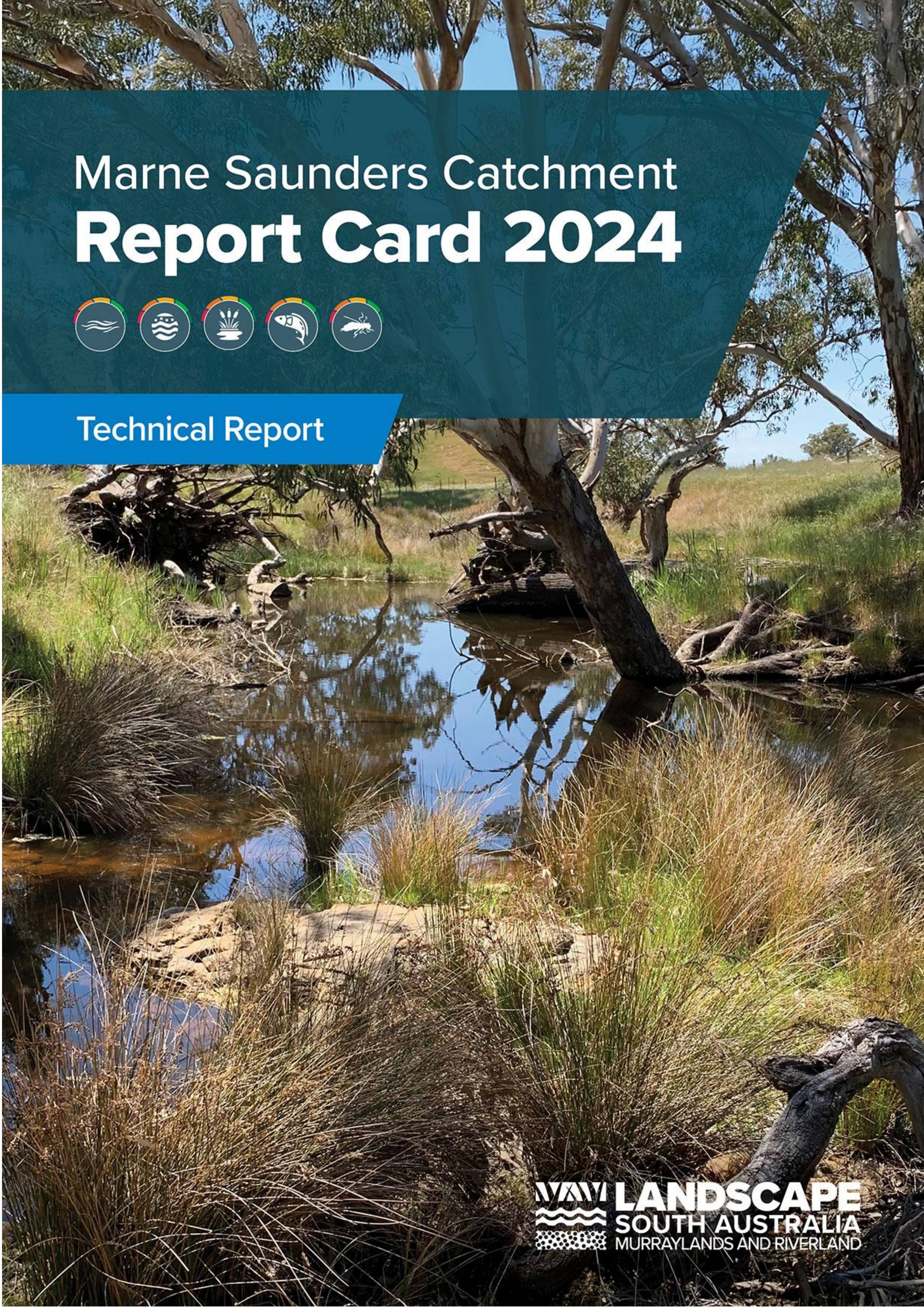
Marne Saunders Catchment
Report Card 2024

Technical Report



LANDSCAPE SOUTH AUSTRALIA
MURRAYLANDS AND RIVERLAND

Contents

Introduction

Technical report for the Marne Saunders catchment report card 2024.

This technical report accompanies the 2024 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 2022/23. The report card serves as a critical tool for tracking environmental changes and assessing water and ecological conditions within the Marne Saunders catchment.

The report card's scoring system draws on multiple indicators, such as surface water flow, groundwater status, macroinvertebrate (waterbug) and fish populations, and permanent pool water quality, 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 DEW, and fish surveys undertaken by Nature Glenelg Trust on behalf of the Murraylands and Riverland Landscape Board (MR Landscape Board). Data analysis was undertaken by the Department for Environment and Water (DEW), the MR 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. Socializing 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 synthesize complex scientific data and make it understandable to decision-makers, landholders, and the broader community. Simplifying this information into an annual 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, 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 MR 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 annual snapshots 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.

Overview of water resources

The Marne Saunders PWRA is divided into the hills zone (in the west, with higher rainfall) and plains zone (in the east, with very low rainfall), as demonstrated in Figure 1 below:

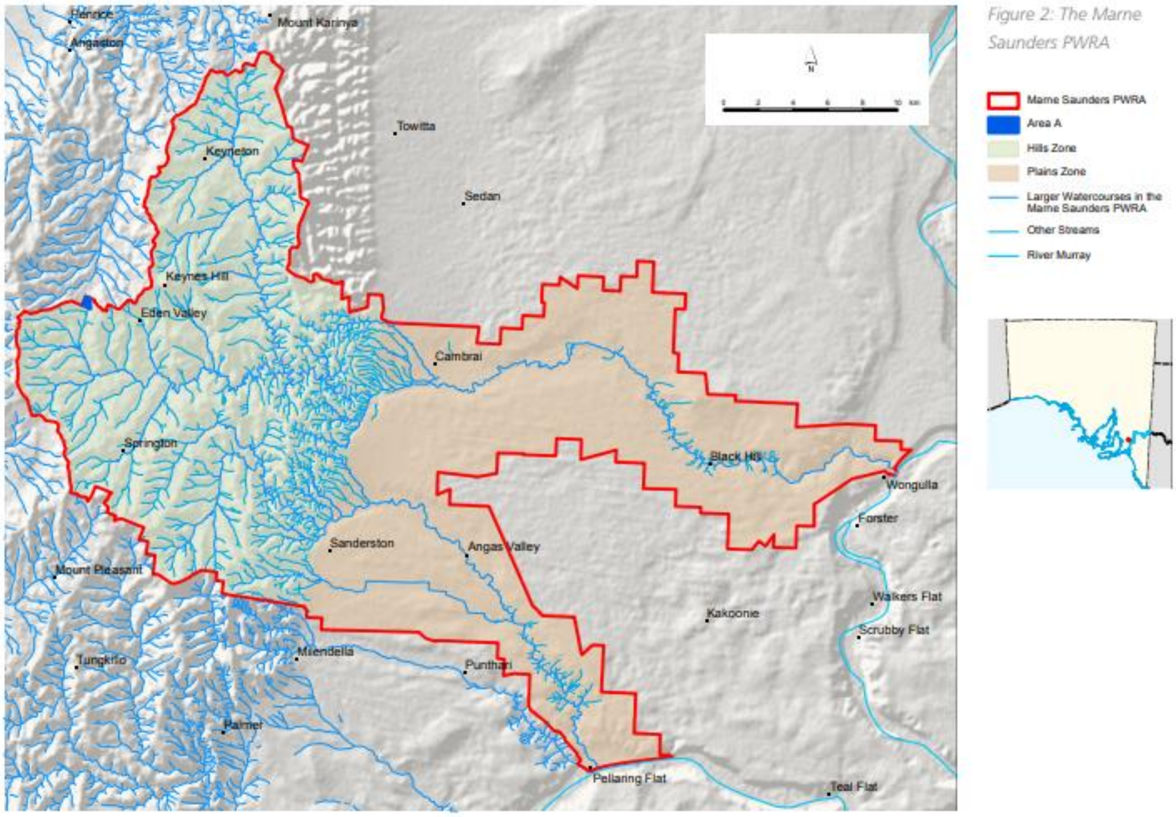


Figure 2: The Marne Saunders PWRA

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

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 Murray River.

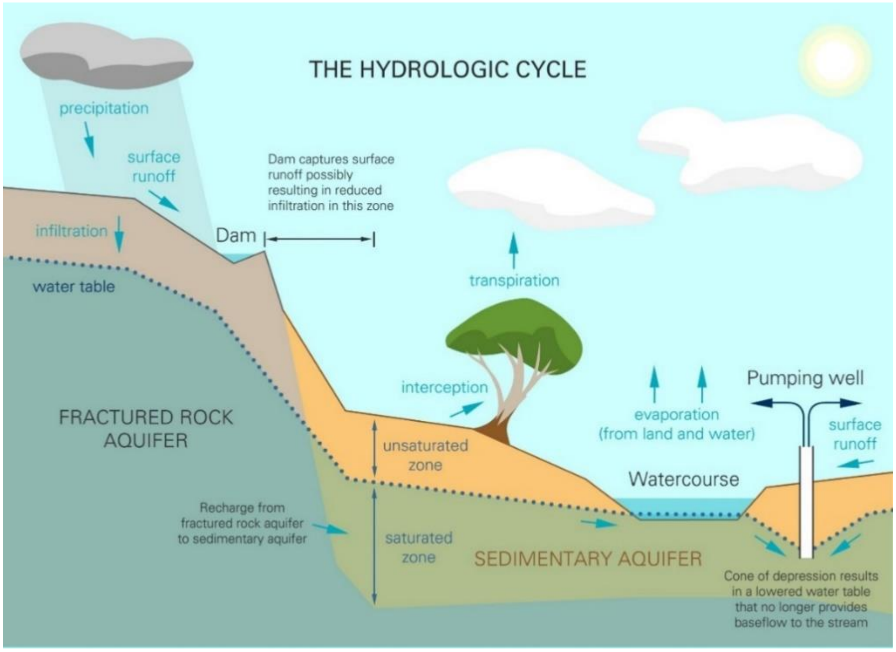


Figure 2: Paths of water movement through the landscape. Figure courtesy of the former Department for Water, Land and Biodiversity Conservation (DWLBC), and Ecocreative.

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).

