

Marne Saunders Catchment Report Card 2026



Technical Report

Reporting on data for 2023, 2024 and 2025

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Introduction

Technical report for the Marne Saunders catchment report card 2026.

This technical report accompanies the 2026 Marne Saunders report card and provides a detailed account of the data sources, methodologies, and analyses used to evaluate the health of the catchment based on data from 2023, 2024 and 2025. The report card serves as a critical tool for tracking environmental changes and assessing water and ecological conditions within the Marne Saunders catchment.

This second report card includes new and improved naming, criteria and data for indicators for the 2023 year, as well as new reporting for the 2024 and 2025 years. Short-term trends over the 3 years and longer-term trends (where data are available) are also included.

The report card's scoring system draws on multiple indicators, such as surface water flow, refuge pool and temporary flowing water quality, groundwater salinity and depth to groundwater, macroinvertebrate (waterbugs) and fish populations, which were assessed using ecological models and statistical techniques.

Indicators are vital for assessing river health as they show the current state of water resources and water dependent environments by measuring key components of datasets. Reporting on indicators will improve knowledge about how the river system is functioning and identify areas that may require attention.

Data sources include the Waterbug Bioblitz citizen science program for macroinvertebrate monitoring, the Environmental Protection Authority's aquatic ecosystem reporting, long-term surface and groundwater monitoring by Department for Environment and Water (DEW), and fish surveys undertaken by Nature Glenelg Trust on behalf of the Murraylands and Riverland Landscape Board. Data analysis was undertaken by the DEW, the landscape board, and Nature Glenelg Trust.

This technical report provides a transparent and thorough explanation of how the raw data is translated into the grades within the report card to communicate the status of the catchment. It serves as a resource for stakeholders, scientists, and policymakers, ensuring that the report card's findings are grounded in rigorous scientific assessment and aligned with long-term environmental monitoring efforts. It offers insight into the ongoing health of the Marne Saunders catchment and can guide future management decisions.



Why is a report card needed?

The Marne Saunders Catchment report card is a vital tool for assessing and communicating the health of this important river basin.

As the [*Practitioner's Guide to Developing River Basin Report Cards*](#) points out “the process of developing a report card facilitates interaction among people governments and industries who have different agendas, perspectives and levels of awareness often leading to a shared vision of what the future will be, and what is needed to get there”.

There are a number of reasons why a report card is needed for the Marne Saunders catchment:

1. Socialising science

The Marne Saunders catchment is facing significant ecological pressures, including reduced water flows, a drying climate, water quality issues, and declining biodiversity in macroinvertebrate and fish populations among other flora and fauna. These issues are often complex and difficult to communicate to a broad audience. A report card provides a straightforward and accessible way to synthesise complex scientific data and make it understandable to decision-makers, landholders, and the broader community. Simplifying this information into a graded report card format will ensure that stakeholders can see at a glance, how the catchment is performing across key indicators.

2. Increasing awareness and enhancing management

The Marne Saunders catchment is heavily impacted by reduced rainfall, changes in seasonal rainfall patterns, development pressures, and patterns of water use, which have all contributed to declining river health. The report card helps to raise awareness of these issues by providing transparent, data-driven insights about the catchment’s condition. This increased awareness fosters better management decisions by local authorities, industry, and the community. By regularly updating the report card, the landscape board can track whether management interventions such as water flow restoration programs like the [*Flows for the Future*](#) program are having the desired impact over time.

2. Catalysing action

The report card will hopefully serve as a catalyst for action by providing clear, measurable indicators of the catchment's health. It creates accountability by tracking the success (or failure) of management and socially driven environmental restoration efforts, like improving water flows or ecological remediation programs. The clarity of the report card's scoring system encourages stakeholder participation and motivates governments, local landholders, and the community to engage more actively in the restoration and sustainable management of the catchment.

4. Supporting long-term monitoring and adaptive management

The dynamic nature of the Marne Saunders catchment, particularly the variability in water flow and quality, requires continuous monitoring. The report card plays a critical role in adaptive management by providing a year-by-year picture of the catchment's health enabling adjustments to management strategies as new data become available. It can also highlight where further monitoring is needed, such as to ensure all sub-catchments are equally represented. This can help ensure interventions remain effective in the face of changing environmental conditions.

The hydrological cycle

Water resources in the Marne Saunders Prescribed Water Resources Area (PWRA) depend very much on rainfall, and water moves through the landscape along various pathways. Water resources above and below ground are strongly interlinked across the area, and actions or changes in one resource can influence another. in in Figure 1 below:

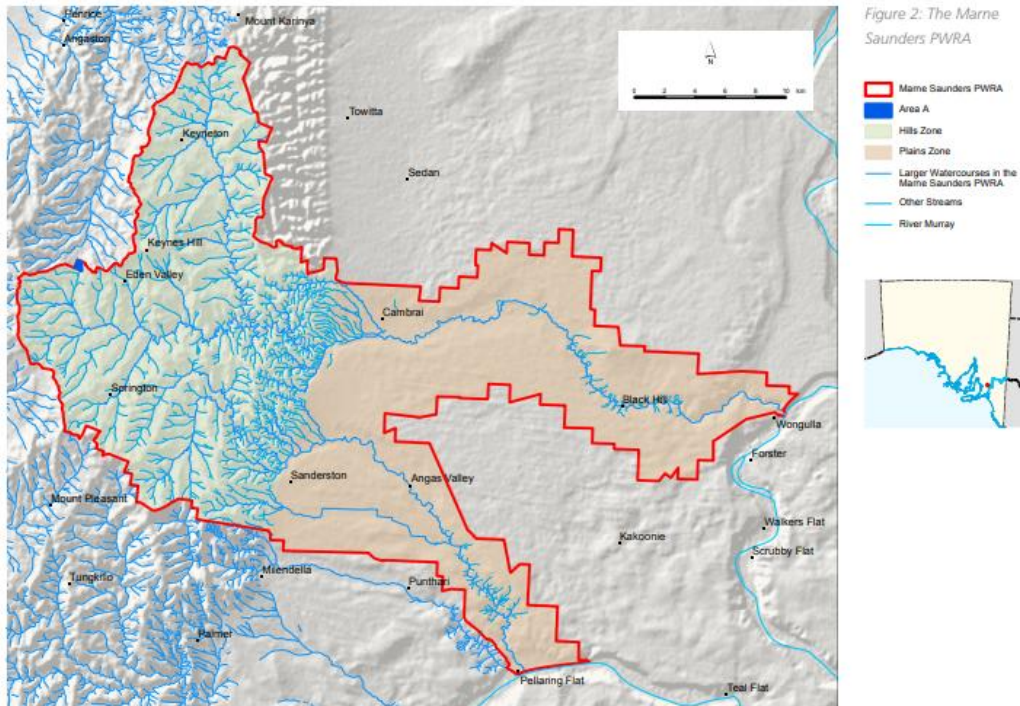


Figure 1: The Marne Saunders PWRA. Orange shading = Plains Zone; Green shading = Hills Zone

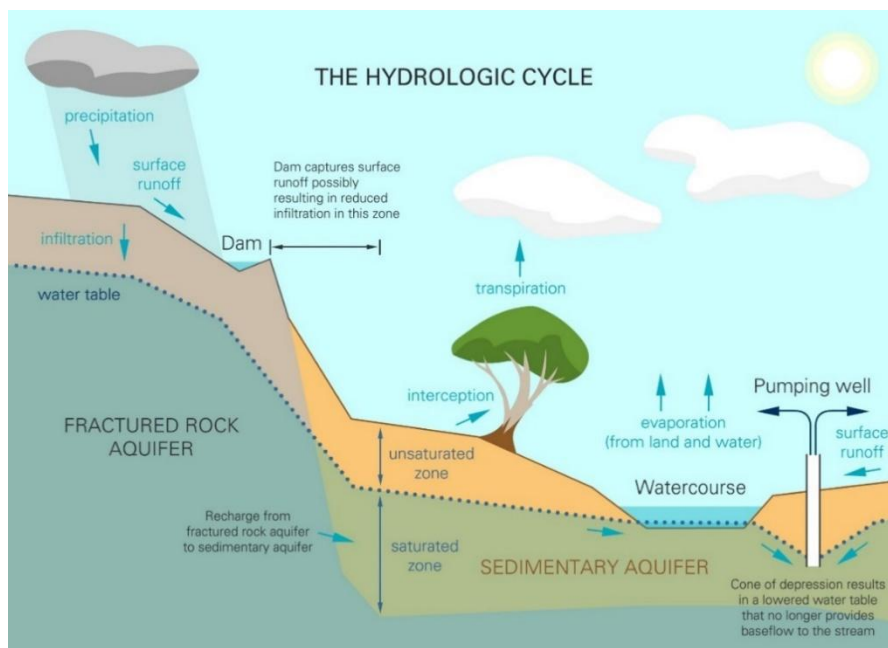


Figure 2: Paths of water movement through the landscape. Figure courtesy of the former Department for Water, Land and Biodiversity Conservation (DWLBC), and Ecocreative

Water moves through the landscape along a variety of paths (Figure 2). Rainfall is the ultimate source of water in the area. Most rainfall leaves the catchment via evaporation or from transpiration by plants. Some rain that falls on the ground runs off the land as surface water and makes its way into watercourses. The Marne River and Saunders Creek begin in the high rainfall hills zone, flowing east down the hills, through gorges and then out onto the plains zone, to eventually discharge into the River Murray.

Rainfall and streamflow also seep down into the pores and cracks of water-bearing rock and sediment layers known as aquifers to become underground water (commonly referred to as groundwater). Underground water also flows from higher to lower levels, with a general movement of underground water from west to east over the Marne Saunders PWRA.

It is important to note that all water resources in the Marne Saunders PWRA are strongly interlinked (Figure 2). Actions affecting one resource can influence another, so they need to be managed together. Surface water running over the land enters watercourses and underground water can also enter the watercourse as “baseflow” via springs and seeps. Flow in the watercourse can seep through the bed and replenish or “recharge” the underground water. Water can also move between different aquifers.

The movement of water through the landscape can be interrupted by water resource development (including dams, weirs and wells) and other constraints such as roads, influencing the volume, water quality and pattern of water availability locally and at the larger scale.

Surface water (water resources above ground)

Streamflow in the watercourses is dependent upon rainfall which is highly variable from year to year. Most streamflow comes from the hills where the rainfall is highest. Annual streamflow measurement in the Marne River began in 1973 at the gauging station in the Marne gorge just before the river reaches the plains and has ranged from 33,500 megalitres (ML) (in 1974) to zero (in 2018-2020) (Figure 3).

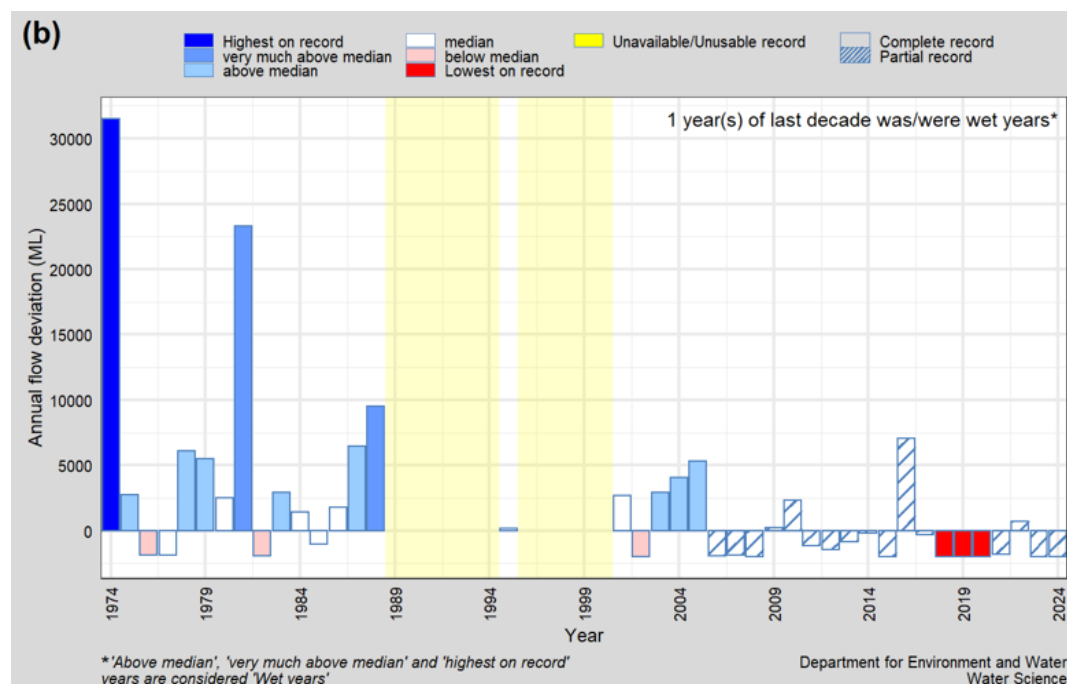


Figure 3: Deviation from long term median streamflow at Marne Gorge 1974-2024

Streamflow is strongly seasonal, reflecting the pattern of mainly winter rainfall, although storm events occur from time to time in drier seasons. Zero streamflow conditions periodically occur in the drier months, although water holding pools (refuge pools) are maintained in some areas by baseflow (inflow of underground water).

Baseflow to watercourses is known to occur throughout the hills and also in some plains locations, such as Black Hill Springs in the Marne River and near Lenger Reserve in Saunders Creek.

Streamflow to the area recharges these local aquifers, and if water doesn't reach the plains and become a stream flowing towards the River Murray, insufficient recharge will occur.

Groundwater (water resources below ground)

There are two main types of underground water aquifers in the Marne Saunders PWRA: the fractured rock aquifer in the hills and the sedimentary aquifers in the plains.

The fractured rock underground water in the hills generally flows to the east and recharges the sedimentary aquifers at the base of the hills (Figure 4).

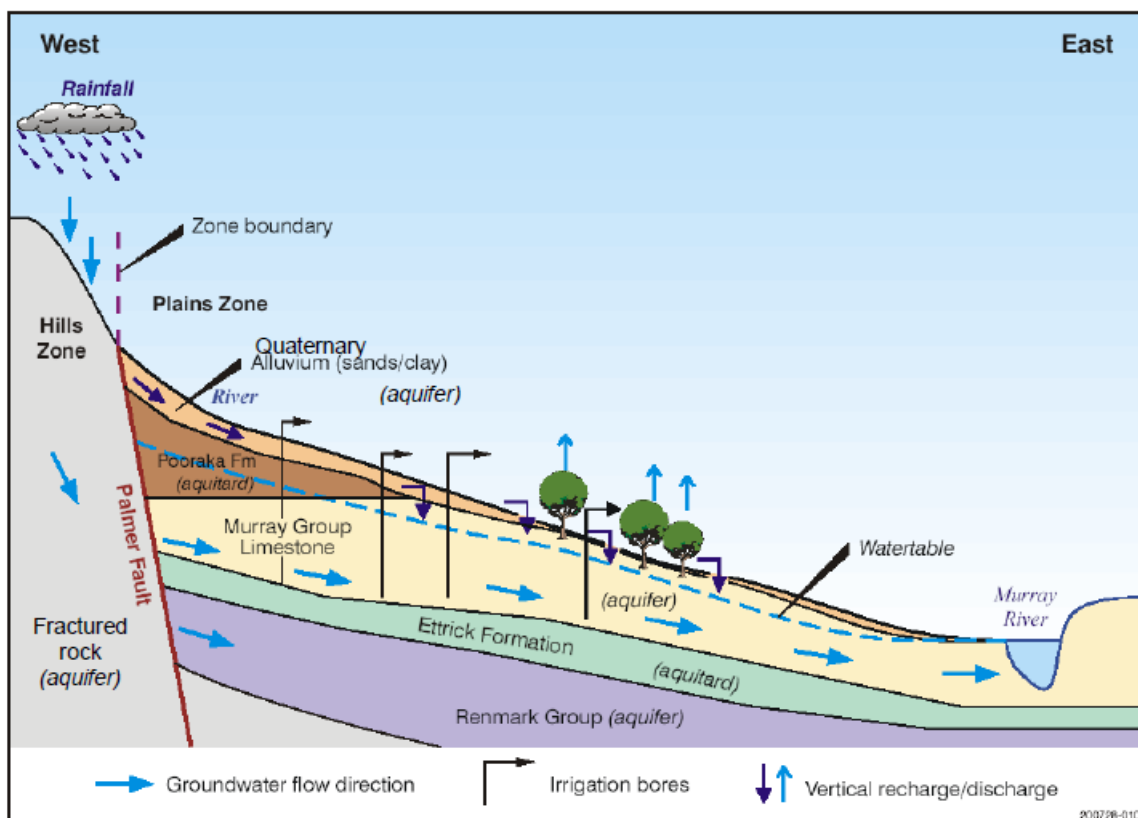


Figure 4: Cross section of key aquifer locations across the Marne Saunders catchment

There are three sedimentary aquifers on the plains, each at a different depth. From shallowest to deepest they are the Quaternary aquifer, the Murray Group Limestone aquifer and the Renmark Group aquifer (Figure 4). Currently all licensed water use is from the Murray Group Limestone aquifer.

The limestone aquifer has two major sections: an unconfined section (open to the soil layers and atmosphere above via pores in the rock), and a confined section (covered by impermeable layers of clay deposited by the Pooraka Formation) (Figure 4). The confined section of the limestone aquifer lies to the west of Cambrai, while east of Cambrai, the aquifer is unconfined (Figure 5).

It is important to note that these two sections of the Murray Group Limestone aquifer are recharged by different sources. Streamflow from rainfall in the hills is responsible for the majority of recharge in the unconfined limestone aquifer (east of Cambrai) in the vicinity of the watercourses, with minimal recharge also provided by the low amount of local rainfall.

Impermeable layers called aquitards (such as the Pooraka Formation) restrict streamflow from reaching some aquifers on the plains. This is the case for the western confined section of the Murray Group Limestone aquifer, and the deeper Renmark Group aquifer. Both aquifers are thought to be recharged by underground water moving from the fractured rock aquifers of the hills zone, rather than by streamflow.

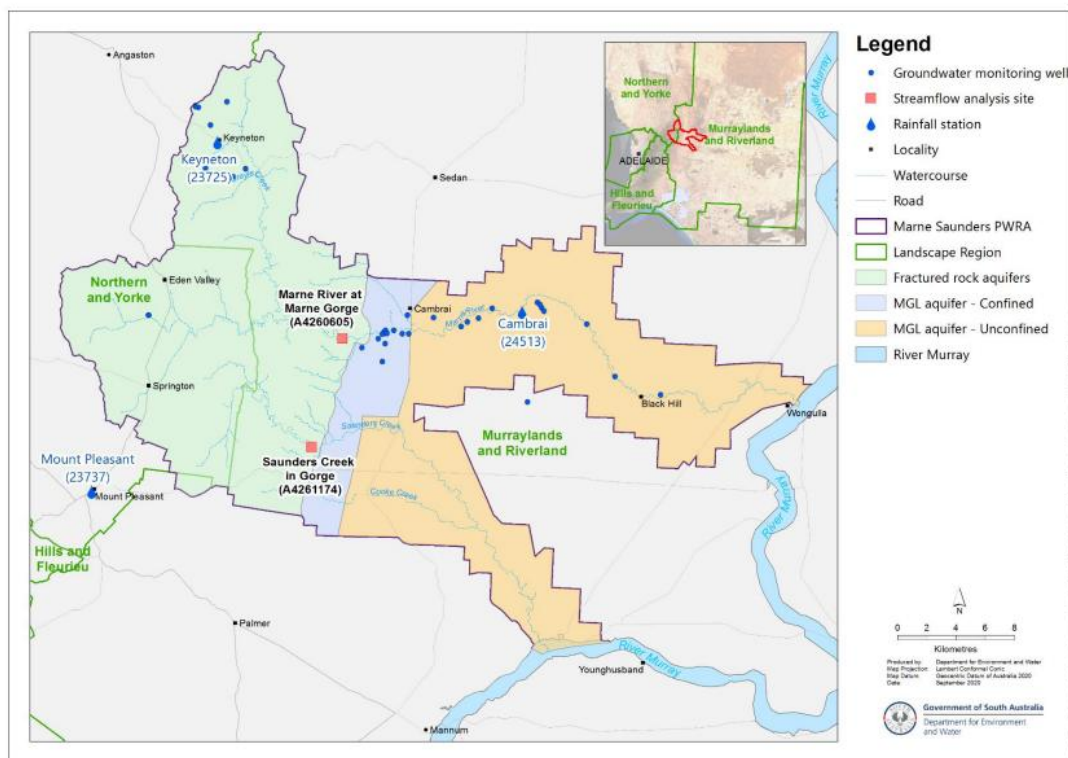


Figure 5: Aerial view of locations of the three key aquifers within the Marne Saunders PWRA: Green shading = Fractured Rock Aquifer; Purple shading = Confined Murray Group Limestone; Yellow shading = Unconfined Murray Group Limestone

Indicators: at the heart of the report card

At the core of the Marne Saunders Catchment report card are the carefully selected indicators, which provide a clear and measurable way to assess the catchment's ecological and water health. These indicators were chosen for their relevance to the specific environmental challenges of the catchment and for their robustness, reliability, and the availability of consistent, high-quality data to enable annual tracking and detection of long-term changes.

The importance of robust and reliable indicators

Indicators were chosen for their relevance to the key challenges facing the Marne Saunders catchment and for their scientific robustness, reliability and the availability of consistent, high-quality data that allow changes in condition to be tracked over time. Many indicators focus on hydrological and ecological processes because these underpin the functioning of the catchment and strongly influence the benefits the system provides to people and the regional economy.

In this iteration of the report card, several additional indicators and measures have been incorporated to improve the representation of important catchment processes. The report now includes depth to the watertable (DTW) as an additional groundwater measure, and introduces a temporary water quality metric, supported by citizen science monitoring through Waterwatch. Put simply, temporary water sites are those that are ephemeral – ie, appear for a relatively short time after rain events. These additions help capture aspects of catchment function that were previously under-represented, particularly the accessibility of groundwater resources and the ecological role of short-lived aquatic habitats.

Indicators provide a way to synthesise complex datasets into clear, understandable scores that describe the condition of the catchment. They allow environmental, social and economic information to be brought together in a form that can be easily interpreted by water users, community members, decision-makers and land managers. In doing so, they help communicate how changes in climate, water use and land management influence both ecosystem condition and the wellbeing of the communities that depend on these resources.

The indicators used in this report therefore represent key processes that collectively describe the condition and performance of the system. Their strength lies in their ability to detect change over time in a scientifically sound and consistent way. As outlined in the *Practitioner's Guide to Developing River Basin Report Cards*, reliable indicators are essential for monitoring trends, informing adaptive management and communicating catchment condition to a wide range of audiences.

To ensure indicators are robust and meaningful, they must meet several key criteria:

- **Relevance:** Indicators must reflect the key values, pressures and processes operating within the catchment, including water availability, salinity, biodiversity, habitat condition, and the social and economic uses of water resources.
- **Data availability:** Indicators must be supported by datasets that are collected consistently through time to allow reliable comparison and trend detection.
- **Simplicity and interpretability:** Indicators must be understandable to a wide range of stakeholders, including scientists, landholders, community members, water users and policymakers.

While the report card scores are based on hydrological and ecological indicators, the importance of the catchment's social and economic values, including agricultural production, regional employment, community wellbeing and cultural connections to water is also recognised. As the health of the catchment directly influences the people and communities who live within it—through factors such as access to cool places to gather, visual amenity, and the ability to irrigate community assets like football ovals and cricket grounds—wellbeing is recognised as an important component of this section.

This includes not only social and economic dimensions, but also cultural values and aspirations. Through multiple on-Country workshops with First Nations groups, the Board has gained a deeper understanding of the importance of water to cultural identity, connection to Country, and the continuation of cultural practices. These perspectives emphasise that water is not only a resource, but a living system with cultural, spiritual and relational significance. The report card acknowledges these values and the need for their continued inclusion in water planning and management.

At present, these economic, social and cultural aspects are not directly “scored” within the report card. Instead, they are reflected indirectly through the assessed health of the catchment. This is primarily due to the absence of consistent, long-term datasets that would enable robust measurement and reporting of these dimensions for the Marne–Saunders catchment.

To provide some insight into the economic contribution of water, the report card includes a summary of a recently commissioned economic analysis examining the value of the water resource in the catchment. The full economic report can be accessed [here](#).

Selection of indicators

Indicators represent measurable components of the environment. Each indicator may consist of one or more measures, which together contribute to the final indicator score. In some cases, these measures are interpreted through established ecological models that compare observations against reference conditions. Table 1 shows how catchment health is assessed across four key indicators, including surface water, water quality, groundwater, and ecological condition by outlining the specific metrics, measures, data sources, and their relevance. It demonstrates how hydrological data, water quality monitoring, groundwater observations, and biological surveys are integrated to provide a comprehensive understanding of ecosystem function, resource sustainability, and environmental resilience within the catchment.

