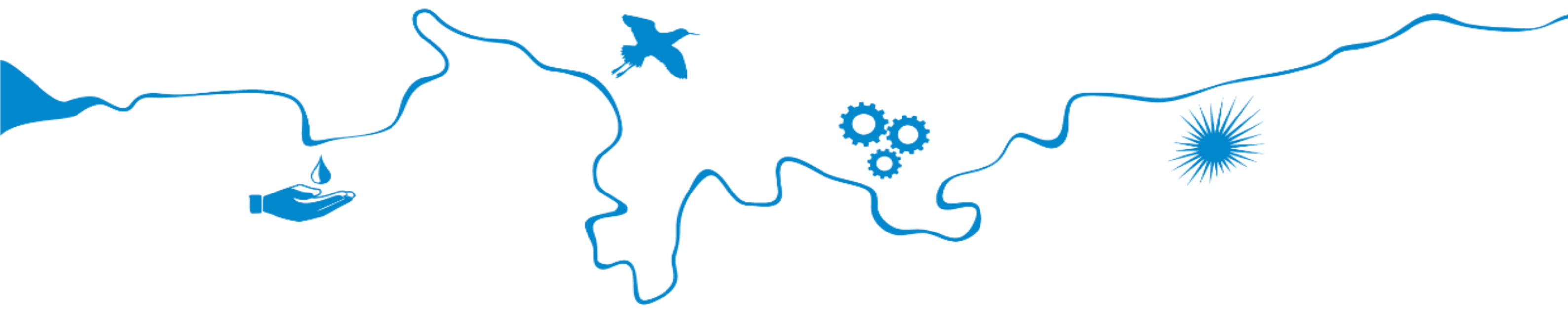
Adaptation of the South-Eastern drainage system under a changing climate
Groundwater, Ecology, Surface water and Wetland Assessment Tool (GESWAT)
Spatial Data Dictionary

Dennis Gonzalez, Adrian Werner, Amir Jazayeri, Jodie Pritchard, Fan Hongxiang, Sue Botting, Ryan Judd



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The Goyder Institute for Water Research is a research alliance between the South Australian Government through the Department for Environment and Water, CSIRO, Flinders University, the University of Adelaide and the University of South Australia. The Institute facilitates governments, industries, and leading researchers to collaboratively identify, develop and adopt innovative solutions for complex water management challenges to ensure a sustainable future.

This *Adaptation of the SE drainage system to a changing climate* project has been jointly funded by the Australian Government through the National Water Grid Authority, the Limestone Coast Landscape Board, and the South Australian Government. The project was delivered by the Goyder Institute for Water Research partners: CSIRO, the University of South Australia, Flinders University and the University of Adelaide in collaboration with the Limestone Coast Landscape Board, South Eastern Water Conservation and Drainage Board (SEWCD Board) and the Department for Environment and Water.

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First Nations Respect and Reconciliation

The Goyder Institute for Water Research and Limestone Coast Landscape Board, acknowledges the Traditional Custodians of the lands and waters of the Limestone Coast and South East region, where this project took place. Together we pay our respects to their Elders—past, present, and emerging—and recognise Aboriginal people as the First Peoples and Nations of South Australia, possessing and caring for these lands under their own laws and customs.

We respect the enduring cultural, spiritual, physical, and emotional connections that Aboriginal peoples maintain with their lands and waters. We recognise the diverse rights, interests, and obligations of First Nations and the deep cultural connections that exist between different First Nations communities. We seek to support their meaningful engagement and honour the continuation of their cultural heritage, economies, languages, and laws, which remain of ongoing importance.

We walk together with the First Nations of the South East and the Ngarrindjeri peoples through organisations such as Burrandies Aboriginal Corporation, Ngarrindjeri Aboriginal Corporation, the Ngarrindjeri Lands and Progress Aboriginal Corporation and South East Aboriginal Focus Group. For the work of generations past, and the benefit of generations future, we seek to be a voice for reconciliation in all that we do.

Acknowledgments

This Adaptation of the SE drainage system to a changing climate project has been jointly funded by the Australian Government through the National Water Grid Authority, the Limestone Coast Landscape Board, and the South Australian Government. The project was delivered by the Goyder Institute for Water Research partners: CSIRO, the University of South Australia, Flinders University and the University of Adelaide in collaboration with the Limestone Coast Landscape Board, South Eastern Water Conservation and Drainage Board and the Department for Environment and Water. The authors acknowledge the expert advice of Claire Harding (Department of Environment and Water), and the technical data support of Tim Noyce and James Cameron (Department of Environment and Water) that enabled the delivery of this work.

Project Summary

The Limestone Coast of South Australia is a highly modified landscape with an extensive cross-catchment drainage system converting what was once a wetland dominated landscape into one dominated by agricultural production. The region now has a diverse agricultural sector and extensive forestry plantations which are highly dependent on reliable rainfall and easy access to the region's substantial groundwater resources. However, as climatic conditions become hotter and drier it's important to understand impacts on ground and surface water resources and consequent risks to primary production and the environment to build a water secure future.

Achieving water security in the Limestone Coast region under a changing climate requires a more integrated and holistic approach to water resource management. In particular, the interactions between surface water and groundwater must be better understood, quantified, and managed to balance the seasonal demands—removing excess water from productive lands during winter while safeguarding groundwater-dependent agriculture and ecosystems during summer.

The "Adaptation of the South Eastern Drainage Network under a changing climate" project aims to inform opportunities to improve water management in the region - including potential use of water in the drainage network - to address risks to primary industries and groundwater dependent ecosystems. Delivered through the Goyder Institute for Water Research, research teams from the CSIRO, Flinders University and the University of South Australia have completed five separate but inter-connected tasks:

1. Quantifying the value of consumptive and non-consumptive uses of water.
   This task assessed the value of additional water for key primary industries in the region, while also estimating the value of water for non-consumptive uses aimed at achieving ecological outcomes. Together, these valuations provide important context to the project's hydrological tasks, informing options to manage additional available water in the region.

