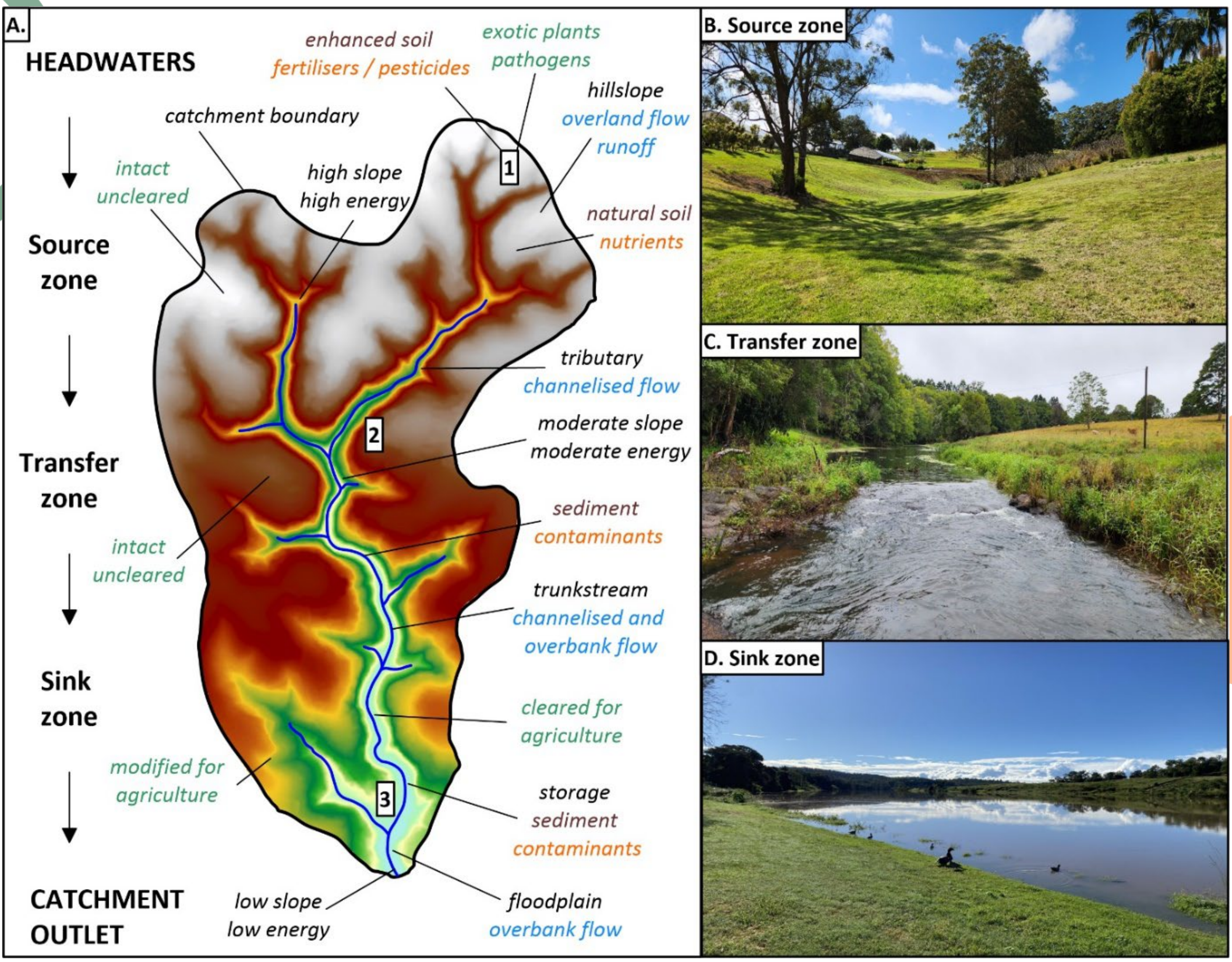

Figure 1. A typical catchment (A) with zones to indicate how water, sediment, and contaminants may move from high-elevation headwaters to a low-elevation outlet, past production nurseries at locations 1, 2 and 3. Example photographs of (B) a small waterway in a source zone, (C) a moderate waterway in a transfer zone, and (D) a large river in a sink zone (Gomes et al., 2025).

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Storms and Floods

OVERVIEW

- Storms and floods may cause damage to agricultural landscapes, including production nurseries.
- Excess water in the landscape can cause soil erosion, disrupt sediment in water bodies (e.g., earth dams), and damage infrastructure.
- Floodwaters move sediment, nutrients, heavy metals, weeds, and pathogens in catchments (**Figure 1**).

KEY FACTORS

- Storm and flood hazards are complex, with several conditions that can increase the risk of severe impacts, including:
  - Size and severity of storm cells.
  - Presence or absence of hard surfaces to influence runoff in catchments.
  - Storm tracking from the top of a catchment to the bottom (i.e., higher risk in lower catchment), or travelling across the headwaters (i.e., higher risk in upper catchment).
  - Successive storms over several days or weeks.
  - Heavy rainfall after drought.
  - Heavy rainfall after a bushfire.
  - Long periods of heavy rainfall.
  - Intensive land use change or bare soil in a catchment.
  - Coincidence with king tides or storm surges in lower parts of coastal catchments.
  - Proximity to waterways and floodplains.

HIGHLIGHTS

- Storms and floods can threaten the safety and productivity of nurseries.
- Floodwaters move contaminants and pathogens through the landscape.
- Awareness of local risk factors is important, including weather and catchment conditions.
- The NSW State Emergency Service, Bureau of Meteorology, and NSW Government have resources available.

MANAGEMENT

- Resources and current flood warnings are available at the NSW SES website.
- The Bureau of Meteorology has resources available at the Flood Knowledge Centre website.
- The NSW Government's Hazards Near Me app can notify you of local emergencies.
- Flood risk maps and flood management plans are available through local councils.
- Being prepared and having a storm and flood plan in place will promote efficient and appropriate actions during severe weather situations.
- It is very important to consider and understand the location within a catchment (headwaters, middle, or low) when evaluating flood risk.

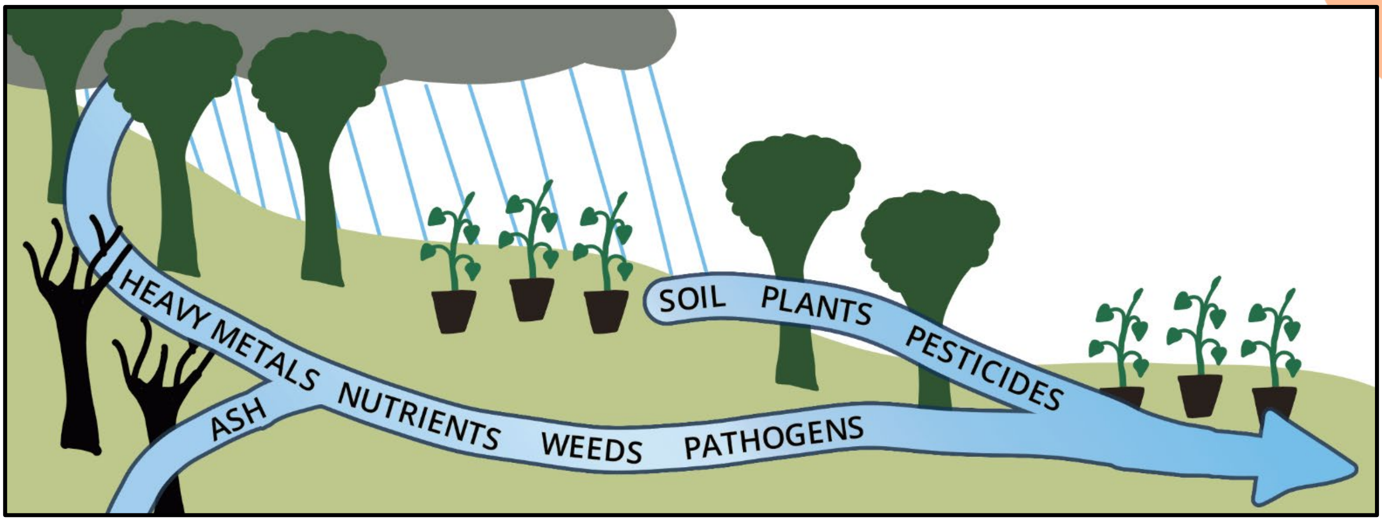

Figure 1. An example of how storms and floods can move overland transporting soil and sediment particles, and contaminants.