All indicators were selected through a collaborative process involving scientific experts, government agencies and community stakeholders. This process aimed to identify measures that best reflect the overall health and functioning of the catchment. Indicators were chosen to represent the most important aspects of catchment condition, including water availability, groundwater status, aquatic ecosystem health and the ways water resources support regional livelihoods. Selection also considered the availability of reliable monitoring programs capable of providing consistent, long-term data so that changes in environmental, social and economic conditions can be tracked over time.

Together, these indicators provide a balanced set of measures that help describe how the catchment is functioning. Additionally, the selected indicators provide information on how the catchment is responding to pressures such as climate variability and water use, and how these changes influence both environmental outcomes and the social and economic values supported by the Marne Saunders system.

1. Surface water flow

Surface water flow is the primary driver of river health in the Marne Saunders catchment. It is assessed using DEW hydrological modelling between 2023–2025 (Savadamuthu & Bamunuarachchi 2025 (in press)), benchmarked against long-term records (at some sites back to 1973).

Key flow metrics include:

- Flow days (duration of flow)
- High-flow events (habitat maintenance and geomorphic function)
- Break of season (timing of first sustained flows)

These metrics describe the timing, duration and magnitude of flows that underpin ecological processes. Reductions in flow days, fewer high flows, and delayed seasonal flows reduce habitat availability, disrupt life-cycle cues, and degrade water quality.

2. Water quality

2.1 Refuge pools

Permanent pools are critical drought refuges sustaining aquatic species during no-flow periods. Condition is assessed using:

- pH
- Dissolved oxygen
- Salinity

The measures are weighted by a pool condition factor (how full or depleted the pool was at time of sampling). Data are drawn from Nature Glenelg Trust surveys (see Gannon et al, 2021), Waterbug Bioblitz and Waterwatch, providing broad spatial and temporal coverage.

2.2 Temporary water

Ephemeral pools and riffles provide short-term habitat, productivity and connectivity following rainfall. They are assessed using the same water quality measures, but without a pool condition factor.

Sites that are dry are recorded as F (dry), reflecting loss of habitat and connectivity. Data sources are consistent with refuge pool monitoring.

3. Groundwater

Groundwater is a key resource, particularly in lower catchments where it supports irrigation. Two indicators are assessed:

3.1 Salinity (water quality and usability)

3.2 Depth to water (resource accessibility and sustainability)

Data are sourced from DEW observation wells (Duszynski & Watt, 2025 – In Press), monitoring bores and licence-holder sampling programs.

4. Ecological status

4.1 Fish

Fish communities integrate flow, water quality and habitat condition. Assessment (via Nature Glenelg Trust modelling) considers:

- Species richness
- Presence of invasive species
- Recruitment (juveniles)

The functional extinction of river blackfish highlights severe ecological stress.

4.2 Macroinvertebrates (Waterbugs)

Waterbugs are sensitive indicators of flow and water quality. Condition is assessed using DEW modelling informed by:

- Species richness
- Abundance
- Presence of sensitive taxa

Data sources include Waterbug Bioblitz, DEW (DEW, 2024) and EPA monitoring.

Table 1: Catchment Health Assessment Framework: Indicators, Metrics, Measures and Data Source

Indicator Categories	Indicator		Measures	Data Source	Why it matters
Surface water	Flow		Number of flow days, high flow events, timing of flow season start	DEW Flow Modelling	Drives aquatic ecosystem health; affects species reproduction and habitat availability
	Refuge Pools		Salinity, Dissolved oxygen, pH	Nature Glenelg Trust surveys, Waterbug Bioblitz citizen science, Waterwatch	Pools are refuges during dry periods, critical for species survival
Water quality	Temporary water		Salinity, Dissolved oxygen, pH	Nature Glenelg Trust surveys, Waterbug Bioblitz citizen science, Waterwatch	Support short-term aquatic biodiversity, enable species dispersal, and enhance ecological connectivity during wet periods.
	Groundwater salinity		Electricity conductivity (EC)	DEW observation wells	Affects water usability for irrigation, stock, domestic use; impacts plant and animal health
Groundwater	Depth to water		DEW Monitoring network analysis	DEW observation wells	Indicates aquifer capacity and long-term availability of groundwater for irrigation and ecosystems
	Fish		Species richness, abundance, and the presence of sensitive or invasive species	Fish surveys by Nature Glenelg Trust	Sensitive indicator of river health; declines indicate ecosystem stress
Ecological	Waterbugs		Species diversity, abundance, and sensitivity to flow conditions	DEW, EPA monitoring, Waterbug Bioblitz citizen science	Bioindicator of water quality and ecosystem health

Getting the grades: The scoring approach

The Marne Saunders Catchment report card translates ecological and hydrological monitoring data into clear grades that represent the overall condition of the catchment. Each indicator is scored using a grading scale from A (very good) to F (very poor), with A representing the healthiest condition and F the least healthy. Where insufficient data exist to assess an indicator, the result is recorded as No Data. There are no refuge pools in a sub-catchment, NA is used in place of a score. Indicator scores are first calculated at the site level, based on the available monitoring data. These site scores are then averaged to produce a sub-catchment score for each indicator, allowing catchment condition to be assessed across different parts of the system.

Threshold determination for indicator grades

Scoring thresholds for each indicator were developed using ecological standards and long-term monitoring data from the catchment. These thresholds provide a scientifically grounded basis for distinguishing between different levels of environmental condition.

The thresholds were designed so that movement between grades reflects meaningful changes in catchment health. In other words, a change from one grade to another corresponds to a measurable shift in environmental condition rather than minor variation within the dataset.

Detailed descriptions of the thresholds and scoring criteria for each indicator are provided in the later sections of this report.

Linear conversions to grades

To ensure consistency across indicators, raw monitoring data were converted to grades using a linear scoring system ranging from 0 to 100. These scores were then translated into the report card grades A through F (Figure 6).

This approach allows indicators that measure different environmental variables to be assessed on a common scale, ensuring comparability across the report card. The linear conversion method provides a transparent way to translate complex ecological datasets into simple, understandable grades.

By applying this consistent grading framework, the report card provides a clear summary of catchment condition and helps stakeholders identify areas where management attention may be required.

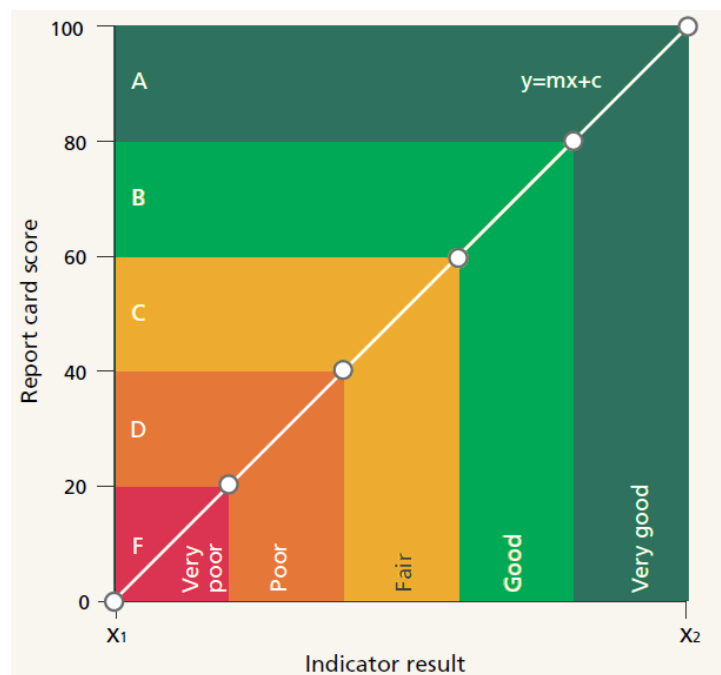


Figure 6: Linear conversion method of scores between 0-100 and the grading letters A, B, C etc

Spatial segmentation of scoring

To better understand how environmental condition varies across the catchment, results were analysed at the sub-catchment scale (Figure 7). Each sub-catchment was scored separately for each indicator where sufficient data were available.

Sub-catchment boundaries largely follow the surface water management zones previously defined by DEW. One exception is the Upper Saunders sub-catchment, which combines the former Upper Saunders and One Tree Hill sub-catchments. These areas were merged due to the limited number of monitoring sites within the One Tree Hill area.

An additional adjustment was made for the Hills Face zone. While this area is technically part of the Lower Marne and Lower Saunders sub-catchments, its environmental characteristics more closely resemble the upper catchment areas. This distinction is particularly important for groundwater assessments, as the Hills Face marks the transition between the fractured rock aquifer of the Hills zone and the Murray Group limestone aquifer of the Plains.

To ensure groundwater results are compared within similar hydrogeological systems, data from the Hills Face zone were incorporated into the adjacent Upper Marne and Upper Saunders sub-catchments. This approach ensures that groundwater condition within each sub-catchment is assessed within the same aquifer type.

Trend analysis in the report card

Incorporating trend analysis

In addition to assessing recent monitoring data, the report card incorporates trend analysis where reliable long-term datasets are available. Trend assessments are based on the longest available monitoring records, which in many cases extend from the post-Millennium Drought period through to the present.

Where trend analysis is applied, the results inform the interpretation of the final grade, ensuring that scores reflect both recent conditions and the longer-term trajectory of the system. As noted above, Bayesian techniques were used to determine long term trends across all indicators.

A key feature of the Marne Saunders Catchment report card is the use of trend analysis to interpret how catchment condition is changing over time, rather than relying only on observations from a single year. For most indicators presented in the report card, each year is interpreted using time-series datasets drawn from the longest reliable monitoring records available, allowing recent conditions to be assessed in the context of historical variability.

For several of the ecological indicators, the report card adopts analytical approaches described in DEW's ecological assessment of the Marne Saunders catchment (DEW, 2024). In that work, ecological condition scores, particularly for fish and macroinvertebrate communities were derived using Bayesian statistical modelling techniques. These methods are well suited to ecological monitoring datasets because they allow information from multiple surveys, sites and years to be combined to estimate the most probable condition of the ecosystem while also explicitly accounting for uncertainty.

The Bayesian approach allows the model to incorporate prior knowledge about ecological responses and environmental conditions, alongside observed monitoring data, to estimate the likelihood of different ecological states. This provides a robust framework for analysing datasets that may vary in sampling intensity across sites and years, which is common in long-term environmental monitoring programs.

Using Bayesian modelling also allows condition scores to be expressed 'probabilistically'. This means that the model estimates the *likelihood* that an indicator is in a particular condition class (for example good, fair or poor). This approach improves confidence in the scores by acknowledging uncertainty and variability.

These modelling approaches underpin much of the trend analysis presented in the report card, particularly for biological indicators. By integrating multiple years of monitoring data and accounting for uncertainty, the analysis provides a more reliable indication of how ecological condition is changing through time.

Overall, the use of Bayesian modelling and long-term time-series analysis strengthens the scientific basis of the report card, allowing it to present a clearer picture of directional change, ecological condition and emerging pressures within the Marne Saunders catchment.

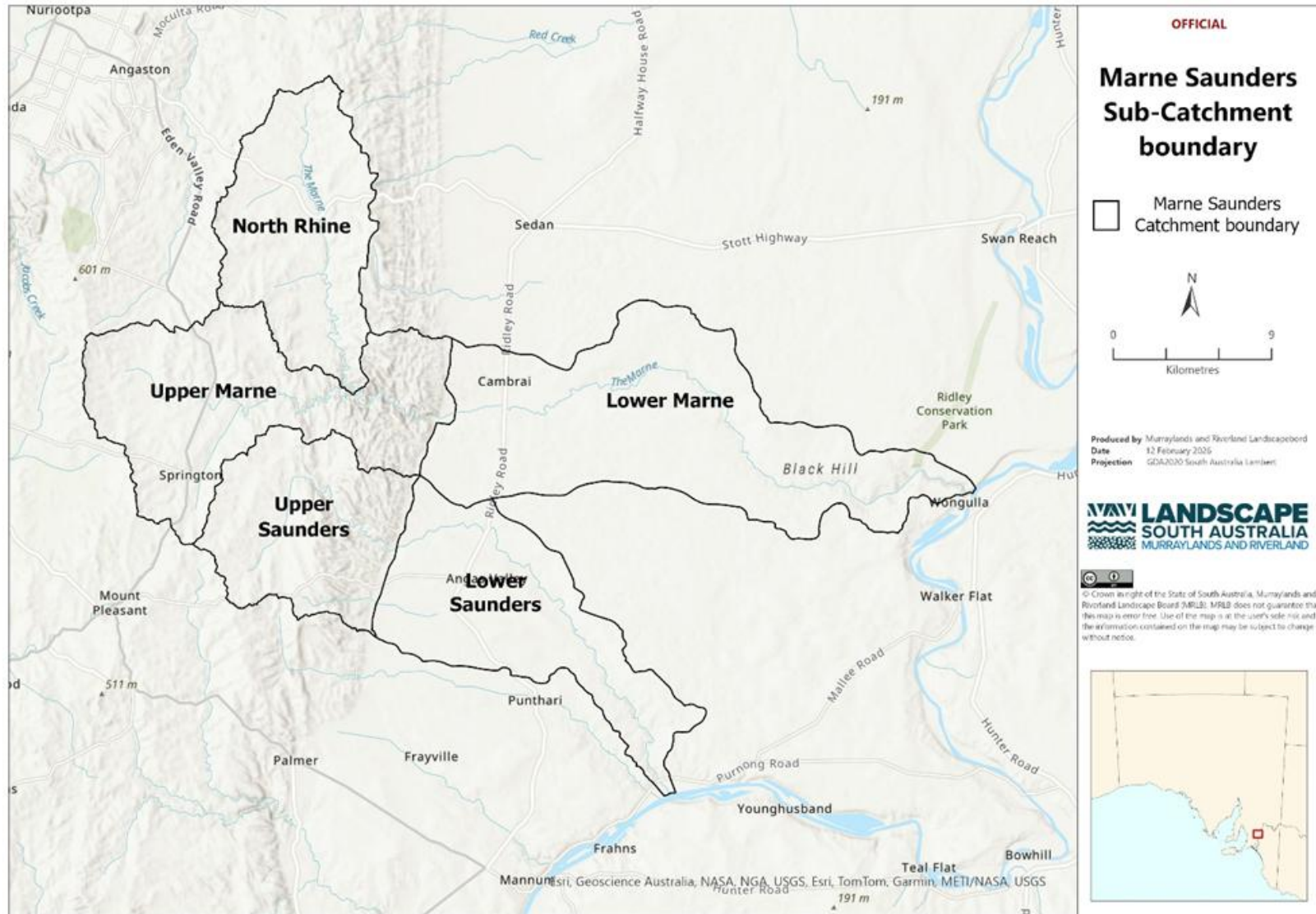


Figure 7: Sub-catchment boundaries across Marne Saunders Catchment

Caveats and shortcomings acknowledgment

Where sufficient data exist, the report card incorporates trend analysis to help interpret how conditions are changing through time. In this context, a trend refers to a consistent directional change in an indicator across the available monitoring record, rather than short-term fluctuations caused by seasonal variability or individual sampling events.

For several ecological indicators, trend interpretation draws on the analytical approach described in the ecological assessment of the Marne Saunders catchment. This work used statistical modelling methods that combine observations from multiple sites and survey years to estimate ecological condition while accounting for uncertainty within the datasets. This approach allows patterns to be identified even when monitoring intensity varies between locations or years. Similarly, many of the scores represented are achieved through the interpretation of complex mathematical models for snapshot years (see methods sections).

Because environmental monitoring programs rarely produce perfectly continuous datasets, identifying trends in ecological systems requires balancing statistical rigour with practical limitations in available data. The approach adopted in this report therefore focuses on detecting broad directional change over time, rather than attempting to resolve fine-scale statistical signals that may not be supported by the available data.

This method represents the most robust and defensible interpretation currently possible given the monitoring records available for the catchment. As monitoring programs expand and datasets lengthen, future report cards may be able to apply more detailed statistical analyses and refine the interpretation of trends.

Further caveats and indicator-specific limitations are discussed within the relevant results sections of this report. These sections also highlight opportunities where additional monitoring or improved data coverage could strengthen future assessments of catchment condition.

Data analysis: data sources, methods, and interpretation

The Marne Saunders Catchment Report Card assesses key indicators of water resource condition across the 2023, 2024 and 2025 reporting years (December of the year before to November of that year). These recent conditions are interpreted against the full extent of available historical monitoring records for each indicator, providing essential context for understanding how the catchment is changing over time.

Indicators were selected to reflect the core processes that underpin catchment function, including flow regimes, water quality, groundwater condition and ecological response. Together, these indicators provide a coherent, process-based assessment of system health, linking changes in hydrology and water quality to ecological outcomes.

Table 2 summarises the indicators, metrics, data sources and temporal coverage used in the analysis, including the introduction of trend assessments based on long-term datasets.

Table 2: Summary of indicators, data sources, and temporal coverage used for and trend analysis

Indicators	Metrics	Data Source	Trends (New)
Surface water	Surface water flow	Flow Modelling	2002-2025
Water quality	Refuge Pool	Nature Glenelg Trust surveys, Waterbug Bioblitz citizen science, Waterwatch	2016-2025
	Temporary water	Nature Glenelg Trust surveys, Waterbug Bioblitz citizen science, Waterwatch	2010-2025
Groundwater	Salinity	DEW observation wells, Water Connect	2000-2025
	Depth to water	DEW observation wells, Water Connect	2000-2025
Ecological	Fish	Aquasave Fish Condition Model (FCM)	2012-2025
	(Waterbugs)	Macroinvertebrate Condition Model (CMCM)	2017-2025

1. Surface water flow

Surface water flow is the primary driver of ecological condition in the Marne Saunders catchment. The timing, duration and magnitude of flows determine habitat availability, water quality, and the ability of aquatic species to complete critical life-cycle processes such as breeding, migration and recruitment.

In this catchment, where rivers are naturally intermittent, relatively small changes in flow regime can have disproportionate ecological consequences. Extended cease-to-flow periods reduce high-flow events, and delays in the break of season can reduce habitat connectivity, degrade refuge pools and place significant stress on aquatic communities.

The flow regime is assessed using hydrological modelling and long-term monitoring data, with key metrics including:

- flow days (duration of flow),
- low-flow season flow days (summer connectivity),
- break of season (timing of initial flows), and
- spring and high flows (magnitude and ecological function).

Assessment across multiple recent years (2023–2025) (Savadamuthu & Bamunuarachchi, 2025 in press), combined with comparison to the historical record, provides a robust understanding of how contemporary flow conditions differ from those that historically supported ecological function in the catchment.

Fluctuations in flow, such as prolonged dry periods or excessive flow, can disrupt these habitats, leading to declines in sensitive species and reducing the overall biodiversity. For example, consistent zero-flow (no flow at all) conditions reduce water quality in permanent water pools, and delayed breaks in seasonal flows (the length of time between dry periods and rainfall, typically after summer) can impede critical life cycle events such as fish migration and breeding. Conversely, regular and healthy flow regimes contribute to habitat stability, promoting species diversity and ecological resilience.

In the Marne Saunders catchment, the assessment of flow regime-through measures such as number of flow days, break of season flows, and low-flow days-therefore provides a vital understanding of the river's health. By monitoring these patterns over time, we can detect trends in river condition which can be used to guide effective water management strategies to ensure the long-term sustainability of the catchment's aquatic ecosystems.

Over recent years, significant changes in flow patterns have been observed, with many sub-catchments experiencing declines that raise concerns for water management and ecosystem sustainability (Savadamuthu & Bamunuarachchi, 2025 - in press; DEW, 2024). In the Upper Marne sub-catchment, the number of flow days and spring flows has shown a decrease, limiting the availability of critical aquatic habitats and reducing the resilience of species dependent on seasonal water flow. This reduction is particularly problematic for fish

recruitment, which relies heavily on consistent spring flows for successful spawning and juvenile survival.

The Lower Marne sub-catchment is also experiencing a decrease in the number of flow days and high flow days, signalling a dramatic reduction in water availability. This is compounded by a delayed break of season, which means that the rivers are taking longer to return to flow after summer dry periods, exacerbating stress on aquatic life and habitats. These changes are likely to be contributing to declining water quality and diminished permanent water pools which provide important refuges for many species, further stressing ecosystems.

In the North Rhine and Upper Saunders sub-catchments, flow metrics such as low flow season days (Table 1) dramatically decreased, reflecting severe reductions in flow during dry periods (Savadamuthu & Bamunuarachchi, 2025 - in press). This is leading to habitat contraction and greater competition for resources among aquatic species, ultimately harming biodiversity (DEW, 2024).

Across all sub-catchments, the decline in flow metrics such as days above median flow and high flow days points (Table 1) to a significant reduction in the frequency and intensity of higher flows, which are essential for maintaining the physical structure of the rivers, flushing sediments, and supporting riparian vegetation (vegetation which inhabits the river system).

The consistent reduction in these key flow regime metrics throughout the Marne Saunders catchment highlights the urgent need for improved strategies to support the long-term health of these rivers and the species that depend on them.

1.1 Surface water flow: where the data came from

The surface water data used in the Marne Saunders Catchment report card is based on the monitoring and modelling described in status reporting from DEW ((Savadamuthu & Bamunuarachchi, 2025 - in press).

Streamflow data from key gauging stations:

The primary data source for surface water in the Marne Saunders catchment comes from a network of automated gauging stations that record flow levels at strategic points. Key sites such as the Marne Gorge gauging station have long-term records dating back several decades. These stations capture daily flow data, allowing for detailed analysis of flow variability across the catchment. The flow days and high flow events measures are directly derived from these gauging stations, which measure the continuity and intensity of water flows throughout the year. There is no gauging station measuring this in the Lower Saunders sub-catchment. Monitoring data are drawn primarily from the long-term network of surface water, groundwater and ecological monitoring sites maintained by the DEW, supplemented by partner monitoring programs and citizen science initiatives (Figure 8).

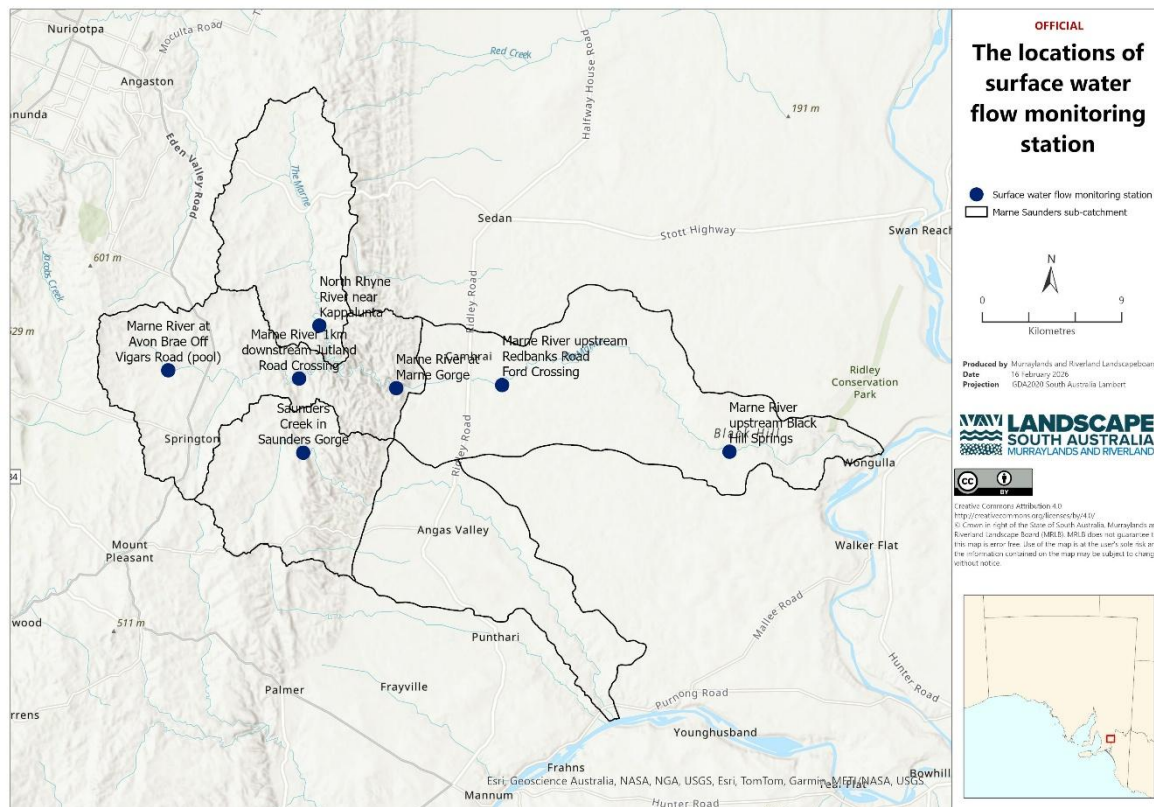


Figure 8: Map showing flow monitoring stations used in these analyses

1.2 Surface water flow: scoring method

The analysis utilises historical streamflow records extending back to 1973, which form the basis for defining thresholds for flow days and high-flow events. Recent conditions are assessed using multiple reporting years (2023-2025) rather than a single year, providing a more representative picture of current hydrological behaviour. These recent observations are interpreted in the context of the full historical record to identify how contemporary flow patterns compare with long-term conditions. This context is particularly important in the Marne Saunders catchment, where streamflow is highly variable and ranges from years with no flow to periods of high discharge following significant rainfall events.