2. Current and future water availability.
   A water balance model for the region has been developed using the Bureau of Meteorology's Australian Water Resources Assessment – Landscape (AWRA-L) model. It integrates national and regional datasets to capture surface runoff, recharge, and soil moisture, while accounting for seasonal dynamics and regional variability. The model enables analysis of climate change impacts on the full water balance, providing insight into future water availability, supporting both short- and long-term water management decisions.

3. Modelling groundwater and wetland interaction.
   Site-specific models representing three-dimensional aquifer-wetland interactions have been developed for two key groundwater dependent sites. The models test the feasibility of changing the water distribution in the local landscape to improve ecosystem health and mitigate impacts of groundwater extraction. Options included redirecting / holding water back in drains, altering surface water inflows and reducing the extent of the wetland basin with levees. The learnings from modelling these two disparate sites will assist decisions to manage additional available water in the region.

4. Sea water intrusion risk.
   The coastal area south of Mount Gambier is an area of high value irrigated agriculture and significant karst springs where the risk of seawater intrusion is of concern for both irrigators and environmental assets. This task set out to understand the extent and hydrodynamics of seawater intrusion in the region with an airborne electromagnetic survey of the south coast area, undertaken in October 2022, and construction of cross-sectional models to simulate seawater intrusion under different scenarios at different regional locations. This work provides the evidential basis to build on previous projects where reinstating wetlands by retaining water in drains appeared to effect some control over the seawater interface.

5. Groundwater, Ecology, Surface water and Wetland Assessment Tool (GESWAT)
   To enable opportunities to improve water management to be easily identified and investigated -

including the potential use of water in the drainage network –a dynamic GIS tool (GESWAT) was built. GESWAT brings together outputs from the other project tasks integrating them in a tool with a range of other critical data (e.g. surface water flows, groundwater levels, and rainfall data, annual water use and allocation data, ecological information and other standard datasets). GESWAT provides the LC Landscape Board and its partner agencies a single platform with which to view, compare and interrogate the diversity of hydrological and ecological information available to inform policy and management decisions.

This report details results from Task 5 of the project.

Further results from this project are presented in the following reports:

Task 1

Cooper, C., Crase, L., Kandulu, J., and Subroy, V. (2025) *Adaptation of the South-Eastern drainage system under a changing climate – Quantifying the value of different water uses and future demands*. Goyder Institute for Water Research Technical Report Series No. 25/2

Task 2

Gibbs, M.S., Montazeri, M., Wang, B., Crosbie, R., Yang, A. (2025) *Adaptation of the South-Eastern drainage system under a changing climate - Water Availability for South East Drainage Adaptation*. Goyder Institute for Water Research Technical Report Series No. 25/3

Task 3

Gholami, A., Werner, A.D., Maskooni, E.K., Fan, H., Jazayeri, A., and Solórzano-Rivas, C. (2025) *Adaptation of the South-Eastern drainage system under a changing climate - Groundwater and wetland modelling*. Goyder Institute for Water Research Technical Report Series No. 25/4

Task 4

Davis A, Munday TJ, and Ibrahimi T (2025) *Adaptation of the South-Eastern drainage system under a changing climate - Limestone Coast Airborne Electromagnetic Survey: Acquisition, Processing and Modelling*. Goyder Institute for Water Research Technical Report Series No. 25/5.1

Davis A, Munday TJ, and Ibrahimi T (2025) *Adaptation of the South-Eastern drainage system under a changing climate - Limestone Coast Airborne Electromagnetic Survey: Conductivity-Depth Sections*. Goyder Institute for Water Research Technical Report Series No. 25/5.2

Gholami, A., Werner, A.D., Solórzano-Rivas, C., Jazayeri, A., Maskooni, E.K., and Hongxiang, F. (2025) *Adaptation of the South-Eastern drainage system under a changing climate - Seawater intrusion risk*. Goyder Institute for Water Research Technical Report Series No. 25/5.3

Task 5

Gonzalez, D., Werner, A., Jazayeri, A., Pritchard, J., Hongxiang, F., Botting, S., Judd, R. (2025) *Adaptation of the South-Eastern drainage system under a changing climate - Groundwater, Ecology, Surface water and Wetland Assessment Tool (GESWAT) Spatial Data Dictionary*. Goyder Institute for Water Research Technical Report Series No. 25/6

Collection description

This data collection contains the products created by the project team as inputs to a Geographic Information System (GIS) tool: Groundwater, Ecology, Surface water and Wetland Assessment Tool – GESWAT.

GESWAT synthesises available information in a ready-to-use format for informing management and policy decisions, and for research and communication purposes. Data file paths relate to storage locations within the South Australian Department for Environment and Water (DEW) servers. Data preparation, analysis and processing steps were performed using several platforms documented in corresponding sections and companion reports. GESWAT was built using ESRI ArcGIS and is held as a project file in ArcPro Version 2.8 and as a map document (.mxd) in ArcMap version 10.6. Support for ArcGIS Desktop including ArcMap and ArcCatalogue will cease on March 1, 2026.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\GESWAT_ARCPRO_READ_ONLY.aprx

file:\\J:\GISWorkspace\LimestoneCoast\Water\GESWAT_ARCMAP_READ_ONLY.mxd

1 Instructions for use

1.1 Key differences between ArcPro and ArcMap

The transition from ArcMap to ArcPro brings significant changes to basic operations and file structures. One of the primary differences is the project file structure. ArcMap uses a single map document file (.mxd) that contains map data links and settings, whereas ArcPro employs a project file (.aprx) that stores all project data links, and can include multiple maps, layouts, and settings.