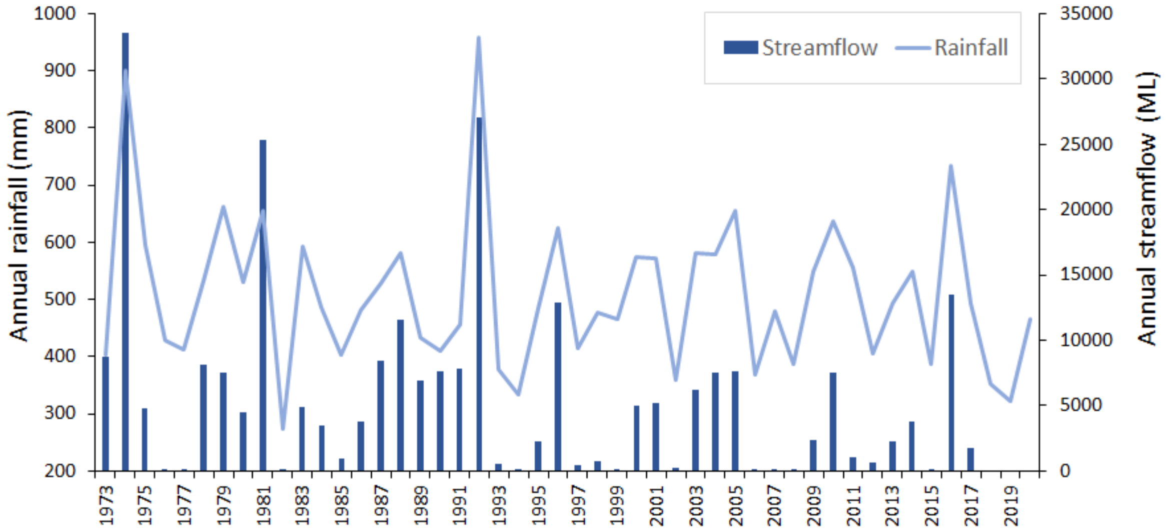


Figure 3: Annual rainfall (Keyneton) and streamflow (Marne Gorge) for 1973 to 2020. Data courtesy of Department for Environment and Water.

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 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).

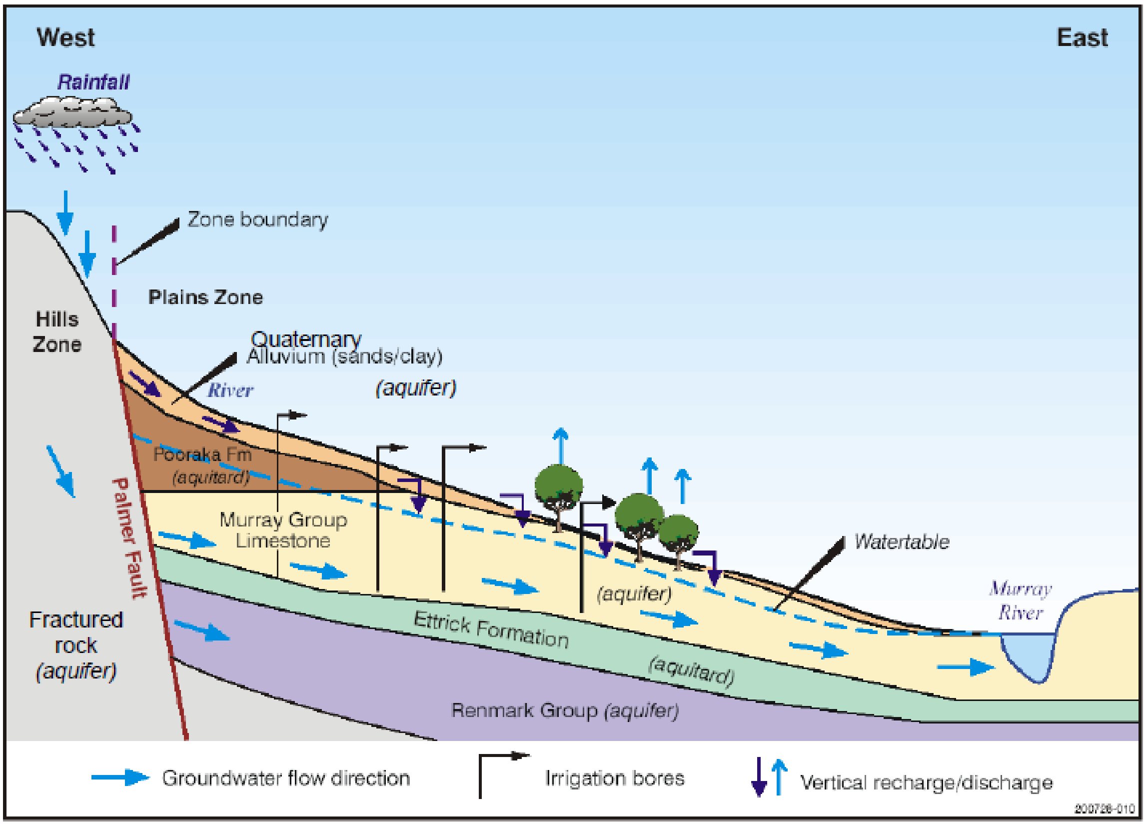


Figure 4: Cross section of key aquifer locations across the Marne Saunders catchment

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.

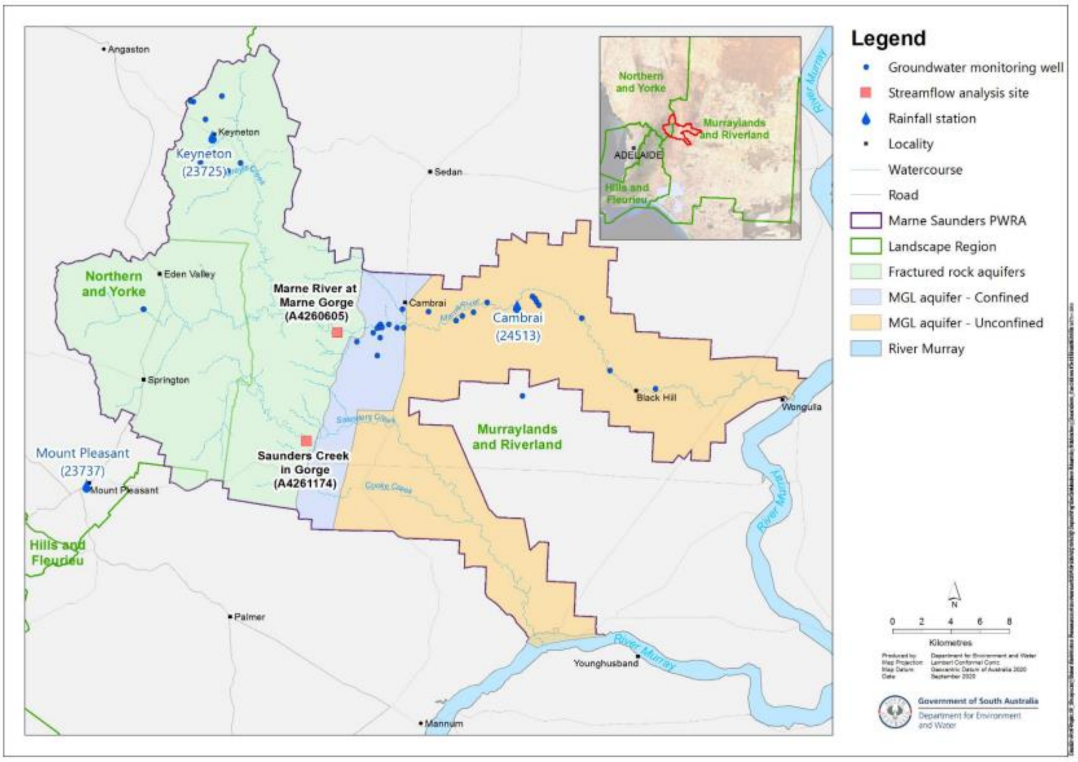


Figure 5: Aerial view of locations of the three key aquifers within the Marne Saunders PWRA: Green shading = Fractured Rock Aquifer; Purple shading = Confined Murray Group Limestone; Yellow shading = Unconfined Murray Group Limestone

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 offer a way to synthesize complex environmental, social, and economic data into simple, understandable scores. While this early iteration of the Marne Saunders Report Card only examines hydrological and ecological indicators, it is envisaged that subsequent report cards may also examine cultural, societal and economic data.

The current indicators have been selected to represent key ecological and hydrological functions that reflect the overall health of the system. The strength of these indicators 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 providing a balanced view of the system's health. To achieve this, indicators must meet the criteria below:

- **Relevance**: Indicators must be closely aligned with the key values and pressures within the catchment, such as water flow, salinity, biodiversity, and land use.
- **Data Availability**: Indicators must be chosen based on the availability of consistent and annually collected data. This ensures that changes in the system can be detected and addressed promptly.
- **Simplicity and Understandability**: Indicators must be easy to interpret by all stakeholders, from scientists to policymakers to the general public.

Selection of indicators

Indicators are a measure of a component of the environment. Each indicator may be composed of one of more measures. Each measure is a value that contributes to the indicator score. Measures that include a pre-existing model reference metrics.

Indicators	Measures/Model - Metrics
Surface Water Flow	Flow Modelling - Intermittency, Low flow season days, Break of season, Spring flows, Median flows, High flows
Groundwater Status	Salinity
Permanent Pools Water Quality	Salinity, Dissolved oxygen, pH
Fish	Aquasave Fish Condition Model (FCM) - species richness, abundance, and the presence of sensitive or invasive species.
Macroinvertebrates (waterbugs)	Macroinvertebrate Condition Model (CMCM) - species diversity, abundance, and sensitivity to flow conditions.

The indicators for the Marne Saunders Catchment Report Card were chosen through a collaborative process, involving scientific experts, government agencies, and community stakeholders. The indicators were selected based on their ability to represent the critical aspects of catchment health, such as water availability, ecosystem health, and species diversity. The key focus was on annual monitoring programs that could reliably provide the data needed to measure changes in the catchment's condition in subsequent iterations of this report. This ensures that the report card captures a snapshot of current conditions and enables tracking of how these conditions evolve over time.

The report card assesses the catchment across five key indicators: surface water flow, groundwater status, permanent pool water quality, fish, and macroinvertebrates (waterbugs).

Surface Water Flow

Surface water flow is one of the most important indicators of river health, especially in a catchment like the Marne Saunders where water availability fluctuates significantly over space and time. This indicator examines modelling work undertaken by DEW who estimated condition for 2023 against all data for previous years, at some locations back as far as 1973. This modelling utilised a number of measures, including number of flow days (total days the river is flowing) and high flow events (intensity of flows that are necessary to sustain aquatic habitats and replenish the system). The starting date of the flow season is monitored to track the timing of the first flow after dry periods, a critical period for species that rely on seasonal cues for reproduction and survival.

This indicator is the most significant of all presented in this report, as surface water flow is a key driver of ecological processes. Any reduction in flow days or delays in flow seasons can drastically reduce habitat availability, exacerbate competition for resources, and decrease species diversity and survival.