Detailed metrics used in DEW's surface water modelling analysis

To assess the condition of the surface water flow regime in the Marne Saunders catchment, a suite of hydrological flow metrics was used. These metrics describe different characteristics of the flow regime that are known to influence the health and functioning of aquatic ecosystems.

The metrics used in this report card are based on the hydrological analysis undertaken by DEW and are defined in Green and Savadamuthu (2023). Each metric captures a different component of the flow regime, including flow duration, timing and magnitude, which together influence habitat availability, species life cycles and ecosystem processes (Table 3).

The key flow metrics assessed are described below.

Table 3: Status assessment thresholds used for the assessment of the flow regime. Adapted from the water resource assessment framework used by DEW

Flow metrics	Unit	Definition	Ecological relevance
Intermittency	Number of days	Days of flow defined as days of recorded flow for gauged sites (See Green and Savadamuthu In Review - 2023).	- Considered the master variable for intermittent rivers (Datry et al. 2014) - Longer cease to flow periods leads to deteriorating water quality in refuge habitat (Chapin et al. 2014, Schmarr et al. 2014) - Length of flow period dictates habitat availability and expected lifecycle completion (Bonada et al. 2007)
Low flow season flow days	Number of days	Days of flow over the low flow season (Dec April inclusive) above the low flow season flow threshold (See Green and Savadamuthu In Review - 2023).	- Flushing of permanent pools - Maintenance of habitat (Vander Vorste et al. 2020) - Watering of in-channel riparian vegetation over low flow season (Nicol 2013) - Opportunities for dispersal (Baumgartner et al. 2014)
Break of season	Number of days	Number of days past 1 April the cumulative flow reaches a flow threshold transitioning from low to higher flow (See Green and Savadamuthu In Review - 2023).	- Cues for migration and breeding (Lucas and Baras 2008, Mackay 1992, Pires et al. 2014) - Increased stress on refuge habitats (Vander Vorste et al. 2020) - Likelihood of lifecycle completion (Mackay 1992)
Spring flows	ML/day/KM ²	Average runoff from August to November (inclusive)	- Promotes resilience leading into the low flow/cease to flow period (eWater 2022) - Promotes fish recruitment success (Green et al. 2014) - Migration of obligate aquatic fauna (Lucas and Baras 2008) - Discourages exotic fish species (Seebacher and Kazerouni-Ghanizadeh 2021)
Median flows	Number of days	Days above the median (50th percentile exceedance) of non-zero daily flows	- Promotes large-scale fish migration (Lucas and Baras 2008) - Discourages exotic fish species (Moore et al. 2008) - Expand riffle habitat for macroinvertebrate species (Bonada et al. 2007)

Flow metrics	Unit	Definition	Ecological relevance
			• Inundate vegetation on benches and lower banks (Maxwell et al. 2015b) • Control terrestrial vegetation in channel (Maxwell et al. 2015b)
High flows	Number of days	Days above the 20th percentile exceedance value of non-zero daily flows	• Inundate vegetation higher on banks (Maxwell et al. 2015b) • Habitat maintenance including silt removal and algae scouring (Fuller et al. 2010, Loire et al. 2019) • Entrain organic material from banks (Caraco and Cole 2004) • Plant propagule transport (Stromberg et al. 2007) • Management of reed beds (Stromberg et al. 2007)

Note: For most of these assessments, higher numbers generally indicate improving conditions for aquatic ecosystems (i.e., better flow conditions benefiting aquatic life). However, the Break of Season metric is an exception. In this case, higher values represent a delay in the onset of flow, which conceptually leads to more challenging conditions for aquatic flora and fauna (i.e., worsening flow conditions for the ecosystem)

The status of the flow regime in the catchment was assessed using the hydrological analysis undertaken by DEW (2023- 2025). In this analysis, each flow metric was evaluated against the historical record using a percentile-based assessment framework.

Under this approach, current flow conditions are compared with the full historical dataset for each monitoring site. The percentile ranking indicates how recent flow conditions compare to historical observations, ranging from lowest on record to highest on record (Table 4).

This method ensures that flow conditions are assessed relative to the historical variability of the catchment, which is particularly important in highly variable systems such as the Marne Saunders where streamflow ranges from years with no flow to periods of high discharge following significant rainfall events.

Table 4: Status assessment thresholds used for the assessment of the flow regime. Adapted DEW's Marne Saunders Flow Metrics Status Report (DEW 2024)

DEW status assessment	Percentile range
Highest on record	100 th
Very much above average	90 th to 99 th
Above average	70 th to 89 th
Average	30 th to 69 th
Below average	10 th to 29 th
Very much below average	2 nd to 9 th
Lowest on record	1 st

Translating flow status to report card grades

The flow status categories derived from the percentile assessment were translated into the report card grading system (A -F) using a standard scoring framework.

Under this system, flow conditions classified as above average or very much above average correspond to higher report card grades, while below average and very much below average conditions correspond to lower grades. This translation enables the hydrological status assessment to be incorporated into the broader report card scoring framework (Table 5).

Table 5: Translation of flow regime status assessment thresholds to report card scoring

DEW status assessment	Percentile range	Report card score
Highest on record	100 th	90
Very much above average	90 th to 99 th	
Above average	70 th to 89 th	
Average	30 th to 69 th	50
Below average	10 th to 29 th	30
Very much below average	2 nd to 9 th	0
Lowest on record	1 st	

1.3 Surface water flow: scores per sub-catchment

Scoring of the surface water indicator evaluates the condition of the river system using key flow metrics, including flow days, low-flow season days, break of season, spring flows, and days above median flow. These metrics describe water availability, flow variability, and the ability of the river to sustain aquatic ecosystems.

Indicator scores were calculated for the 2023, 2024 and 2025 reporting years, while longer-term trends are discussed in the following section.

Tables 6-8 below present the flow status results derived from the DEW analysis, alongside the equivalent report card scores assigned for each monitored site across the catchment.

Table 6: Breakdown of water flow sites values from DEW modelling and corresponding 2023 report card score

Site location	Sub-catchment	Flow Days				Low Flow days				Break of season			
		2023 value	Status	Report card score	Grade	2023 value	Status	Report card score	Grade	2023 value	Status	Report card score	Grade
Marne River 1km downstream Jutland Road Crossing	Upper Marne	110	Above average	70	B	27	Below average	30	D	149	Above average	30	D
Marne River at Avon Brae Off Vigars Road (pool)	Upper Marne	1	Average	50	C	0	Below average	30	D	214	Very much above average	0	F
Marne River at Marne Gorge	Upper Marne	0	Average	50	C	0	Below average	30	D	214	Above average	30	D
Marne River upstream Black Hill Springs	Lower Marne	4	Average	50	C	1	Below average	30	D	214	Very much above average	0	F
Marne River upstream Redbanks Road Ford Crossing	Lower Marne	122	Above average	70	B	29	Below average	30	D	100	Above average	30	D
North Rhine River near Kappalunta	North Rhine	24	Average	50	C	4	Below average	30	D	144	Very much above average	0	F
Saunders Creek in Saunders Gorge	Upper Saunders	275	Very much above average	90	A	82	Average	50	C	84	Average	50	C

Site location	Sub-catchment	Spring flow				Days above median flow				Days above high flow			
		2023 value	Status	Report card score	Grade	2023 value	Status	Report card score	Grade	2023 value	Status	Report card score	Grade
Marne River 1km downstream Jutland Road Crossing	Upper Marne	0.363	Below average	30	D	23	Average	50	C	1	Below average	30	D
Marne River at Avon Brae Off Vigars Road (pool)	Upper Marne	0	Average	50	C	0	Average	50	C	0	Average	50	C
Marne River at Marne Gorge	Upper Marne	0	Average	50	C	0	Average	50	C	0	Average	50	C
Marne River upstream Black Hill Springs	Lower Marne	0	Average	50	C	0	Average	50	C	0	Average	50	C
Marne River upstream Redbanks Road Ford Crossing	Lower Marne	0.717	Average	50	C	21	Average	50	C	1	Average	50	C
North Rhine River near Kappalunta	North Rhine	0.011	Below average	30	D	5	Average	50	C	0	Average	50	C
Saunders Creek in Saunders Gorge	Upper Saunders	1.482	Below average	30	D	253	Very much above average	90	A	109	Average	50	C

Table 7: Breakdown of water flow sites values from DEW modelling and corresponding 2024 report card score

Site location	Sub-catchment	Flow Days				Low Flow days				Break of season			
		2024 value	Status	Report card score	Grade	2024 value	Status	Report card score	Grade	2024 value	Status	Report card score	Grade
Marne River at Marne Gorge	Upper Marne	11	Average	50	C	7	Below average	30	D	214	Above average	30	D
Marne River upstream Redbanks Road Ford Crossing	Lower Marne	0	Average	50	C	0	Below average	30	D	214	Very much above average	0	F
Marne River upstream Black Hill Springs	Lower Marne	0	Average	50	C	0	Below average	30	D	214	Above average	30	D
North Rhine River near Kappalunta	North Rhine	0	Average	50	C	0	Below average	30	D	214	Very much above average	0	F
Marne River 1km downstream Jutland Road Crossing	Upper Marne	0	Average	50	C	0	Below average	30	D	214	Very much above average	0	F
Saunders Creek in Saunders Gorge	Upper Saunders	5	Average	50	C	3	Below average	30	D	214	Highest on record	0	F
Marne River at Avon Brae Off Vigars Road (pool)	Upper Marne	187	Highest on record	90	A	53	Average	50	C	214	Above average	30	D

Site location	Sub-catchment	Spring flow				Days above median flow				Days above high flow			
		2024 value	Status	Report card score	Grade	2024 value	Status	Report card score	Grade	2024 value	Status	Report card score	Grade
Marne River at Marne Gorge	Upper Marne	0.000	Below average	30	D	0	Average	50	C	0	Below average	30	D
Marne River upstream Redbanks Road Ford Crossing	Lower Marne	0	Average	50	C	0	Average	50	C	0	Average	50	C
Marne River upstream Black Hill Springs	Lower Marne	0	Average	50	C	0	Average	50	C	0	Average	50	C
North Rhine River near Kappalunta	North Rhine	0	Average	50	C	0	Average	50	C	0	Average	50	C
Marne River 1km downstream Jutland Road Crossing	Upper Marne	0.000	Average	50	C	0	Average	50	C	0	Average	50	C
Saunders Creek in Saunders Gorge	Upper Saunders	0.000	Below average	30	D	2	Average	50	C	0	Average	50	C
Marne River at Avon Brae Off Vigars Road (pool)	Upper Marne	0.057	Below average	30	D	44	Above average	70	B	0	Average	50	C

Table 8: Breakdown of water flow sites values from DEW modelling and corresponding 2025 report card score

Site location	Sub-catchment	Flow Days				Low Flow days				Break of season			
		2025 value	Status	Report card score	Grade	2025 value	Status	Report card score	Grade	2025 value	Status	Report card score	Grade
Marne River at Marne Gorge	Upper Marne	0	Average	50	C	0	Below average	30	D	214	Very much above average	0	F
Marne River upstream Redbanks Road Ford Crossing	Lower Marne	0	Below average	30	D	0	Below average	30	D	214	Very much above average	0	F
Marne River upstream Black Hill Springs	Lower Marne	0	Average	50	C	0	Below average	30	D	214	Above average	30	D
North Rhine River near Kappalunta	North Rhine	0	Below average	30	D	0	Below average	30	D	214	Very much above average	0	F
Marne River 1km downstream Jutland Road Crossing	Upper Marne	71	Average	50	C	0	Below average	30	D	151	Very much above average	0	F
Saunders Creek in Saunders Gorge	Upper Saunders	0	Average	50	C	0	Below average	30	D	214	Very much above average	0	F
Marne River at Avon Brae Off Vigars Road (pool)	Upper Marne	129	Very much above average	90	A	0	Average	50	C	126	Above average	30	D

Site location	Sub-catchment	Spring flow				Days above median flow				Days above high flow			
		2025 value	Status	Report card score	Grade	2025 value	Status	Report card score	Grade	2025 value	Status	Report card score	Grade
Marne River at Marne Gorge	Upper Marne	0.000	Very much below average	0	F	0	Below average	30	D	0	Very much below average	0	F
Marne River upstream Redbanks Road Ford Crossing	Lower Marne	0	Very much below average	0	F	0	Very much below average	0	F	0	Lowest on record	0	F
Marne River upstream Black Hill Springs	Lower Marne	0	Below average	30	D	0	Very much below average	0	F	0	Lowest on record	0	F
North Rhine River near Kappalunta	North Rhine	0	Very much below average	0	F	0	Very much below average	0	F	0	Lowest on record	0	F
Marne River 1km downstream Jutland Road Crossing	Upper Marne	0.430	Below average	30	D	2	Below average	30	D	0	Very much below average	0	F
Saunders Creek in Saunders Gorge	Upper Saunders	0.000	Below average	30	D	0	Below average	30	D	0	Lowest on record	0	F
Marne River at Avon Brae Off Vigars Road (pool)	Upper Marne	0.795	Very much below average	0	F	71	Above average	70	B	10	Average	50	C

To provide scoring, scores located within each sub-catchment were averaged across each of the 5 metrics, with the mean of averages subsequently calculated to provide a total score per sub-catchment as show in Table 9-11.

Table 9: 2023 Report card flow scoring across metrics for each sub-catchment

Sub-catchment	Average flow days score	Average low flow days score	Average break of season score	Average spring flow score	Average of days > median score	Average of days > high score	Sub-catchment average	Report Card grade
Upper Marne	76	36	36	36	63	43	48.88	C
Lower Marne	50	30	15	50	50	50	40.83	C
North Rhine	50	30	0	50	50	50	38.33	C
Upper Saunders	50	30	0	30	50	50	35	C
Lower Saunders	No data							
Marne Saunders Total Score							40.76	C

**No data = There is insufficient data available to score an indicator of health*

Table 10: 2024 Report card flow scoring across metrics for each sub-catchment

Sub-catchment	Average flow days score	Average low flow days score	Average break of season score	Average spring flow score	Average of days > median score	Average of days > high score	Sub-catchment average	Report Card grade
Upper Marne	63	36	20	36	56	43	42.77	C
Lower Marne	50	30	15	50	50	50	40.83	C
North Rhine	50	30	0	50	50	50	38.33	D
Upper Saunders	50	30	0	30	50	50	35	D
Lower Saunders	No data							
Marne Saunders Total Score							39.23	D

**No data = There is insufficient data available to score an indicator of health*

Table 11: 2025 Report card flow scoring across metrics for each sub-catchment

Sub-catchment	Average flow days score	Average low flow days score	Average break of season score	Average spring flow score	Average of days > median score	Average of days > high score	Sub-catchment average	Report Card grade
Upper Marne	63	36	10	10	43	16	30	D
Lower Marne	40	30	15	15	0	0	16.66	F
North Rhine	30	30	0	0	0	0	10	F
Upper Saunders	50	30	0	30	30	0	23.33	D
Lower Saunders	No data							
Marne Saunders							20.00	D
Total Score								

**No data = There is insufficient data available to score an indicator of health*

Fluctuations in flow such as prolonged dry periods can disrupt habitats, leading to declines in sensitive species and reducing the overall biodiversity. For example, extended cease-to-flow conditions reduce water quality in permanent water pools, and delayed breaks in seasonal flows can impede critical life cycle events such as fish migration and breeding. Conversely, regular and healthy flow regimes contribute to habitat stability, promoting species diversity and ecological resilience.

The scoring shows that most sub-catchments in the Marne Saunders region experienced below-average flow conditions, with scores generally ranging from C (Fair) to D (Poor). Low flow days were notably high in several areas, indicating prolonged periods of insufficient water, while delays in the break of season further stressed aquatic habitats by postponing critical water flows. Spring flow and days above median flow were also lower than historical averages in many sub-catchments, limiting habitat replenishment and the ecological benefits of seasonal flows.

One key finding was the average break in season is at historically high levels (i.e. higher values represent a delay in the onset of flow). This resulted in very low scores for this metric across much of the Marne Saunders catchment. This is concerning, as this delay conceptually leads to more challenging conditions for aquatic flora and fauna (i.e., worsening flow conditions for the ecosystem), and is likely to be representative of a change in climatic patterns seen in the catchment over recent years.

Overall, the report card assigns lower scores to sub-catchments like the North Rhine and Upper Saunders, where flow conditions are significantly diminished. While there is no flow data available for the Lower Saunders its scores for other indicators and local observations make it clear that flow conditions are equally dire in this area. In contrast, the Upper Marne showed relatively better performance with more consistent flow patterns, though still reflecting some ecological stress.

1.4 Surface water flow: trend analysis method

Trend analysis for the surface water flow indicator was undertaken using the same dataset used for the flow scoring analysis. Statistical modelling was conducted in RStudio (version 1.2.5042) running R version 4.0.0 (R Core Team, 2013).

Trends were estimated using Bayesian Generalised Linear Mixed Models (GLMMs) implemented through the `stan_glmer` function in the `rstanarm` package (Stan Development Team, 2016). This modelling approach generates repeated estimates of the slope of change through time for the indicator.

Each model run produces a distribution of slope estimates representing the direction and magnitude of change across the monitoring record. The proportion of positive and negative slope estimates returned by the model was then used to assess the likelihood of increasing or decreasing trends in surface water flow conditions.

Trend likelihood classifications were interpreted using the Intergovernmental Panel on Climate Change (IPCC) likelihood framework (Mastrandrea et al., 2010). Under this approach, the proportion of positive or negative slope estimates is used to determine the likelihood that a trend is increasing or decreasing (Table 12).

Table 12: summarises the likelihood categories applied to interpret model results

% positive slope results	% negative slope results	Trend assessment
99-100	0-1	Virtually certain increase
95-99	5-1	Extremely likely increase
90-95	10-5	Very likely increase
66-90	10-33	Likely increase
33-66	33-66	About as likely as not
10-33	66-90	Likely decrease
10-5	90-95	Very likely decrease
5-1	95-99	Extremely likely decrease
0-1	99-100	Virtually certain decrease

1.5 Surface water flow: trend analysis results

The Bayesian trend analysis indicates that surface water flow conditions across the Marne Saunders catchment have generally declined over the monitoring period. Across most monitoring sites and flow metrics, the modelling returned a higher proportion of negative slope estimates than positive slopes, indicating a likely decreasing trend in flow conditions (Table 13).

Taken together, the results indicate a shift in the catchment flow regime toward fewer and later flow events, with a reduced occurrence of moderate and high flows. These patterns align with the broader

rainfall runoff changes observed in the Marne Saunders catchment since the Millennium Drought, where comparable rainfall now produces less runoff and streamflow.

Changes in the timing, duration and magnitude of flows have important ecological implications. Extended cease-to-flow periods delayed seasonal flows and fewer high-flow events can reduce aquatic habitat availability, place pressure on refuge pools and limit opportunities for movement and breeding of aquatic species.

It is important to note that the creeks and rivers of the Marne Saunders catchment are naturally intermittent systems and therefore exhibit substantial variability in flow conditions. The Bayesian modelling approach used in this analysis accounts for this variability by estimating the probability of directional change over time rather than relying on deterministic trend tests alone.

As additional monitoring data become available, future analyses will allow these trend estimates to be refined and will further improve understanding of long-term hydrological change in the catchment.

Table 13: Trend result for surface water flow across the Marne Sauders catchment

Indicator		Mean slope	Proportion of negative slopes	Credible interval (5th and 95th percentile)	Trend
Surface water flow		-0.699977275	0.9906	-1.17583484 to -0.211731572	Virtually certain decrease

2. Water quality status

Water quality is assessed across both refuge (permanent) pools and temporary (ephemeral) waterbodies, reflecting the different but complementary roles these habitats play within the catchment. Water quality influences the suitability of aquatic habitats, particularly during periods of low or no flow when conditions can deteriorate rapidly. In the Marne Saunders catchment, declining flow conditions increase the importance of water quality as a driver of ecological persistence, especially within refuge pools.

Assessments are based on key parameters—dissolved oxygen, salinity and pH—which together provide an indication of habitat suitability for aquatic species. These parameters are sensitive to changes in flow regime, climate and water use, and therefore provide an important link between hydrological change and ecological response. Water quality is assessed across multiple recent years (2022–23 to 2024–25 water years), allowing comparison across varying climatic and hydrological conditions.

2.1 Refuge pools

Refuge pools are critical habitats in the Marne Saunders catchment, providing the primary means for aquatic species to persist through extended dry periods when streams cease to flow. Their condition is therefore a key indicator of the resilience of the aquatic ecosystem.

The ecological function of refuge pools is closely linked to both water quality and hydrological connectivity. Poor water quality, reduced inflows, and extended isolation can lead to increased salinity, reduced dissolved oxygen and declining habitat suitability, particularly for sensitive native species.

Refuge pool condition is assessed using dissolved oxygen, salinity and pH, supported by data from multiple monitoring programs including Nature Glenelg Trust surveys, Waterbug Bioblitz and Waterwatch. These complementary datasets provide broad spatial coverage and capture variability across the catchment.

The condition of refuge pools is an important indicator of broader catchment health. Healthy permanent pools support biodiversity during dry periods and provide insight into the overall resilience of the river system under variable flow conditions.

2.1.1 Refuge pools: where the data came from

Nature Glenelg Trust's (NGT) fish monitoring (see Gannon et al, 2021) and the Waterbug Bioblitz program provided data on water quality across regions of the catchment which contain refuge pools. Together they represent the best available data that provides comprehensive coverage of permanent pools, however, no NGT sites with permanent water are in the Upper Saunders and the Waterbug Bioblitz did not sample in the Lower Marne or Lower Saunders until 2025 when new sites were added in response to community requests. Data were also collected at different times of the year (NGT in April 2023, Bioblitz in October 2023), which may introduce variations due to the time of year and exact location. Figure 10 below shows the location of all sites factored into this analysis. Figure 9 below shows the location of all sites factored into this analysis.

While these monitoring programs have different focuses, both monitoring efforts measure key water quality parameters using calibrated multi-meters, including:

- **Dissolved oxygen (DO)** which is vital for supporting aquatic life, especially during periods of low flow or drought when oxygen levels in pools can become dangerously low.
- **Salinity (conductivity or EC)** measures the salt concentration in the water, which can affect aquatic species and water quality. High conductivity levels may render pools unsuitable for freshwater species.
- **pH** indicates the acidity or alkalinity of the pool water, which impacts species' survival and overall habitat health.

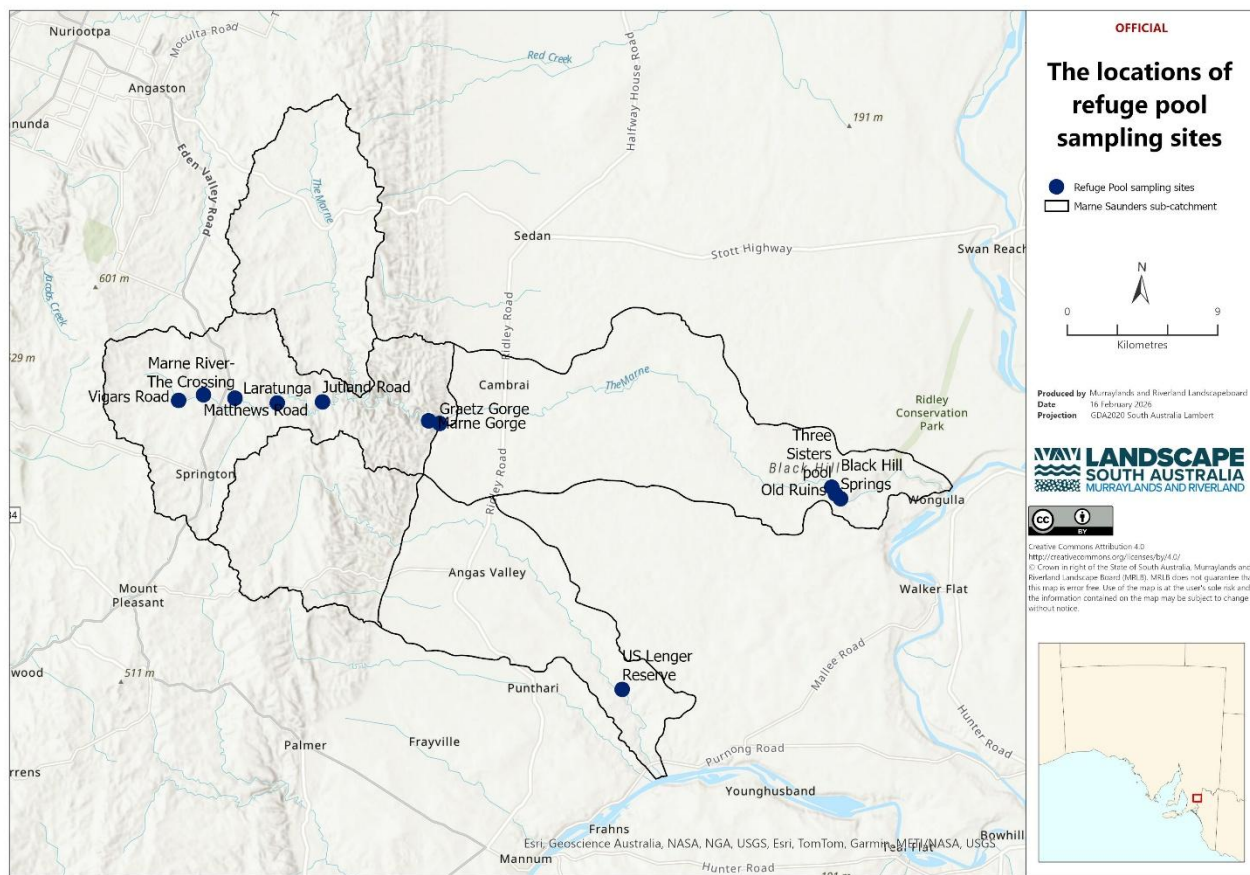


Figure 9: Map showing the location of sampling sites where permanent pool health data was gathered

Dissolved oxygen, salinity, and pH data are combined to form a water quality index, which is used to assess the overall health of permanent pools. This index integrates the 3 parameters to provide a holistic view of water quality in each pool.