In terms of map organization, ArcMap uses a single data frame with layers listed in the Table of Contents (TOC). In contrast, ArcPro organizes maps into multiple maps, each with its own set of layers, accessible through the "Maps" pane. This change enables users to manage and switch between multiple maps more easily. Layout management has also undergone a transformation, with ArcMap storing layouts within the map document file and ArcPro managing layouts through the "Layout" pane and storing them as separate layout files (.pagx) within the project file.

Layer management has also changed. ArcMap uses the TOC to manage layers within the map document file whereas ArcPro uses the "Contents" pane to manage layers, which can be stored within the project file or as separate layer files (.lyrx). Data management in ArcPro is handled through the "Data" pane, allowing users to store data within the project file, in a separate file geodatabase (.gdb) associated with the project, or in an enterprise geodatabase or linked server.

ArcPro integrates analysis and geoprocessing tools through the "Analysis" tab accessed through the ribbon. This allows users to run tools as separate tools or as part of a model or script. ArcPro allows users to run Python scripts through the "Python" window or as part of a model or script. Overall, these changes reflect a more modern and streamlined approach to GIS operations, with a focus on project-based workflows and improved data management.

There are online resources available to assist users new to ArcPro including information on set up, quick-start tutorials, extensions and migration from ArcMap. The following subsections present a summary of basic operations in ArcPro and ArcMap environments. For further detail users should consult the comprehensive online resources for ArcPro and ArcMap.

1.2 Opening and navigating the ArcPro project file

Launching ArcGIS Pro

- Double-click on the ArcGIS Pro icon on your computer to launch the application.
- Alternatively, you can search for "ArcGIS Pro" in your computer's search bar and select the application.

Opening an Existing Project File

- Once ArcGIS Pro is launched, click on the "Open" button in the start page.
- Navigate to the location of the project file (.aprx) and select it.
- Click "Open" to open the project file.
- Alternatively, you can open the file directly (e.g. via File Explorer or a shortcut)
- Resave the ArcPro READ ONLY Project file as a new file (.aprx) and uncheck the READ ONLY box in file properties to allow the new file to be modified and saved.
- Ensure you have the necessary data and permissions to access the project files.

Navigating the Map

- In the ArcGIS Pro interface, the map view is displayed in the centre pane.
- To navigate the map, use the following tools:
- Zoom In/Out: Use the mouse wheel or the zoom buttons in the toolbar.
- Pan: Click and drag the mouse while holding down the left button.
- Explore: Use the Explore tool to interact with maps. This tool allows you to pan, zoom, and access feature information through pop-ups.

- Utilize bookmarks to quickly navigate to specific areas of the map. Adjust the map scale as needed to view details or get a broader perspective.

Accessing Map Contents

- To access the map contents, click on the "Contents" pane in the left sidebar.
- In the Contents pane, you can:
- View Layer List: Expand or collapse the layer list to view the layers in your map.
- Turn Layers On/Off: Check or uncheck the boxes next to each layer to turn them on or off.
- Access Layer Properties: Right-click on a layer and select "Properties" to access its properties.
- Managing multiple views within a project is essential for efficient workflow, switch between open views, close views that are not needed, and reopen them from the Catalog pane, only one view can be active at a time so organize views to suit preferences.

Working with feature attributes

- Attribute tables store information about map features.
- Open and navigate these tables to select features based on their attributes and perform queries.
- You can also manage the display and selection of records to focus on specific data.
- Floating and docking views can help you organize your workspace.

Work with layer symbology

- Customize the appearance of map layers by changing their symbology.
- Select different basemaps and modify layer symbols using the Symbology pane.
- This customization helps in better visualizing and interpreting spatial data.
- Save your project frequently to avoid losing changes.

Navigating the Layout

- Layouts include map frames, legends, scale bars, and other elements.
- Modify these elements to enhance the layout's appearance and convey information effectively.
- To access the layout, click on the "Layout" button in the toolbar or navigate to the "View" tab and select "Layout View".
- In the layout view, you can:
- View Map Surrounds: View the map surrounds, such as the title, legend, and scale bar.
- Access Layout Elements: Click on the "Elements" pane in the left sidebar to access the layout elements, such as text, images, and graphics.
- Customize Layout: Use the tools in the toolbar to customize the layout, such as moving or resizing elements.
- Regularly save your project to preserve your modifications.

1.3 Opening and navigating the ArcMap project file

Launching ArcMap

- Double-click on the ArcMap icon on your computer to launch the application.
- Alternatively, you can search for "ArcMap" in your computer's search bar and select the application.

Opening an Existing Map Document File

- Once ArcMap is launched, click on the "File" menu and select "Open" or press Ctrl+O (Windows) or Command+O (Mac).
- Navigate to the location of your map document file (.mxd) and select it.
- Click "Open" to open the map document file.

- Resave the ArcMap READ ONLY Project file as a new file (.mxd) and uncheck the READ ONLY box in file properties to allow the new file to be modified and saved

Navigating the Map

- In the ArcMap interface, the map view is displayed in the center pane.
- To navigate the map, use the following tools:
    - Zoom In/Out: Use the mouse wheel or the zoom buttons in the toolbar.
    - Pan: Click and drag the mouse while holding down the left button.
    - Zoom To: Use the "Zoom To" tool in the toolbar to zoom to a specific extent or feature.