Groundwater Status

Groundwater serves as an essential resource in the Marne Saunders catchment, particularly during dry periods when surface water is scarce. A vast majority of water used for irrigation in the lower catchment is sourced from underground aquifers. There are 2 aspects of groundwater that are of key relevance to irrigators and the environment – the water quality (in particular salinity), and the depth to the groundwater ie the accessibility of the resource for a bore, tree roots or a natural spring. source.

Groundwater salinity examines salt concentrations in groundwater, a critical factor that can limit the usability of water for agriculture, and stock and domestic purposes. This indicator provides information on the suitability of water for use in the catchment, potentially impacting crop selection, and in extreme circumstances, stock welfare. All data was collected from bores located across the catchment, either via the DEW observation well network, readings taken at other bores, and bore water samples sent to the MR Landscape board for testing by water license holders through the annual groundwater salinity sampling program.

Depth to the water table is a key concern for users of groundwater – if this level drops too far, bores may no longer be able to efficiently extract water. Changes in water table depth (or delta) were measured by comparing the difference between current groundwater levels and the highest water table on record from 1993, providing a gauge of aquifer capacity and therefore water availability for plants, animals, and human use. Due to the different types of aquifers in the catchment, this is only measurable in the Lower Marne sub-catchment scores so was not included in the report card as the restricted data set meant it did not satisfy the criteria for a suitable catchment wide indicator. (The Lower Marne groundwater depth analysis can be found in Appendix 1).

Permanent Pool Water Quality

Permanent pools act as refuges for aquatic species during dry periods when the rivers are not flowing and play a crucial role in maintaining biodiversity in the Marne Saunders catchment. The health of these pools is examined in this report card using several water quality measures, including pH levels (to assess water acidity or alkalinity), dissolved oxygen (critical for supporting aquatic life), and salinity (affects both species survival and water quality). Data for permanent pool water quality were collected by a combination of contracted ecologists (Nature Glenelg Trust) during annual fish surveying and the Waterbug Bioblitz citizen science initiative (a collaboration between the local community, the MR Landscape Board, the Department for Environment and Water and specialist ecologists). Due to interpretation complexities, water quality data collected monthly through the Waterwatch program were not used in this first analysis. Alternative ways to analyse these data are being explored and it is expected that the Waterwatch data will be used to augment this indicator in the next annual report card.

Fish

Fish populations are a key indicator of overall river health because they are highly sensitive to changes in water flow, quality, and habitat availability. The decline in fish populations, particularly the functional extinction of species such as the river blackfish *Gadopsis marmoratus* in the Marne Saunders catchment, highlights the urgent need for interventions to improve habitat conditions and restore flow regimes. Scores for this indicator are based on work carried out by specialist ecologists. Nature Glenelg Trust have been undertaking fish population surveys for MR Landscape Board (previously the SA Murray-Darling Basin NRM Board) for over 20 years, and have modelled fish condition scores across the catchment. Their modelling examined various facets of the fish population(s) to arrive at a score for their 2023 data. This included reviewing species diversity (the number of different fish species present reflecting the ecological richness of the system); presence of invasive species (assesses the extent to which non-native species are displacing native fish); and breeding success (the presence of juvenile fish, indicating the reproductive health of the population).

Macroinvertebrates

Macroinvertebrates, or waterbugs, are another essential bioindicator used in the report card. These species are sensitive to changes in water quality, salinity, and flow regimes, making them reliable indicators of the health of aquatic ecosystems. The report card applies scoring based on findings from modelling of macroinvertebrate populations in the catchment undertaken by DEW. Data examined in this indicator were collected during citizen science Waterbug Bioblitz activities, and from monitoring undertaken by DEW and the Environmental Protection Authority (EPA). In this model, species richness, presence of species sensitive to environmental changes, and abundance are used to assess the condition of macroinvertebrate communities.

Getting the grades: The scoring approach

The scoring system for the Marne Saunders Catchment Report Card was carefully designed to translate the ecological and hydrological data into clear, meaningful grades that represent the current health of the catchment. Scoring thresholds were assigned to a grade on a scale from A (very good) to F (very poor) for each indicator. A is the healthiest that an indicator can score whereas F is least healthy. Where there is insufficient data to score an indicator of health, a No Data result takes the place of a grade. Grades were assigned for each site, which were then averaged to provide a score for the sub-catchment for each indicator

Threshold determination for indicator grades

The choice of the scoring thresholds was informed by ecological standards and long-term data on the health of the catchment, allowing for a consistent, transparent, and scientifically grounded assessment. The thresholds have been designed to capture significant changes, ensuring that shifts between grades correspond to meaningful improvements or declines in catchment health.

These thresholds ensure that the scoring system reflects current conditions accurately and succinctly. All methodological and analysis descriptions in later sections of this document describe each threshold / cutoff demarcation between grades for each indicator.

Linear Conversions to Grades

To ensure consistency and comparability, the scoring system for the report card applied linear conversions to translate raw ecological data into grades ranging from A to F. See figure 6 below

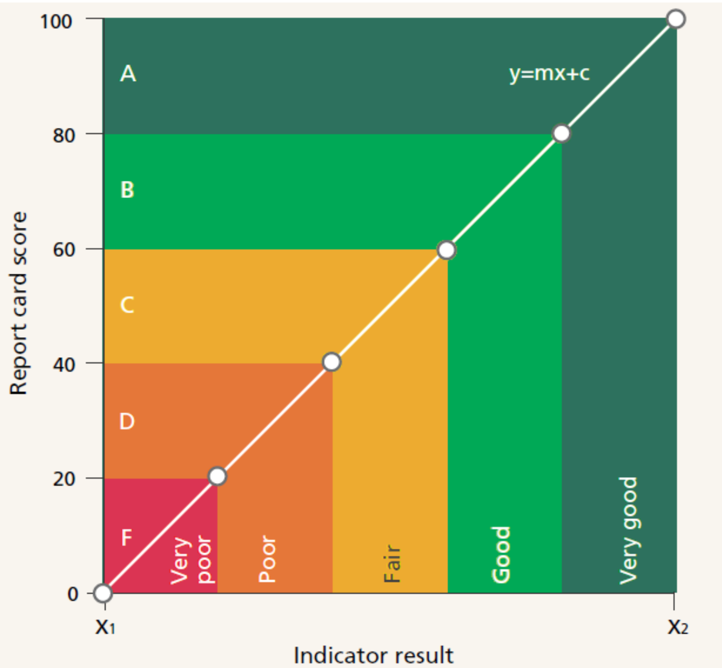


Figure 6: Linear conversion method of scores between 0-100 and the grading letters A,B,C etc

The use of linear conversions allows for a uniform grading system across different indicators, ensuring that all ecological components are assessed on a consistent scale. By applying this grading method, the report card provides a clear and accessible summary of the catchment's health, making it easier for stakeholders to identify areas of concern and target management interventions effectively. It offers a transparent and scientifically grounded approach to understanding the complex interactions within the catchment's ecosystems, guiding both current and future conservation efforts.

Spatial Segmetation of Scoring

In order to investigate indicator health across different environments within the catchment, it was segmented by sub-catchments (Figure 7 overleaf). Each sub-catchment was scored for each indicator where data was available in the sub-catchment for that indicator.

The sub-catchments follow surface water management zones previously defined by the Department of Environment and Water (DEW) . The exception is the Upper Saunders sub-catchment which combines two sub-catchments; Upper Saunders and One Tree Hill into a single Upper Saunders sub-catchment. This merging of these two sub-catchments into one was triggered as a result of very few data collection sites in the One Tree Hill sub-catchment.

A further modification to the sub-catchments was created to account for the fact that the hills face area while technically part of the Lower Marne and Lower Saunders sub-catchments is more charateristic of the upper (hills) sub-catchments (overleaf). This is particularly relevant for groundwater data as the dotted line marking the bottom of the hills face transition zone follows the boundary of the fractured rock aquifer of the hills zone and Murray Group limestone aquifer of the plains. All data from this area are included with the adjacent Upper Marne or Upper Saunders sub-catchments. This ensures that groundwater scoring within a sub-catchment remains within the same type of aquifer.