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Water Sampling

OVERVIEW

- Collecting water samples for further testing is a good way to assess and monitor water quality and identify potential issues.
- Selecting the right time to collect water samples is important, with factors including recent weather, storm and flood events, and water levels to be considered.
- If your sample cannot be sent to the laboratory immediately, follow their instructions for storage.

HIGHLIGHTS

- Collecting water samples to send to a laboratory for testing of water quality parameters is a fast and simple way to assess water quality.
- Label sample collection forms and containers consistently and in multiple locations.
- Collect water samples without disturbing underlying sediment for more accurate results.

SAMPLING PROCEDURE

1. Fill out a collection form with sample details (**Figure 1**).
- Include contact information, sample location and date, and which tests you want performed.

2. Label a sample container (**Figure 2**).
- Check that the sample label matches the form.
- Label top and sides of container.

3. Collect a water sample (**Figure 3**).
- Use appropriate PPE, including disposable gloves.
- Try to collect water without disturbing the underlying sediment.
- Try to collect water from the middle of the water column (not exclusively from the surface).

4. Place the water sample container in a sample bag.
- Wipe off the sample container so that the interior of the bag stays dry, then carefully seal and label the bag.

5. Affix the collection form to the sample bag and ready for delivery to the laboratory for analysis (**Figure 4**).

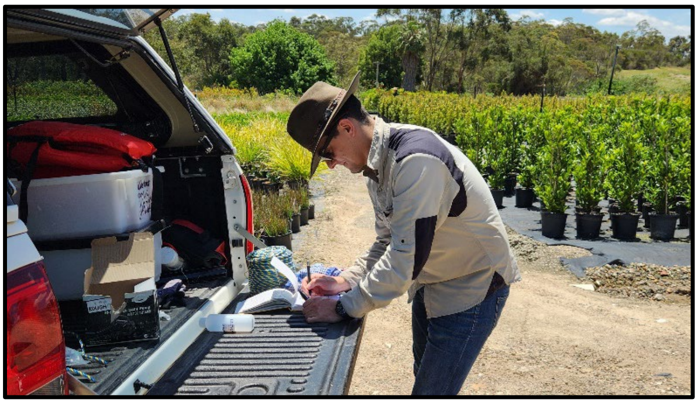

Figure 1. Filling out the sample collection form.

Figure 2. Labeled sample containers on top and sides.

Figure 3. Collecting a sample from a shallow water column.

Figure 4. Affixing the sample collection form to the sample bag and preparing the sample for delivery to the laboratory.

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pH and Alkalinity

OVERVIEW: pH

- pH is a measure of how acidic or alkaline (basic) a solution is, linked to its hydrogen ion concentration.
- A pH of 5.5–7.0 is considered optimal for most nursery plants; values below 5.5 are generally too acidic, and above 7.5 are generally too alkaline.
- The pH scale is logarithmic, as each whole-number change represents a tenfold difference in acidity or alkalinity. For example, water with pH 5 is 10 times more acidic than water with pH 6.
- pH directly affects nutrient solubility and uptake by plants (**Figure 1**) and can impact the performance and lifespan of irrigation infrastructure (**Figure 2**).

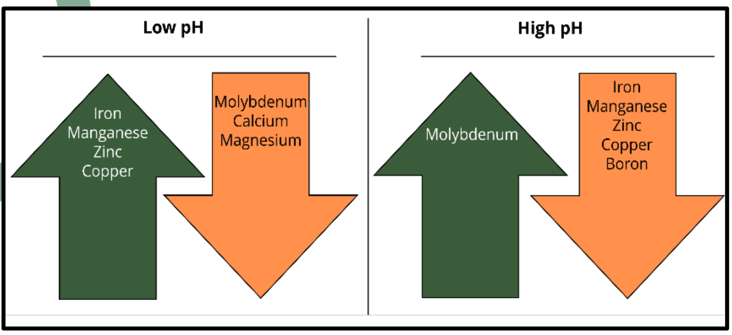

Figure 1. Effects of low and high pH on plant nutrient uptake.

HIGHLIGHTS

- Water pH and alkalinity strongly influence nutrient solubility and plant health.
- In general, a pH level between 5.5 to 7.0 is good for most nursery crops.
- Managing both pH and alkalinity is essential for maintaining healthy, productive nursery plants, especially in container systems with limited buffering capacity.
- Regular monitoring and timely adjustments of pH and alkalinity can prevent long-term issues.

OVERVIEW: Alkalinity

- Alkalinity is a measure of the capacity of water to neutralise acids and indicates how resistant a solution is to changes in pH, or its buffering capacity.
- Alkalinity is not the same as water being "alkaline."
- Alkalinity is influenced by dissolved compounds such as carbonates, bicarbonates and hydroxides, and is often linked to water hardness.
- High alkalinity can interfere with nutrient availability, particularly calcium and magnesium, and make pH adjustments more difficult (**Figure 3** on next page).

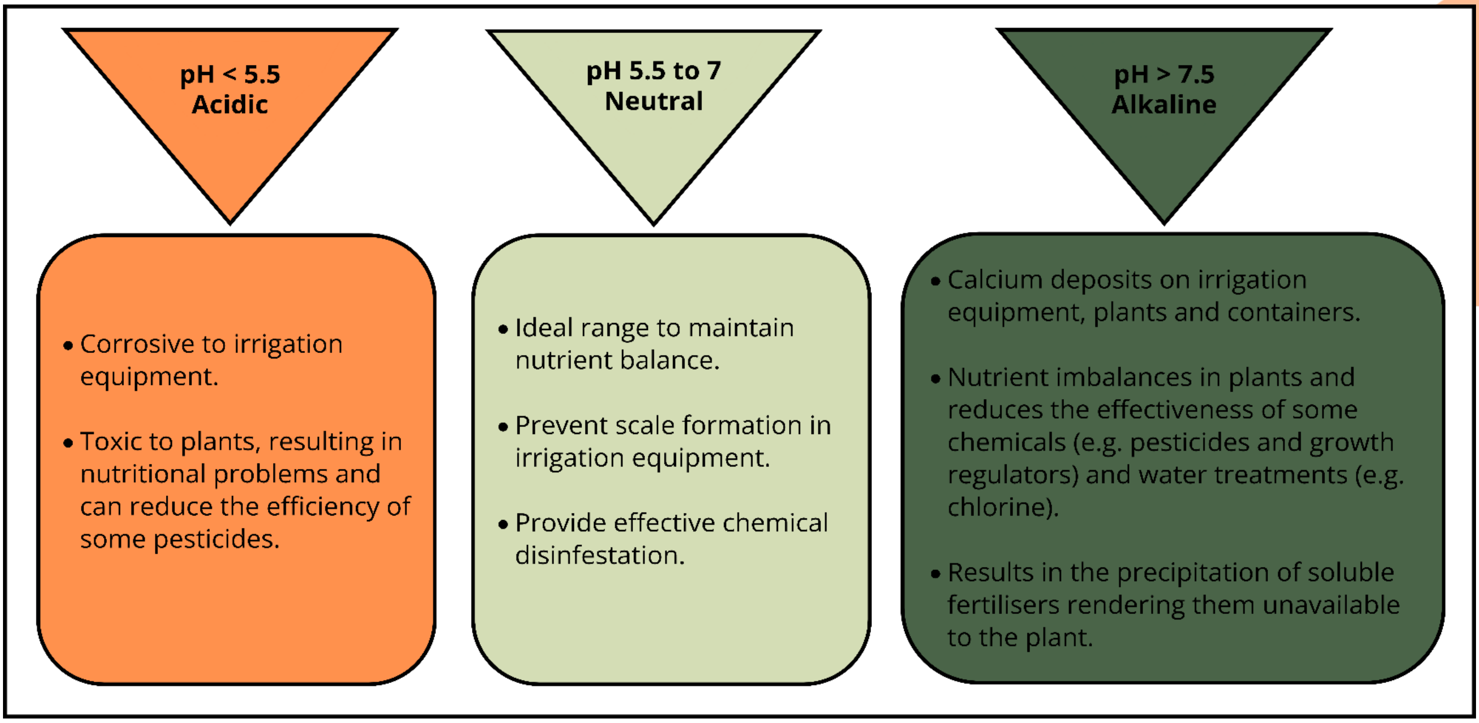

Figure 2. Potential effects of low, neutral, and high pH conditions for containerised nursery plants and equipment.