Accessing Map Contents

- To access the map contents, click on the "Table Of Contents" (TOC) button in the upper left corner of the map view.
- In the TOC, you can:
    - View Layer List: Expand or collapse the layer list to view the layers in your map.
    - Turn Layers On/Off: Check or uncheck the boxes next to each layer to turn them on or off.
    - Access Layer Properties: Right-click on a layer and select "Properties" to access its properties.

Navigating the Layout

- To access the layout, click on the "View" menu and select "Layout View" or press Ctrl+Shift+L (Windows) or Command+Shift+L (Mac).
- In the layout view, you can:
    - View Map Surrounds: View the map surrounds, such as the title, legend, and scale bar.
    - Access Layout Elements: Click on the "Elements" toolbar to access the layout elements, such as text, images, and graphics.
    - Customize Layout: Use the tools in the toolbar to customize the layout, such as moving or resizing elements.

Saving Changes

- To save changes to your map document file, click on the "File" menu and select "Save" or press Ctrl+S (Windows) or Command+S (Mac).
- Make sure to save your map document file regularly to avoid losing your work.

1.4 Accessing the ArcPro Geoprocessing Pane and Running a Tool

This is an example of a typical workflow adapted from a tutorial given in the online resources and can be modified to apply a wide range of geoprocessing tools available.

Step 1: Open the Geoprocessing Pane

- Click the "View" tab on the ribbon.
- In the "Windows" group, click "Reset Panes" and select "Reset Panes for Geoprocessing".
- Alternatively, click the "Analysis" tab, then click "Tools" in the "Geoprocessing" group.

Step 2: Navigate to the Desired Toolbox

- In the Geoprocessing pane, click the "Toolboxes" tab.
- Browse to the desired toolbox, such as "Analysis Tools" > "Pairwise Overlay".

Step 3: Select the Desired Tool

- In the Pairwise Overlay toolset, click "Pairwise Buffer".
- The Pairwise Buffer tool will open in the Geoprocessing pane.

Step 4: Review Tool Parameters

- Review the tool's parameters, noting required fields marked with a red asterisk.
- Hover over the tool's Help button for a brief description and illustration of the tool.

Step 5: Set Input Features

- On the Pairwise Buffer tool, click the "Input Features" drop-down arrow and select the desired features.

Step 6: Set Output Feature Class

- In the "Output Feature Class" parameter, set the output dataset name by highlighting and replacing the existing name or deleting the entire path and typing the new feature class name.

Step 7: Set Distance and Units

- In the "Distance [value or field]" box, type a value and select the desired distance units.

Step 8: Review and Run the Tool

- Review the tool parameters and hover over any parameter for additional information.
- At the bottom of the Geoprocessing pane, click "Run" to execute the tool.

Step 9: Review Results and Set Symbology

- When the tool finishes running, review the completion message and click or hover over "View Details" for additional information.
- A new feature class is created in your project geodatabase, and a layer is added to the map. Set the new layer symbology using the Symbology pane.

Step 10: Save the Project

- On the Quick Access Toolbar, click "Save Project" to save your changes.

1.5 Creating and Running a Geoprocessing Model in ArcPro

A geoprocessing model is a visual representation of a workflow that sequences multiple geoprocessing tools. It depicts the workflow as a diagram and can be run to execute the workflow. Models can be used for various purposes, including, automating repetitive tasks, exploring alternative outcomes with different datasets and tool parameters, visually documenting geoprocessing methodology, incrementally developing and improving workflows, and sharing knowledge and best practices.

This is an example of a typical workflow adapted from a tutorial given in the online resources and can be modified to apply a wide range of geoprocessing tools available in the model builder environment.

Step 1: Create a New Model

- On the ribbon, click the "Analysis" tab.
- In the "Geoprocessing" group, click "ModelBuilder".
- An empty model view opens in the project.

Step 2: Add Input Data

- From the "Contents" pane, drag the target layer into the model view.
- This will be represented as an input data variable in the model.

Step 3: Add Geoprocessing Tools

- On the ModelBuilder toolbar, click "Tools".
- In the Geoprocessing pane, search for the desired tool.
- Drag the tool from the Geoprocessing pane to the model view.

Step 4: Connect Input Data to Tools

- Click and drag to draw a connector line from the input layer to the tool element.
- Release the mouse button and select the correct input parameter from the pop-up menu.

Step 5: Set Tool Parameters

- Right-click the tool element and click "Open".
- Set the required tool parameters, including any necessary values or fields.

Step 6: Validate, save and run the Model

- On the ModelBuilder toolbar, click "Validate".
- On the ModelBuilder toolbar, click "Save" (saving the model doesn't save the project, nor does saving the project save the model).
- By default, the model will be save in the project’s default toolbox.
- On the ModelBuilder toolbar, click "Run".
- The model will run, and a message will inform you of its success.

Step 7: Validate and Rerun the Model (Optional)

- If you need to rerun the model, validate it by making the model view active.
- The model is now ready to run again.

2 Administrative layers

2.1 Project study area

Polygons of the project study area were created by intersecting the Lower Limestone Coast and Padthaway Prescribed Well Area boundaries with the Hydrogeological Zones (Figure 1).