To improve the water quality index, it is weighted by a pool condition factor. This factor is determined through in situ observations at each site, indicating how full or depleted the pool is at the time of sampling. Pools that are closer to their maximum capacity generally have better water quality and more stable ecological conditions, while pools that are nearly dry are likely to experience elevated salinity, reduced oxygen, and poor habitat conditions.

2.1.2 Refuge pool: scoring method

Grades are assigned using thresholds of the above index based on the requirements of 3 priority native fish species that are endemic to the Marne Saunders catchment - river blackfish, obscure Galaxias and carp gudgeon.

1. Water quality index calculation

Dissolved oxygen (DO): Dissolved oxygen is critical for the survival of aquatic organisms, particularly fish. Low oxygen levels can lead to fish stress, reduced reproduction rates, and even cause fish kills during extreme conditions.

Most fish species within the catchment require dissolved oxygen levels between 4 mg/L and 6 mg/L for healthy survival, with 6 mg/L being the optimum threshold for growth, reproduction, and recruitment. Species such as the river blackfish and obscure Galaxias are more sensitive and thrive in well-oxygenated waters, typically needing levels above 6 mg/L (Pitman and Tinkler, 2005). Generalist species, like the carp gudgeon, can tolerate lower oxygen conditions but dissolved oxygen should not drop below 3 mg/L, as lower levels can severely impact fish health and lead to declines in populations.

- River blackfish (*Gadopsis marmoratus*) requires well-oxygenated water with dissolved oxygen levels ideally above 6 mg/L. Levels below 6 mg/L can negatively affect survival and recruitment, and levels below 3 mg/L are likely unsustainable for this species.
- Galaxiid fishes prefer dissolved oxygen levels in the range of 4 to 6 mg/L with optimal conditions above 6 mg/L. Levels lower than 4 mg/L can cause stress and impact population health (Urich, 2017)
- Carp gudgeon (*Hypseleotris spp.*) is more tolerant of lower oxygen levels and is able to survive in environments with dissolved oxygen levels as low as 3 mg/L, but it thrives in more oxygenated conditions around 5-6 mg/L (Dwyer et al, 2014)

Based on these biological threshold levels, the grades for DO readings were implemented as below as shown in table 14.

Table 14: The biological threshold levels, the grades for DO readings were implemented

Grade	DO	Notes	Score
A (Very Good)	Above 6 mg/L	Optimal for supporting fish health, particularly for species requiring high oxygen levels.	100
B (Good)	Between 5-6 mg/L	Sufficient for most fish species but potentially stressing sensitive species during prolonged periods.	75
C (Moderate)	Between 4-5 mg/L	May lead to stress in fish, particularly during warmer months when oxygen demand is higher.	50
D (Poor)	Between 2-4 mg/L	Poses a significant risk to fish survival, especially for species requiring higher oxygen for sustained health.	25
F (Very Poor)	Below 2 mg/L	Considered hypoxic and lethal for most fish and other aquatic organisms.	0

Salinity (conductivity): Salinity, measured by electrical conductivity (EC), affects water quality and the ability of freshwater species to survive. High salinity levels can disrupt fish physiology and reduce reproductive success.

Most native fish species are sensitive to high salinity levels, which should ideally remain below 1500 $\mu\text{S/cm}$ to support healthy populations. However, some more tolerant species, such as the carp gudgeon, can persist at levels approaching 10,000 $\mu\text{S/cm}$. For freshwater specialists like river blackfish and obscure Galaxias, conductivity levels exceeding 1000-1500 $\mu\text{S/cm}$ can significantly hinder their survival, recruitment, and reproduction (Dunlop et al, 2005).

- River blackfish (*Gadopsis marmoratus*) prefers low to moderate conductivity, ideally below 1500 $\mu\text{S/cm}$. Elevated conductivity levels above this can hinder their survival, recruitment, and overall health (Whiterod and Hammer, 2013).
- Obscure Galaxias (*Galaxias oliros*) can tolerate slightly higher conductivity but thrives in levels below 1500 $\mu\text{S/cm}$. Conductivity levels exceeding this can lead to stress and reduced recruitment.
- Carp gudgeon (*Hypseleotris* spp.) is a more tolerant species and can survive in a wide range of conditions, with conductivity levels tolerable up to 10,000 $\mu\text{S/cm}$ though optimal health is seen in lower conductivity environments around 1500-2000 $\mu\text{S/cm}$.

Based on these biological threshold levels, the grades for salinity readings were implemented as below as shown in table 15.

Table 15: The biological threshold levels, the grades for salinity readings were implemented

Grade	Salinity	Notes	Score
A (Very Good)	Below 1500 $\mu\text{S/cm}$	Represents freshwater conditions ideal for native fish species and other aquatic organisms.	100
B (Good)	Between 1500 and 5000 $\mu\text{S/cm}$	Acceptable for most native fish, but potentially affecting more sensitive species over time.	75
C (Moderate)	Between 5000 and 7500 $\mu\text{S/cm}$	Poses stress for freshwater fish species, potentially leading to lower reproductive success and species diversity.	50
D (Poor)	Between 7500 and 10,000 $\mu\text{S/cm}$	Beyond the tolerance of many native fish species, leading to reduced health and survival rates.	25
F (Very Poor)	Above 10,000 $\mu\text{S/cm}$	Salinity at this level is harmful, if not lethal, to freshwater fish species and many other aquatic organisms, severely reducing biodiversity and ecosystem function.	0

pH: pH levels indicate the acidity or alkalinity of the water, which is described with a logarithmic scale ranging from 0-14 with numbers below 7 being acidic and above 7 alkaline. Extreme values for either being harmful to aquatic life. Most freshwater species, including native fish, thrive in neutral (7) to slightly alkaline conditions.

The pH range recorded in the catchment across 2022-2023 was approximately 7.2 to 8.7, which falls within the tolerable range for most freshwater species (Alabaster and Lloyd, 1980). However, extreme shifts could affect recruitment and survival rates for some species which tend to have narrower environmental tolerances. Maintaining this stable pH is crucial for the continued health of fish populations within the catchment.

- River blackfish (*Gadopsis marmoratus*) prefers a neutral to slightly alkaline pH range, typically between 7.0 and 7.8. Deviations from this range can negatively impact recruitment and survival.
- Obscure Galaxias (*Galaxias oliros*) generally tolerate pH levels within the range of 6.5 to 8.0 with optimal conditions closer to 7.0 to 7.5
- Carp gudgeon (*Hypseleotris spp.*) is a more generalist species and can tolerate a wider pH range, typically from 6.0 to 8.5, but it thrives in near-neutral waters around 7.0 to 7.5.

Based on these biological threshold levels, the grades for pH readings were implemented as below as shown in table 16.

Table 16: The biological threshold levels, the grades for pH readings were implemented

Grade	pH	Notes	Score
A (Very Good)	Between 7.0 and 7.5	Optimal for native species, supporting healthy metabolic and reproductive processes.	100
B (Good)	Between 6.5 and 7.0 or 7.5 and 8.0	Still supportive of aquatic life but may cause stress in some species.	75
C (Moderate)	Between 6.0 and 6.5 or 8.0 and 8.5	May cause physiological stress to fish and other aquatic organisms.	50
D (Poor)	Between 5.5 and 6.0	Survival and reproduction rates for native fish begin to decline.	25
F (Very Poor)	Below 5.5 or above 8.5	Water conditions are unsuitable for sustaining most freshwater fish species, leading to poor survival rates.	0

2. Weighting by pool condition factor

To ensure that the water quality index accurately reflects the real-time state of each pool, the index is weighted by a pool condition factor. This factor is based on in situ observations that assess how full or depleted each pool is relative to its typical capacity. A value is assigned to each category, to be applied as a weighting to the average of (salinity+pH+DO/3):

- **Bank level = 1**
- **Low level = .75**
- **Concentrating = .5**
- **Dry = 0**

3. Final scoring and grade assignment

To arrive at a final score for each site (out of 100, to which a grade is assigned), the following process was followed.

Site example:

Site Code	Sub Catchment	Pool condition	Pool condition factor	pH	pH Score	Conductivity (uS/cm)	Conductivity Score	DO	DO score	Grade score
Vigars Road	Upper Marne	Concentrated	0.5	7.52	75	3734	75	3.4	25	29.16666667

$$\text{Final scoring} = \frac{\text{Conductivity score (75)} + \text{DO score (25)}}{3} \times \text{Pool condition factor} = 29.16$$

Where one or more parameters are unavailable, the site score is calculated as the average of the available parameters only.

Example (DO not available):

$$\text{Water Quality Score} = (\text{pH score (75)} + \text{conductivity score (75)})/2 = 75$$

Site-level water quality scores are then averaged across all temporary water sites within each sub-catchment to produce a sub-catchment level water quality score. Sub-catchment grades are assigned based on these average water quality scores, using the grading criteria outlined.

This water quality index for each site is then given a grade following the cutoff thresholds below:

- **A (80- 100; Very Good):** Overall scores above 80, indicating optimal water quality and a well-maintained pool capable of supporting diverse aquatic life, particularly native fish species.
- **B (Good):** Scores between 60-79, reflecting good conditions with some minor stressors, but still supportive of healthy aquatic ecosystems.

- C (Moderate): Scores between 40-50, indicating moderate stress on water quality and pool condition, which may limit the pool's capacity to fully support aquatic biodiversity.
- D (Poor): Scores between 20-39, representing significant ecological degradation, where water quality is poor, and native species survival is at risk.
- F (Very Poor): Scores below 20, reflecting critically poor water quality and habitat conditions.

2.1.3 Refuge pools: scores per sub-catchment

The permanent pool assessment reveals significant variability in the condition of permanent pools across the catchment.

Key findings:

Variability in water quality across different sub-catchments highlights concerns for some permanent pools, particularly regarding dissolved oxygen (DO) levels, salinity and pH. The analysis provides a clearer picture of the health of these key aquatic refuges, with some pools showing significant stress.

Dissolved oxygen (DO)

Table 17 represents the dissolved oxygen (DO) levels across the sub-catchments present a varied with some areas showing critically low values and others demonstrating healthier conditions.

- Lower Marne consistently recorded low DO levels across all snapshot years (2023: 1.5–3.4 ppm; 2024: 1.9–3.5 ppm; 2025: 1.8–4.3 ppm). Although there is a slight improvement in 2025, the values remain within ranges that may stress fish and other aquatic life.
- Lower Saunders recorded relatively high DO levels compared to other sub-catchments (2023: 11 ppm; 2024: 13.58 ppm; 2025: 9.9 ppm). While there was a decline in 2025, the levels remain generally suitable for supporting aquatic life.
- Upper Marne shows the greatest variability across the three years. In 2023, DO ranged from 2.1–8.2 ppm, indicating moderately stressed to healthy conditions. However, in 2024, levels dropped sharply to 0.86–3.47 ppm, suggesting significant oxygen stress in several pools. In 2025, the range widened dramatically (0.2–8.8 ppm), indicating unstable conditions, with some pools experiencing critically low oxygen levels that could severely impact aquatic organisms.

Overall, 2024 reflects a noticeable decline in average DO levels (3.87 ppm), indicating poorer overall water quality during that year, followed by partial recovery in 2025 (4.62 ppm). However, the wide ranges observed, particularly in Upper Marne, suggest fluctuating and potentially unstable oxygen conditions across the system.

Table 17: Dissolved Oxygen (DO) Concentrations (ppm) across sub-catchments from 2023–2025

Sub-catchment	Dissolved oxygen (DO) 2023	Dissolved oxygen (DO) 2024	Dissolved oxygen (DO) 2025
Lower Marne	1.5-3.4	1.9-3.5	1.8-4.3
Lower Saunders	11	13.58	9.9
North Rhine	N/A	N/A	N/A
Upper Marne	2.1-8.2	0.86-3.47	0.2-8.8
Upper Saunders	N/A	N/A	N/A

*N/A = *There are no refuge pools in a sub-catchment*

Salinity (conductivity)

Table 18 demonstrate the salinity levels, measured as conductivity, are a key concern in many pools. The salinity concentration indicates considerable spatial variation between sub-catchments and increasing variability over time, particularly in Upper Marne.

- Lower Marne pools display consistently moderate to high salinity levels, ranging from 6,090–7,588 $\mu\text{S}/\text{cm}$ in 2023, increasing to 6,098–8,692 $\mu\text{S}/\text{cm}$ in 2024, and slightly decreasing to 5,198–7,020 $\mu\text{S}/\text{cm}$ in 2025. Although there is a reduction in 2025, salinity remains elevated, suggesting ongoing salinisation pressure within this sub-catchment.
- Lower Saunders exhibits persistently high salinity levels, with conductivity recorded at 13,103 $\mu\text{S}/\text{cm}$ in 2023, decreasing slightly to 11,818 $\mu\text{S}/\text{cm}$ in 2024, and ranging between 11,818–11,957 $\mu\text{S}/\text{cm}$ in 2025. These values are extremely high for freshwater systems and are likely to be detrimental to most native freshwater species, reducing biodiversity and affecting overall ecosystem function.
- Upper Marne pools show substantial variability and an increasing salinity trend over time. Conductivity ranged from 1,895–6,818 $\mu\text{S}/\text{cm}$ in 2023, increasing dramatically to a maximum of 12,186 $\mu\text{S}/\text{cm}$ in 2024, and further expanding to 15,616 $\mu\text{S}/\text{cm}$ in 2025. This widening range indicates escalating salinity stress, with some pools reaching levels that may severely impact sensitive aquatic organisms.

Table 18: Salinity concentrations ($\mu\text{S/cm}$) across sub-catchments from 2023–2025

Sub-catchment	Salinity ($\mu\text{S/cm}$) 2023	Salinity ($\mu\text{S/cm}$) 2024	Salinity ($\mu\text{S/cm}$) 2025
Lower Marne	6090-7588	6098-8692	5198-7020
Lower Saunders	13103	11818	11818-11957
North Rhine	N/A	N/A	N/A
Upper Marne	1895-6818	1915-12186	1895-15616
Upper Saunders	N/A	N/A	N/A

*N/A = *There are no refuge pools in a sub-catchment*

pH levels

Table 19 show the pH levels across the catchment fall within a range that is generally suitable for aquatic life, although there are slight deviations.

- Upper Marne pools show variability, with pH ranging from 6.0 to 8.64 over 2023 to 2025 year. While most values fall within the acceptable range for freshwater species, the increase toward more alkaline conditions in 2025 (up to 8.64).
- Lower Marne pools maintain relatively stable pH levels between 7.24 and 7.65 across all snapshot years, remaining tolerable range for most freshwater organisms and indicating stable water.
- Lower Saunders pools also display consistent pH values (7.45–7.68), which fall within the acceptable range for aquatic life.

Table 19: pH level across sub-catchments from 2023–2025

Sub-catchment	pH 2023	pH 2024	pH 2025
Lower Marne	7.25-7.56	7.24-7.46	7.27-7.65
Lower Saunders	7.66	7.68	7.45
North Rhine	N/A	N/A	N/A
Upper Marne	6-8.18	7.44-8.09	7.8-8.64
Upper Saunders	N/A	N/A	N/A

*N/A = *There are no refuge pools in a sub-catchment*

This analysis reveals that primary concerns should focus on low dissolved oxygen and high salinity levels in several key pools, particularly in the Lower Marne sub-catchments. These conditions are likely to significantly reduce the ecological function of these refuge pools, putting native species at risk. However, some pools, particularly in the Upper Marne, show more favourable conditions, with higher oxygen levels and more manageable salinity.

The report card assessment of the sub-catchments indicates a decline in overall catchment between 2023 and 2025. The total catchment grade decreased from C in 2023 to D in 2024, remaining at D in 2025, reflecting a sustained deterioration in environmental performance. Lower Marne held a C grade in 2023 and 2024 before declining to D in 2025, corresponding to a decrease in score over the period. Lower Saunders improved from a D grade in 2023 to C in 2024, reflecting a temporary increase in score, but fell back to D in 2025. Upper Marne declined from C in 2023 to D in both 2024 and 2025, showing a consistent reduction in score and grade. No grades or scores were available for North Rhine and Upper Saunders due to the absence of any pools retaining water all year, limiting full catchment comparison. Overall, the combined grade and score demonstrate a downward in the health of the catchment over snapshot period (Table 20).

Table 20: Summary refuge pool scoring and grade per sub-catchment across the Marne Saunders for snapshot year

	2023		2024		2025	
Sub-catchment	Score	Grade	Score	Grade	Score	Grade
Lower Marne	50.00	C	41.66	C	32.63	D
Lower Saunders	29.16	D	43.75	C	33.33	D
North Rhine	N/A	N/A	N/A	N/A	N/A	N/A
Upper Marne	53.38	C	28.12	D	19.44	D
Upper Saunders	N/A	N/A	N/A	N/A	N/A	N/A
Total MS catchment	50.52	C	35.15	D	27.08	D

**N/A = There are no refuge pools in sub-catchment*

2.1.4 Refuge pool: trend analysis method

Trend data for refuge pool condition were assessed using the same Bayesian analysis framework applied to the surface water flow indicators. This approach uses repeated model runs to estimate the direction and magnitude of change through time, allowing the probability of increasing or decreasing trends to be assessed while accounting for natural variability in the monitoring record.

2.1.5 Refuge pool: trend analysis finding

The refuge pool trend results across the catchment showed a decreasing trend. The trend result based on Bayesian linear modelling shown in the table 21, indicates that the mean slopes are negative across overall monitoring catchment, suggesting a statistically credible downward trend in flow over the study period.

Table 21: Trend result for refuge pool across the Marne Sauders catchment

Indicator	Mean slope	Proportion of negative slopes	Credible interval (5th and 95th percentile)		Trend
Refuge pool	-0.918033741	0.7614	-3.274677259	to 1.453421281	Likely decrease

The “likely decrease” in water-quality scores (mean slope -0.918; 76% negative slopes) indicates refuge pools are trending downward – with reduced water quality and resilience. Consistent with DEW’s ecological argument that intermittency (longer dry/isolation periods and delayed flow breaks) compromises refuge function, increasing salinity/stress and lowering habitat suitability for sensitive taxa.

2.2 Temporary water quality

Temporary waterbodies, including ephemeral pools and short duration flowing habitats, play an important role in maintaining ecological function during wetter periods. Although they do not provide long-term refuge, they support pulses of productivity, enable species movement and dispersal, and contribute to connectivity between habitats.

The condition of temporary water sites is assessed using the same core water quality parameters as refuge pools—dissolved oxygen, salinity and pH—allowing comparison across habitat types while recognising their different ecological roles.

Due to their ephemeral nature, temporary sites are not assessed using a pool condition factor. Sites that are dry at the time of monitoring are recorded as F (dry), reflecting the absence of available habitat and loss of connectivity at that time.

Water quality for temporary (ephemeral) water sites is calculated using the same scoring framework applied to permanent refuge pools; however, *the pool condition weighting factor is not applied*. At each site, individual water quality parameter scores for pH, electrical conductivity (salinity), and dissolved oxygen (DO) are averaged to derive an overall water quality score.

2.2.1 Temporary water: where the data came from

Data sources

Nature Glenelg Trust (NGT) fish monitoring and the Waterbug Bioblitz (macroinvertebrate) program and Waterwatch. Figure 10 below shows the location of temporary water all sites factored into this analysis.

Monitoring methods for the Waterbug Bioblitz include field measurements using calibrated multimeters to record standard pool water quality parameters. Waterwatch uses Electrical Conductivity meters and pH strips.

- Dissolved oxygen (DO) critical for aquatic life, especially during low-flow/drought when pools may stratify or deoxygenate.
- Salinity (conductivity, EC) controls species tolerance; high EC can make refuge pools unsuitable for many freshwater taxa.
- pH affects physiology and survival; extremes reduce habitat suitability.

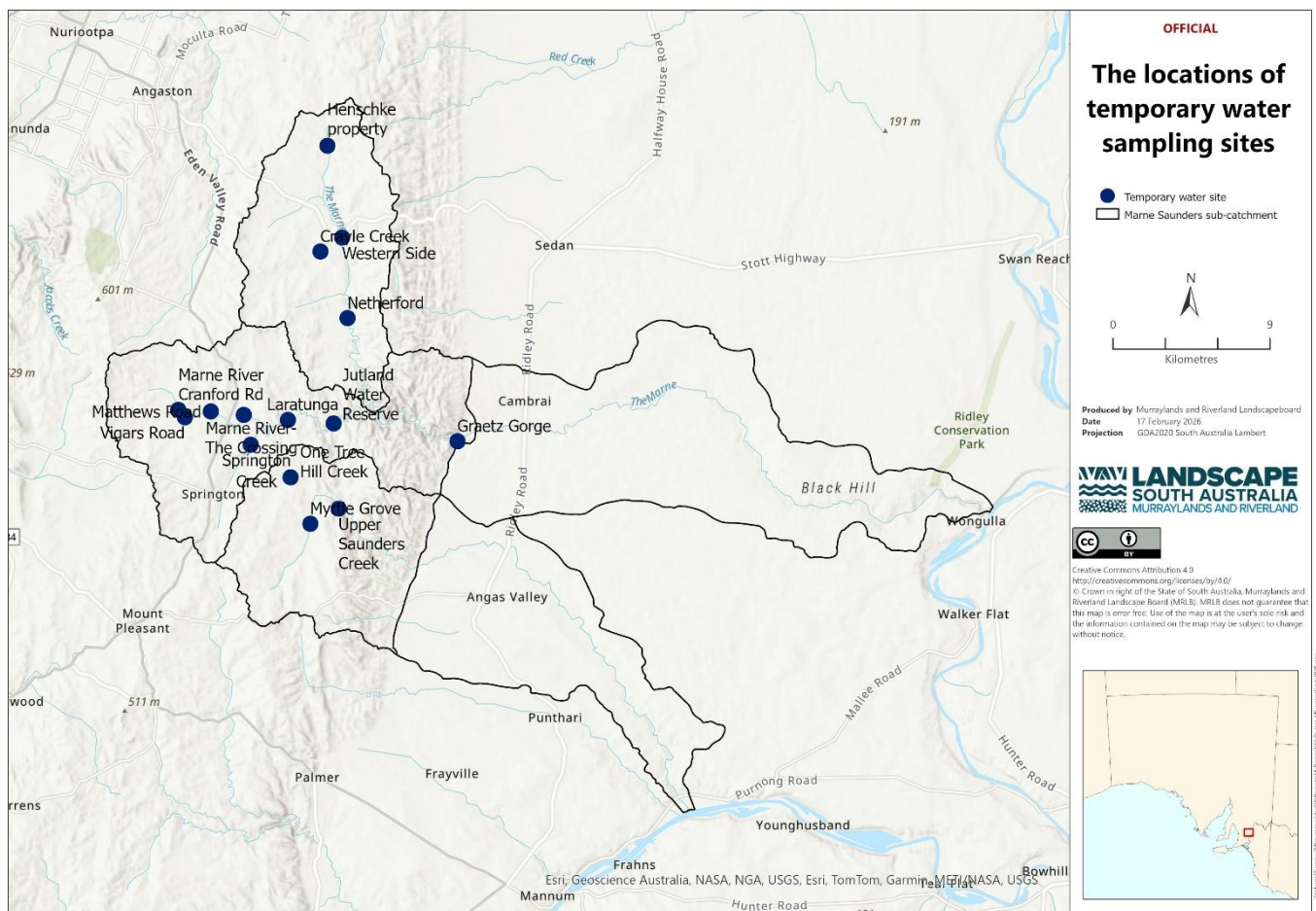


Figure 10: Map showing the location of sampling sites where temporary water site data was gathered

Dissolved oxygen, salinity, and pH data are combined to form a water quality index, which is used to assess the overall health of permanent pools. This index integrates the 3 parameters to provide a holistic view of water quality in each pool.

2.2.2 Temporary pool: scoring method

Grades are assigned using thresholds of the above index based on the requirements of 3 priority native fish species that are endemic to the Marne Saunders catchment - river blackfish, obscure Galaxias and carp gudgeon.