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pH and Alkalinity

KEY FACTORS

- Water pH influences container soil and substrate solution pH. Soil-less substrates (e.g. peat-based or coconut coir mixes) are generally more susceptible to fluctuations in pH.
- Local underlying geology and sources of water (e.g. surface water, groundwater, rainwater) determine the baseline pH and alkalinity in irrigation water.
- Seasonal changes in rainfall and temperature can cause shifts in water chemistry.
- Fertilisers and supplements can influence pH and alkalinity of irrigation water. For instance, the application of lime to treat soil acidity can raise the pH of both the substrate and irrigation water.
- Sediment, suspended particles, and decomposing organic matter can interact with water and release minerals and organic acids that can influence pH and alkalinity.

MANAGEMENT

- Monitor and test the pH of irrigation water using good quality pH strips or an electronic meter regularly to make informed decisions about pH adjustment and nutrient management.
- pH issues can be resolved by adjusting the buffering capacity of the substrate. For example, high acidity can be treated with agricultural lime (calcium carbonate). Alternatives include changing or blending water sources to bring pH closer to 7.
- Use good quality alkalinity test strips regularly to monitor alkalinity. High alkalinity water can be treated with acid injections (e.g. sulfuric acid, phosphoric acid).
- Alternatively, the addition of sulfate or organic matter can modify soil pH and improve nutrient availability.

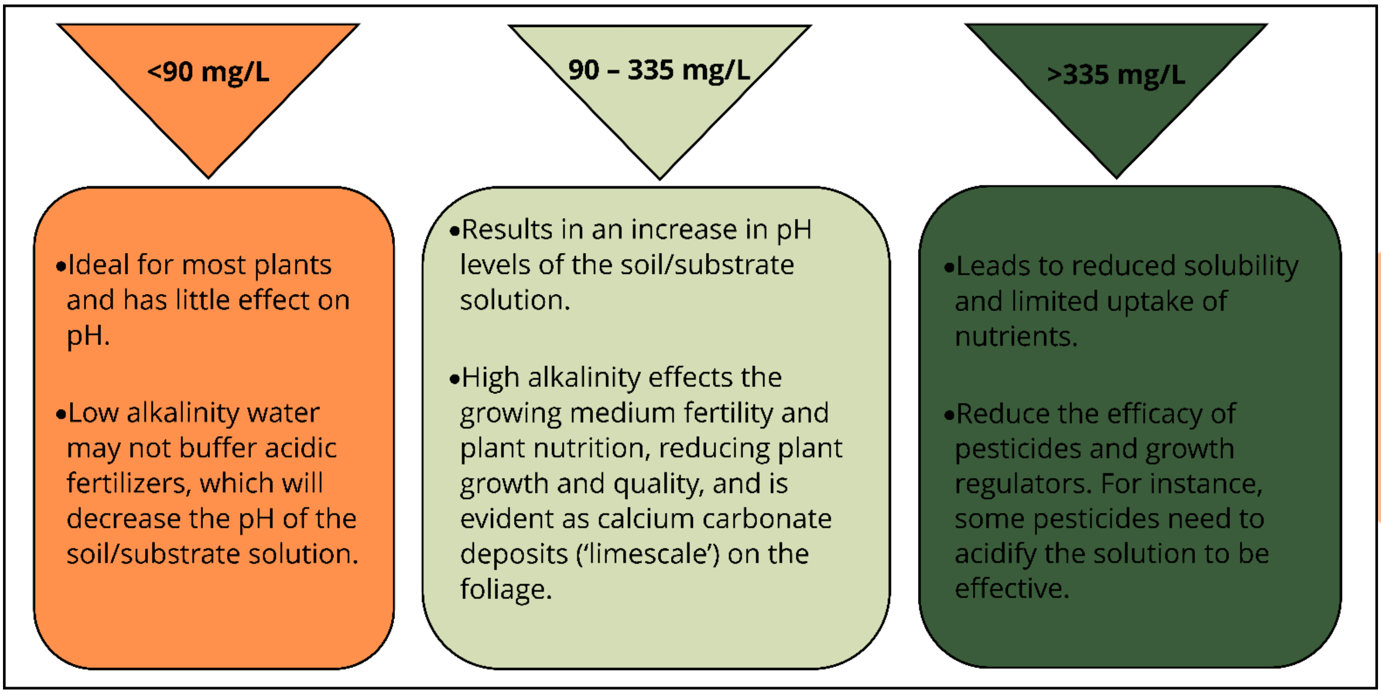

Figure 3. Effects of low, moderate, and high alkalinity on container plants (ANZECC & ARMCANZ, 2000; NSW DPI, 2021).

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Salinity

OVERVIEW

- Salinity refers to the total concentration of soluble salts/ions in water or soil (sometimes called total dissolved solids; TDS).
- High salinity in irrigation water may cause extreme ionic ratios in the soil/substrate solution which can induce nutritional imbalances in plants.
- A primary cause of salinity is excess sodium, but other salts contribute to salinity as well (**Figure 1**).

KEY FACTORS

- Salt is produced by natural processes, like weathering of rocks, and can be stored deep in soils, or as surface salt crusts, or dissolved in water (**Figure 2**).
- Anthropogenic inputs of salt occur through altered land use (e.g., vegetation clearance, poor land management, excess irrigation, and industrial practices).
- Factors that affect water volume can affect salinity (e.g., heavy rain or evaporation).
- Runoff or flooding over soils that are high in salts or minerals can cause a spike in salinity despite the increase in water flow.
- Sodium is an essential element for some plants, but most nursery plants have low sodium requirements.
- Gypsum is used to address high sodium content in soil, as it helps break down clay and improve drainage, promoting root growth and nutrient uptake.
- Sodicity and chlorine are two important components within salinity (**Figure 3** on next page).
- Sodicity is measured by the sodium absorption ratio (SAR) which refers to the amount of sodium, calcium, and magnesium ions present.
- Chlorine is a micronutrient needed in small quantities by plants. Excessive amounts can be toxic to plants and negatively affect plant growth and cause plant damage or reduced yields.

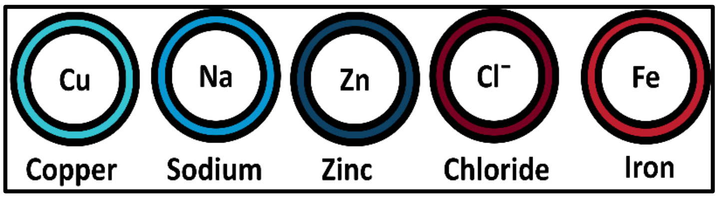

Figure 1. Examples of salts that can impact salinity.

HIGHLIGHTS

- Salinity is a measure of the concentration of dissolved salts present in water or soil.
- Salinity can affect plant growth and quality by either a specific ion toxicity or as a general salinity effect by reducing water availability to plants.
- High salinity can be managed by changing fertiliser and irrigation water sources and by growing plants with higher salinity tolerances.

MANAGEMENT

- Salinity is usually measured indirectly by checking electrical conductivity (EC). EC does not indicate the type of salts present (e.g. sodium, chloride, iron, copper, or zinc).
- Salinity requirements vary depending on what species of plants are present (**Table 1**).
- Calcium can balance high sodium levels in water.
- Employing efficient irrigation and drainage techniques, and redesigning the timing, volumes and locations of irrigation could help to reduce salinity levels.
- Reducing fertiliser rates and using less soluble fertilisers can reduce salinity.
- Organic fertilisers may contribute to soil salinisation due to unbalanced nutrients.
- Controlled leaching may alleviate salinity problems.