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\commondata\boundary_incl_hydrozones\Boundary_including_hydrozones.shp

2.2 Cadastral boundaries

Cadastral boundaries were sourced from the DEW Oracle Enterprise Geodatabase and exported as a shapefile clipped to the view extent of the study area in the coordinate system of the project file (GDA94 MGA Zone 54S) for drawing efficiency:

- LGA.shp – SA Local Government Areas
- DCDB_HUNDRED.shp – SA Hundreds
- dcdbid.shp – SA land parcels

Data path: file:\\J:\GISWorkspace\LimestoneCoast\Water\Oracle_SDE

2.3 Groundwater Management and Prescribed Well Areas

Shapefiles for unconfined and confined management areas were provided by the Limestone Coast Landscape Board. These were merged to produce another polygon shapefile (Figure 1) with an attribute to distinguish respective areas which can be viewed separately and with different symbology. These areas correspond to those detailed in the Water Allocation Plan. Three shapefiles were created:

- Unconfined_MA_MGA54_LLC.shp
- Confined_MA_MGA54_LLC.shp
- Unconf_Conf_MA_MGA54_LLC.shp

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\groundwater_management_areas_mga54

Prescribed well areas (ADMIN.PrescribedGroundwater) were sourced from the Oracle Enterprise Geodatabase and exported to a shapefile in the project coordinate system for drawing efficiency (Figure 1).

Data path: file:\\J:\GISWorkspace\LimestoneCoast\Water\Oracle_SDE\ADMIN_PrescribedWellsAreas.shp

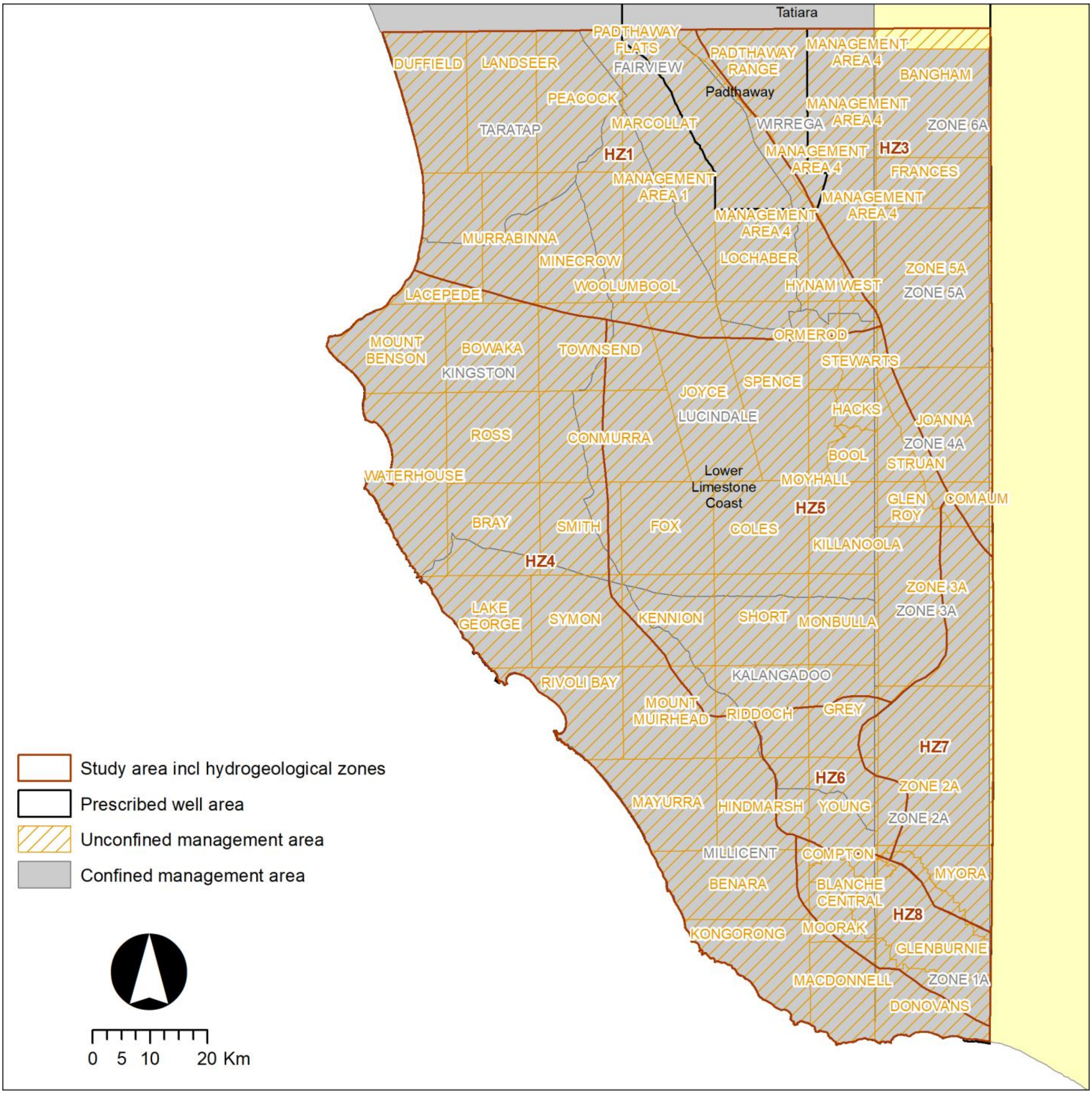

Figure 1 Study area and administrative boundaries.

2.4 Land use

Catchment-scale land use in the study area, represented at a 50 m grid scale, was extracted from a national grid and included for context (ABARES, 2024). These data are symbolised with three different layer files: 19 class; agricultural industries; secondary, that are included as part of the national dataset.

Data path: file:\\J:\GISWorkspace\LimestoneCoast\Water\clum_50m_2023_v2_se

2.5 Topographic layers

Topographic layers including mainland areas and populated places were sourced from national datasets for contextual and cartographic purposes (Geoscience Australia, 2017).