1. Water quality index calculation

For the temporary pool, the water quality index calculation for dissolved oxygen (DO) and pH was the same as that used for the refuge pool indicator.

However, unlike the refuge pool, salinity scoring criteria, salinity scores for temporary pools were estimated using a percentile method (see below):

Salinity (conductivity):

Salinity measures the salt concentration in the water, which can affect aquatic species and water quality. High conductivity levels may render pools unsuitable for freshwater species (percentile method).

Percentile calculation

Percentiles are summary statistics used to describe the distribution of a variable within each bore dataset and across the catchment. They indicate the relative position of individual values within a dataset and are useful for identifying central tendency, variability, and extremes.

Salinity datasets were first quality-checked and then ordered from the smallest to the largest value. The median (50th percentile) was calculated as the central value of the ordered dataset, representing the point at which 50% of observations fall below and 50% fall above. In addition to the median, the 25th and 75th percentiles were calculated to describe the interquartile range, along with the minimum and maximum values to capture the full spread of observed conditions.

Percentile calculations were performed using Microsoft Excel, applying standard percentile functions to each bore dataset (see example below). To support catchment-scale assessment, bore datasets were grouped by sub-catchment, and percentiles were calculated across all bores within each sub-catchment. Specifically, the 25th, 50th, and 75th percentiles, as well as minimum and maximum values, were derived for each indicator.

These percentile values were subsequently used to define threshold ranges that determine scoring boundaries and report card grades. This approach ensures that scores are based on the observed distribution of data within the catchment, allowing for consistent, transparent, and statistically robust comparison across bores, sub-catchments, and reporting periods.

Percentile method example calculation:

Salinity data (measured as electrical conductivity, $\mu\text{S}/\text{cm}$) collected from the North Rhine sites ranged between 2,230 and 28,400 $\mu\text{S}/\text{cm}$. Descriptive statistical analysis was undertaken to summarise central tendency and variability within the dataset.

The following statistical measures were calculated:

- Minimum (Min): The lowest recorded value in the dataset (2,230 $\mu\text{S/cm}$).
- Maximum (Max): The highest recorded value in the dataset (28,400 $\mu\text{S/cm}$).
- Median (50th percentile): The middle value of the ordered dataset (6,030 $\mu\text{S/cm}$), representing the central tendency and reducing the influence of extreme values.
- 25th percentile (Q1): The value below which 25% of observations fall (4,860 $\mu\text{S/cm}$).
- 75th percentile (Q3): The value below which 75% of observations fall (12,680 $\mu\text{S/cm}$).

Conversion of percentile values to report card scores and grades

Salinity level (expressed as electrical conductivity, EC; $\mu\text{S/cm}$) were translated into report card scores and corresponding condition grades using a percentile-based threshold approach (Table 24). This method standardises raw EC data into a 0–100 scoring framework to enable consistent condition assessment and reporting.

Percentile values derived from the dataset distribution (minimum, 25th percentile, median, 75th percentile, and maximum) were assigned fixed performance scores representing a gradient from very good to very poor condition. Lower EC values correspond to better ecological condition and therefore receive higher scores. Conversely, higher EC values indicate elevated salinity and reduced condition, resulting in lower scores (Table 22).

Table 22: Salinity concentration range converted to report card score and grade

Minimum EC	Score	Grade
2,230	100	A
4,860	75	B
6030	50	C
12,680	25	D
28,400	0	F

Notes: This is the usual “inclusive” method used by Excel’s PERCENTILE.INC; other definitions exist (e.g., different index formulae) but the interpolation rule above is the standard approach for reporting 25th, 50th and 75th percentiles.

pH:

Scoring for temporary pool pH followed that in section 2.1.2 (for refuge pool pH) above.

Based on these biological threshold levels, the grades for pH readings were implement as show in table 23 below:

Table 23: The biological threshold levels and scores for pH

Grade	pH	Notes	Score
A (Very Good)	Between 7.0 and 7.5	Optimal for native species, supporting healthy metabolic and reproductive processes.	100
B (Good)	Between 6.5 and 7.0 or 7.5 and 8.0	Still supportive of aquatic life but may cause stress in some species.	75
C (Moderate)	Between 6.0 and 6.5 or 8.0 and 8.5	May cause physiological stress to fish and other aquatic organisms.	50
D (Poor)	Between 5.5 and 6.0	Survival and reproduction rates for native fish begin to decline.	25
F (Very Poor)	Below 5.5 or above 8.5	Water conditions are unsuitable for sustaining most freshwater fish species, leading to poor survival rates.	0

DO:

Scoring for temporary pool DO followed that in section 2.1.2 (for refuge pool pH) above. Based on these biological threshold levels, the grades for DO readings were implemented as show in table 24 below:

Table 24: The biological threshold levels and scores for DO

Grade	DO	Notes	Score
A (Very Good)	Above 6 mg/L	Optimal for supporting fish health, particularly for species requiring high oxygen levels.	100
B (Good)	Between 5 6 mg/L	Sufficient for most fish species but potentially stressing sensitive species during prolonged periods.	75
C (Moderate)	Between 4 5 mg/L	May lead to stress in fish, particularly during warmer months when oxygen demand is higher.	50
D (Poor)	Between 2 4 mg/L	Poses a significant risk to fish survival, especially for species requiring higher oxygen for sustained health.	25
F (Very Poor)	Below 2 mg/L	Considered hypoxic and lethal for most fish and other aquatic organisms.	0

3. Final scoring and grade assignment

To arrive at a final score for each site (out of 100, to which a grade is assigned), the following process was followed:

Site-level water quality scores are then averaged across all temporary water sites within each sub-catchment to produce a sub-catchment-level water quality score. Sub-catchment grades are assigned based on these average water quality scores, using the grading criteria outlined in table 25

Table 25: Water quality report card grading framework

Grade	Score range	Condition	Description
A (Very Good)	80-100	Optimal water quality	Indicates a well-maintained pool capable of supporting diverse aquatic life, particularly native fish species.
B (Good)	60-79	Minor stressors present	Reflects good conditions with some minor stressors, but still supportive of healthy aquatic ecosystems.
C (Moderate)	40-59	Moderate stress	Indicates moderate stress on water quality and pool condition, which may limit the pool's capacity to fully support aquatic biodiversity.
D (Poor)	20-39	Significant degradation	Represents significant ecological degradation where water quality is poor and native species survival is at risk.
F (Very Poor)	Below 20	Critically poor	Reflects critically poor water quality and habitat conditions.

2.2.3 Temporary pool: score per sub-catchment

Key findings:

Dissolved oxygen (DO)

The dissolved oxygen results show clear differences between sub-catchments and across years (Table 26).

The dissolved oxygen levels present a mixed picture, with some pools showing critically low values.

- North Rhine (2023) recorded DO levels between 5.1 ppm and 8.61 ppm. While the highest values reflect healthy conditions, the low range indicate that some water site may be stressed.
- Upper Marne notable variability over time. In 2023, DO levels ranged from 8.18 ppm to 14.81 ppm, indicating generally well-oxygenated conditions suitable for most aquatic life. However, in 2024, levels declined significantly, ranging from 4.24 ppm to 10.51 ppm.

- Upper Saunders shows relatively strong DO level over catchment. In 2023, DO levels ranged from 7.92 ppm to 10.63 ppm, indicating good ecological conditions. In 2024, a recorded value of 10.9 ppm suggests continued healthy oxygen levels capable of supporting aquatic life.

Table 26: Dissolved Oxygen (DO) Concentrations (ppm) across sub-catchments from 2023–2025

Sub-catchment	Dissolved oxygen (DO) 2023	Dissolved oxygen (DO) 2024	Dissolved oxygen (DO) 2025
Lower Marne	N/A	N/A	N/A
Lower Saunders	N/A	N/A	N/A
North Rhine	5.1-8.61	N/A	N/A
Upper Marne	8.18-14.81	4.24-10.51	N/A
Upper Saunders	7.92-10.63	10.9	N/A

**N/A = There are no temporary water site in a sub-catchment*

Salinity (conductivity)

Salinity levels, measured as conductivity, are a key concern in many pools (Table 27).

- North Rhine consistently records salinity. In 2023, conductivity level ranged from 2,230 to 26,640 $\mu\text{S/cm}$, indicating highly saline conditions in some pools. In 2024, salinity ranged from 5,140 to 17,310 $\mu\text{S/cm}$, and in 2025 a value of 28,400 $\mu\text{S/cm}$. These concentrations suggest persistent salinity stress and potential long-term ecological impacts.
- Upper Marne shows considerable variability, in 2023, salinity ranged from 197 to 7,970 $\mu\text{S/cm}$, indicating mostly fresh to moderately saline conditions. In 2024, the range widened significantly (235–17,020 $\mu\text{S/cm}$), and by 2025 reached 424–33,500 $\mu\text{S/cm}$. The salinity concentration in 2025 was extremely high and may stressed or unsuitable conditions for many freshwater species.
- Upper Saunders also demonstrates increasing salinity concentration over snapshot year. In 2023, salinity ranged from 174.8 to 6,190 $\mu\text{S/cm}$. In 2024, the range expanded considerably to 191–16,405 $\mu\text{S/cm}$, indicating a substantial rise in salinity in some pools. No data are currently available for 2025.

Table 27: Salinity concentrations ($\mu\text{S}/\text{cm}$) across sub-catchments from 2023–2025

Sub-catchment	Salinity ($\mu\text{S}/\text{cm}$) 2023	Salinity ($\mu\text{S}/\text{cm}$) 2024	Salinity ($\mu\text{S}/\text{cm}$) 2025
Lower Marne	N/A	N/A	N/A
Lower Saunders	N/A	N/A	N/A
North Rhine	2230-26640	5140-17310	28400
Upper Marne	197-7970	235-17020	424-33500
Upper Saunders	174.8-6190	191-16405	N/A

*N/A = There are no temporary water site in a sub-catchment

pH levels

The pH levels across the catchment fall within a range that is generally suitable for aquatic life, although there are slight deviations (Table 28).

- North Rhine, pH values between 6.5 and 9.0 in 2023 and 7.5–9.0 in 2024, indicating predominantly neutral to alkaline conditions. In 2025, a pH of 7 was recorded, reflecting neutral water quality and conditions suitable for aquatic life.
- Upper Marne shows moderate variability snapshot year. In 2023, pH ranged from 6.0 to 8.5, reflecting slightly acidic to moderately. In 2024, the range widened to 6.0–10.0, with high pH value indicating highly alkaline conditions that may stress sensitive species. In 2025, pH stabilised within a range of 6.0–7.0, suggesting generally neutral and more stable conditions.
- Upper Saunders demonstrates relatively stable pH conditions. In 2023, values ranged from 5.5 to 7.6, indicating slightly acidic to neutral conditions. In 2024, pH ranged from 6.0 to 7.7, showing a shift toward more consistently neutral conditions. No data are available for 2025.

Table 28: pH level across sub-catchments from 2023–2025

Sub-catchment	pH 2023	pH 2024	pH 2025
Lower Marne	N/A	N/A	N/A
Lower Saunders	N/A	N/A	N/A
North Rhine	6.5-9	7.5-9	7
Upper Marne	6-8.5	6-10	6-7
Upper Saunders	5.5-7.6	6-7.7	N/A

*N/A = There are no temporary water site in a sub-catchment

The overall catchment score declined from 62.98 (B) in 2023 to 49.79 (C) in 2024, before slightly improving to 57.29 (C) in 2025, indicating a drop in condition followed by partial recovery. Lower Marne and Lower Saunders remained dry in all three years and were consistently graded F (Dry). North Rhine showed a noticeable decline from 59.77 (C) in 2023 to 33.33 (D) in 2024, but improved to 50.00 (C) in 2025. Upper Marne followed a similar pattern, decreasing from 66.67 (B) in 2023 to 51.04 (C) in 2024, then recovering to 64.58 (B) in 2025. Upper Saunders performed relatively well in 2023 and 2024 with B grades, but became dry in 2025, resulting in a grade of F (Dry). Overall, the results indicate fluctuating conditions across the catchment, with several areas experiencing dry conditions that influenced the overall catchment score (Table 29).

Table 29: Summary of the average temporary water site scoring and grade per sub-catchment across the Marne Saunders for each snapshot year

Sub-catchment	2023		2024		2025	
	Score	Grade	Score	Grade	Score	Grade
Lower Marne	Dry	F (Dry)	Dry	F (Dry)	Dry	F (Dry)
Lower Saunders	Dry	F (Dry)	Dry	F (Dry)	Dry	F (Dry)
North Rhine	59.77	C	33.33	D	50.00	C
Upper Marne	66.67	B	51.04	C	64.58	B
Upper Saunders	62.50	B	65.00	B	Dry	F (Dry)
Total MS catchment	62.98	B	49.79	C	57.29	C

Temporary pools: caveats

It is important to reiterate that water quality samples were collected at different times of the year and by different organizations, including Nature Glenelg Trust and the citizen science Waterbug Bioblitz program. This variation in sampling times, the former in April prior to winter rains and the latter in October towards the end of the normal flow season may introduce inconsistencies, as seasonal factors such as temperature and rainfall can affect water quality parameters like dissolved oxygen, conductivity, and pH. Despite these challenges, this approach provides the best available information for assessing permanent pool health across the catchment.

Additionally, these programs did not monitor all pools in the catchment and did not each sample the exact same pools although there was some overlap. As such, these values can be viewed as indicative only.

2.2.4 Temporary pool: trend analysis methods

Trend analysis for the temporary pool indicator used the same flow dataset that supported the flow scoring. All trend analyses followed Bayesian approaches outlined for previous indicators. The classification rules applied are consistent with the IPCC guidance and are shown here for reference:

- Virtually certain increase/decrease: 99-100% positive/negative slopes
- Extremely likely increase/decrease: 95-99% positive/negative slopes
- Very likely increase/decrease: 90-95% positive/negative slopes
- Likely increase/decrease: 66-90% positive/negative slopes
- About as likely as not: 33-66% positive/negative slopes

Likely/Very likely/Extremely likely/Virtually certain decrease correspond to the complementary negative-slope percentages in the same percentile bands.

We report for each metric and site: the posterior mean slope, the 90% credible interval for slope, the proportion of negative and positive slope iterations, and the resulting IPCC likelihood class. Where the 90% credible interval overlaps zero and the proportion of positive and negative slopes are both within the ~33-66% band, the trend is described as “about as likely as not / stable” to reflect substantial uncertainty.

2.2.5 Temporary pool: trend analysis findings

The temporary water site trend results across the catchment showed a decreasing trend. The trend result based on Bayesian linear modelling show in the table 30, indicates that the mean slopes are negative across overall monitoring catchment, suggesting a statistically credible downward trend in flow over the study period.

The scores indicate temporary pools in the Marne Saunders PWRA are generally degraded and under stress: many refuge pools show low macroinvertebrate condition (mostly “poor”, few “fair”), fish condition is variable but several sites are declining, and flow metrics show long-term reductions in flowing days, low-flow season days and spring flows plus a delayed break-of-season. Together these lines of evidence point to reduced pool quality, reduced connectivity and increased physiological stress in temporary pools.

Table 30: Trend result for refuge pool across the Marne Saunders catchment

Indicator	Mean slope	Proportion of negative slopes	Credible interval (5th and 95th percentile)	Trend
Temporary pool	-0.529245556	0.839	-1.460803871 to 0.368525114	Likely decrease

3. Groundwater status

Groundwater is a critical component of the Marne Saunders water resource system, particularly in lower sub-catchments where it supports a substantial proportion of water use and contributes to ecological function in connected surface water systems.

The condition of groundwater is assessed through two key indicators:

- salinity, which influences water usability and ecological health, and
- depth to water (DTW), which reflects resource accessibility and long-term sustainability.

These indicators capture both the quality and availability of groundwater, and provide insight into the balance between recharge, extraction and climatic influences.

Groundwater data are derived from DEW observation well networks, WaterConnect datasets and monitoring undertaken by licence holders. Assessment across multiple years allows both current condition and longer-term patterns to be evaluated.

In this analysis, groundwater data were collected from a network of monitoring wells across the catchment as well as tested bore water samples supplied by water license holders and tested by DEW staff annually. Comparing salinity concentrations to benchmark values (ie values for suitability for relevant crop types), the report card evaluates the overall health of the groundwater system. The results help identify areas where groundwater water quality may limit its usability, highlighting the need for targeted management actions to ensure the long-term sustainability of groundwater resources in the Marne Saunders catchment.

3.1 Groundwater salinity

3.1.1 Groundwater salinity: where the data came from

The groundwater analysis in the Marne Saunders Catchment report card relies on data from monitoring wells, observation bores and private bores located [across the catchment](#) (Duszynski & Watt, 2025 – In Press).

The salinity is calculated by measuring the electrical conductivity (EC) of groundwater from collected water samples. Both government staff and private landholders supply water samples for testing and data are stored on the publicly accessible DEW [WaterConnect](#) website.

- Database extraction: salinity data was derived from government observation wells and privately-owned bores within the Marne Saunders PWRA. The most recent readings taken after the winter recharge period (typically in August), were used for the report card. If multiple readings were available for 2023, then the reading closest to the post-winter recharge was selected to ensure consistency in comparing salinity levels.
- Monitoring range: data collection focused on capturing the freshest (least saline) available readings, ensuring that salinity levels reflect the current state of groundwater post-recharge.

Locations of bores accessed for indicator analyses are described in Figure 11 below.

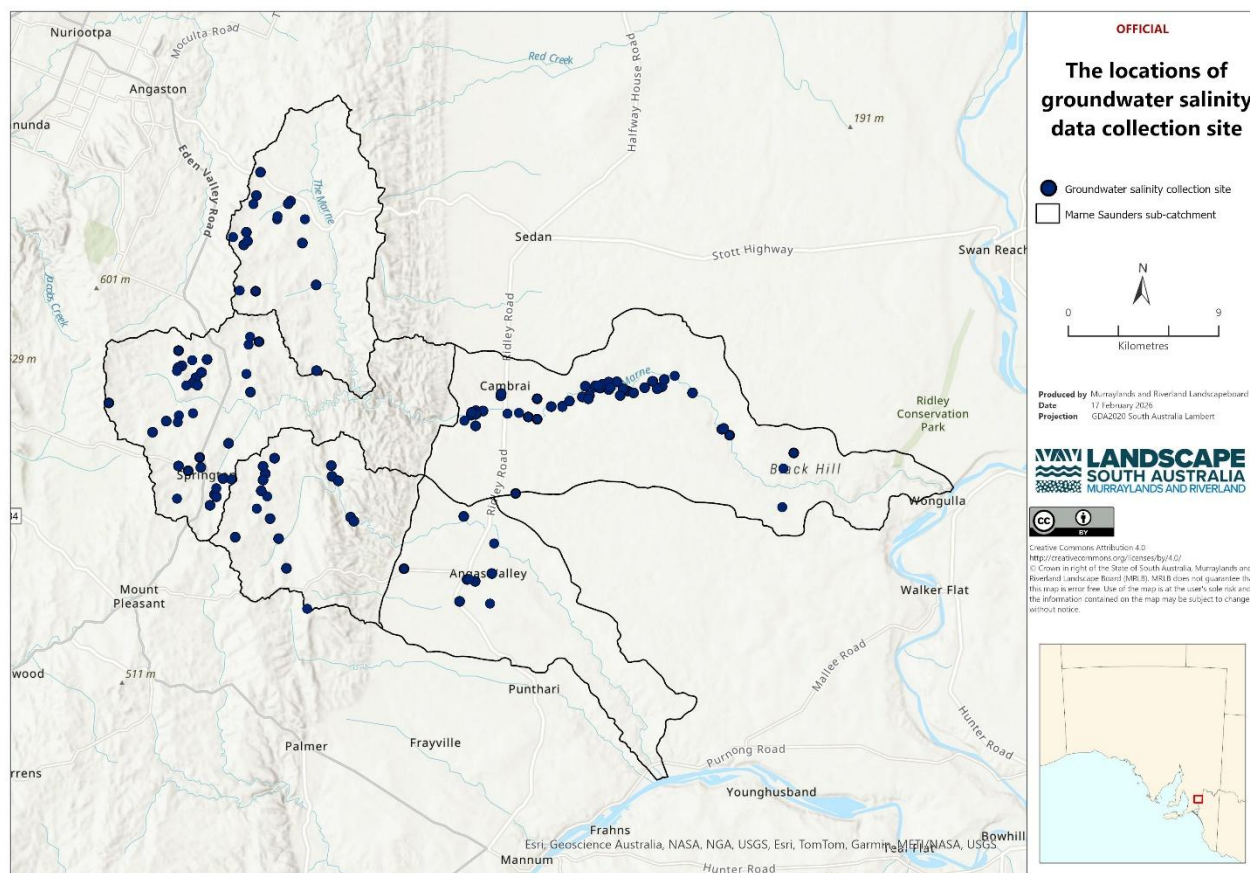


Figure 11: Map displaying data collection sites from monitoring and privately owned sites

3.1.2 Groundwater salinity: scoring method

The salinity scoring method applies specific thresholds based on crop tolerance to salinity, which serves as a proxy for water quality and agricultural suitability.

Salinity levels were assigned scores based on established thresholds for suitability of groundwater for different agricultural production (primarily based on the salinity tolerance of crops such as lucerne, wine grapes, and turf). Crop salinity thresholds can be found here: [Salinity tolerance in irrigated crops \(nsw.gov.au\)](https://www.nsw.gov.au/salinity-tolerance-in-irrigated-crops). Stock thresholds for salinity tolerance are not included as few instances fall beyond salinity levels where a decline in animal growth is noted (for sheep & cattle - ~ 10,000 $\mu\text{S}/\text{cm}$) and are all below max threshold (15,000 $\mu\text{S}/\text{cm}$).

Yield reduction for lucerne, turf, and winegrapes associated with increasing salinity is noted in Table 31 below.

Table 31: Salinity -induced crop yield reduction (adapted from Primary Industries NSW)

Crop type	Salt value = No Crop reduction ($\mu\text{S/cm}$)	Salt Value = 10% Reduction ($\mu\text{S/cm}$)	Salt value = 25% Reduction ($\mu\text{S/cm}$)
Lucerne	1300	2200	3600
Winegrape	1000	1700	2700
Turf (Kikuyu)	2000	4200	7500

Salt concentration thresholds applicable to all three crop types are shown below and have been used to determine the scoring threshold.

$$\begin{aligned}\text{No reduction} &= ((1300 \mu\text{S/cm} + 1000 + 2000)/3) \\ &= 1433 \mu\text{S/cm}\end{aligned}$$

$$\begin{aligned}\text{10\% reduction} &= ((2200 + 1700 + 4200)/3) \\ &= 2700 \mu\text{S/cm}\end{aligned}$$

$$\begin{aligned}\text{25\% reduction} &= ((3600 + 2700 + 7500)/3) \\ &= 4600 \mu\text{S/cm}\end{aligned}$$

The scoring threshold schema based on salt concentration thresholds are:

- A (Very Good): conductivity is less than 800 $\mu\text{S/cm}$, indicating excellent water quality suitable for all uses, including irrigation and drinking.
- B (Good): conductivity is between 800 and 1400 $\mu\text{S/cm}$, indicating good quality groundwater, generally safe for irrigation and suitable for most crops.
- C (Fair): conductivity is between 1400 and 2700 $\mu\text{S/cm}$, indicating moderately saline water that can still be used for irrigation but may affect sensitive crops. Water may require treatment for drinking purposes.
- D (Poor): conductivity is between 2700 and 4600 $\mu\text{S/cm}$, indicating poor water quality that will likely result in crop yield reductions.
- F (Very Poor): conductivity is greater than 4600 $\mu\text{S/cm}$, indicating saline groundwater that is unsuitable for irrigation purposes (of selected crop types) without treatment.

3.1.3 Groundwater salinity: scores per sub-catchment

The groundwater analysis provides an assessment of the condition and sustainability of groundwater resources across the catchment using best available data (Duszynski & Watt, 2025 – In Press). It provides insights into the quality of groundwater in different sub-catchments. Salinity in groundwater is a crucial parameter to monitor in the Marne Saunders catchment due to its potential influence on environmental health and ultimately agricultural productivity. Elevated salinity in groundwater can pose risks. Saline water impacts soil structure and fertility, potentially reducing the productivity of crops and pastures. In turn, this may affect the economic outputs of farming in the region, which is a cornerstone of local livelihoods. Furthermore, saline groundwater can degrade native vegetation and aquatic ecosystems, particularly in areas where groundwater feeds permanent pools, leading to loss of biodiversity and habitat.

Table 32 summarises the groundwater salinity condition scores and grades for each sub-catchment within catchment from 2023 to 2025. Overall, the results indicate generally poor groundwater salinity condition across the catchment, with limited variation between years. Groundwater salinity over the catchment remained in the D grade, with the total score declining slightly from 25.30 in 2023 to 23.84 in 2024, before improving to 26.00 in 2025.

Upper Marne consistently experienced the highest scores, increasing from 35.23 in 2023 to 36.66 in 2024, followed by a slight decrease to 32.14 in 2025, while maintaining a D grade across all years.