Figure 2. Surface salt deposits in an agricultural plot. (Photograph: Petrus Langenhoven)

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Salinity

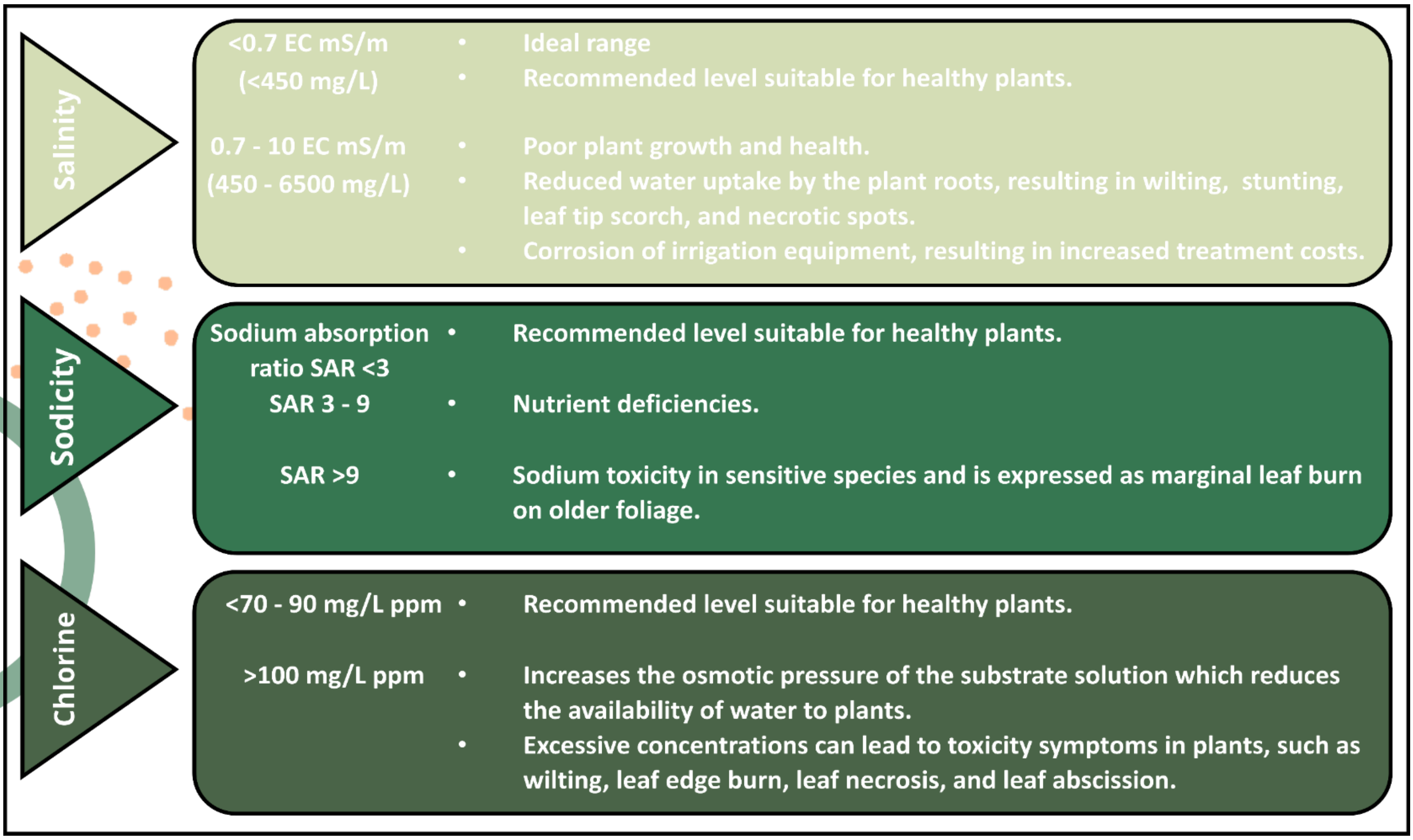

Figure 3: Effects of salinity, sodicity, and chlorine on container production plants and nursery equipment (ANZECC & ARMCANZ, 2000; NSW DPI, 2016).

Salt tolerance	Examples of plants
Sensitive EC: 0–0.7 mS/m Salt: 0–400 mg/L	African violet, Azalea, Begonia, Camellia, Dahlia, Fuchsia, Gardenia, Hydrangea, Magnolia, Primula, Violet
Low tolerance EC: 0.65–1.3 mS/m Salt: 400–850 mg/L	Acacia longifolia, Australian tea–tree, Aster, Bauhinia, Geranium, Gladiolus, Lily, Poinsettia, Rose, Strelitzia, Zinnia
Medium tolerance EC: 1.3–3 mS/m Salt: 830–1900 mg/L	Algerian ivy, bottlebrush, Chrysanthemum, carnation, false acacia, heavenly bamboo, Hibiscus, Japanese yew, morrell, Musa, orchid tree, Podocarpus, redleaf, banana, stock, swamp yate, York gum
High tolerance EC: 3.0–5 mS/m Salt: 1900–3200 mg/L	Bougainvillea, bamboo, canary palm, NZ Christmas bush, native pine, oleander, Sansevieria, Vinca
Very high tolerance EC: 5–8 mS/m Salt: 3200–5100 mg/L	Banksia, Coprosma, ice plants, Norfolk Island pine, pampas grass, salt bushes, salt river gum, she–oak, tamarisk

Table 1: Examples of the salt tolerance of different plants, indicated by EC units in millisiemens per metre (mS/m) and corresponding salt levels in milligrams per liter (mg/L) (ANZECC & ARMCANZ, 2000; Cassaniti et al., 2012; NSW DPI, 2016).

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Water Hardness

OVERVIEW

- 'Hard water' refers to water with high concentrations of dissolved minerals, specifically calcium and magnesium ions (**Figure 1**).
- Hard water tends to be associated with high levels of bicarbonate and serves as an indirect indicator of water alkalinity.
- Plants have varying sensitivities to water hardness, which is important for selecting appropriate plant varieties and assessing the suitability of a water source for irrigation (**Figure 2**).
- The ideal range for water hardness is 60–180 ppm of calcium carbonate ($CaCO_3$) (i.e., moderate to hard).

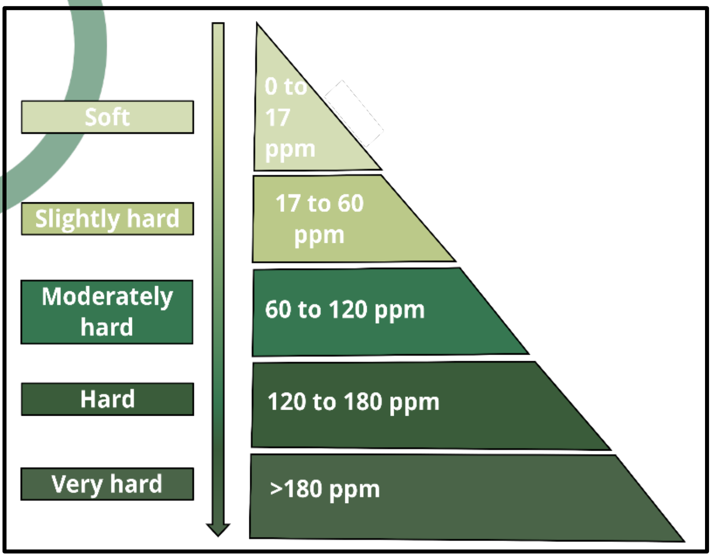

Figure 1. Hardness ranges of water sources, measured in parts per million (ppm) of calcium carbonate ($CaCO_3$) (USGS, N.D.)

KEY FACTORS

- The geological characteristics of a region influences water hardness. Groundwater that flows through calcium and magnesium-rich geological formations, including limestone, dolomite, gypsum, or chalk is likely to have elevated hardness levels.
- The use of fertilisers containing calcium and magnesium can also lead to the leaching of these minerals into water sources.
- Rivers can also be sources of hard water if they receive runoff from areas with naturally occurring minerals.

HIGHLIGHTS

- High water hardness is often associated with increased salinity and alkalinity, which can negatively impact plant growth and productivity.
- Hard water can lead to scale buildup on irrigation equipment, resulting in increased maintenance costs.
- Managing water hardness is crucial for maintaining optimal conditions for plant growth and may require water treatment.

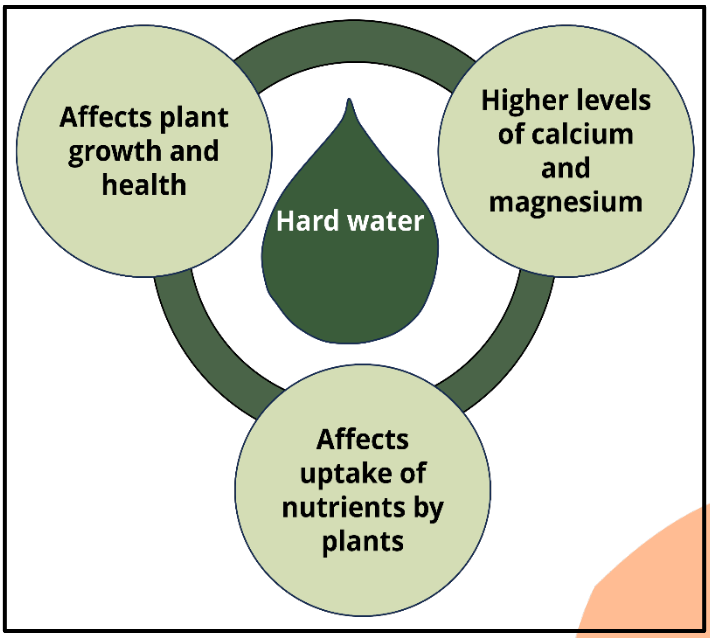

Figure 2. Effects of hard water on plants.