Data path: file:\\J:\GISWorkspace\LimestoneCoast\Water\topographic

3 Drainage infrastructure

3.1 Drainage infrastructure

Point shapefile of locations of drainage infrastructure in the South East region were provided by the South Eastern Water Conservation and Drainage Board. These are symbolised based on the 'myAssetdes' attribute into six classes: bridge, causeway, control structure, culvert, drain channel, and watercourse (Figure 2). These data also include pertinent construction attributes.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\commondata\sewcdb_assets\SEWCDB_Structures.shp

3.2 Drains, water courses and water bodies

A polyline feature class was included representing water courses and channels, drains, canals and ditches. Features are symbolised according to FeatureCode attributes (watercourse, braided river, connector, braid connector, channel, drain, canal, ditch), see Figure 2. Water bodies representing dams, lakes and inundation areas are also included and symbolised according the FeatureCode field. These features were sourced from the DEW Oracle Enterprise Geodatabase, clipped to the study area and saved in the project folder for drawing efficiency.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\sde_shp_lyr\topo_watercourses_clip.shp

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\sde_shp_lyr\topo_waterbodies_clip.shp

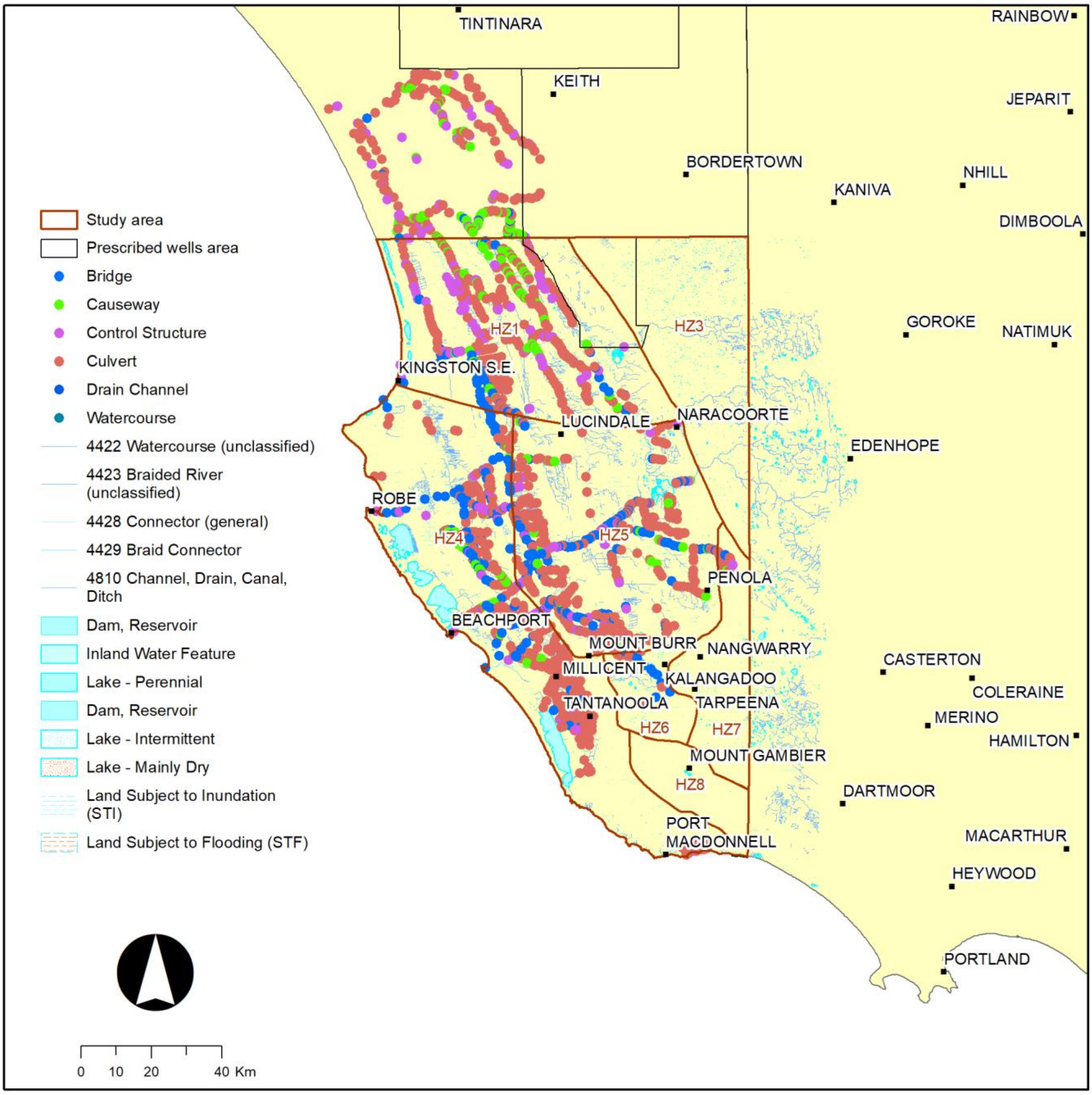

Figure 2 Drainage infrastructure, watercourses and waterbodies.

4 Wetlands

4.1 South Australian Wetland Inventory Database

The South Australian Wetland Inventory Database (SAWID) contains a polygon feature class (SAWID_Wetlands) of wetlands held within a file geodatabase (SAWID_V18.gdb) that was converted from a personal geodatabase format (.mdb) for compatibility with ArcPro. The SAWID file geodatabase contains numerous relational tables for a wide range of attributes and information. Additional SAWID tables were created that hyperlinked corresponding photos and Wetland Vegetation Component conceptual model descriptions (see Section 5.5) to the SAWID polygon based on unique identifiers (AUSWETNR). These were configured as clickable pop-ups for the wetland features.