Lower Marne showed relatively stable results, with scores of 29.26, 30.76, and 29.89 between 2023 and 2025, also remaining within the D grade category. Upper Saunders exhibited minimal variation, with scores of 25.00 in 2023 and 2024 and a small increase to 26.92 in 2025, maintaining a D grade throughout the period.

In contrast, North Rhine showed a decline in groundwater salinity score, with the score dropping from 22.73 (D) in 2023 to 12.50 (F) in 2024, followed by a partial improved to 16.07 (F) in 2025. Lower Saunders recorded the lowest scores initially, remaining at 14.29 (F) in both 2023 and 2024, but improved to 25.00 (D) in 2025.

All sub-catchments show elevated groundwater salinity with catchment grade D across 2023-2025. Localised changes (Lower Saunders improvement in 2025; North Rhine variability) warrant investigation, but the broad pattern is persistent salinity risk that threatens agricultural productivity, ecosystem health and refuge pool condition. Immediate priority should be targeted monitoring, driver analysis and coordinated groundwater surface water intervention.

Table 32: Summary of the average groundwater salinity scoring per sub-catchment across the Marne Saunders for each snapshot year

	2023		2024		2025	
Sub-catchment	Score	Grade	Score	Grade	Score	Grade
Lower Marne	29.26	D	30.76	D	29.89	D
Lower Saunders	14.29	F	14.29	F	25.00	D
North Rhine	22.73	D	12.50	F	16.07	F
Upper Marne	35.23	D	36.66	D	32.14	D
Upper Saunders	25.00	D	25.00	D	26.92	D
Total MS catchment	25.30	D	23.84	D	26.00	D

3.1.4 Groundwater salinity: trend analysis method

For the groundwater salinity trend analysis we fitted simple linear regressions (ordinary least squares) through the full set of salinity observations for each sub-catchment (all data points pooled by year/site). This was an explicit, non-Bayesian approach: each model estimates a best-fit straight line ($y = a + b \cdot t$) where y is salinity, t is time, a is the intercept and b is the slope. The resulting slope indicates the average annual change in salinity (positive = increasing salinity; negative = decreasing), and model outputs reported include the slope, intercept, coefficient of determination (R^2) and the p-value for the slope.

How the linear regression works (overview)

- Data ordering: all salinity measurements are treated as paired (time, salinity) observations.
- Fit: ordinary least squares finds the line that minimises the sum of squared vertical errors (differences between observed salinity and the line).
- Interpretation:
 - Slope (b) = average change in salinity per unit time (e.g., $\mu\text{S}\cdot\text{cm}^{-1}$ per year).
 - Intercept (a) = modelled salinity at $t = 0$ (reference).
 - R^2 = proportion of variance in salinity explained by time (0–1).
 - p-value (for b) tests whether the slope differs from zero (statistical evidence of a trend).

3.1.5 Groundwater salinity: trend analysis findings

The linear regressions showed little coherent temporal pattern (low R^2 , non-significant slopes at many sites), but the fitted lines and raw data together highlight consistently elevated salinity values across the dataset. In other words, there is not a strong, consistent upward or downward time trend, but salinity is persistently high across observations (Figure 12). Overall, the catchment shows persistent salinity problems rather than a clear, sustained improvement. Small year-to-year score changes are evident (notably Lower Saunders improvement in 2025 and North Rhine variability), but the dominant signal is elevated salinity across sub-catchments.

Where grades improved (Lower Saunders 2025), further monitoring is needed to confirm sustained improvement and to identify drivers (e.g., climatic variation, groundwater abstraction changes, remediation actions).

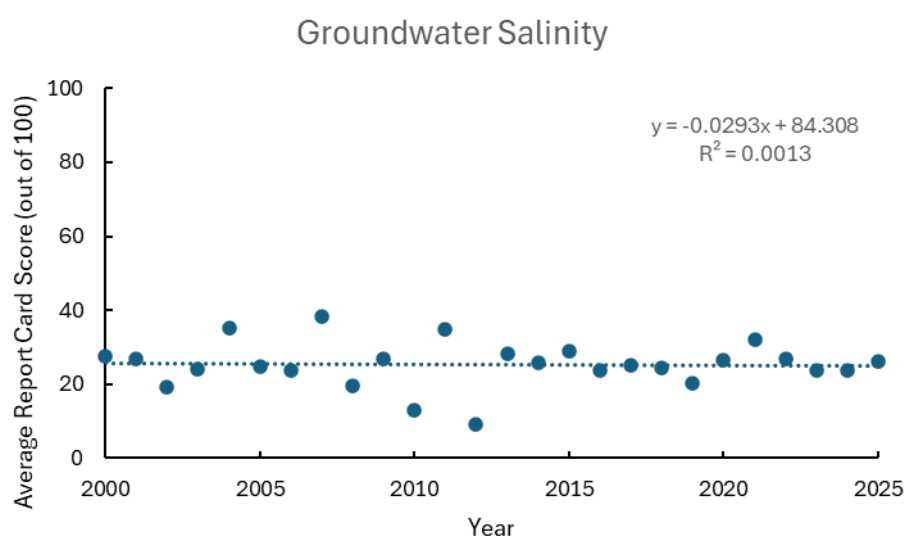


Figure 12: Groundwater salinity trend between 2000-2025

Limitations

No coherent temporal trend: the regression shows no meaningful increase or decrease in groundwater salinity scores across the monitoring period. Individual annual scores scatter around the long-run mean (the dotted line), with values repeatedly in the low-to-mid score range (≈ 10 – 40).

Persistent elevated salinity: although there is no clear trend, the absolute level of scores remains low (poor condition). The dataset therefore signals widespread salinity pressure rather than a directional change over time.

Ecological and management implications

Status *over* trend: management concern is driven by consistently poor scores (D/F grades in sub-catchments), not by a recent upward trend. Persistent elevated salinity continues to pose risks to agriculture, riparian vegetation and aquatic refugia.

Prioritise action where absolute scores are worst (Lower Saunders, Lower Marne, parts of North Rhine), even though the linear trend is flat.

Key caveats and reasons for the weak trend signal

- Pooling/all-data regression hides spatial structure: combining sites/bores and all observations into a single year-based regression averages out local increases or decreases at individual sites.
- Irregular sampling, differing record lengths and site heterogeneity reduce the power of a simple OLS trend to detect real site-level changes.
- Short/variable time series and natural year-to-year variability (climate, pumping, recharge) mask gradual change. A near-zero slope with very low R^2 is therefore not evidence of “no problem” - it indicates no consistent linear trend detectable at the catchment scale given the data configuration.

3.2 Groundwater depth to water (DTW)

Depth to water (DTW) data are analysed to assess groundwater resource condition, identify long-term changes in groundwater levels, and support sustainable water resource management. DTW data were derived from groundwater level measurements collected from wells within the monitoring network using both manual measurements and continuous water-level loggers. All available data were verified and processed to determine the annual maximum (recovered) groundwater level for each well, representing the unstressed water level following seasonal pumping for irrigation and other uses.

3.2.1 Groundwater DTW: where the data came from

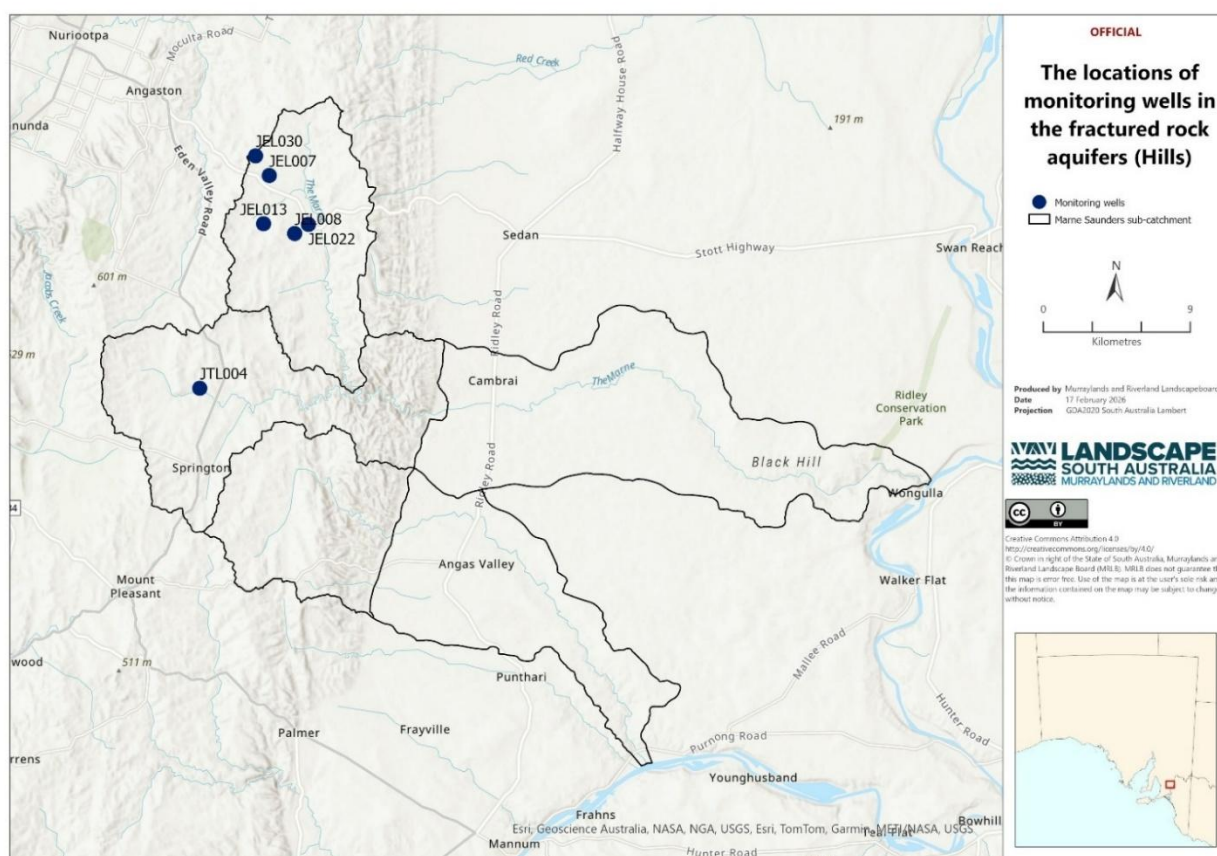


Figure 13: Locations of monitoring wells in the fractured rock (Hills)

Groundwater level data were obtained from wells within the Marne Saunders Prescribed Water Resources Area (PWRA) groundwater *aquifers* monitoring network (Duszynski & Watt, 2025 – In Press). Water levels were measured using a combination of manual

field measurements and continuous water-level loggers. All available measurements were verified and processed to determine the annual maximum (recovered) water level for each well, representing the unstressed groundwater level following seasonal pumping for irrigation and other uses. These recovered water levels were subsequently used for groundwater condition assessment and trend analysis. Figure 13 and 14 show the observation well in the fractured rock aquifers (Hills) and in the Murray Group Limestone aquifer (plains).

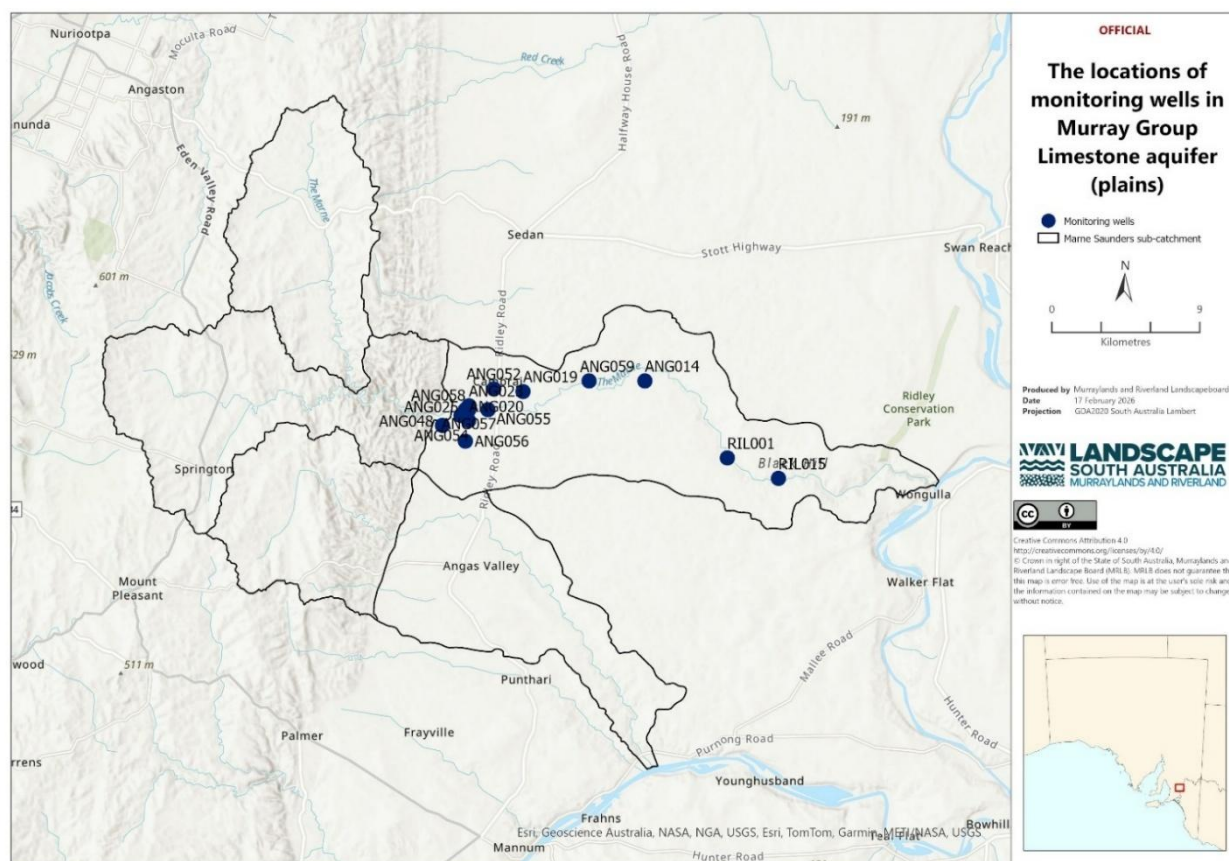


Figure 14: Locations of monitoring wells in the Murray Group limestone aquifer (plains)

3.2.2 Groundwater DTW: scoring method

Depth to water (DTW) results presented in this report card are derived from groundwater monitoring data provided by DEW.

The scoring method for groundwater status assessment is based on percentile ranges derived from the historical distribution of monitoring data. Each observation is ranked relative to the record and assigned a descriptive status category based on its percentile position as shown in the table 33. The status assessment turns into report card score and grade.

Table 33: Translation of water level status assessment to report card scoring

Status assessment	Percentile range	Report card score
Highest on record	100 th	
Very much above average	90 th to 99 th	90
Above average	70 th to 89 th	70
Average	30 th to 69 th	50
Below average	10 th to 29 th	30
Very much below average	2 nd to 9 th	
Lowest on record	1 st	0

3.2.3 Groundwater DTW: scores per sub-catchment

The assessment of sub-catchments within the total catchment reveals a declining score from 2023 to 2025. In 2023, the overall catchment score was 46, earning a grade of C. However, the score dropped sharply to 22.22 in 2024, resulting in a grade of D, and further declined to 19.83 in 2025, failing to grade F. Similar patterns were observed in individual sub-catchments such as Lower Marne and Upper Marne, where scores decreased substantially, leading to poorer grades over the three years. Data were not available for Lower Saunders and Upper Saunders during this period as show in table 34 and 35.

Table 34: Scores for DTW across entire catchment

Aquifer	Well	Sub-catchment	DTW score 2023		DTW score 2024		DTW score 2025	
			DEW Status	Report Card Score	DEW Status	Report Card Score	DEW Status	Report Card Score
fractured rock (FRA)	JEL008	North Rhine	Average	50	Below average	30	Below average	30
	JEL013	North Rhine	Below average	30	Very much below average	0	Lowest on record	0
	JEL007	North Rhine	Average	50	Below average	30	Lowest on record	0
	JEL022	North Rhine	Average	50	Very much below average	0	Lowest on record	0
	JEL030	North Rhine	Average	50	Lowest on record	0	Below average	30
	JTL004	Upper Marne	Average	50	Below average	30	Below average	30
Murray Group Limestone	RIL001	Lower Marne	Below average	30	Very much below average	0	Lowest on record	0
	ANG014	Lower Marne	Below average	30	Very much below average	0	Lowest on record	0
	ANG020	Lower Marne	Below average	30	Below average	30	Below average	30
	ANG023	Lower Marne	Average	50	Below average	30	Below average	30
	ANG025	Lower Marne	Average	50	Below average	30	Below average	30
	ANG019	Lower Marne	Below average	30	Very much below average	0	Lowest on record	0
	ANG048	Lower Marne	Below average	30	Below average	30	Below average	30
	RIL015	Lower Marne	Below average	30	Lowest on record	0	Below average	30
	ANG052	Lower Marne	Below average	30	Very much below average	0	Lowest on record	0
	ANG055	Lower Marne	Below average	30	Very much below average	0	Lowest on record	0
	ANG056	Lower Marne	Average	50	Below average	30	Below average	30
	ANG050	Lower Marne					Lowest on record	0
	ANG054	Lower Marne	Average	50	Average	50	Average	50
	ANG057	Lower Marne	Average	50	Average	50	Lowest on record	0
	ANG058	Lower Marne	Average	50	Average	50	Lowest on record	0
	ANG059	Lower Marne	Highest on record	90	Above average	70	Average	50

*Source: DEW's Marne Saunders Prescribed Water Resources Area, 2026 Water Resources Assessment.

Table 35: Summary of the average DTW score and grade per sub-catchment across the Marne Saunders for each snapshot year

	2023		2024		2025	
Sub-catchment	Score	Grade	Score	Grade	Score	Grade
Lower Marne	42	C	24.67	D	17.5	F
Lower Saunders	No data	No data	No data	No data	No data	No data
North Rhine	46	C	12	F	12	F
Upper Marne	50	C	30	D	30	F
Upper Saunders	No data	No data	No data	No data	No data	No data
Total MS catchment	46	C	22.22	D	19.83	F

*No data = There is insufficient data available to score an indicator of health

3.2.4 Groundwater DTW: trend analysis method

For the DTW trend analysis we fitted simple linear regressions (ordinary least squares) through the full set of salinity observations for each sub-catchment (all data points pooled by year/site). This was an explicit, non-Bayesian approach: each model estimates a best-fit straight line ($y = a + b \cdot t$) where y is salinity, t is time, a is the intercept and b is the slope. This method follows precisely the trend analysis employed for groundwater salinity in the previous section.

3.2.5 Groundwater DTW: trend score finding

Linear regression analysis of groundwater DTW scores indicates a declining trend over time, as evidenced by the negative slope of the fitted regression line. The coefficient of determination ($R^2 = 0.404$) suggest that time explains a moderate proportion of the variability in DTW score, indicating a meaningful but not strong relationship (Figure 15).

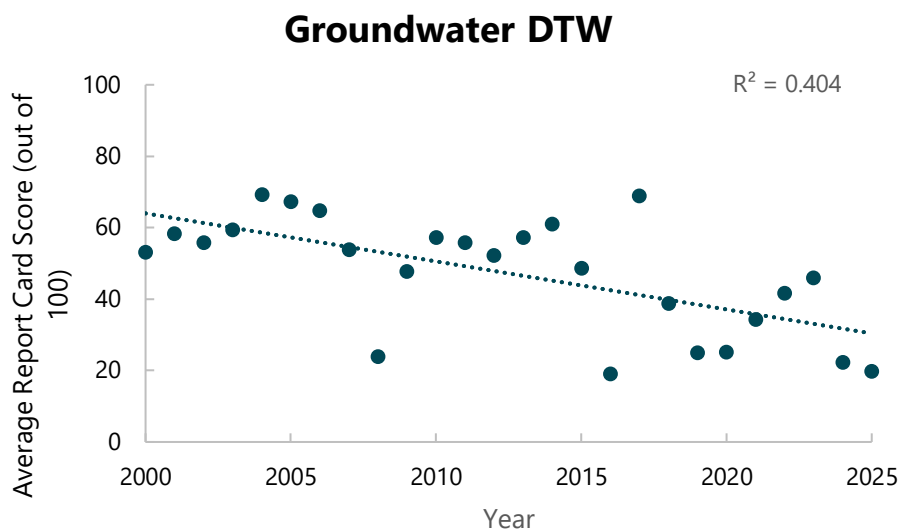


Figure 15: Groundwater depth to water trend between 2000-2025

4 Ecological status

Ecological indicators provide an integrated measure of catchment health, reflecting the combined influence of flow regime, water quality and habitat condition over time.

Fish and macroinvertebrate (waterbug) communities are used as key indicators because they respond to changes in hydrology and water quality at different temporal scales. Fish populations reflect longer-term changes in habitat availability and connectivity, while macroinvertebrates respond more rapidly to changes in flow and water quality.

Together, these indicators provide a complementary and biologically meaningful assessment of ecosystem condition across the catchment.

4.1 Fish

Fish communities are a key indicator of river health, integrating the effects of flow, water quality and habitat condition over time. Their presence, diversity and recruitment provide insight into the ability of the system to support aquatic life under changing conditions.

In the Marne Saunders catchment, fish populations are particularly sensitive to reduced flows, declining refuge pool condition and loss of connectivity. The observed decline, including the functional extinction of river blackfish, highlights the extent of ecological stress within the system.

Fish condition is assessed using modelling undertaken by Nature Glenelg Trust (see Gannon et al, 2021), incorporating species richness, abundance, recruitment and the presence of introduced species.

Monitoring focused on native and introduced species, evaluating their abundance, species richness, age classes of fish sampled, and the presence of sensitive native species. Data was collected from key aquatic habitats, including permanent pools and intermittent streams, where fish populations are most vulnerable to seasonal fluctuations in water availability.

The assessment methods incorporated a standardized scoring approach, the fish condition model (FCM), which evaluated the health of fish communities and expressed the results as a proportion of a maximum possible score. Like the macroinvertebrate analysis, modelled condition values were expressed as a proportion of the maximum possible score to bring the modelled scores into line with the report card's 0-100 scoring schema. This proportional scoring system ensured consistency and comparability across sites and sub-catchments.

The results provide a detailed understanding of the health of fish communities across the catchment (although no sites in the Upper Saunders were sampled), highlighting areas of ecological resilience as well as areas where introduced species and habitat degradation have impacted native fish populations. This section outlines the methods used for fish monitoring and presents the key findings of the 2023, 2024 and 2025 fish analysis.

4.1.1 Fish: where the data came from

The NGT fish survey aimed to assess the status of native and introduced fish species across critical aquatic habitats, particularly permanent pools and intermittent streams which are vital for fish survival during dry periods.

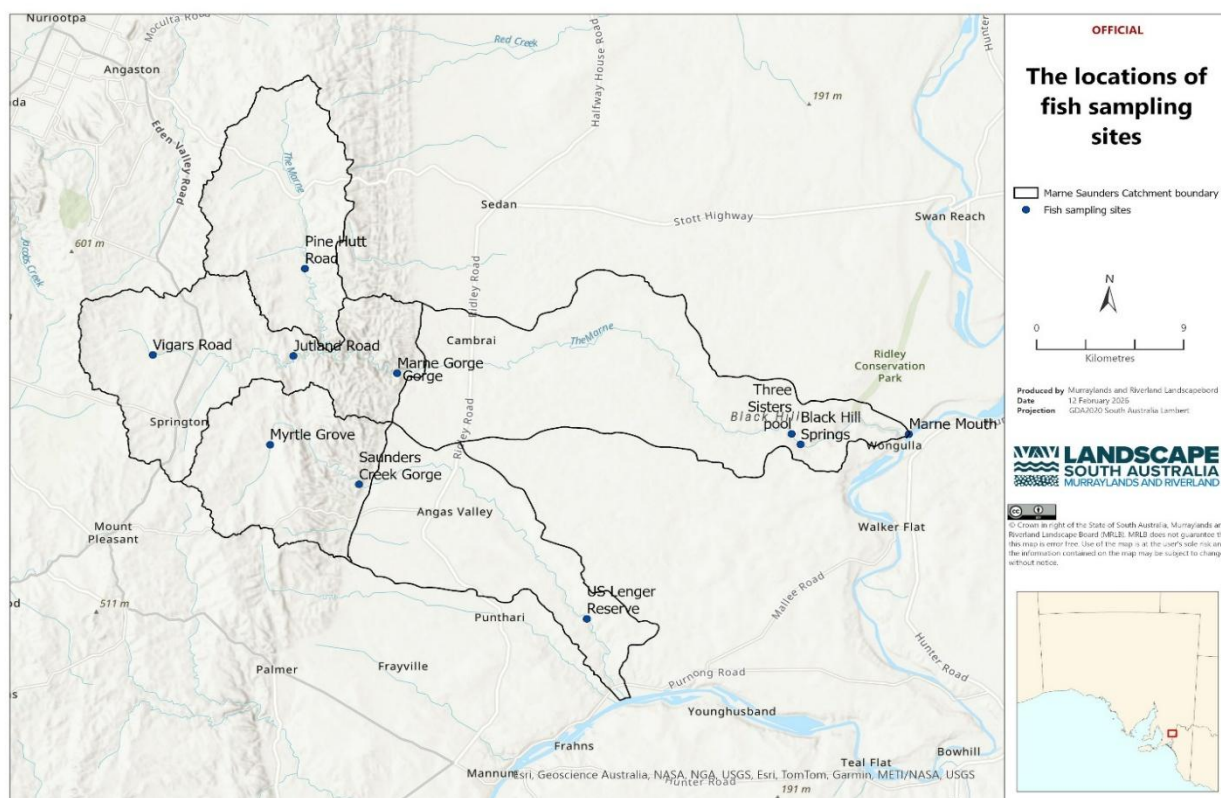


Figure 16: Location of fish sampling sites

Sampling was carried out at 9 sites, using methods such as fyke netting and visual inspection to capture a broad range of fish species. The surveys captured data on species richness, fish abundance, and the presence of sensitive species, such as obscure Galaxias and river blackfish, as well as documenting the presence of introduced species, including eastern Gambusia and common carp, to assess overall ecological health (see Gannon et al, 2021). Permanent pools were the primary focus as they act as refuges for fish during low-flow and no-flow conditions. Figure 16 below shows the locations of sample sites for this survey.