MANAGEMENT

- Test irrigation water for hardness monthly using a handheld meter to understand its mineral composition and quality.
- Hard water can occur without high alkalinity. A good method for testing hard water is to first assess alkalinity, then chloride, calcium, and magnesium concentrations.
- Water treatment methods that use chemicals, such as lime to adjust pH and coagulate suspended particles can increase water hardness.
- Common methods for softening hard water include ion exchange (water softeners), lime softening, and reverse osmosis.

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Heavy Metals

OVERVIEW

- Heavy metals are elements in the environment that can become contaminants in water and soil through various activities.
- Trace metals and some heavy metals (in low doses) are important micronutrients needed for plant metabolism.
- High loads of heavy metals are a significant concern, as they can have detrimental effects on soil/growing media quality and plant health (**Figure 1**).

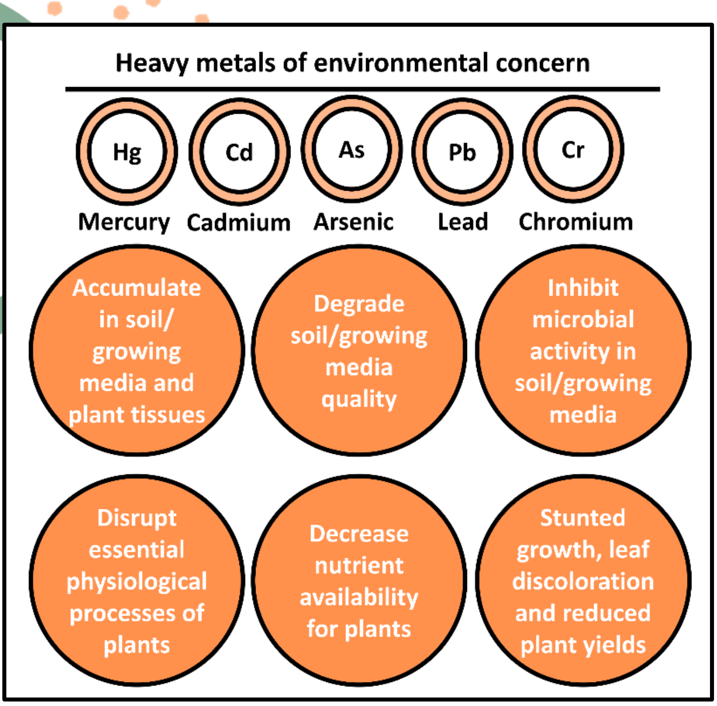

Figure 1. Some heavy metals of environmental concern and their possible effects on plant life.

KEY FACTORS

- Heavy metals can be released into the environment through natural processes (e.g., bushfires, floods) and human activities (e.g., land use, soil disturbance).
- Some fertilisers and pesticides can introduce heavy metals into soil/growing media and water.
- High levels of heavy metals in irrigation water can be toxic to plants (**Table 1**).
- The discharge of water containing heavy metals into natural water bodies or the environment can lead to pollution which can affect aquatic life and impact ecosystems.

HIGHLIGHTS

- Heavy metals can be harmful to plants and the environment.
- Irrigation water should be tested for heavy metals and consideration given to their impacts.
- Phytoremediation, erosion control, soil additives, and pre-application water treatment can reduce heavy metal availability to plants.

MANAGEMENT

- Test irrigation water sources for the presence of heavy metals on a regular basis.
- Pre-application water treatment options (e.g., filtration, coagulation, and sedimentation) can remove heavy metals from the irrigation water.
- Phytoremediation, the process of using plants to accumulate heavy metals, can be used to remove heavy metals from the surrounding land around the edges of the nursery/dam.
- The addition of soil organic matter and lime can improve soil/growing media quality and reduce heavy metal availability to plants.
- Implement best management practices, including erosion control measures, to prevent the entry of heavy metals into water sources.

Element	Limit (mg/L)	Element	Limit (mg/L)
Aluminium	5.0	Lithium	2.5
Arsenic	0.1	Lead	5.0
Beryllium	0.1	Manganese	0.2
Cadmium	0.01	Molybdenum	0.01
Cobalt	0.05	Nickel	0.2
Chromium	0.1	Selenium	0.02
Copper	0.2	Vanadium	0.1
Fluoride	1.0	Zinc	2.0
Iron	5.0		

Table 1. Recommended limits for heavy metals and trace elements in irrigation water, based on a use rate of 10,000 m^3/hectare/year (ANZECC & ARMCANZ, 2000).

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Nutrients

OVERVIEW

- Macro- and micro-nutrients are essential for healthy plant growth.
- In a water source, high nutrients and increased temperature can lead to an increase in biological growth and harmful algal blooms.
- Algae blooms (**Table 1**) and biofilm or bacterial growths can block irrigation equipment and may be health hazards for humans, plants, or animals.
- In some cases, excess nutrients allow blue-green algae to grow in the soil of container plants, potentially leading to pathogenic collar rot fungi.
- More information is available from NSW DPI: https://www.dpi.nsw.gov.au/agriculture/water/quality/pubs-and-info/blue-green-algae

Common name	Scientific name
Filamentous green algae	*Godophora spp.* *Hydrodictyon spp.* *Spirogyra spp.*
Stoneworts	*Charo spp.* *Nitella spp.*
Blue-green algae	*Anocystis cyonea* *Anabaeno circinalis*
Diatoms	*Navicula spp.* *Cycotella spp.* *Aulacoseira spp.*
Euglenoids	*Euglena spp.*

Table 1. Common types of algae found in water sources.

KEY FACTORS

- Overapplication of fertilisers can lead to excess nutrients and the accumulation of salts and toxic ions in plants.
- Overwatering can lead to nutrients leaching out of container plants into drains, where they eventually accumulate in a water source.
- Surface runoff from agricultural, urban, and industrial areas can introduce nutrients, sediments, and organic matter into water sources, resulting in increased algal growth and turbidity levels.
- Erosion and bushfires, particularly preceding large storms, can result in increased nutrient loads in water sources.

HIGHLIGHTS

- It is important to test water nutrient concentrations, allowing the development of a targeted treatment plan.
- Treatment of nutrients in irrigation water is essential for maintaining optimal conditions for plant growth while preventing nutrient-related issues, including over-fertilisation, nutrient imbalances, and environmental contamination.

MANAGEMENT

- Keep nutrient concentrations in irrigation water within the recommended limits (**Table 2**).
- Regular testing of water quality will help track nutrients in irrigation water and pick treatments.
- Reverse osmosis (RO) systems remove a wide range of nutrients. RO water can be used to dilute nutrient-rich water.
- Filtration systems, settling tanks, aeration pumps, and sedimentation basins can be used to remove particulate matter, which may carry nutrients.

Macronutrients	Upper limit for greenhouse plants
Total Nitrogen	<5 mg/L
Nitrate	<5 mg/L
Ammonium	<5 mg/L
Phosphorus	<0.05 mg/L
Phosphate	<0.05 mg/L
Potassium	<3 mg/L
Calcium	<120 mg/L
Magnesium	<25mg/L
Sulfur and Sulfate	20–30 mg/L
Micronutrients	
Aluminium	<5 mg/L
Boron	<0.5 mg/L
Copper	<0.2 mg/L
Fluoride	<1 mg/L
Iron	<0.2 mg/L
Manganese	<0.2 mg/L
Zinc	<2 mg/L

Table 2. Recommended concentration limits for nutrients in irrigation water for greenhouse and nursery plants (NSW DPI, 2021; ANZECC & ARMCANZ, 2000; UC Cooperative Extension, 2009), Cassanti et al., 2012).