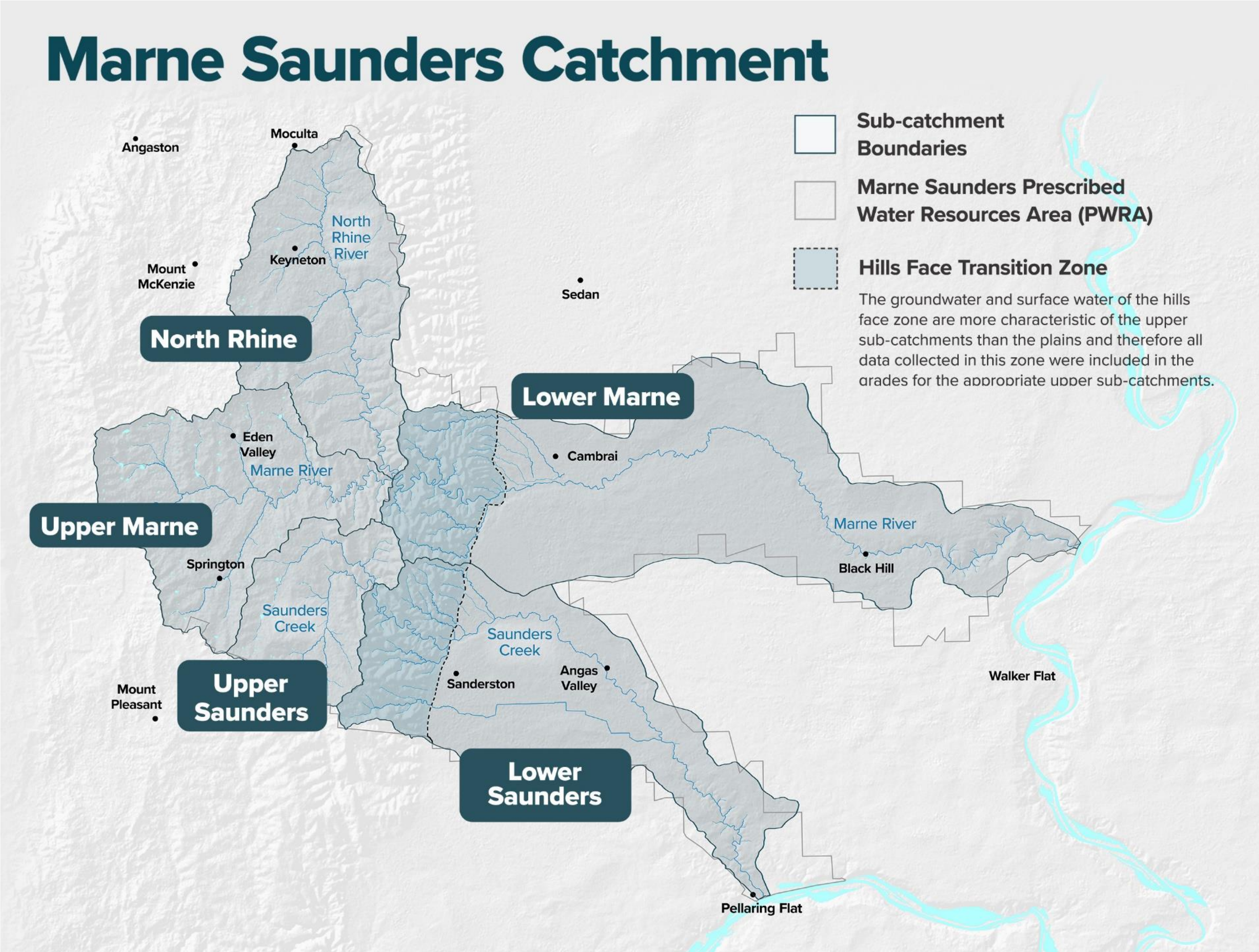


Figure 7: Sub-catchments

Caveats and shortcoming acknowledgment

It is important to note that ecological and hydrological sampling is not always undertaken across a wide area of a catchment. Infrastructure, access, resourcing and environmental variability all pose distinct limitations. Similarly, some of the scores for indicators herein are based on modelling, and while this allows the creation of visual representations of complex data and is underpinned by robust data, it is acknowledged that there is a margin for error inherent in all modelling.

Modeling is a way of using computers and mathematics to represent and understand real-world systems. Think of it as creating a "virtual version" of a place, like the Marne Saunders catchment area, to see how it behaves under different conditions. This virtual model helps scientists and decision-makers explore what might happen without having to test things in real life.

In some of the data sources within the report card (particularly the macroinvertebrate and the surface water indicators), modelling was used to better understand the system**.** Models are built using real-world data, like rainfall, river flow, and water quality measurements. These data points are combined with scientific knowledge about how water moves and interacts with the environment.

Further important caveats and acknowledgement of shortcomings are presented for each indicator in the relevant results section below. These are also an opportunity to pinpoint where data collection and/or analysis is lacking. There is opportunity for further refinement of the scoring in future iterations of this report card should monitoring programs and analyses change.

Data analysis: data sources, methods, and interpretation

1. Surface Water Flow

The surface water flow regime is a critical indicator of river health, providing insight into the ecological conditions and sustainability of aquatic ecosystems. In the Marne Saunders catchment flow patterns influence the availability and quality of habitats for aquatic species, from fish to macroinvertebrates. Regular flow is essential to maintain water quality, prevent excessive salinity, and ensure that aquatic plants and animals have access to sufficient habitat for feeding, breeding, and shelter.

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. 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. This is leading to habitat contraction and greater competition for resources among aquatic species, ultimately harming biodiversity.

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.

Surface water: 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.

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. Figure 8 below demonstrates the locations of the monitoring stations used in these analyses.

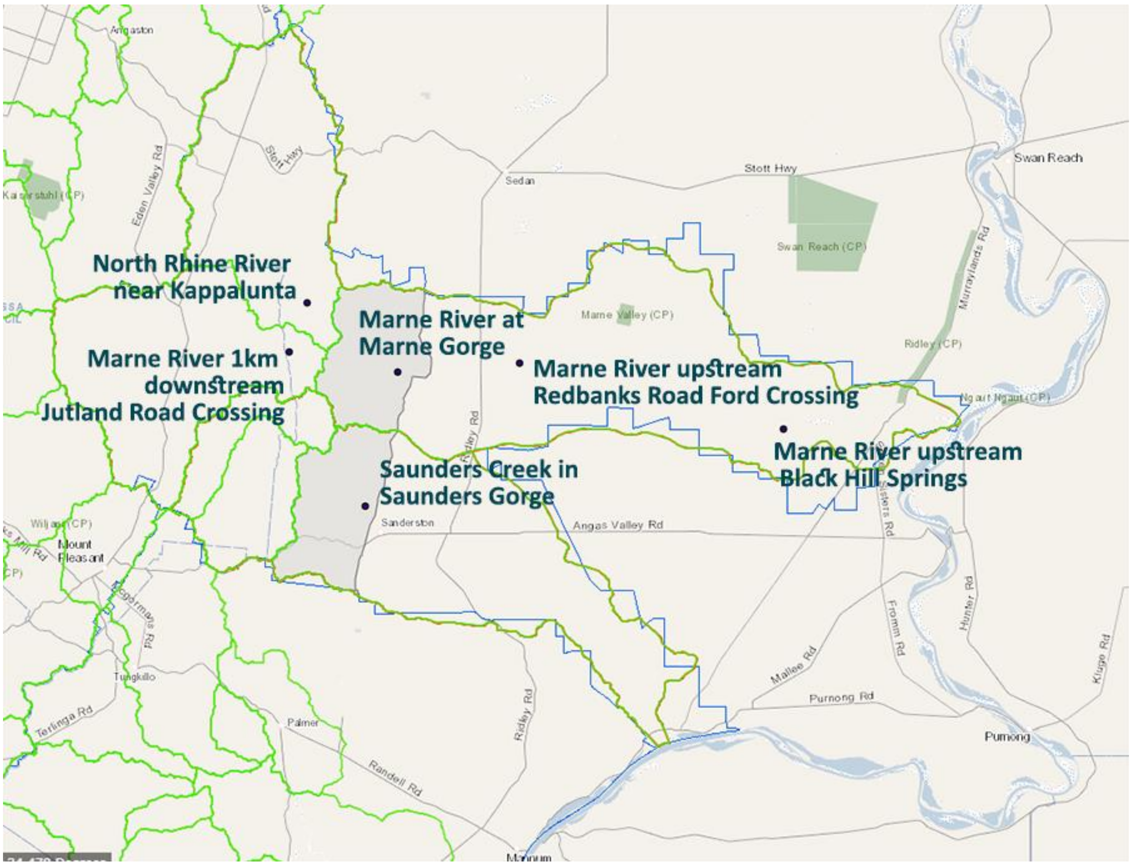


Figure 8: Map showing flow monitoring stations used in these analyses.

DEW's historical flow data and trend analysis

The analysis utilizes historical streamflow data from 1973 onwards. These historical records form the basis for defining the thresholds for flow days and high flow events. The trends derived from this long-term data provide context for understanding how recent hydrological patterns compare to historical averages. This is particularly important in a catchment that experiences extreme variability in flow, ranging from years with zero flow to periods of high discharge during heavy rainfall events.

Detailed metrics used in DEW's surface water modelling analysis

The surface water analysis is built around a series of key hydrological metrics or measures that reflect the health and variability of the catchment's watercourses. Table 1 (Adapted from DEW 2024) describes each of these metrics:

Table 1: 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)

Flow metrics	Unit	Definition	Ecological relevance
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) • 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: It is important to note that, 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).

Surface water: scoring method

Firstly, the findings relating to the status of the flow regime in the catchment (as presented in DEW's analysis of flow) were considered. The scoring system for those analyses utilized a percentile range to assign scores based on how current flow metrics compared to historical benchmarks. This approach ensures that the metrics are assessed relative to long-term data for this catchment, providing a clear picture of the river system's health. For each metric, percentile ranges were presented, as demonstrated in Table 2 below:

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}

Table 2: Status assessment thresholds used for the assessment of the flow regime. Adapted DEW's Marne Saunders Flow Metrics Status Report (DEW 2024)

Each of the flow measure statuses derived through this percentile-based system were translated to a score (A,B,C,D,or F), using the following schema (Table 3):

Table 3: Translation of flow regime status assessment thresholds to report card scoring

<table>
<tr><th>Status assessment</th><th>Percentile range</th><th>Report Card Score</th></tr>
<tr><td>Highest on record</td><td>100^{th}</td><td rowspan="2">90</td></tr>
<tr><td>Very much above average</td><td>90^{th} to 99^{th}</td></tr>
<tr><td>Above average</td><td>70^{th} to 89^{th}</td><td>70</td></tr>
<tr><td>Average</td><td>30^{th} to 69^{th}</td><td>50</td></tr>
<tr><td>Below average</td><td>10^{th} to 29^{th}</td><td>30</td></tr>
<tr><td>Very much below average</td><td>2^{nd} to 9^{th}</td><td rowspan="2">0</td></tr>
<tr><td>Lowest on record</td><td>1^{st}</td></tr>
</table>

Surface water: scores per sub-catchment

Scoring of the surface water indicator evaluates the river system's health through key flow measures, including flow days, low flow days, break of season, spring flow, and days above median flow. These metrics are critical for determining water availability, flow variability, and the river's ability to sustain aquatic ecosystems.

Table 4 overleaf demonstrates DEW's findings while incorporating the equivalent report card scoring for each monitored site across the catchment

Table 4: Breakdown of sites values from DEW modelling and corresponding report card scores

Site	Flow Days			Low Flow days			Break of season		
	2023 value	Status	Report Card Score	2023 value	Status	Report Card Score	2023 value	Status	Report Card Score
Marne River at Marne Gorge (Upper Marne)	221	Above average	70 (B)	54	Below average	30 (D)	214	Average	50 (C)
Marne River 1km downstream Jutland Road Crossing (Upper Marne)	123	Above average	70 (B)	28	Below average	30 (D)	100	Above average	30 (D)
Marne River upstream Black Hill Springs (Lower Marne)	0	Average	50 (C)	0	Below average	30 (D)	214	Above average	30 (D)
Marne River upstream Redbanks Road Ford Crossing (Lower Marne)	1	Average	50 (C)	0	Below average	30 (D)	214	Very much above average	0 (F)
North Rhine River near Kappalunta (North Rhine)	4	Average	50 (C)	1	Below average	30 (D)	214	Very much above average	0 (F)
Saunders Creek in Saunders Gorge (Upper Saunders)	24	Average	50 (C)	4	Below average	30 (D)	214	Very much above average	0 (F)

Site	Spring flow			Days above median flow			Days above high flow		
	2023 value	Status	Report Card Score	2023 value	Status	Report Card Score	2023 value	Status	Report Card Score
Marne River at Marne Gorge (Upper Marne)	0.363	Below average	30 (D)	44	Average	50 (C)	2	Average	50 (C)
Marne River 1km downstream Jutland Road Crossing (Upper Marne)	0.717	Average	50 (C)	19	Average	50 (C)	2	Average	50 (C)
Marne River upstream Black Hill Springs (Lower Marne)	0.000	Average	50 (C)	0	Average	50 (C)	0	Average	50 (C)
Marne River upstream Redbanks Road Ford Crossing (Lower Marne)	0.000	Above average	70 (B)	0	Average	50 (C)	0	Average	50 (C)
North Rhine River near Kappalunta (North Rhine)	0.000	Average	50 (C)	0	Average	50 (C)	0	Below average	30 (D)
Saunders Creek in Saunders Gorge (Upper Saunders)	0.011	Below average	30 (D)	5	Average	50 (C)	0	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:

Table 5: Report card 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
Upper Marne	70	30	40	40	50	50	**46.66 (C)**
Lower Marne	50	30	15	60	50	50	**42.5 (C)**
North Rhine	50	30	0	50	50	30	**35 (D)**
Upper Saunders	50	30	0	30	50	50	**35 (D)**
Lower Saunders	No data available						
					Marne Saunders Total Score	**39.79 (D)**	

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 (ie higher values represent a delay in the onset of flow). This resulted in very low scores for this metricacross 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.