The fish condition model (FCM)

Key metrics in the FCM

The FCM assesses fish health using several key metrics that reflect the biological diversity and population structure of fish communities in the catchment.

- Species richness measures the number of native fish species present at each site. Higher species richness indicates a diverse and stable ecosystem, supporting a broad range of aquatic life.
- Abundance is the total number of individuals from each species found at the site. High abundance of native species, especially sensitive species, is an indicator of good habitat quality.
- Presence of sensitive species such as obscure Galaxias and river blackfish, serve as indicators of healthy water quality and habitat conditions. Their presence signals good ecological conditions as they are less tolerant of pollution and habitat degradation.
- Presence of introduced species like eastern Gambusia or common carp is seen as a sign of habitat degradation. These species tend to dominate and outcompete native species, particularly in altered or degraded environments, so sites with fewer introduced species score higher in the FCM.

4.1.2 Fish: scoring method

The FCM uses a multi-metric approach to assess the health of fish communities, focusing on factors such as species richness, abundance, and the presence of sensitive or invasive species. The above metrics were analysed using the FCM to produce a score between 0-9. FCM results were translated into 0-100 scores which were converted to grades for the report card, following a process similar to that used for macroinvertebrates, where each site's fish condition was expressed as a proportion of the maximum possible score.

$$\text{Report card score calculation} = \frac{\text{FCM condition score} \times 100}{9 \text{ (proportion of the maximum possible score)}}$$

4.1.3 Fish: scores per sub-catchment

The 2023 fish monitoring program provided valuable insights into the health of fish populations across the Marne Saunders catchment. Table 36 below indicates FCM scoring and associated report card grades for each surveyed site.

Table 36: Breakdown of sites values and condition scores from FCM modelling and corresponding report card scores

Site	Sub-catchment	Fish's score 2023				Fish's score 2024				Fish's score 2025			
		FCM Condition score	FCM Rating	Report card score (/100)	Grade	FCM Condition score	FCM Rating	Report card score (/100)	Grade	FCM Condition score	FCM Rating	Report card score (/100)	Grade
Black Hill Springs	Lower Marne	2.5	Poor	27.78	D	2.5	Poor	27.78	D	1.5	Poor	16.67	F
Jutland Road	Upper Marne	7	Good	77.78	B	0	Poor	0	F	0	Poor	0	F
Lenger Reserve	Lower Saunders	0	Poor	0	F	4	Moderate	44.44	C	0	Poor	0	F
Marne Gorge	Upper Marne	4	Moderate	44.44	C	4	Moderate	44.44	C	0	Poor	0	F
Pine Hut Road	North Rhine	0	Poor	0	F								
Three sisters pool	Lower Marne	2.5	Poor	27.78	D	2.5	Poor	27.78	D	0.5	Poor	5.56	F
Vigars Rd	Upper Marne	9	Good	100	A	8	Good	88.89	A	0	Poor	0	F

As is evident in Table 36, large variation is seen in condition scores for fish communities across the catchment. One striking observation is the high scores presented for the Upper Marne sites. NGT reporting indicates this is an artefact of the modelling process. Some species have boom/bust population dynamics, and at these sites such species predominated the sampling in high abundance. The following section on caveats provides more explanation.

Table 37 above provides averaged fish community scores, aggregated per sub-catchment. Key findings for each sub-catchment include:

- Sites in the Upper Marne showed good native fish populations, with high numbers of obscure Galaxias and carp gudgeon, and minimal presence of introduced species. This suggests relatively good water quality and habitat conditions and is also influenced by a short-term breeding response by some fish species due to the wetter than average year.
- In the Lower Marne, there was a higher prevalence of introduced species such as eastern and a low diversity of native species in the other sampled pools, leading to lower scores for fish community health. Habitat degradation and reduced water quality are likely to be impacting native species.
- Lower Saunders and North Rhine showed the poorest results, with low native species richness and high numbers of introduced species. These findings highlight the need for habitat restoration and water management efforts in these regions to support native fish populations.
- Sadly, it is clear from the assessment that the population of river blackfish has not been maintained and is now considered functionally extinct from the Marne River.

Table 37: Aggregated average fish scores for each sub-catchment analysed, including total score for Marne Saunders catchment

	2023		2024		2025	
Sub-catchment	Score	Grade	Score	Grade	Score	Grade
Lower Marne	25.93	D	25.93	D	14.81	F
Lower Saunders	0	F	44.44	C	0	F
North Rhine	0	F	Dry	F (Dry)	Dry	F (Dry)
Upper Marne	74.07	B	44.44	C	0	F
Upper Saunders	Dry	F (Dry)	Dry	F (Dry)	Dry	F (Dry)
Total MS catchment	25.00	D	38.27	D	4.94	F

Overview: Fish community results

The 2023 fish monitoring and FCM (Aquasave) analyses reveal a highly variable and generally degraded picture for fish communities across the Marne Saunders catchment. Aggregated sub-catchment scores and grades (Table 38) show a mixture of outcomes between sites and years but an overall decline in catchment condition from 2023 to 2025 (total catchment score 25.0 → 38.3 → 4.9; catchment grade D → D → F).

Key patterns

- Upper Marne: highest scores in 2023 (grade B) reflect strong local counts of native species (notably Obscure Galaxias and Carp Gudgeon) and low incidence of introduced species. Part of this signal is biological (local refugia and recent recruitment following wetter conditions), and part is a modelling artefact boom–bust dynamics of opportunistic natives can inflate short-term FCM scores when sampling catches recruitment pulses. Scores fell markedly in subsequent years (to C then to F), illustrating high interannual variability and vulnerability to dry periods.
- Lower Marne: consistently low scores, declining to F by 2025. Sites show low native diversity and substantial presence of introduced species (e.g., Eastern Gambusia, consistent with degraded habitat and water-quality pressures in lower reaches.
- Lower Saunders showed highly variable water quality, scoring 0 (F) in 2023, improving to C in 2024, then dropping back to 0 (F) in 2025.
- North Rhine remained consistently dry over the three-year period, the sub-catchment received a grade of F each year, reflecting the persistent dry conditions.
- Upper Saunders: many monitoring sites were dry during sampling windows and are reported as F (Dry) grade.
- Iconic species status: River Blackfish is now considered functionally extinct from the Marne River; Obscure Galaxias populations persist in some upper-catchment refugia but remain at risk.

4.1.4 Fish: trend analysis method

Trend data for fish condition were assessed using the same Bayesian analysis framework applied to the surface water flow indicators (DEW, 2025). This approach uses repeated model runs to estimate the direction and magnitude of change through time, allowing the probability of increasing or decreasing trends to be assessed while accounting for natural variability in the monitoring record.

Trend assessment was undertaken for the overall catchment report card score across the monitoring period, providing an indication.

4.1.5 Fish: trend analysis finding

The Bayesian trend analysis indicates a likely, catchment-scale decrease in fish condition that corroborates the FCM scores and grades. Although variability and model uncertainty remain, the preponderance of evidence supports urgent, targeted management to halt and reverse declines. The Bayesian analysis provides credible evidence that fish community condition across the PWRA is more likely decreasing than increasing. This statistical result aligns with the aggregated FCM results and grades described earlier (catchment grade declining to F in 2025, multiple sub-catchments showing falling scores).

The modelling is consistent with persistent pressures identified in the dataset: loss of refuge quality, rising salinity, reduced or delayed flows, and increasing prevalence of introduced species. These pressures explain the regional shift from intermittent local recoveries (boom years) to an overall trajectory of worsening condition (Table 38).

Table 38: Trend result for fish across the Marne Saunders catchment

Indicator	Mean slope	Proportion of negative slopes	Credible interval (5th and 95th percentile)	Trend
Fish	-0.841402364	0.8792	-2.052720313 to 0.407388792	Likely decrease

Uncertainty and caveats

- Credible interval crosses zero: while most of the posterior supports decline, uncertainty exists driven by interannual variability, boom–bust recruitment dynamics (which can temporarily inflate site scores), variable record lengths and some dry/missing sites. That is consistent with the data narrative: high short-term variability (especially in Upper Marne) but an overall negative tendency.
- Aggregation effect: the analysis summarises across many sites and years; local patterns may differ (some refugia stable or improving episodically). Site-level trend analyses could detect stronger local declines or recoveries masked by the aggregate.
- Model strengths: the Bayesian GLMM quantifies uncertainty explicitly and is robust to irregular sampling; the high negative-slope proportion is therefore a meaningful signal despite variability.

4.2 Waterbugs

Macroinvertebrates (waterbugs) are widely used indicators of aquatic ecosystem health due to their sensitivity to changes in flow, water quality and habitat condition.

In the Marne Saunders catchment, macroinvertebrate communities reflect the cumulative effects of intermittent flows, elevated salinity and habitat degradation. The presence or absence of flow-sensitive taxa provides a strong signal of ecological condition.

Assessment is based on modelling undertaken by DEW (DEW, 2025), using data from Waterbug Bioblitz, EPA monitoring and other programs, and incorporates measures of diversity, abundance and sensitivity to environmental change.

The macroinvertebrate assessment in this report card reveals a generally degraded condition, with poor community diversity and an overall low abundance of flow-sensitive species. Of the sites assessed, the majority showed poor condition ratings, with only a few classified as fair. Tolerant species, such as non-biting midges and diving beetles, dominate the macroinvertebrate populations across the catchment, indicating that the aquatic environment favours species capable of surviving in harsh, intermittent flow conditions and higher salinity levels. The low occurrence of flow-sensitive species that require flowing rivers and creeks, suggests a significant decline in river health, exacerbated by prolonged dry periods and insufficient flow recovery.

While there was higher taxa diversity at some sites, most sites continue to indicate low diversity and ongoing challenges in maintaining healthy macroinvertebrate communities.

4.2.1 Waterbugs: where the data came from

DEW employed a comprehensive analysis process to assess the ecological condition of macroinvertebrate communities across the Marne Saunders PWRA, utilizing data from the citizen science Waterbug Bioblitz program, EPA's aquatic ecosystem reporting (AECRs), and utilizing a specially developed contemporary [macroinvertebrate condition model \(CMCM\)](#). Both the Waterbug Bioblitz and EPA sampling use the same collection methods and survey in permanent pools, along with any flowing 'riffle' habitat linked with the pool if it is available. The Waterbug Bioblitz project was designed to monitor the impacts of low flow bypasses installed on dams as part of the [Flows for the Future](#) program and only surveyed sites in the hills sub-catchments until 2025 when a site within each of the Lower Marne and the Lower Saunders were included to make the monitoring program more comprehensive for this report card process.

This model adopts a biological condition gradient framework, assigning scores to sites based on species diversity, and sensitivity to flow conditions. Scoring in this report translates the ecological condition scores provided by DEW into accessible report card measures, helping stakeholders understand the overall health of the aquatic ecosystems and track changes over time.

Sampling regime:

Figure 17 below indicates all sites which provide DEW's CMCM model with data to estimate macroinvertebrate community status and trend for 2023. Sampling involved collecting macroinvertebrates from multiple sites on a single day in October 2023, with pool and riffle results pooled for each site.

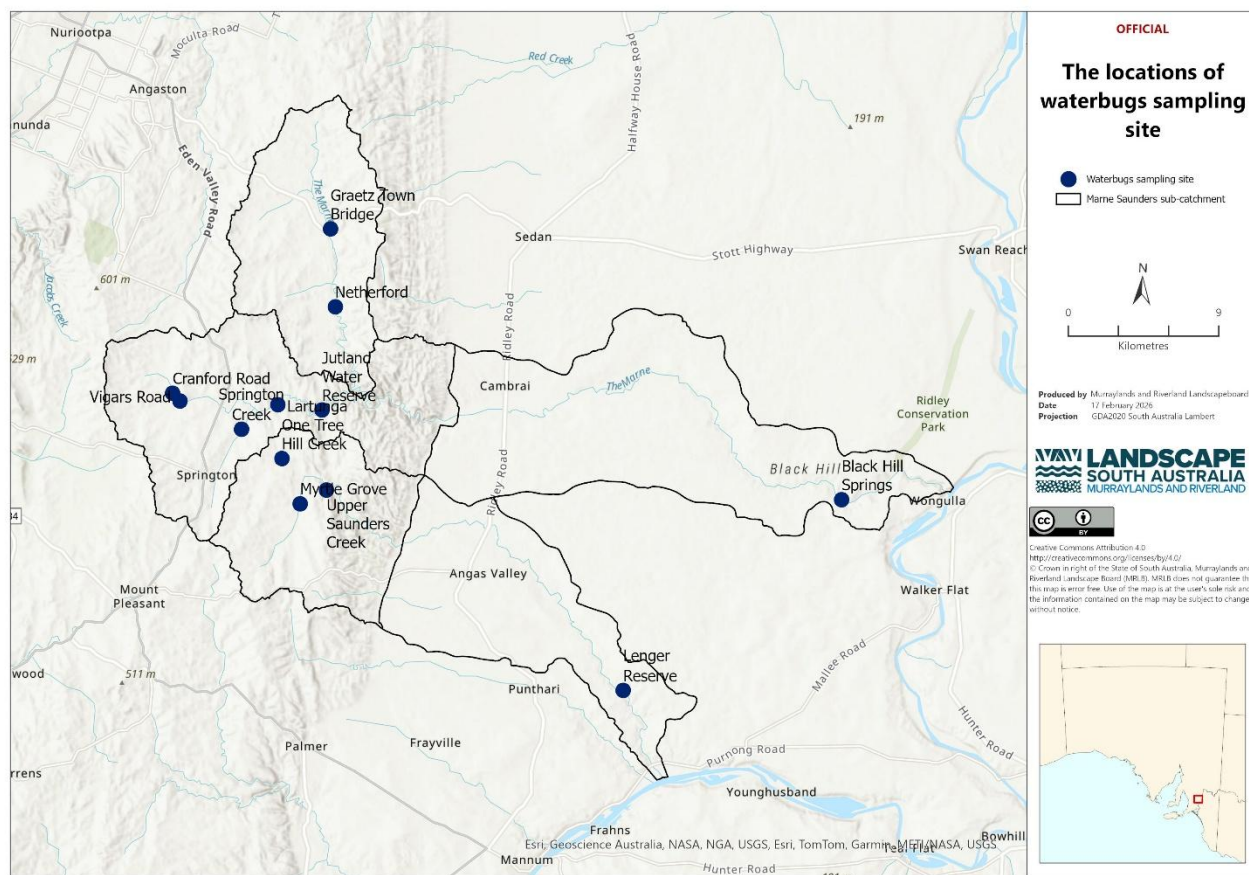


Figure 17: Map showing the location of Waterbug sampling sites

DEW's CMCM Model:

This model adopts a biological condition gradient approach, which rates the community condition on a scale from 1 (very poor) to 6 (excellent) (DEW, 2025). The model looks at community attributes such as diversity, abundance and presence of species sensitive to water quality changes and flow, assessing the ecological condition by comparing the macroinvertebrate community composition to expected reference conditions based on historical data for each site, thereby taking the inherent variability of aquatic habitats within this catchment into account.

The DEW macroinvertebrate condition model was applied to the collected data to assess the health of macroinvertebrate communities. This model evaluates ecological condition based on 3 primary measures:

- **Diversity:** the total number of different macroinvertebrate taxa identified at each site. Higher taxa richness indicates a more diverse and robust community, suggestive of a healthy ecosystem.
- **Abundance:** the total number of individual macroinvertebrates collected in each sample. Higher abundance typically correlates with better habitat quality and water availability.
- **Presence of Sensitive Taxa:** the model examines the presence of sensitive macroinvertebrate families, such as *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies), which are indicators of a healthy stream. A decrease in these taxa often signals deteriorating water conditions.

4.2.2 Waterbugs: scoring method

CMCM condition scores were converted into the report card's 0-100 scoring and A-F grading system using a percentile-based approach. The translation process follows the following steps:

Step 1: The raw CMCM condition score for each site is determined, with higher scores representing better ecological health with more diverse and sensitive macroinvertebrate communities.

Step 2: The CMCM score is expressed as a proportion of the maximum possible CMCM score (6), to bring in line with the 0-100 scoring format.

Step3: Applying linearly derived grade thresholds to each score, under the schema noted in Figure 6.

$$\text{Report card score calculation} = \frac{\text{CMCM condition score} * 100}{6 (\text{Maximum possible CMCM score})}$$

4.2.3 Waterbugs: scores per sub-catchment

Most sites across the catchment showed poor condition, with only a few sites rated as fair. Notably, sites such as Vigars Road in the Upper Marne were classed as having better conditions due to higher diversity and more stable populations of flow-sensitive species. DEW's trend assessment indicated that the macroinvertebrate condition was generally declining across the catchment, with some sites showing improvement due to better flow conditions in recent years. DEW's report can be accessed [here](#).

Scoring derived from DEW modelling for the condition of macroinvertebrates across the catchment in 2023 is demonstrated in table 39-41 below:

Table 39: Breakdown of macroinvertebrates site values and condition score from DEW modelling and corresponding 2023 report card score and grade

Site	Sub-catchment	DEW Condition score	Condition Rating	Report card score (/100)	Grade
Vigars Road	Upper Marne	2.89	Fair	47.744	C
Lartunga	Upper Marne	2.15	Poor	35.859	D
Netherford	North Rhine	2.32	Poor	38.725	D
Jutland Water Reserve	Upper Marne	2.61	Fair	43.558	C
Graetz Town Bridge	North Rhine	2.30	Poor	38.272	D
Myrtle Grove	Upper Saunders	1.77	Poor	29.441	D
Upper Saunders Creek	Upper Saunders	2.03	Poor	33.833	D
Springton Creek	Upper Marne	2.53	Fair	42.146	C
One Tree Hill Creek, near Springton	Upper Saunders	1.85	Poor	30.832	D

Table 40: Breakdown of macroinvertebrates site values and condition score from DEW modelling and corresponding 2024 report card score and grade

Site	Sub-catchment	DEW Condition score	Condition Rating	Report card score (/100)	Grade
Black Hill Springs	Lower Marne	2.28	Poor	38.04	D
Cranford Road	Lower Marne	2.26	Poor	37.69	D
Vigars Road	Lower Marne	1.83	Poor	30.57	D
Lartunga	Lower Marne	2.09	Poor	34.83	D
Jutland Water Reserve	Upper Marne	1.94	Poor	32.28	D
Lenger Reserve	Lower Saunders	2.15	Poor	35.79	D
Myrtle Grove	Upper Saunders	1.68	Poor	28.03	D

Upper Saunders Creek	Upper Saunders	1.50	Poor	25.04	D
Springton Creek	Upper Marne	2.23	Poor	37.09	D

Table 41: Breakdown of macroinvertebrates site values and condition score from DEW modelling and corresponding 2025 report card score and grade

Site	Sub-catchment	DEW Condition score	Condition Rating	Report card score (/100)	Grade
Cranford Road	Upper Marne	1.91	Poor	31.83	D
Vigars Road	Upper Marne	2.43	Poor	40.50	C
Lartunga	Upper Marne	2.38	Poor	39.67	D
Jutland Water Reserve	Upper Marne	1.96	Poor	32.67	D
Upper Saunders Creek	Upper Saunders	1.64	Poor	27.33	D
Black Hill Springs	Lower Marne	2.28	Poor	38.04	D
Lenger Reserve	Lower Saunders	2.15	Poor	35.79	D
Myrtle Grove	Upper Saunders		Dry		F
Upper Saunders Creek	Upper Saunders		Dry		F
Springton Creek	Upper Marne		Dry		F

The waterbugs assessment reveals a generally degraded condition across the surveyed sub-catchments, with poor community diversity and an overall low abundance of flow-sensitive species. Tolerant species, such as non-biting midges and diving beetles, dominate the macroinvertebrate populations, indicating that the aquatic environment favours species capable of surviving in harsh, intermittent flow conditions and higher salinity levels. The lack of flow-sensitive species suggests a significant decline in river health, exacerbated by prolonged dry periods and insufficient flow recovery.

Table 42 show that from 2023 to 2025, overall conditions in the catchment remained poor, with grades consistently in the D range. The total catchment score declined from 36.69 in 2023 to 31.75 in 2024, before a slight improvement to 33.71 in 2025. Upper Marne showed a steady decline from a C (40.20) in 2023 to a D by 2024–2025, while Upper Saunders also worsened gradually across all years. North

Rhine recorded dry conditions in 2024 and 2025, both graded F (Dry), after a D in 2023. Lower Marne and Lower Saunders only reported data in 2025, both scoring in the mid-to-high 30s with D grades. Overall, the data indicates declining or consistently poor environmental conditions across most sub-catchments.

Table 42: Aggregated average macroinvertebrates scores for each sub-catchment analysed, including total score for Marne Saunders catchment

Sub-catchment	2023		2024		2025	
	Score	Grade	Score	Grade	Score	Grade
Lower Marne	No data	No data	No data	No data	38.04	D
Lower Saunders	No data	No data	No data	No data	35.79	D
North Rhine	38.49	D	Dry	F (Dry)	Dry	F (Dry)
Upper Marne	40.20	C	36.17	D	34.49	D
Upper Saunders	31.37	D	27.33	D	26.54	D
Total MS catchment	36.69	D	31.75	D	33.71	D

**No data = There is insufficient data available to score an indicator of health – no sites visited in this case.*

Waterbugs: caveats

When interpreting the analysis of macroinvertebrate communities, several caveats should be noted, based on the findings from modelling conducted by DEW. First, macroinvertebrate populations are highly sensitive to seasonal variations and short-term environmental changes such as fluctuations in water flow and quality. This means that sampling conducted during or shortly after unusual weather events, such as heavy rains, may not accurately reflect the typical community structure and could either overestimate or underestimate the health of macroinvertebrate communities.

There is also spatial variability in habitat conditions between different sampling sites, which can lead to inconsistencies in data if not all habitat types are equally represented in the sampling regime. The limited number of sampling sites in certain sub-catchments can result in data that may not be fully representative of the broader area, leading to potential biases in the assessment of overall catchment health. The monitoring did not originally include any 'lower' sub-catchment sites on the plains, however this was addressed in 2025 so that a fuller picture (covering a greater geographical spread) was achieved.

4.2.4 Waterbugs: trend analysis method

Trend data for waterbugs condition were assessed using the same Bayesian analysis framework applied to the surface water flow indicators. This approach uses repeated model runs to estimate the direction and magnitude of change through time, allowing the probability of increasing or decreasing trends to be assessed while accounting for natural variability in the monitoring record.

Trend assessment was undertaken for the overall catchment report card score across the monitoring period, providing an indication.

4.2.5 Waterbugs: trend analysis finding

Trend analyses were carried out using Bayesian methodologies as outlined in Table 43. The posterior sign proportions show 43.78% negative slopes and 56.22% positive slopes, placing the result within the IPCC “about as likely as not” range (33–66%) and therefore classifying the trend as stable. The posterior mean slope is +0.1274 report card score units per year, indicating a very small positive change. However, the 90% credible interval (–1.4199 to +1.6243) is wide and spans zero, highlighting a high level of uncertainty and suggesting no clear evidence of a meaningful trend.

Table 43: Trend result for water bugs across the Marne Saunders catchment

Indicator	Mean slope	Proportion of negative slopes	Credible interval (5th and 95th percentile)	Trend
Water bugs	0.127419655	0.4378	-1.419918136 to 1.624266352	Stable

Uncertainty and caveats

- Wide credible interval and near-balanced sign proportions reflect limited power to detect a trend given natural variability, irregular sampling and differing site records.
- Aggregating sites into a catchment-scale trend masks local declines or recoveries; site-level analyses often show different outcomes.

Marne Saunders catchment: final scores and discussion

The combination of detailed assessments of key hydrological and ecological indicators in the Marne Saunders Catchment Report Card provides a comprehensive evaluation of the status of the catchment. Each of these indicators contributes part of the overall picture of the catchment's health, revealing a range of challenges that require attention. A description of all aggregated scores is detailed in Table 44-46 and Figure 18-20.