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Ralph et al. (2025). Water quality fact sheets for production nurseries. https://doi.org/10.25949/JH43-4N56

Turbidity

OVERVIEW

- Turbidity is a measurement of the cloudiness or clarity of water.
- Turbidity is affected by total suspended solids (TSS). Suspended sediments and dissolved organic matter increase the turbidity of water.
- Turbid water can contain microorganisms, including pathogens and algae (**Figure 1**).
- Turbid water reduces nutrient and fertiliser effectiveness due to suspended particles. Clear water ensures that nutrients are delivered to plants.
- Turbid water can reduce the aesthetic appearance of plants with possible effects on their marketability and price (**Figure 2**).

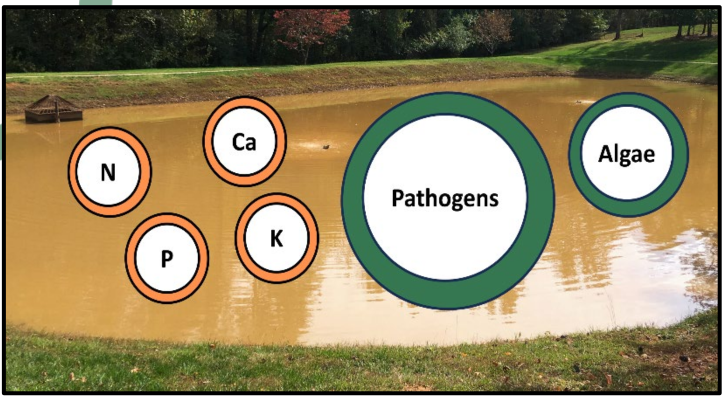

Figure 1. Suspended sediments, pathogens, and algae can contribute to high turbidity.

KEY FACTORS

- Soil erosion and sediment runoff in the landscape are natural processes, but particularly during heavy rainfall and flood events, water sources are prone to increased sedimentation.
- Runoff from urban and agricultural areas transfers debris, pollutants and sediments into water sources.
- Cyanobacteria blooms and die-off can release organic matter and cellular debris that can increase water turbidity.
- Water treatment systems can contribute to turbidity if not properly maintained. Corrosion, pipe scaling, or sediment buildup can release particles into the water source.

HIGHLIGHTS

- Turbidity is a measure of how much matter is suspended in water.
- High turbidity can negatively affect plants by reducing nutrient uptake and water absorption.
- High turbidity can be caused by sediment, microorganisms, or dissolved organic matter.
- Water filtration, irrigation maintenance, and erosion control can help keep turbidity low.

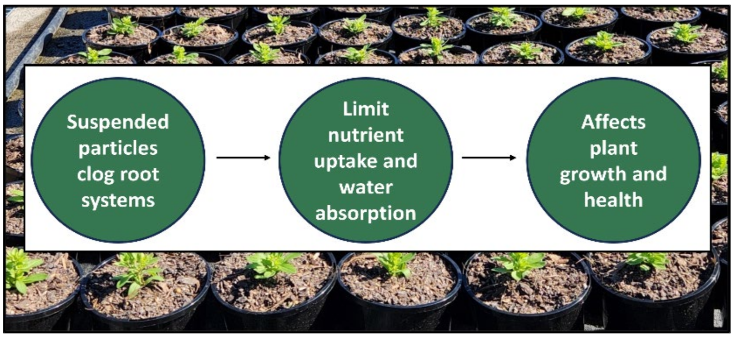

Figure 2. High turbidity may have negative effects on plants.

MANAGEMENT

- Regular monitoring is essential to managing water turbidity. Treating water turbidity can ensure optimal growing conditions, reduce the risk of disease, enhance plant yields, and reduce operational and maintenance costs.
- Control measures, like filters, nutrient retention ponds, sedimentation basins, or coagulation-flocculation processes can be used to settle suspended particles before water is used for irrigation.
- Ultraviolet disinfection systems can be used to eliminate microorganisms and algae that may contribute to turbidity.
- Regular maintenance and service of irrigation systems and other equipment to prevent clogging and damage caused by turbid water.
- Best management practices for water use, including erosion control measures and responsible use of water resources can ensure good water quality.

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Sediment

OVERVIEW

- Sediment refers to particles of soil and other matter (e.g., organic particles) that can move in the landscape.
- Sediments in waterways, drains and water storages may contain contaminants, including trace elements (e.g., heavy metals), nutrients, salt, and pathogens.
- Phytophthora can be found on the surface of pond sediments and throughout the water column.
- Below the top few centimetres, underwater sediment is typically anoxic (without oxygen). This affects how contaminants can move through the system.
- Disturbing sediment on nursery lots and in water storages leads to chemical and biological reactions.

KEY FACTORS

- Sediment build-up in water storages is caused by erosion uphill, and runoff carries loose material into the water storage where it settles on the bottom.
- The addition of sediment to the water, or disturbance of sediment in the bottom of a water storage, releases trapped nutrients, metals, pathogens and other contaminants into the water.
- Dredging, heavy rainfall, flooding, manual removal of aquatic plants, fish, and use of ponds by humans or animals can all disturb sediment.
- The release of nutrients from sediment after major disturbance can encourage algal blooms.

HIGHLIGHTS

- Sediment in waterways and in water storages can contain high loads of heavy metals, nutrients, and pathogens including *Phytophthora*.
- Disturbing sediment can release those contaminants into the water.
- Filtration of water before using it in irrigation is encouraged.
- After a disturbance to sediment in a water storage, allow enough time for the sediment to settle again before using the water for irrigation.

MANAGEMENT

- Maintenance and dredging of water storages should be carefully planned.
- Performing sediment testing ahead of time is recommended, especially if you plan to reuse the sediment elsewhere on-site.
- After a significant disturbance event, try to allow the sediment to settle before the pond is used to provide irrigation water.
- Filtering pond water (e.g., through a sand filter, flocculation tank, or bioreactor) before using it to irrigate plants is encouraged.
- Sediment build-up can be slowed by reducing erosion and planting vegetation around the edges of a water storage.

Figure 1. Example of photos of a water storage showing changes in water level and water quality indicated by turbidity. A) before rainfall and runoff, B) hours after rainfall and runoff with suspended sediment, pathogens, and algae.

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Pathogens

OVERVIEW

- Pathogens are microorganisms, including bacteria, viruses, protozoa, and parasites, that can cause diseases in plants of production nurseries.
- These organisms can impair plant growth by disrupting nutrient and water uptake, reducing yield and overall plant health (**Figure 1**).
- Infected plants often exhibit increased vulnerability to environmental stress and secondary pests or diseases.

HIGHLIGHTS

- Production nursery water sources can be a major vector for pathogen spread, affecting both plant health and water quality.
- Preventive action and infrastructure hygiene are critical for reducing pathogen load in nurseries.
- Management approaches combining water treatment, sanitation, and monitoring are the most effective way to protect plant health.

KEY FACTORS

- Pathogens such as *Phytophthora*, *Phytopythium*, and *Pythium* are widespread in nursery soils, water bodies (e.g., dams and tanks) and irrigation systems, and can cause severe root and stem diseases (**Figure 2**).
- Fungal infections, including powdery mildew and downy mildew, affect aboveground tissues like leaves and stems, resulting in lesions, wilting, or discoloration.
- Soil-borne pathogens such as root-knot nematodes and pathogenic fungi cause diseases like damping-off and root rot, weakening root systems and limiting plant access to water and nutrients.
- Pathogens may enter water supplies through surface runoff from agricultural and urban areas, especially after rain events.
- Damaged or poorly maintained irrigation infrastructure (e.g., cracked pipes, leaks) can become entry points or reservoirs for pathogens.

Figure 1. Fusarium wilt symptoms on leaflets. Source: UC Cooperative Extension, Los Angeles County. Accessed September 9, 2024.

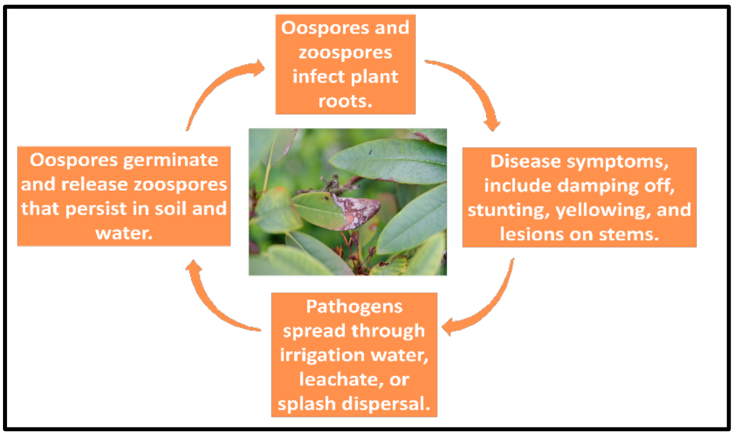

Figure 2. Example of *Phytophthora* infection and its lifecycle.