Data path: file:\\J:\GISWorkspace\SouthEast\CHarding\SAWID\SAWID_V18.gdb

4.2 Wetland ecological values

The SAWID database was updated in 2020, wetlands were reassessed into four ranked ecological value classes—Very High, High, Moderate, and Low—based on significant cut-off values (Harding, 2014), see Figure 3. Many wetlands were categorized as "Not assessed" due to insufficient data. Groundwater-dependent wetlands classified as High or Very High Ecological Value are subject to protection policies within various Water Allocation Plans for the Tatiara, Tintinara-Coonalpyn, Padthaway, and Draft Lower Limestone Coast Prescribed Wells Areas (Harding, 2014).

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\commondata\gde_shapefiles\Wetlands_EVA_GDE_June2020.shp

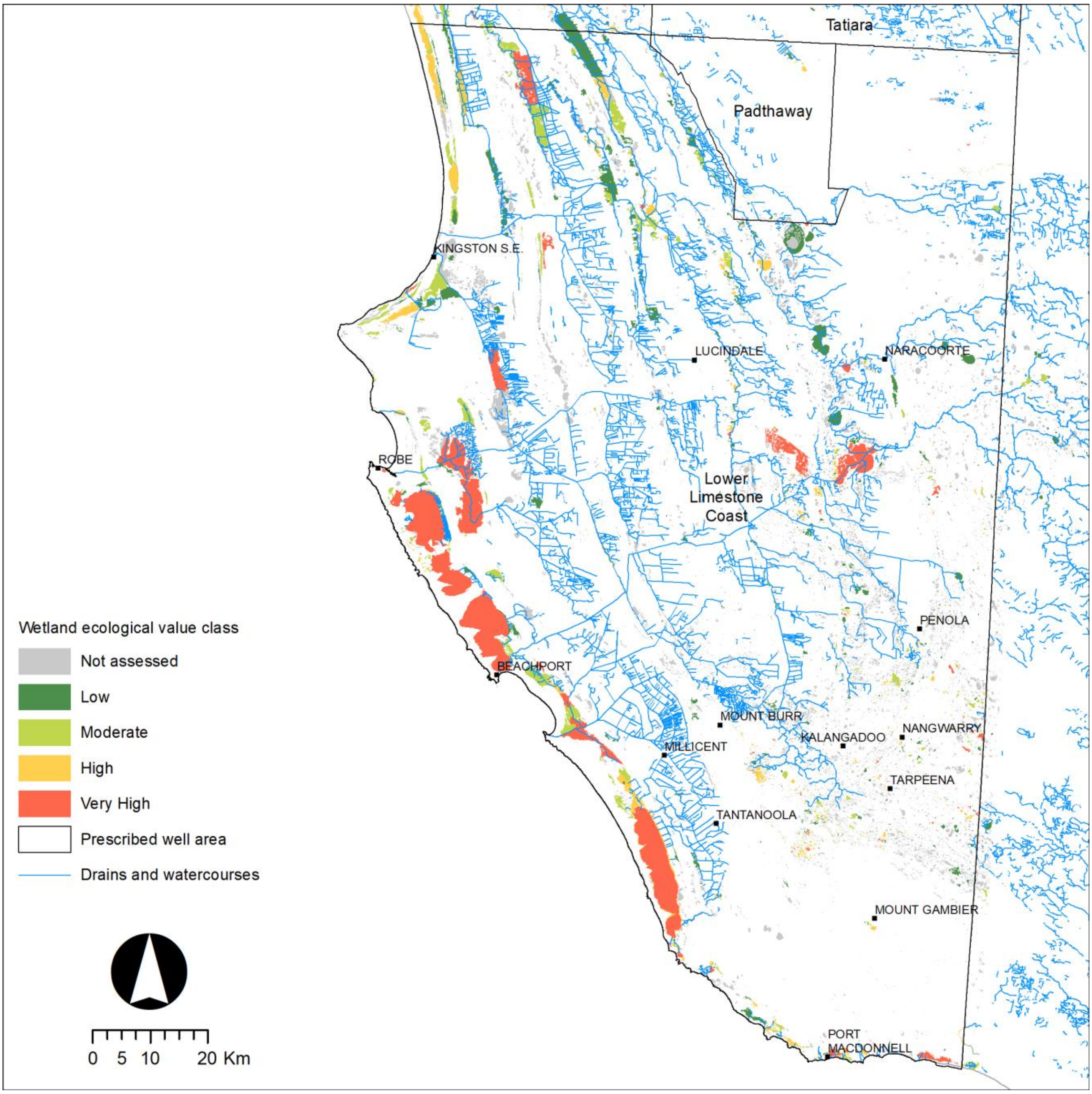

Figure 3 Wetland ecological value classes (Harding, 2014).

4.3 Wetland groundwater dependence likelihood

Historical declines in groundwater levels in the South East region have altered groundwater-surface water interactions. The likelihood of gaining conditions for wetlands, drains, and watercourses was assessed by analysing groundwater levels from 1985 to 2017 (Cranswick and Herpich, 2018). Water table surfaces were compared with minimum surface water levels to classify the likelihood of gaining conditions as very high, high, moderate, low, or very low. It is suggested that the classifications be used as a baseline for future assessments of groundwater-dependent ecosystems (GDEs) and their water needs, incorporating recent data for improved accuracy and understanding of seasonal groundwater-surface water interactions (Cranswick and Herpich, 2018).

These data are represented as a polygon shapefile representing wetlands assessed for likelihood of groundwater dependence symbolised using the 'GDE_Likeli' attribute (low, moderate, high, very high) based on the 1990-2005 baseline (Cranswick and Herpich, 2018) as identified in the current Water Allocation Plan (Figure 4).

Polygon attribute field descriptions are:

- GDE_Likeli - GDE_Likelihood_1990-2005, this is the SKM 1990-2005 baseline as identified in the current LLC WAP. All wetlands that are VH,H,M GDE Likelihood are considered GDEs (of the unconfined aquifer). Combine this field with the EVA to identify high value GDEs.