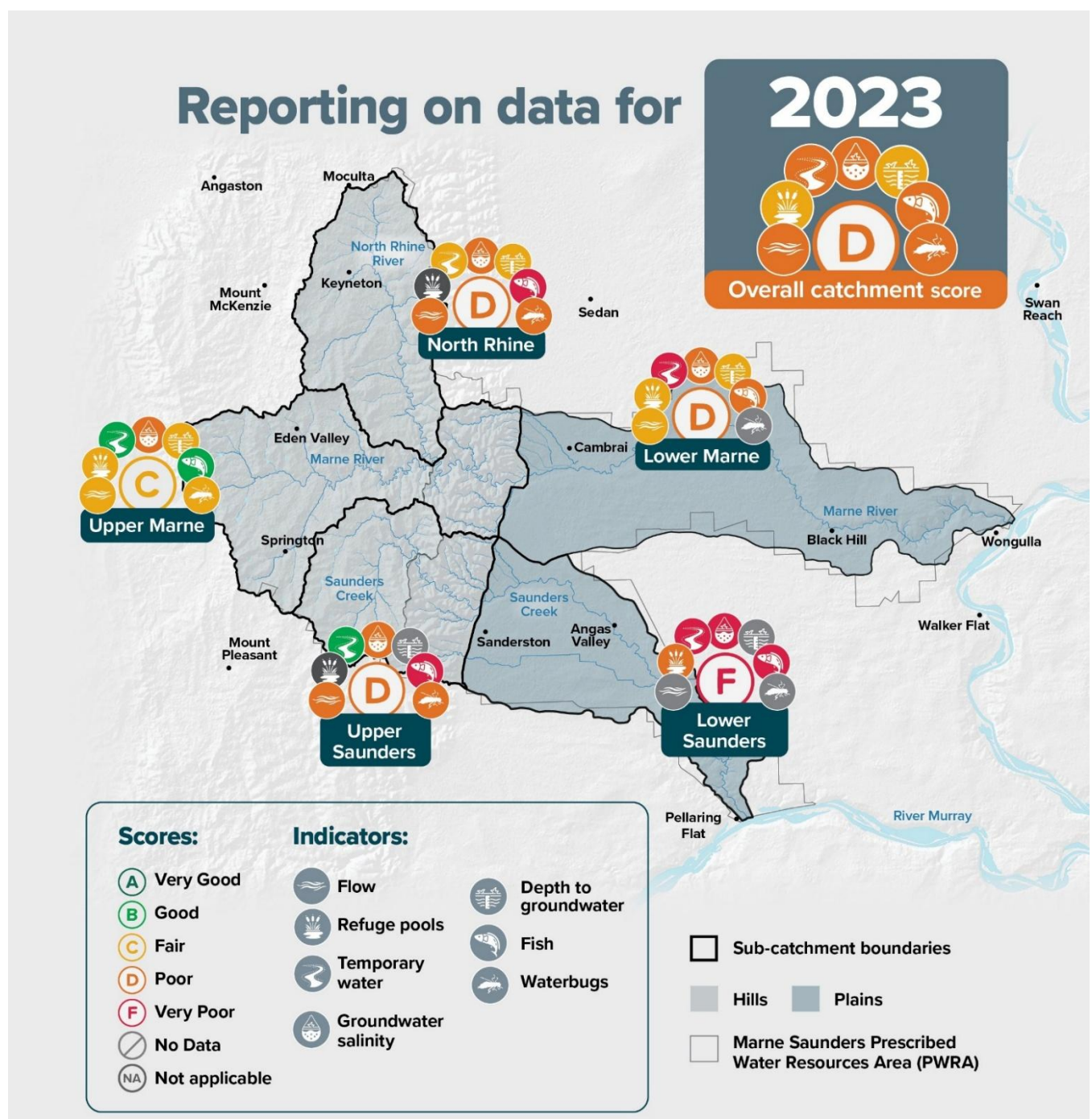


Figure 18: 2023 final scores for all indicators for each sub-catchment and overall catchment score

Table 44: All indicator scores for all sub-catchments in 2023

2023	Sub-catchment					
Indicators	Measures	Lower Marne	Lower Saunders	North Rhine	Upper Marne	Upper Saunders
Surface water	Flow	C	No data	D	C	D
Water quality	Refuge pools	C	D	N/A	C	N/A
	Temporary water sites	F (Dry)	F (Dry)	C	B	B
Groundwater	Salinity	D	F	D	D	D
	Depth to Water (DTW)	C	No data	C	C	No data
Ecological	Fish	D	F	F (Dry)	B	F (Dry)
	Waterbugs	No data	No data	D	C	D
	Average each sub-catchment	D	F	D	C	D

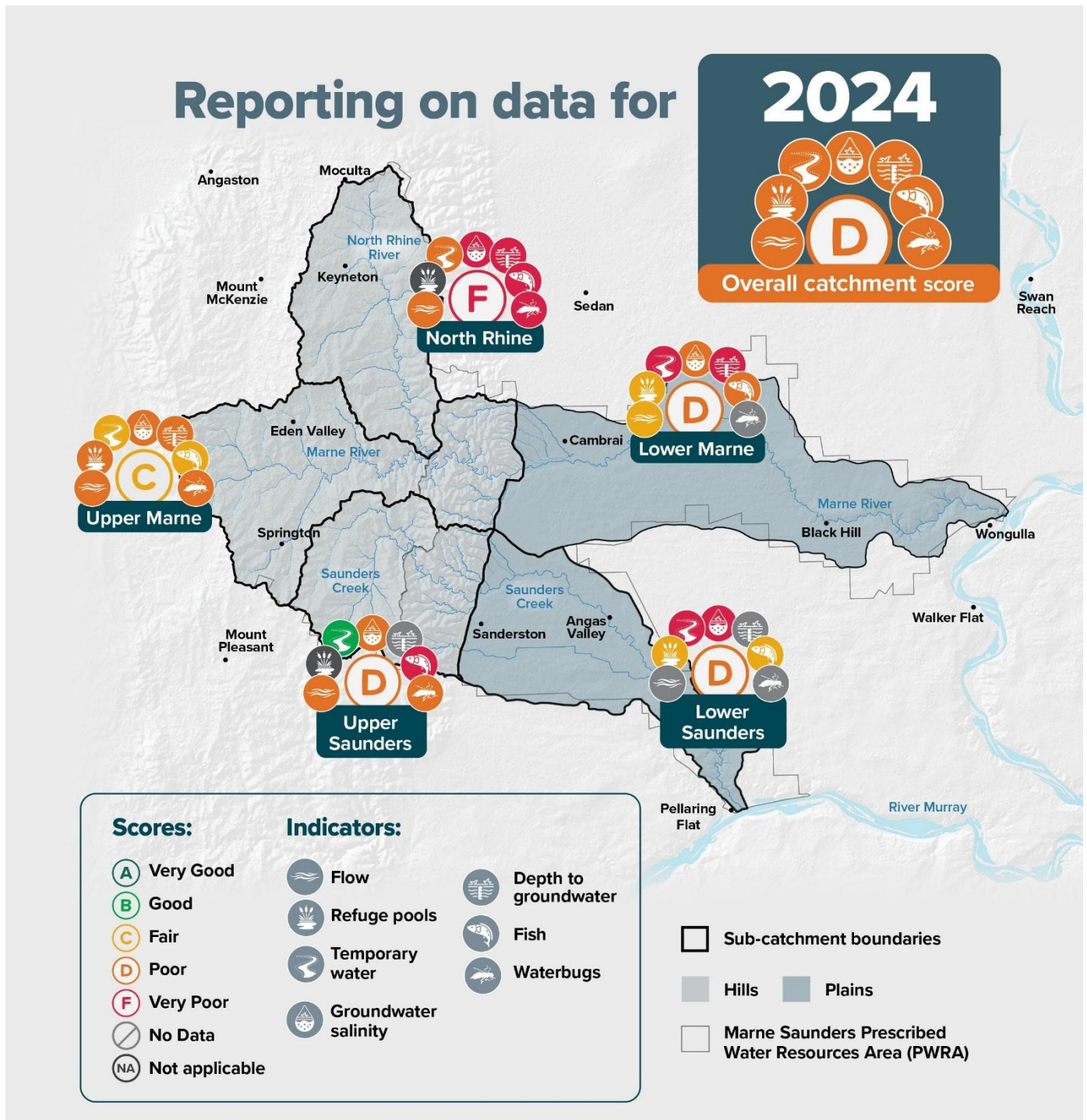


Figure 19: 2024 final scores for all indicators for each sub-catchment and overall catchment score

Table 45: All indicator scores for all sub-catchments in 2024

2024	Sub-catchment					
Indicators	Measures	Lower Marne	Lower Saunders	North Rhine	Upper Marne	Upper Saunders
Surface water	Flow	C	No data	D	C	D
Water quality	Refuge pools	C	C	N/A	D	N/A
	Temporary water sites	F (Dry)	F (Dry)	D	C	B
Groundwater	Salinity	D	F	F	D	D
	Depth to Water (DTW)	F	No data	F	D	No data
Ecological	Fish	D	C	F (Dry)	C	F (Dry)
	Waterbugs	No data	No data	F (Dry)	D	D
	Average each sub-catchment	D	D	F	C	D

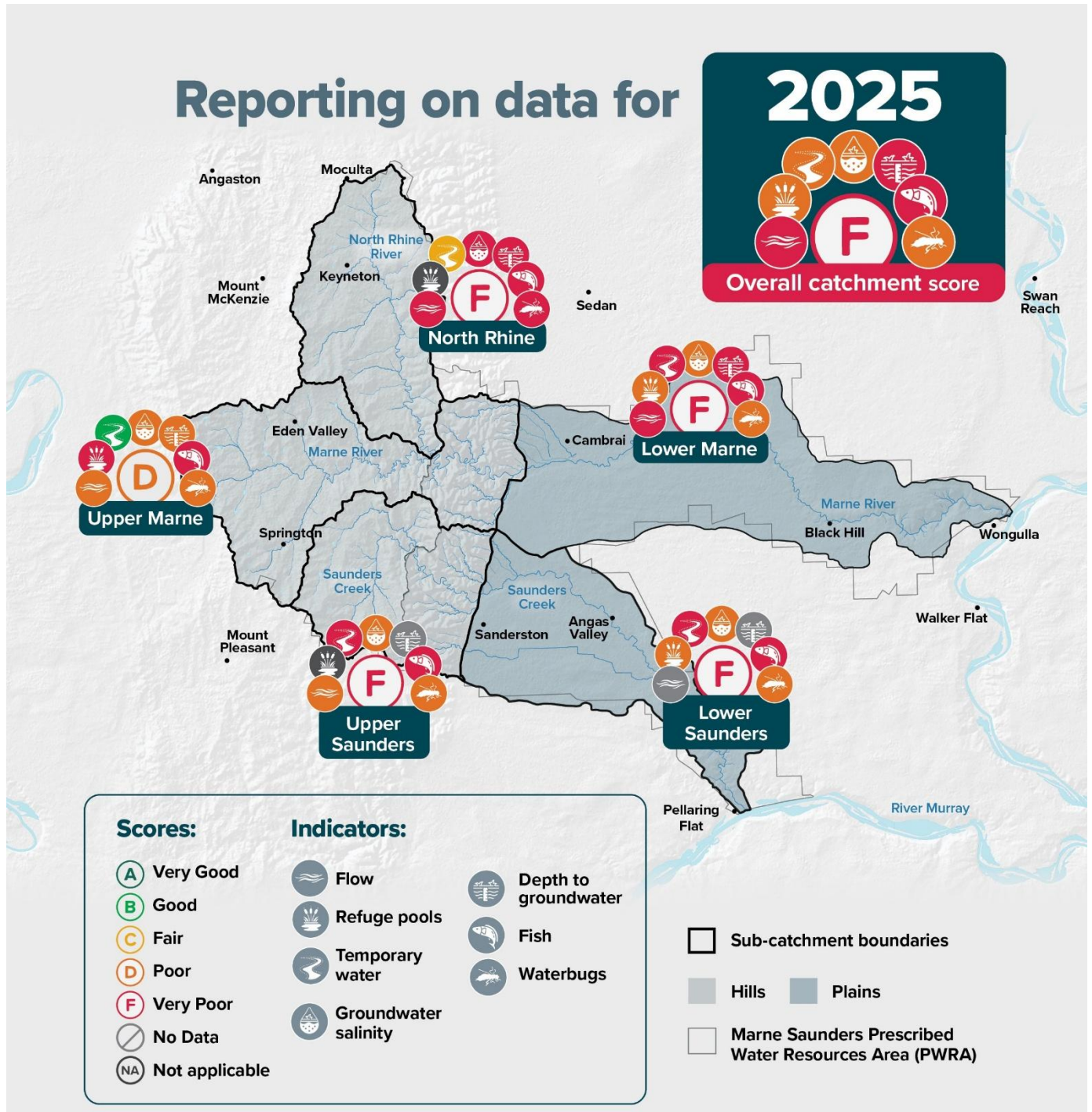


Figure 20: 2025 final scores for all indicators for each sub-catchment and overall catchment scores

Table 46: All indicator scores for all sub-catchments in 2025

2025	Sub-catchment					
Indicators	Measures	Lower Marne	Lower Saunders	North Rhine	Upper Marne	Upper Saunders
Surface water	Flow	F	No data	F	D	D
Water quality	Refuge pools	D	D	N/A	F	N/A
	Temporary water sites	F (Dry)	F (Dry)	C	B	F(Dry)
Groundwater	Salinity	D	D	F	D	D
	Depth to Water (DTW)	F	No data	F	D	No data
Ecological	Fish	F	F	F (Dry)	F	F (Dry)
	Waterbugs	D	D	F (Dry)	D	D
	Average each sub-catchment	F	F	F	D	F

Discussion

Taken together, the indicator assessments across the three reporting years show a clear and consistent pattern of reduced water availability and increasing ecological stress across the Marne Saunders catchment. The use of multiple years (2023–2025), rather than a single snapshot, provides a more reliable representation of recent conditions and demonstrates that these patterns are not confined to an individual year. While some indicators vary between years, the overall signal is one of sustained pressure on the system.

There are important limitations that should inform interpretation. Although the inclusion of multiple years and trend analysis strengthens the assessment, some indicators remain constrained by uneven spatial coverage, differences in sampling frequency and variation in monitoring methods. Refuge pool and temporary water site data are derived from multiple programs, groundwater monitoring is not evenly distributed across the catchment, and some ecological datasets remain patchy. As a result, findings at finer spatial scales should be interpreted with caution. However, the consistency of results across independent indicators, datasets and analytical approaches provides a high level of confidence in the overall direction of change.

Hydrology remains the primary driver of the observed patterns. Across the reporting period, surface water flow metrics consistently indicate fewer flow days, reduced occurrence of moderate and high flow events, and a delayed break of season. These changes reduce habitat availability, disrupt ecological processes and limit opportunities for breeding, recruitment and dispersal. Trend analysis indicates that these conditions are not only evident in recent years but are very likely part of a longer-term shift toward fewer, later and less reliable flows. This change in flow regime is fundamental to understanding broader ecological responses across the catchment.

These surface water changes interact with groundwater processes to further influence system condition. Groundwater salinity remains elevated across much of the catchment, with little evidence of improvement over time. While trend analysis does not indicate a strong directional change, the prevailing condition is consistently poor. In contrast, depth to water results suggest a likely decline in groundwater accessibility in monitored areas, indicating reduced recharge and increasing pressure on groundwater-dependent systems. Together, these findings point to sustained stress across both surface and groundwater systems under current conditions.

Refuge pools and temporary water sites, which are critical for maintaining aquatic life during dry periods, show variable but generally declining condition. Some upper catchment pools continue to provide suitable habitat in certain years; however, many sites, particularly in the Lower Marne and Lower Saunders, are characterised by low dissolved oxygen and elevated salinity. Trend analysis suggests a likely decline in refuge pool condition over time. Temporary water sites show a similar pattern, where short-term improvements may occur in wetter years, but overall condition reflects reduced flow connectivity and increasing environmental stress.

Biological indicators are consistent with these hydrological and habitat patterns. Macroinvertebrate communities remain dominated by tolerant species, with low diversity and limited representation of flow-dependent taxa. At the catchment scale, condition appears relatively stable but at a degraded level. Fish communities, however, show a likely declining trend in condition, reflecting reduced flow, habitat quality and connectivity. While some localised recovery can occur following wetter conditions, these responses are not sustained across the catchment. The continued absence of river blackfish is indicative of long-term ecological change and reduced system resilience.

The integration of three years of report card results with long-term trend analysis provides a more robust evidence base than previous single-year assessments. Snapshot scores describe current condition, while trend analysis places these results within a longer-term context. Together, they indicate that many indicators are either declining or persistently in poor condition, reinforcing that current pressures are ongoing rather than transient.

From a management perspective, these findings highlight the importance of focusing on the processes that underpin system function. In particular, the timing, duration and connectivity of flows remain central to ecological condition. Within the scope of the WAP, this may be supported through settings that influence flow regimes, such as allocation frameworks, rules governing take, and mechanisms that protect low flows or improve connectivity where feasible. Complementary landscape board-led activities outside the WAP, including targeted investment programs, partnerships and on-ground works, may further support improvements in flow function at priority locations.

Protecting and maintaining key refuge habitats will be important for supporting persistence during dry periods. This can be supported within the WAP through provisions that recognise and protect critical habitats, while external landscape board activities such as habitat restoration, riparian management, and targeted works at high-value refuge sites can enhance their condition and resilience.

Improving understanding of groundwater dynamics and salinity processes will be critical for both ecological and water resource outcomes. Within the WAP, this may be addressed through monitoring, reporting and adaptive review provisions, while broader landscape board activities can include investment in expanded monitoring networks, targeted investigations, and integration of new knowledge into future plan amendments.

These responses sit within a broader context of ongoing climate variability and water use, and should be considered as part of an adaptive and integrated management approach rather than as single-point solutions. Achieving meaningful outcomes will likely require a combination of WAP-based settings, complementary landscape board programs, and coordination with wider regional and state initiatives

In summary, the Marne Saunders catchment is experiencing sustained pressure on flow regimes, groundwater condition and refuge habitats over the reporting period. These pressures are reflected in biological condition and reduced system resilience. While there is variability between years and across locations, the overall direction of change indicates that current conditions are not supporting the ecological functions and values expected of the system. Continued monitoring, alongside targeted and coordinated management responses, will be important to better understand and respond to these changes over time.

References

- Alabaster, J. S., and R. Lloyd. 1980. Water quality criteria for freshwater fish. European Inland Fisheries Advisory Commission Report (FAO). Buttersworth, London-Boston. 297 pp.
- Baumgartner, L.J., Conallin, J., Wooden, I., Campbell, B., Gee, R., Robinson, W.A. and Mallen-Cooper, M. (2014) Using flow guilds of freshwater fish in an adaptive management framework to simplify environmental flow delivery for semi-arid riverine systems. *Fish and Fisheries* 15(3), 410-427.
- Bonada, N., Rieradevall, M. and Prat, N. (2007) Macroinvertebrate community structure and biological traits related to flow permanence in a Mediterranean river network. *Hydrobiologia* 589(1), 91-106.
- Caraco, N. and Cole, J. (2004) When terrestrial organic matter is sent down the river: the importance of allochthonous carbon inputs to the metabolism of lakes and rivers. *Food webs at the landscape level*, 301-316.
- Costanzo, S.D., Blancard, C., Davidson, S., Dennison, W.C., Escurra, J., Freeman, S., Fries, A., Kelsey, R.H., Krchnak, K., Sherman, J. and Thieme, M., 2017. Practitioner's guide to developing river basin report cards. *Cambridge (MD): IAN*.
- Datry, T., Larned, S.T., Fritz, K.M., Bogan, M.T., Wood, P.J., Meyer, E.I. and Santos, A.N. (2014) Broad-scale patterns of invertebrate richness and community composition in temporary rivers: effects of flow intermittence. *Ecography* 37(1), 94-104.
- DEW (2024). *Marne Saunders PWRA ecological condition assessment 2024*, DEW Technical report 2024/XX, Government of South Australia, Department for Environment and Water, Adelaide.
- Dunlop, J., McGregor, G. and Horrigan, N., 2005. Potential impacts of salinity and turbidity in riverine ecosystems. *National Action Plan for Salinity and Water Quality. State of Queensland*.
- Duszynski A and Watt E (2025). Marne Saunders PWRA WAP review: Evaluation of the groundwater resources, DEW Technical report 2025/XX, Government of South Australia, Department for Environment and Water, Adelaide.
- Dwyer, G.K., Stoffels, R.J. and Pridmore, P.A., 2014. Morphology, metabolism and behaviour: responses of three fishes with different lifestyles to acute hypoxia. *Freshwater biology*, 59(4), pp.819-831.
- Fuller, R.L., Griego, C., Muehlbauer, J.D., Dennison, J. and Doyle, M.W. (2010) Response of stream macroinvertebrates in flow refugia and high-scour areas to a series of floods: a reciprocal replacement study. *Journal of the North American Benthological Society* 29(2), 750-760.
- Gannon, R., Whiterod, N., and Green, D. (2021). A review of the status of water resources and fish communities within the Marne Saunders Prescribed Water Resource Area. Report to the Murraylands and Riverland Landscape Board. Aquasave–Nature Glenelg Trust, Victor Harbor, South Australia.
- Green, D.J., Maxwell, S., VanLaarhoven, J. and Deane, D. (2014) Barossa Valley Prescribed Water Resource Area Hydro-Ecological Risk Assessment, Department of Environment, Water and Natural Resources Technical Report 2014/08. Government of South Australia.

Loire, R., Grosprêtre, L., Malavoi, J.-R., Ortiz, O. and Piégay, H. (2019) What discharge is required to remove silt and sand downstream from a dam? An adaptive approach on the Selves River, France. *Water* 11(2), 392.

Lucas, M. and Baras, E. (2008) *Migration of freshwater fishes*, John Wiley & Sons.

Mackay, R.J. (1992) Colonization by lotic macroinvertebrates: a review of processes and patterns. *Canadian Journal of Fisheries and Aquatic Sciences* 49(3), 617-628.

Mastrandrea, M.D., Field, C.B., Stocker, T.F., Edenhofer, O., Ebi, K.L., Frame, D.J., Held, H., Kriegler, E., Mach, K.J., Matschoss, P.R., Plattner, G.K., Yohe, G.W. and Zwiers, F.W. 2010. Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties. Intergovernmental Panel on Climate Change (IPCC). Available at <http://www.ipcc.ch>.

Maxwell, S.E., Green, D.J., Nicol, J., Schmarr, D., Peeters, L., Holland, K. and Overton, I. (2015b) *Water Allocation Planning: Environmental Water Requirements*. GWAP Project: Task 4, Goyder Institute for Water Research Technical Report Series No. 15/53, Adelaide, South Australia. ISSN: 1839-2725 (PDF 2.4 MB).

Nicol, J. (2013) *Characterisation of the in stream and riparian plant communities in the Barossa Prescribed Water Resources Area. Data and Methods Report*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2013/000413-1. SARDI Research Report Series No. 745. 25pp.

Pires, D.F., Beja, P. and Magalhaes, M.F. (2014) Out of pools: movement patterns of Mediterranean stream fish in relation to dry season refugia. *River Research and Applications* 30(10), 1269-1280.

Pitman, K.S. and Tinkler, P., 2005. Distribution and Habitat of River Blackfish. *Ecology of Freshwater Fish*, 13, pp.285-293.

Savadamuthu K and Bamunuarachchi S (2025 – In Press). *Impacts of changing rainfall patterns on the hydrology of the Marne Saunders PWRA*, DEW Technical report 2025/XX, Government of South Australia, Department for Environment and Water, Adelaide.

Schmarr, D., Mathwin, R. and Cheshire, D. (2014) *Western Mount Lofty Ranges Fish Condition Report 2012-2013 incorporating the Barossa Valley Prescribed Water Resource Area fish community study, the verification of water allocation science project (VWASP) and the Western Mount Lofty Ranges fish community monitoring*, SARDI Publication No. F2014/000113-1, South Australian Research and Development Institute Aquatic Sciences, Adelaide.

Stromberg, J.C., Beauchamp, V., Dixon, M., Lite, S. and Paradzick, C. (2007) Importance of low - flow and high - flow characteristics to restoration of riparian vegetation along rivers in arid south - western United States. *Freshwater Biology* 52(4), 651-679.

Ulrich, C., 2017. *Comparative hypoxia responses and oxygen sensing in galaxiid fishes* (Doctoral dissertation, The University of Waikato).

Vander Vorste, R., Obedzinski, M., Nossaman Pierce, S., Carlson, S.M. and Grantham, T.E. (2020) Refuges and ecological traps: Extreme drought threatens persistence of an endangered fish in intermittent streams. *Global Change Biology* 26(7), 3834-3845.

Whiterod, N, & Hammer, M (2013) River Blackfish in Rodwell Creek, 2012-13 update. Report to the Goolwa to Wellington LAP and South Australian Murray-Darling Basin NRM Board. Aquasave Consultants, Adelaide. 15 p

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