MANAGEMENT

- Routinely inspect plants for symptoms of disease. Quarantine new stock before integrating with existing nursery plants to limit pathogen introduction.
- Avoid excess watering because saturated soils promote pathogen proliferation. Use drip irrigation where possible to reduce moisture on foliage and soil surfaces.
- Treat irrigation water using UV disinfection, chlorination, ozonation, or filtration to inactivate or remove pathogens.
- Practice strict hygiene and regularly clean equipment, remove diseased plant material and standing water to limit pathogen persistence.
- Adopt an integrated pathogen management strategy that combines preventive practices, ongoing monitoring and testing, and targeted control measures to minimise impacts.

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Aquatic Biota

OVERVIEW

- Aquatic biota such as fish, invertebrates, and zooplankton are often used to monitor ecosystem health in rivers, lakes, and ponds.
- Invertebrates and zooplankton are part of the aquatic food web and provide food for fish, platypuses, birds, bats, and other animals (**Figure 1**).
- Some aquatic biota are pollution-tolerant and can survive in low-quality habitat. Others are pollution-sensitive and require high-quality habitat (**Figure 2**).
- Healthy water bodies generally have many different species, including ones that are sensitive to pollution.

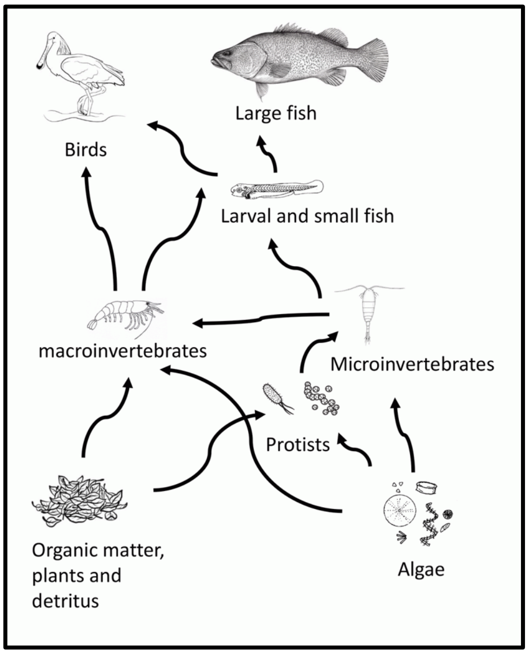

Figure 1. Simplified aquatic food web (Hitchcock, 2021).

KEY FACTORS

- Water temperature, pH, dissolved oxygen, organic matter, plants, and flow are all important aspects of habitat for aquatic biota.
- Many human activities can indirectly affect aquatic habitat. One example is non-point source pollution, which increases the amount of sediment and fertiliser in the water.
- Pollution can change the pH, increase the bioavailability of metals, add excess nutrients, and reduce dissolved oxygen, all of which harm aquatic biota.

HIGHLIGHTS

- Aquatic biota are indicators of water quality and ecosystem health.
- Many aquatic biota are sensitive to pollution and can be affected by human activities, including non-point source pollution.
- Biomonitoring can provide insight about water quality and ecosystem health.

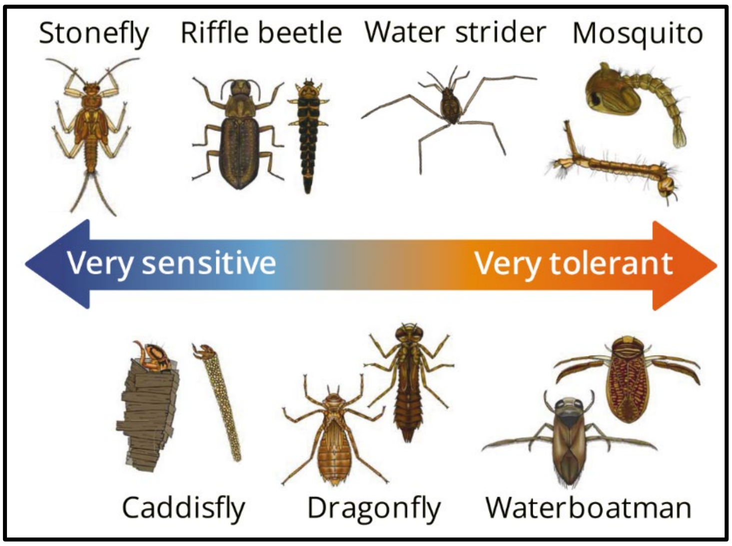

Figure 2. Aquatic macroinvertebrate sensitivity (modified from Waterwatch NSW (N.D.); illustrations by C. Rockley).

MANAGEMENT

- Most management of aquatic biota in agricultural settings is indirect. Adjusting land use to minimize sediment- and fertiliser-laden runoff can provide significant benefits.
- Biomonitoring provides more insight into aquatic health and water quality than water samples alone, especially with repeated samples over time.
- Compare observed biotic responses with environmental quality standards to evaluate contamination impacts.
- Identify areas of high ecological importance and monitor signs of ecosystem stress or degradation.
- Aquatic biota rely on good water quality but also help to improve water quality through filtration and bio-uptake of nutrients and contaminants.

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Weeds

OVERVIEW

- 'Weeds' are different in legal, agricultural, and environmental contexts, but are generally defined as plants growing in an undesirable place.
- Many aquatic plants, even ones that are normally beneficial, can become weeds under the right conditions (**Table 1**).
- Weed seeds may be introduced from upstream in the catchment, or from elsewhere on the nursery lot.
- Not all plants are weeds – aquatic plants in water storages play an important role in nutrient buffering, bank stabilisation, sediment trapping, and oxygenation. In addition, they reduce evaporation rates, keep a consistent water temperature, and provide habitat for aquatic biota.
- However, rapid aquatic plant growth can lead to the entire water surface being covered, resulting in oxygen depletion and deterioration of water quality.
- Additionally, some plants cause blockages to irrigation pipes or impede water intake to pumping equipment (**Figure 1**).

Aquatic habitat	Example species
Free-floating plants	Lemna species, Wolffia species and Spirodela species, salvinia (*Salvinia molesta*), water hyacinth (*Eichhornia crassipes*), and water lettuce (*Pistia stratiotes*)
Floating attached plants	Waterlilies (*Nymphaea* species) and alligator weed (**Figure 1**; *Alternanthera philoxeroides*)
Submerged plants	Native ribbon weed (*Vallisneria americana*), elodea (*Elodea canadensis*), dense waterweed (*Egeria densa*), water milfoils (*Myriophyllum species*), and Cabomba (*Cabomba caroliniana*)
Emergent plants	Peruvian water primrose (*Ludwigia peruviana*), glush weed (*Hygrophila costata*), Senegal tea (*Gymnocoronis spilanthoides*), and horsetails (*Equisetum species*).

Table 1: Examples of aquatic plants that can become weeds.

HIGHLIGHTS

- Aquatic weeds can grow excessively when nutrients and other contaminants sit in water storages, which can be problematic and may cause eutrophication once they die and decompose.
- Prevention measures include reducing nutrient inputs to dams and filtering and aerating dam water.
- Treat aquatic weeds when they become problematic and clog irrigation pumps. Identify problem species and apply the correct treatment. Manual removal of decaying plants is essential.

Figure 1. Alligator weed (*A. philoxeroides*) grows in water and on land and can form dense mats that block irrigation pumps. Reporting requirements vary in NSW (Photo: R.H. Mohlenbrock, USDA public domain).

KEY FACTORS

- Nutrient-rich water can lead to excess plant growth.
- Warm temperatures and sunlight encourage plant and weed growth in water storages, so shading dams may help to slow plant growth.
- Surface runoff from surrounding agricultural, urban, and industrial areas can introduce nutrients, sediments, particulate organic matter, and dissolved organic matter into dams, resulting in increased aquatic plant growth.
- Aquatic weeds (e.g., algal blooms) can be problematic and may cause eutrophication once they die and decompose.