Surface water: caveats

In the analysis of the surface water flow indicator, caveats should be noted regarding the variability in rainfall and flow patterns across the Marne Saunders catchment, particularly in the context of drought years and intermittent flow conditions. DEW's reporting highlights that variability is significant between seasons and years, with some years experiencing extremely low or zero flow. This variability can skew short-term data and may not fully reflect long-term trends in water availability. The comparison with historical flow data also meant that the Lower Marne scored a C-Fair as the very low flow has been the norm for many years on the plains, but perhaps this does not give an accurate representation of the health status of this section of the catchment. Gauging station data also may not capture all local flow events, particularly smaller, short-duration flows in the upper catchments, which could lead to underreporting of actual water flow days or high flow events. There is also a lack of data for the Lower Saunders where there is no gauging station. These factors should be considered when interpreting surface water scores and trends to avoid overgeneralizing from limited data.

2. Groundwater Status

Groundwater is a critical resource in the Marne Saunders catchment, and is vital to both agricultural activities and the region's ecosystems, particularly during periods of low rainfall and limited surface water flow. More than 70% of all metered water use in the catchment comes from groundwater. The groundwater system in this catchment is variable, with significant spatial differences in water availability and quality, making it essential to monitor and assess the condition of these sub-surface reserves.

The groundwater analysis presented in the Marne Saunders Catchment Report Card focuses on one primary measure: groundwater salinity.

Salinity levels in groundwater are measured in terms of electrical conductivity (EC), which reflects the concentration of dissolved salts in the water. High salinity can make groundwater unsuitable for irrigation and negatively affect both ecosystems and agricultural productivity.

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.

Groundwater: 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.

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 acessible 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 9 below.

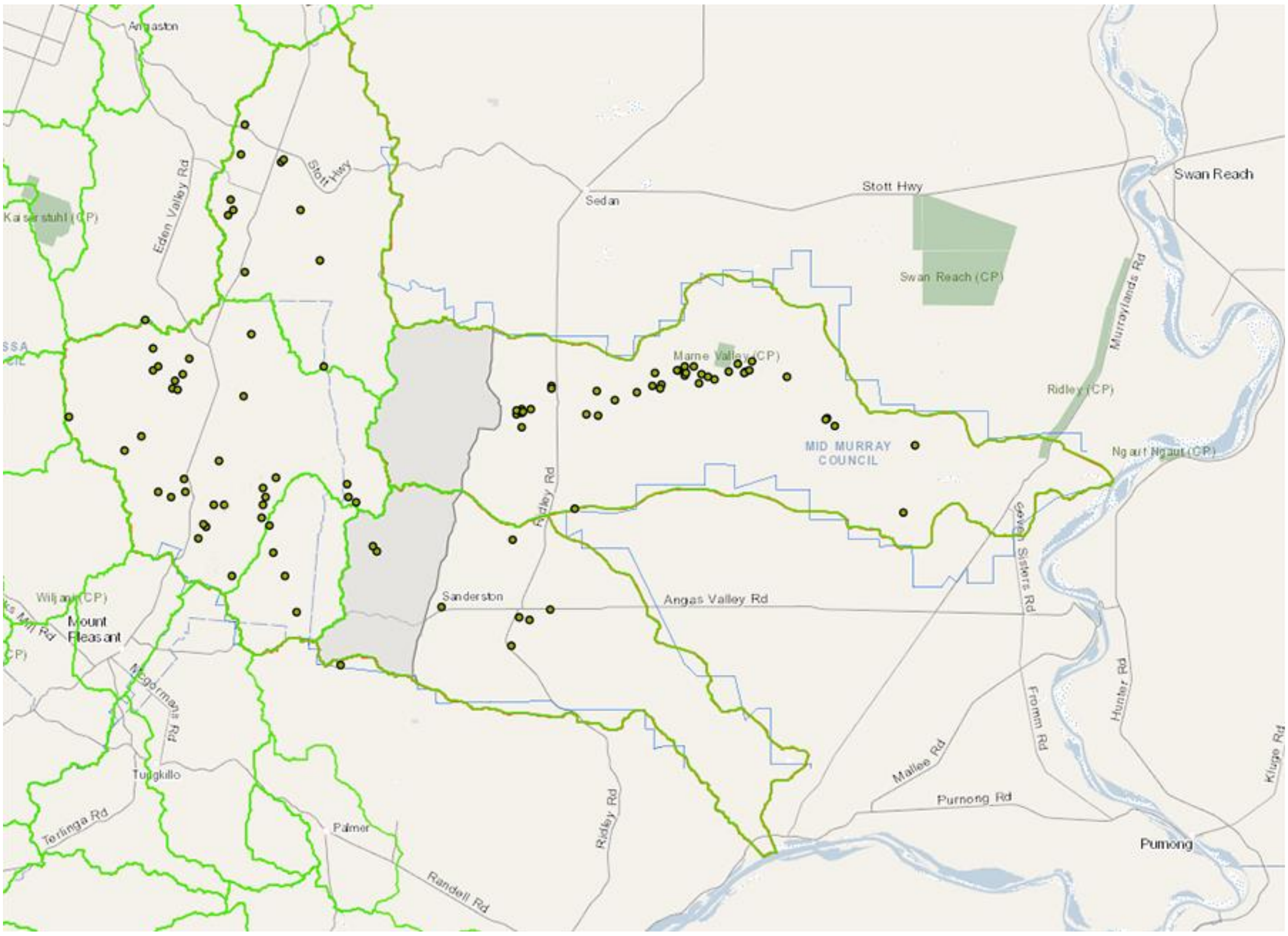


Figure 9: Map displaying data collection sites from monitoring and privately owned sites

Groundwater: 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).](#) 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 µS/cm), and are all below max threshold (15,000 µS/cm).

Yield reduction for lucerne, turf, and winegrapes associated with increasing salinity is noted in Table 7 below.

Table 7: Salinity -induced crop yield reduction (adapted from Primary Industries NSW)

Crop Type	Salt value = No Crop reduction (µS/cm)	Salt Value = 10% Reduction (µS/cm)	Salt value = 25% Reduction (µS/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.

No reduction = ((1300 µS/cm +1000+2000)/3)

= 1433 µS/cm

10% reduction = ((2200+1700+4200)/3)

= 2700 µS/cm

25% reduction= ((3600+2700+7500)/3)

= 4600 µS/cm

The scoring threshold schema based on salt concentration thresholds are:

- A (Very Good): conductivity is less than 800 µS/cm, indicating excellent water quality suitable for all uses, including irrigation and drinking.
- B (Good): conductivity is between 800 and 1400 µS/cm, indicating good quality groundwater, generally safe for irrigation and suitable for most crops.
- C (Fair): conductivity is between 1400 and 2700 µS/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 µS/cm, indicating poor water quality that will likely result in crop yield reductions.
- F (Very Poor): conductivity is greater than 4600 µS/cm, indicating saline groundwater that is unsuitable for irrigation purposes (of selected crop types) without treatment

Groundwater: 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. 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 8 below shows all groundwater scores per sub-catchment analysed. All sub-catchments demonstrate elevated salinity.

Table 8: Groundwater salinity scoring applied to each sub-catchment based on an average of all wells scored.

Sub-catchment	Salinity Score (out of 100)	Grade
Upper Marne	32.3	**D**
Lower Marne	29.1	**D**
North Rhine	22.7	D
Upper Saunders	23.4	**D**
Lower Saunders	12.5	**F**
Marne Saunders total groundwater score	**24**	**D**

- Sub-catchment scoring: each sub-catchment is assigned a grade based on the average score of these two measures.
    - Most scored a D (Poor) due to their high salinity levels.
    - The Lower Saunders showed very poor results for salinity, scoring an F.

Groundwater: caveats

Salinity calculations were calculated using all bore information across the entire catchment. However, only those bores which were read in the year 2023 were suitable for analysis. Similarly, where possible only bores with a reading taken after the 'winter recharge' (ie August – October) were used to ensure that data remained comparable. In cases where readings were not taken during those specific time periods, the lowest salinity for that bore during the year of interest was used.

3. Permanent pools water quality

Permanent pools play a crucial role in the Marne Saunders catchment particularly when the watercourse ceases to flow during the summer months. These pools provide critical refuges for aquatic species, maintaining biodiversity, and supporting ecological processes during dry periods. The quality and sustainability of these key habitats is assessed by examining several indicators of water quality and habitat condition.

The health of permanent pools is influenced by a combination of factors, including rainfall, aquifer levels (in the case of pools fed by groundwater), water quality, and habitat stability. Measures used to evaluate permanent pool health for this report card include water quality measure of pH, dissolved oxygen (DO), and salinity, which together provide an understanding of how well these habitats are functioning and whether they can continue to support diverse aquatic species assemblages. These measures are particularly sensitive to changes in flow regimes, climate, and water extraction.

Data for these analyses were drawn from a network of monitored pools throughout the catchment. Key data were provided by Nature Glenelg Trust (as a part of ongoing fish surveying in the region) and the Murraylands and Riverland Landscape Board's citizen science Waterbug Bioblitz program. The report card provides an objective assessment of how well the permanent pools are performing relative to ecological outcomes by comparing current conditions to established ecological thresholds.

This analysis highlights the condition of these refuges and serves as an important indicator of the broader health of the catchment's aquatic ecosystems. Healthy permanent pools are essential for sustaining biodiversity during dry periods and their condition can offer insights into the overall resilience of the river system.