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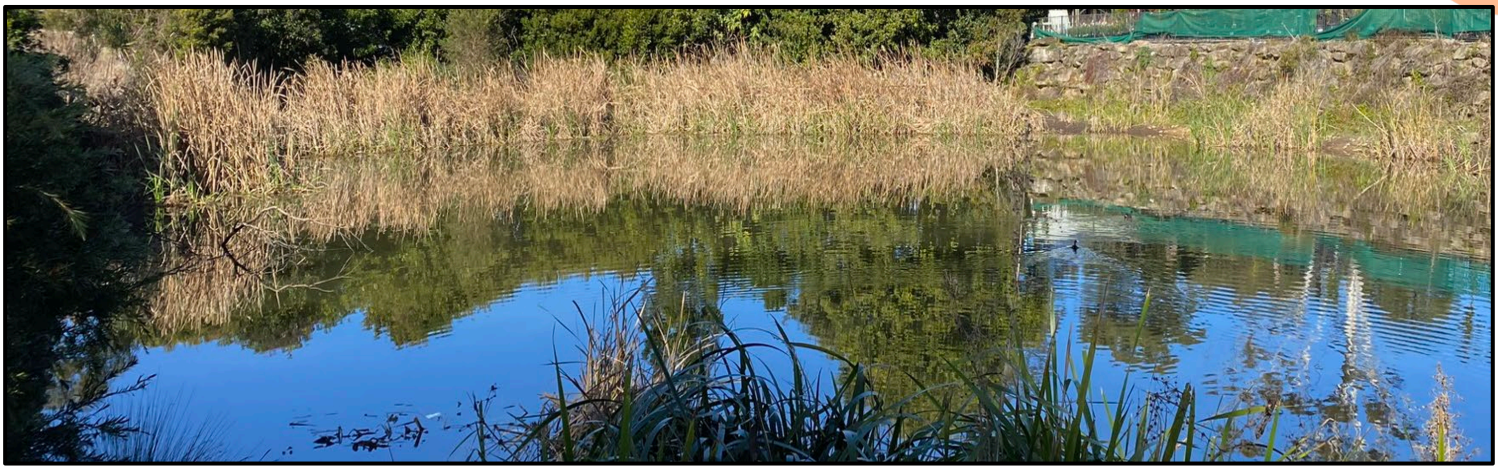
Weeds

MANAGEMENT

- Free tools such as NSW WeedWise (https://weeds.dpi.nsw.gov.au/), iNaturalist (https://www.inaturalist.org/), and Which Plant Where (https://www.whichplantwhere.com.au/) can be used to identify aquatic plants, check management options, and learn if a plant is reportable under the Biosecurity Act.
- Collect samples of weeds from areas vulnerable to seed dispersal, especially around water entry and exit points, and within water storages. Measure and analyse weed seeds to identify species that may have been transported by floodwaters, aiding in early detection and control.
- Correct identification of the aquatic plant and assessment of the plant's ecology is necessary to ensure the most cost-effective and environmentally sound control techniques are used.
- Chemically treating plants can leave dead and decaying plants in the water which can cause deoxygenation of the water and reduction in water quality. Manually remove dead plants where possible.
- Avoid or minimise algae weed growth by monitoring and treating water storages (e.g., aeration) when eutrophication starts to occur during or after events
- To prevent a recurrence of the problem, manage the water body and its surrounds and use an integrated management approach to provide adequate long-term control.
- Filter water or divert nutrient-rich run off away from the dam, for example, by placing aquatic weed mats or geotextile to prevent spread of weeds and their seeds.
- Plant trees to shade the dam to decrease light available to plants.
- Only consider biological control agents if they are suitable for the particular situation and monitor continuously.



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Adaptive Management

OVERVIEW

- Adaptive management refers to the practice of working to solve a problem by evaluating and learning from the effects of prior actions (**Figure 1**).
- Using an adaptive management approach may take additional time and effort at first, but it is likely to save time in the long-term.
- Keeping organized, consistent records is a key part of adaptive management.
- The approach will depend on the nature of the problem and actions planned to address it.
- Adopting an adaptive management framework approach drawing on existing and new information to identify and prioritise actions can help build resilience in the production nursery industry to storm and flood events.

HIGHLIGHTS

- Adaptive management is a conceptual framework to help guide decision-making, assessment, and monitoring.
- Identify the goals and strategy before taking actions.
- Collect samples consistently so that you can determine if actions were effective.
- Adaptive management is a flexible cycle that builds learning from experiences, so that if a strategy or an action is not working, they can be refined or replaced by new ones.

- For more information, see: Ralph, T.J., Graves, B.P., Gomes, M., 2025. Framework to identify and mitigate water storage contamination concerns at NSW and ACT production nurseries. Macquarie University. https://doi.org/10.25949/AS0X-VX91

STARTING POINT

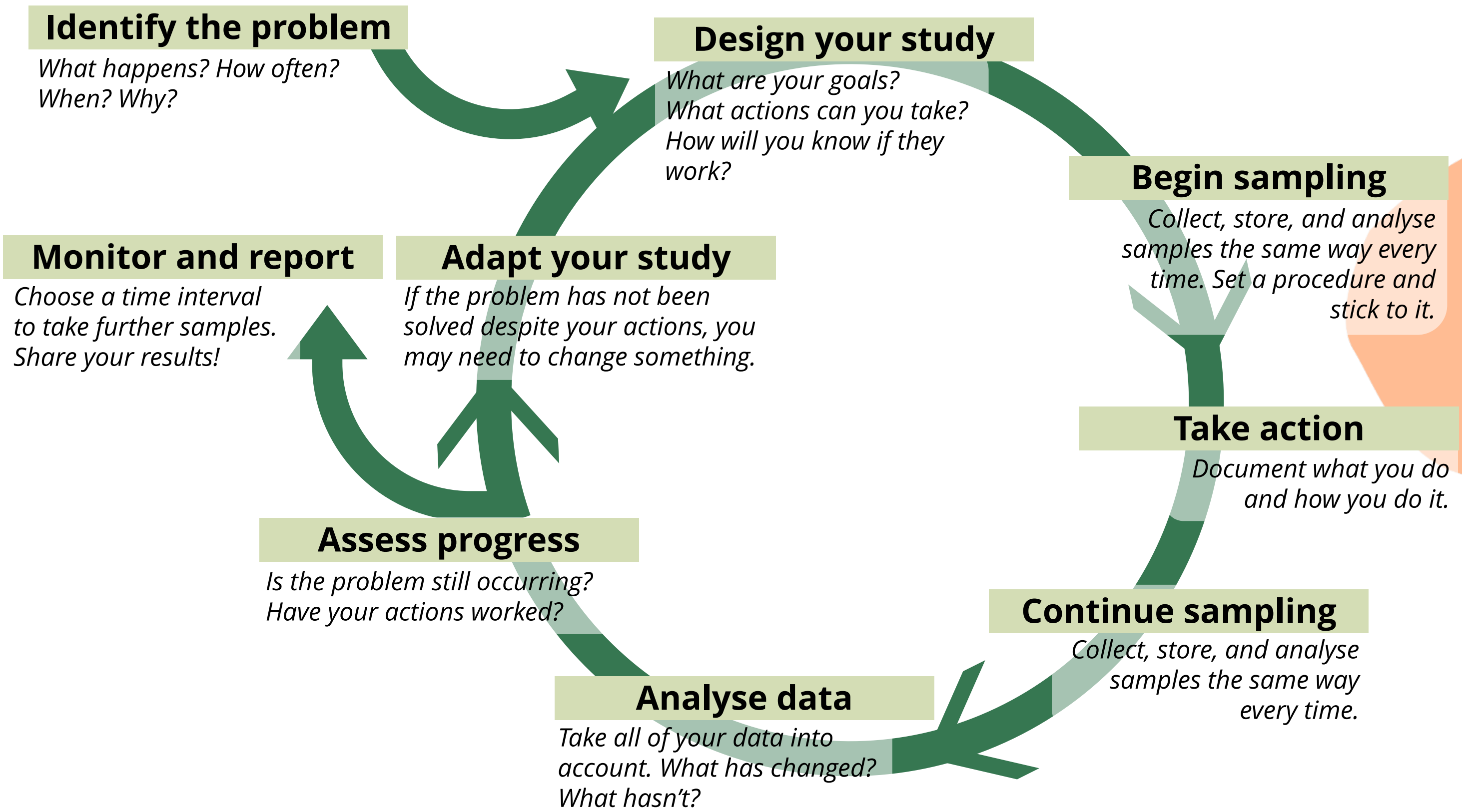

Figure 1. An example adaptive management cycle that is a structured, iterative process for decision-making and focuses on adjusting management strategies based on outcomes and new information.

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