Permanent pools: where the data came from

Nature Glenelg Trust's (NGT) fish monitoring and the Waterbug Bioblitz program provided data on water quality across most of the catchment. Together they represent the best available data that provides comprehensive coverage of permanent pools, however, no NGT sites are in the Upper Saunders and the Waterbug Bioblitz did not sample in the Lower Marne or Lower Saunders. 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.

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.

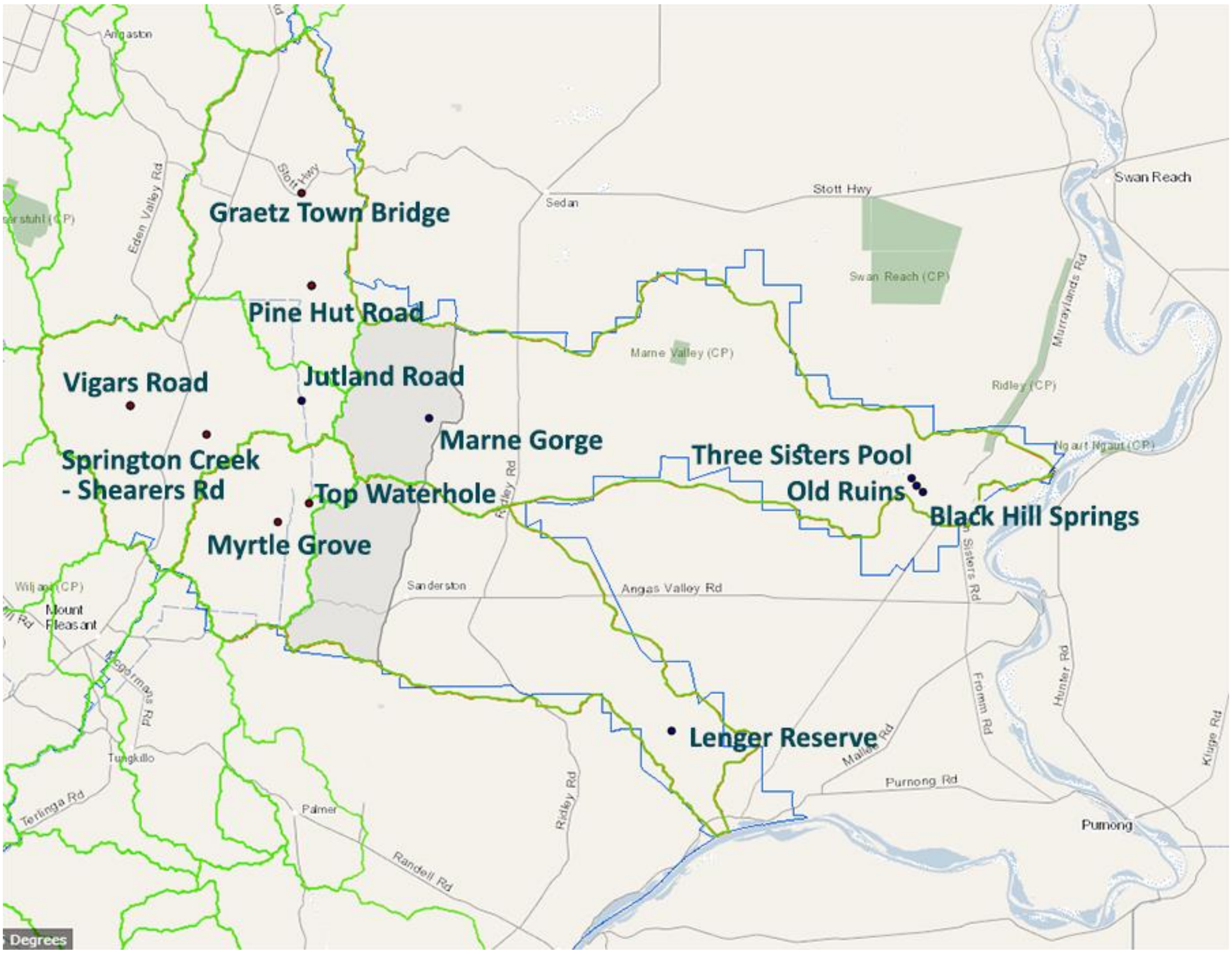


Figure 10: Map showing the location of sampling sites where permanent pool health data was gathered

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.

Permanent pools: 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)

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 µS/cm to support healthy populations. However, some more tolerant species, such as the carp gudgeon, can persist at levels approaching 10,000 µS/cm. For freshwater specialists like river blackfish and obscure Galaxias, conductivity levels exceeding 1000-1500 µS/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 µS/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 µS/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 µS/cm though optimal health is seen in lower conductivity environments around 1500-2000 µS/cm.

Grade	Salinity	Notes	Score
A (Very Good)	Below 1500 µS/cm	Represents freshwater conditions ideal for native fish species and other aquatic organisms.	**100**
B (Good)	Between 1500 and 5000 µS/cm	Acceptable for most native fish, but potentially affecting more sensitive species over time.	**75**
C (Moderate)	Between 5000 and 7500 µS/cm	Poses stress for freshwater fish species, potentially leading to lower reproductive success and species diversity.	**50**
D (Poor)	Between 7500 and 10,000 µS/cm	Beyond the tolerance of many native fish species, leading to reduced health and survival rates.	**25**
F (Very Poor)	Above 10,000 µS/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.

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

= (pH score (75) + conductivity score (75) + DO score (25)) / 3) * (pool condition factor (0.5))

= 29.16

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.

Permanent 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 and salinity. The analysis provides a clearer picture of the health of these key aquatic refuges, with some pools showing significant stress.

Dissolved oxygen (DO)

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

- Upper Marne pools vary significantly, with DO levels ranging from 3.4 ppm to 12.3 ppm. Pools with lower oxygen levels, are likely to stress aquatic organisms, particularly fish species that require higher oxygen levels for survival. However, some pools in the same sub-catchment display DO levels above 8 ppm, indicating healthier conditions capable of supporting aquatic life.
- In the Lower Saunders sub-catchment, DO levels remain low at 3.5 ppm, which is concerning for fish survival and indicates poor water quality overall.
- The Lower Marne shows low DO levels, with some pools recording DO levels as low as 1.5 ppm, while others reach up to 3.4 ppm. This low range suggests that some pools may be stressed.

Salinity (conductivity)

Salinity levels, measured as conductivity, are a key concern in many pools.

- The Lower Saunders pool exhibits high salinity, with conductivity levels of 13,103 µS/cm which is far above the threshold for supporting healthy freshwater ecosystems. This salinity level is detrimental to most native fish species, reducing biodiversity and ecosystem function.
- Upper Marne pools show a range of conductivity, from 2,765 µS/cm to 6,818 µS/cm, indicating moderately saline conditions that can still support some freshwater species but may stress sensitive organisms.
- The Lower Marne pools also exhibit moderate to high salinity, with some pools reaching as high as 7,284 µS/cm. The high variation suggests that some pools are becoming increasingly saline.

pH levels

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 maintain pH values between 7.5 and 7.9, which are within the acceptable range for most freshwater species.
- Lower Marne pools are also within the tolerable range .
- The Lower Saunders and North Rhine pools display pH values that remain within the tolerable range.

This analysis reveals that primary concerns should focus on low dissolved oxygen and high salinity levels in several key pools, particularly in the Lower Saunders and Lower Marne sub-catchments. These conditions are likely to significantly reduce the ecological function of these permanent 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.

Table 9 below summarises all permanent pool health scores and grades aggregated by sub-catchment.

Table 9: Permanent pool scoring applied to each sub-catchment.

Sub-catchment	Average of score *(post-pool condition weighting)*	Grade
Upper Marne	48.98	**C**
Lower Marne	50	**C**
North Rhine	44.4	**C**
Upper Saunders	50	**C**
Lower Saunders	29.1	**D**
Marne Saunders total	**44.5**	**C**

Permanent 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, one in April prior to winter rains and the other 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 sample the exact same pools although there was some overlap. As such, these values can be viewed as indicative only.

4. Macroinvertebrates (waterbugs)

One of the most effective methods of assessing riverine health is through the study of macroinvertebrates—small aquatic creatures like insects (such as water beetles and the aquatic juvenile life stages of midges, mayflies and dragonflies) and crustacea (such as freshwater shrimp) and molluscs (such as aquatic snails) that are visible to the naked eye. The common name for macroinvertebrates is waterbugs and we have used this term on the report card but will use macroinvertebrates in this report.

Macroinvertebrates are sensitive to changes in water quality, habitat structure, and flow regimes, making them commonly used, reliable indicators of river health. Unlike chemical tests, which provide a snapshot of water quality at a given moment, macroinvertebrate populations reflect the cumulative effects of pollution, habitat modification, and water quality and flow over longer time periods. By studying the diversity of different species (taxa), whether sensitive species are present, and the abundance of these organisms, we can better gauge the overall health of river ecosystems and detect subtle changes that may not be immediately visible.

This macroinvertebrate assessment 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.

Marcroinvertebrates: 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 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 is it 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 currently only surveys sites in the hills sub-catchments.

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 11 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 11: Map showing the location of sampling

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). 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.

Macroinvertebrates: 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.

Macroinvertebrates: 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 10 below:

Table 10: Breakdown of sites values and condition scores from DEW modelling and corresponding report card scores

Site	Sub-catchment	DEW Condition score	Condition rating	Report card score (/100)
Cranford Road	Upper Marne	1.91	Poor	**31.8 (D)**
Vigars Road	Upper Marne	3	Fair	**50 (C)**
Lartunga	Upper Marne	2.16	Poor	**36 (D)**
Springton Creek	Upper Marne	2.61	Fair	**43.5 (C)**
Jutland Water Reserve	Upper Marne	2.63	Fair	**43.8 (C)**
Springton Creek	Upper Marne	2.61	Fair	**43.5 (C)**
Graetz Town Bridge	North Rhine	2.37	Poor	**39.5 (D)**
Netherford	North Rhine	2.33	Poor	**38.8 (D)**
North Rhine	North Rhine	2.13	Poor	**35.5 (D)**
Upper Saunders Creek	Upper Saunders	2.03	Poor	**33.8 (D)**
One Tree Hill Creek, near Springton	Upper Saunders	1.85	Poor	**20.8 (D)**

The macroinvertebrate 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 11 below summarises the average macroinvertebrate soring per sub-catchment across the Marne Saunders for 2023:

Table 11: Aggregated average macroinvertebrate scores for each sub-catchment analysed, including total score for Marne Saunders catchment

Sub-catchment	Score (out of 100)	Grade
Upper Marne	41	**C**
Upper Saunders	31	**D**
North Rhine	38	**D**
Total Catchment Average Score	**36**	**D**

Macroinvertebrate communities: 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 include any 'lower' sub-catchment sites on the plains, which should be addressed in future so that a fuller picture (covering a greater geographical spread) is achieved.

5. Fish

Fish communities in the Marne Saunders catchment also serve as important indicators of aquatic ecosystem health, reflecting changes in water quality, habitat connectivity, and flow conditions over even longer time frames than macroinvertebrates. In the 2023 fish monitoring program, conducted by Nature Glenelg Trust and supported by DEW, the condition of fish populations across the catchment was assessed to provide insights into the broader ecological health of the river system.

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. The terminal wetland of the Marne River at Wongulla was also included, which provides a very different but important habitat for fish. This section outlines the methods used for fish monitoring and presents the key findings of the 2023 fish analysis.

Fish: where the data came from

The 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.

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.

Permanent pools were the primary focus as they act as refuges for fish during low-flow and no-flow conditions. Figure 12 below shows the locations of sample sites for this survey.

Figure 12: Location of fish sampling sites

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.

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**.

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 12 below indicates FCM scoring and associated report card grades for each surveyed site.

Table 12: Breakdown of sites values and condition scores from FCM modelling and corresponding report card scores

Site	Sub - catchment	FCM Condition score	FCM Rating	Report card score (/100)	Grade
Jutland Road	Upper Marne	7	Good	77.7	B
Vigars Rd	Upper Marne	9	Good	100	A
Marne Gorge	Upper Marne	4	Moderate	44.4	C
Marne Mouth	Lower Marne	2	Poor	22.2	D
Three sisters pool	Lower Marne	2.5	Poor	27.7	D
Black Hill Springs	Lower Marne	2.5	Poor	27.7	D
Pine Hut Road	North Rhine	0	Poor	0	F
Lenger Reserve	Lower Saunders	0	Poor	0	F

As is evident in Table 12, 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. Aquasave's 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 12: Aggregated average fish scores for each sub-catchment analysed, including total score for Marne Saunders catchment.

Sub-catchment	Score (out of 100)	Grade
Upper Marne	74.4	**A**
Lower Marne	25.9	**D**
North Rhine	0	**F**
Lower Saunders	0	**F**
Total Marne Saunders Average Score	**25**	**D**

Table 12 above provides averaged fish community grades, 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 Gambusia and common carp in the Wongulla Wetland 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.

Fish: caveats

In the analysis of the fish monitoring indicator, several caveats should be considered based on findings. One major caveat is related to the seasonal and cyclical nature of fish populations in the Marne Saunders catchment. Some native species, such as the obscure Galaxias, exhibit boom-bust population cycles where numbers can fluctuate drastically from year to year depending on water availability and habitat conditions. This variability can cause short-term spikes in population numbers which may not reflect longer-term population trends or overall ecosystem health.

Furthermore, as only 9 sites are included, spatial coverage of fish surveys across sub-catchments may lead to data gaps or inconsistencies (no sites were surveyed at all in the Upper Saunders), making it challenging to provide an accurate representation of fish community health across the entire catchment.

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 13 below and illustrated in Figure 13:

Table 13: All indicator scores for all sub-catchments *note: scores are average of measures where applicable.

Upper Marne		
Indicator Category	**Score (out of 100)**	**Grade**
Surface water status	46.6	C
Groundwater status	32.3	D
Permanent pools	48.9	C
Fish	74.4	A
Macroinvertebrates	41	C

Upper Marne total: 48.6 (C)

Lower Marne		
Indicator Category	**Score (out of 100)**	**Grade**
Surface water status	42.5	C
Groundwater status	29.1	D
Permanent pools	50	C
Fish	26	D
Macroinvertebrates	NA	NA

Lower Marne total: 36.9 (D)

Upper Saunders		
Indicator Category	**Score (out of 100)**	**Grade**
Surface water status	35	D
Groundwater status	23.4	D
Permanent pools	50	C
Fish	NA	NA
Macroinvertebrates	31	D

Upper Saunders total: 34.8 (D)

Lower Saunders		
Indicator Category	**Score (out of 100)**	**Grade**
Surface water status	NA	NA
Groundwater status	12.5	F
Permanent pools	29.1	D
Fish	0	F
Macroinvertebrates	NA	NA

Lower Saunders total: 13.8 (F)

North Rhine		
Indicator Category	**Score (out of 100)**	**Grade**
Surface water status	35	D
Groundwater status	22.7	D
Permanent pools	44.4	C
Fish	0	F
Macroinvertebrates	38	D

North Rhine total: 28.2 (D)

Total Marne Saunders Score: 33.9(D)

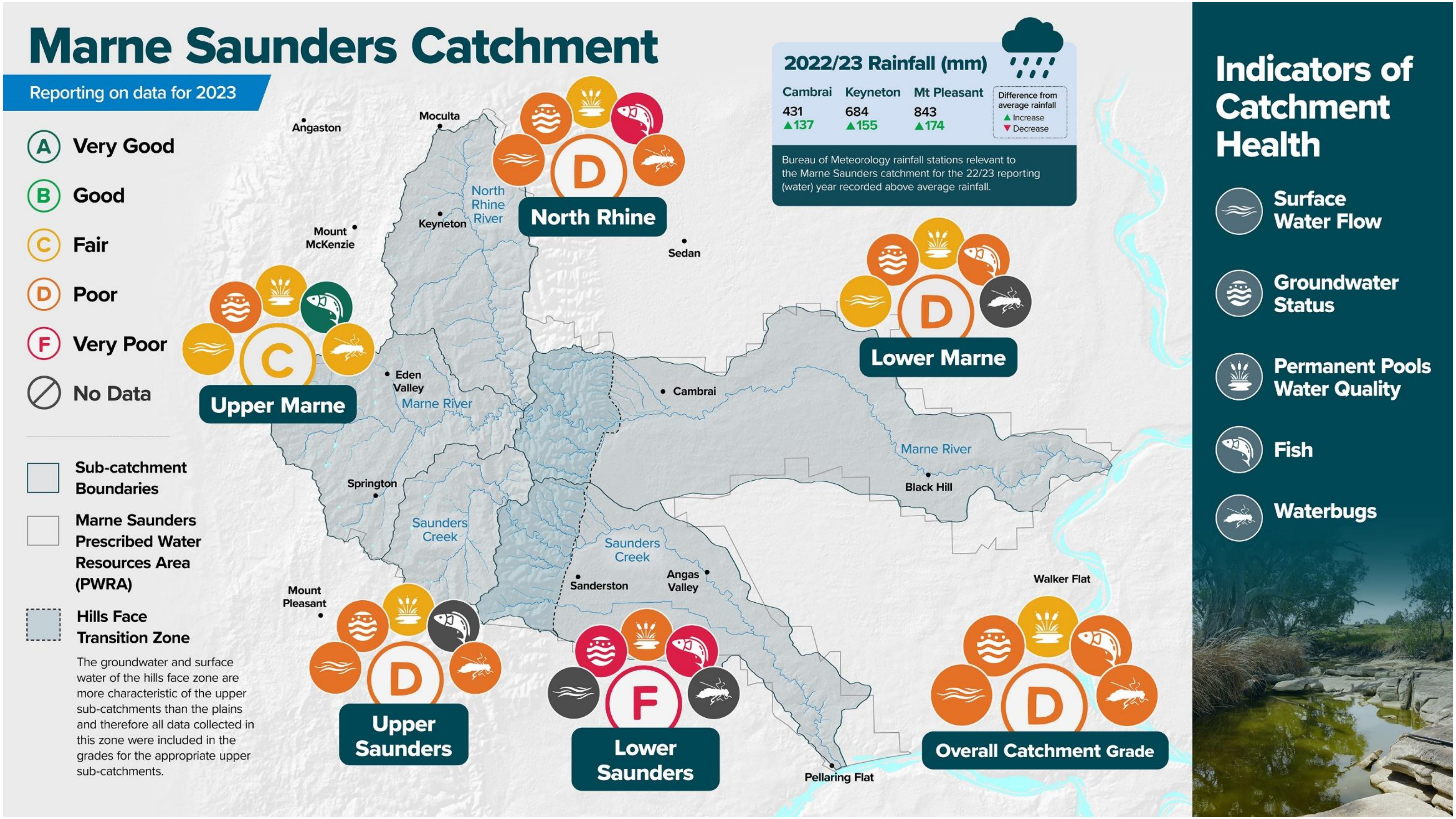


Figure 13: Final scores for all indictors for each sub-catchment and overall catchment scor

The analysis for the surface water flow indicator in the Marne Saunders catchment showed an overall score of 'D', indicating significant concerns about the reduction in flow across most sub-catchments. This is a critical issue, signalling the need for enhanced water management strategies that can support both the ecological processes and the needs of the local community. While the Upper Marne sub-catchment emerges slightly better off compared to others, like the rest of the river system, this sub-catchment is not without its challenges, including a general decline in the number of flow days which could impact long-term water availability and habitat quality. And while the Lower Marne also scored a fair grade this is due to the low to zero flow regime being a regular occurrence in this area in recent history.

Contrastingly, the Upper Saunders and North Rhine sub-catchments displayed more acute surface water flow issues, with each scoring poorly. These areas experienced a sharp reduction in both all flow days and high flow days. This is indicative of water management challenges, leading to reductions in water availability which, in turn, exacerbate stress on aquatic life and habitats.

Perhaps most concerning in the surface water analysis is the trend toward an increase in the number of days until the break of season, which has significant repercussions for water availability and catchment health. This delay in the onset of seasonal flows is particularly troubling as it disrupts the natural timing of water replenishment. Such delays can lead to prolonged dry periods where water is scarce, adversely affecting both the ecology and the local communities that rely on consistent water supply. Aquatic species, especially those that depend on specific flow conditions for breeding and feeding, may experience life cycle interruptions that potentially lead to decreased populations and biodiversity loss. Furthermore, this extended interval before the break of season can exacerbate competition for already limited water resources, compounding stress on agricultural activities and natural habitats.

In terms of groundwater, the catchment also scored a 'D', reflecting variability in salinity recordings across different areas but generally poor results. The Lower Marne sub-catchment was the only region where data was available to examine the change in water table height (relative to the best on record). It is important to note that while most wells scored highly on this measure, these values are expressed relative to a previous height (ie best on record) to benchmark the scores and only a small number of bores could be used in the analysis. Anecdotal and empirical evidence indicates that the water level is dropping across this sub-catchment, impacting water availability to some users.

The health of permanent pools, which play a crucial role in providing refuges for aquatic life during dry periods, also showed variability. Some pools were in good condition and appeared able to support diverse assemblages of aquatic life, while others were adversely affected by factors such as low dissolved oxygen levels and high salinity. These conditions suggest a need for ongoing monitoring and interventions being required to maintain these critical habitats, especially considering changing climatic conditions and likely further reduced rainfall across the catchment into the future. Some permanent pools in the Upper Saunders and Lower Marne sub-catchments showed signs of stress including low dissolved oxygen levels and high salinity.

Macroinvertebrate communities within the catchment were generally in poor health as indicated by an overall 'D' score. This low score in macroinvertebrate health is likely indicative of poor water quality and habitat conditions. Sub-catchments with poorer water flow and water quality tended to show more significant declines in these communities, reflecting the interconnected nature of water management and biodiversity.

Fish populations were similarly under stress, with the overall health also scored as 'D', although the A score for the Upper Marne demonstrates the ability for some fish species to still be able to respond in the short-term when conditions improve. Factors such as the presence of invasive species, habitat degradation, and altered flow conditions have negatively impacted native fish diversity and health. Fish population decline, and particularly the functional extinction of blackfish in the Marne Saunders catchment, highlights the urgent need for habitat restoration and flow regime improvements to support these populations.

Across all sub-catchments, a consistent pattern of reduced surface water availability and ecological stress is evident. This widespread issue suggests that current water management and usage practices are likely to need to adapt to sustain the ecological and human needs of the catchment. The ongoing declines in biodiversity, exemplified by deteriorating conditions for macroinvertebrates and fish, underscore the cascading effects of environmental stressors on the catchment's ecological balance.

To address these challenges, it is essential to develop and implement improved water and environmental strategies for the catchment. Enhanced monitoring of ecological indicators combined with targeted policy and land management interventions may help restore and conserve critical habitats, particularly permanent pools and river flows. Engaging local communities and stakeholders in these efforts is crucial to raise awareness and foster collaboration towards sustainable catchment management.

The detailed analysis presented in this technical note serves as a valuable resource for stakeholders, providing the necessary data to understand the complex interactions and challenges within the Marne Saunders catchment. By addressing the identified issues, there is potential to improve the ecological health and sustainability of this region. This is important as it is likely that the catchment will continue to dry out and its health to decline further if predicted future climatic conditions eventuate.

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Appendix A:

Depth to groundwater for the Lower Marne sub-catchment

The sub-indicator examining depth to water table measures the change in water table depth relative to the ‘best on record’ levels, providing an estimate of how much the water table has fallen over time. The year 1993 was selected as the baseline for "best on record" due to its notably high water levels, which were driven by significant recharge following wet years. This year serves as a reference point for assessing the depletion of groundwater reserves in subsequent years. The ‘delta value’ is calculated as the difference between the water table depth in 1993 and the depth measured in 2023. This change is expressed as a proportion of the average aquifer ‘thickness’ (total depth to bottom), contextualizing the drop in water levels relative to the aquifer's capacity.

As noted below, only a small number of wells met the criteria for being able to make this calculation. Foremost, the method requires that the overall depth, or ‘thickness’ of the aquifer is known (or can be estimated). This knowledge is only available for aquifers on the plains (namely, the Murray Group Liestone aquifer) – discounting this method’s suitability for the hills zone sub catchments. Nonetheless, these data are important for many users of groundwater on the plains, and therefore are included in this report

Depth to water table (delta value)

Data for the depth to water table (delta value) sub-indicator was collected from a network of groundwater monitoring wells within the Marne Saunders catchment. These wells are managed by DEW and provide long-term records of seasonal water table fluctuations. The specific wells used for this measure were chosen based on the availability of historical data, particularly from the year 1993, which was established as the "best on record" due to high recharge levels in that year.

- Monitoring Wells: wells that provided 1993 and 2023 readings were used to calculate the delta value. The change in the depth to the water table (from 1993 to the current levels) was expressed as a proportion of the average aquifer thickness to understand the extent of groundwater depletion.
- Monitoring Frequency: readings from these wells are taken after the winter recharge period, typically in August. These readings provide a reliable measure of groundwater replenishment and overall availability within the aquifer.

Depth to water table calculation process

Determine the 'best on record ' (1993): historical records from monitoring wells in the Marne Saunders catchment identified 1993 as a baseline due to the significant recharge that occurred that year, marking it as the period with the highest recorded water table levels in recent decades (DEW, 2009; Figure A1). This factor required that only wells that were measured in both 1993 and in 2023 were available for analysis.

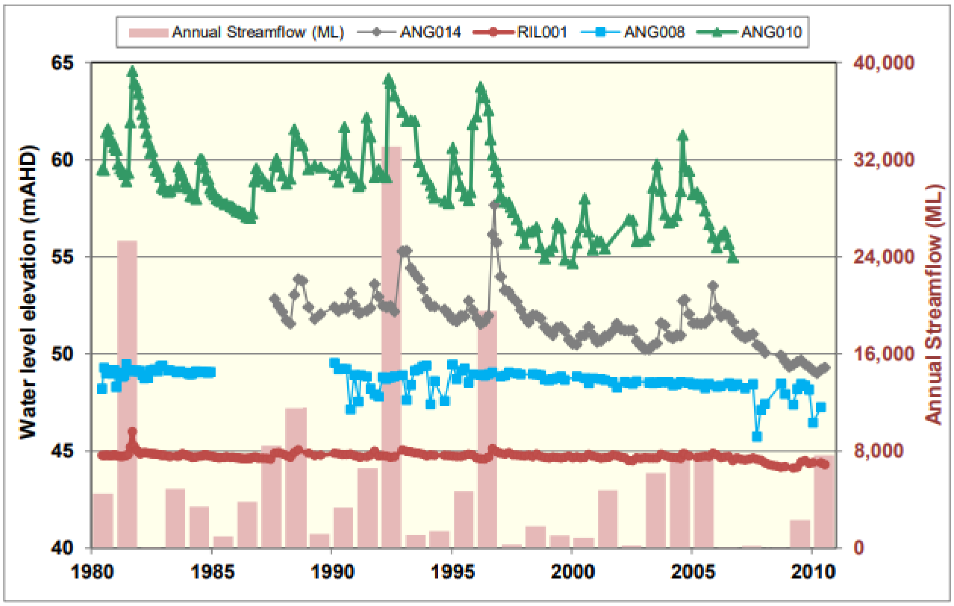

Figure A1: Groundwater level trends of the unconfined limestone aquifer in the Marne Saunders catchment

Delta calculation: The delta value is the difference between the water table height in 1993 and the height in 2023. For example, if the water table was 8.35 meters in 1993 and 15.03 meters in 2023, the delta value (change in height to water table) would be 6.68 meters. For each well, the standing water level (SWL equals the depth from the surface to the water table) was taken post winter recharge which is likely to be the lowest likely depth from the surface.

Expressed as proportion of aquifer thickness: Delta value is then expressed as a percentage of the average thickness of the aquifer to provide context for the scale of depletion. For instance, if the aquifer thickness (total depth of water-bearing rock) is 25 meters, the delta value of 6.68 meters represents 26.72% of the aquifer thickness. This factor reduced available wells to those on the Murray Group limestone aquifer, as this is the only estimate of aquifer thickness available.

Depth to water table (delta) scoring method

The delta value is used to assign a score on a scale from A to F, reflecting the degree of groundwater depletion:

- A (Very Good): delta is less than 10% of aquifer thickness, indicating minimal change (relative to best on record) and a well-saturated aquifer with stable groundwater levels.
- B (Good): delta is between 10% and 25% of aquifer thickness, showing a slight decrease but groundwater availability remains strong.
- C (Moderate): delta is between 25% and 50%, indicating a significant drop in groundwater levels with the aquifer showing signs of stress.
- D (Poor): delta is between 50% and 75%, reflecting substantial groundwater depletion and signalling stress on the aquifer's capacity to provide water.
- F (Very Poor): delta is greater than 75%, indicating severe depletion of the aquifer with critically low groundwater levels

Depth to water table (delta) scoring

Table A1 represents all suitable well data to calculate the delta value for lower Marne wells.

Table A1: Recorded well SWL levels in 1993 and 2023, demonstrating the difference (delta value) between these, and expression of this value of the total thickness of the aquifer. Report card scores noted.

DHNO (well number)	1993 SWL	2023 SWL	Delta (m)	Delta as a % of aquifer	Score (/100)	Grade
73082	8.35	15.03	6.68	26.7%	50	C
74983	36.95	38.7	1.76	7%	100	A
75208	8.07	8.98	0.91	3.6%	100	A
75502	6.63	12.81	6.18	24.7%	75	B

Calculation example, for DHNO 73082 (top line in table A1 above):

- 1993 best height = 8.35 m
- 2023 best height = 15.03m
- Delta = (15.03-8.35)
- **=6.68m**

➔ Expressed as a proportion of average thickness - this helps contextualize the delta value in terms of the total capacity of the aquifer, and any changes in depth to water table are interpreted relative to how much water is still available in the aquifer.

- = (6.68m / 25m)
  =0.26 (26%)

Depth to water table (delta) result for the Lower Marne

This analysis reveals that relative to the best on record, the depth to the water table at surveyed sites in the Lower Marne has not significantly dropped, and that the capacity of the resource is not under immediate threat.

Score: 81.5; A

Depth to water table (delta value) caveats

A number of caveats and shortcomings exist for this analysis. Depth to water table needed to be compared against a baseline, to give some relevance to the measurement. Research indicated that 1993 was the wettest year on record so this year would most likely represent the lowest depth to water table (owing to recharge across the catchment being most likely at its highest).

Only wells which were recorded in 1993 and 2023 were used for analysis.

The total depth or thickness of the aquifer must be known or estimated to give the delta value context in terms of the total capacity of the aquifer. Any changes can be used to interpret how much water is still available in the aquifer. At this stage, only the sedimentary aquifer on the plains (the Murray Group Limestone aquifer) has an estimation of average thickness available (approximately 25m). The fractured rock aquifer in the hills is not able to be estimated as fractures may span the entire depth of the hill base rock. Therefore, only aquifers on the plains were available for this analysis.

Filtering for these parameters reduced the number of suitable wells in this analysis to four, all in the lower Marne. These four bores displayed wide variability in delta value. The bores in the Lower Saunders while also being in the sedimentary aquifer did not have data available from 1993.

Finally, while the depth to water table analyses (as expressed as a proportion of average aquifer thickness) demonstrates that the drop in water table height *relative* to the best year on record is not necessarily severe, it is important to note that Standing Water Levels (SWLs) across much of the catchment are estimated to be near their lowest.

Owing to these caveats, this component of groundwater scoring should be taken as indicative. While it is calculated using the best available data, the limited geographical spread of wells providing suitable data meeting analysis criteria means that individual wells and water users will likely yield different results.

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