- Perched – Yes/No field, those with a Y are likely reliant on perched aquifers (e.g. the marshes / honans).
- GDE_Like_1 - GDE_Likelihood_2010-2015, most current GDE likelihood assessment (Cranswick and Herpich, 2018). Note: this is only a 5-year epoch and is post Millennium Drought. Not the baseline for the current Water Allocation Plan.
- DTGW_Cat_2 - DTGW_Cat_2010-15, depth to groundwater category for 2010-2015 epoch (Cranswick and Herpich, 2018).
- GDE_Like_2 - GDE_Likelihood_1990-95, pre-Millennium Drought GDE likelihood (Cranswick and Herpich, 2018). Note: this is only a 5-year epoch and is pre-Millennium Drought. Not the baseline for the current WAP.
- DTGW_Cat_1 - DTGW_Cat_1990-95, depth to groundwater category for 1990-95 epoch (Cranswick and Herpich, 2018).

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\commondata\gde_shapefiles\Wetlands_EVA_GDE_June2020.shp

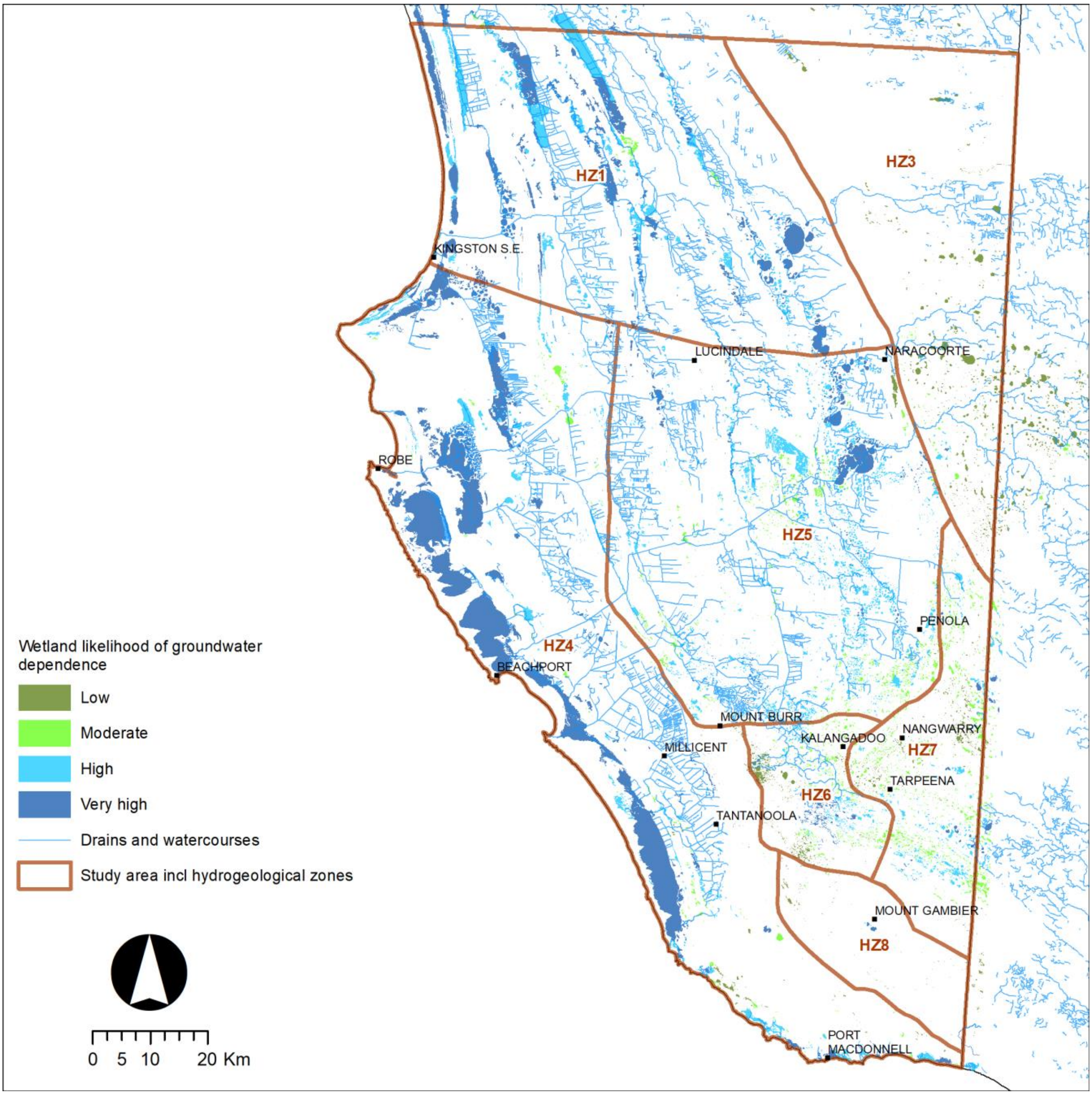

Figure 4 Wetland likelihood of groundwater dependence based on the 1990-2005 baseline as identified in the current Water Allocation Plan (Cranswick and Herpich, 2018).

4.4 Wetland inundation extent and frequency

An allied project conducted by Auricht Projects produced several key outputs for the South East region, including the creation of a spatial layer and associated data files for 2,551 polygons, assessing relationships between water observation data and Digital Earth Australia (DEA) water body polygons, and developing algorithms to clean DEA Water Observations data (Auricht, 2024). Additionally, the project investigated correlations between groundwater and surface water depths, applied the Wetlands Insight Tool (Dunn et al., 2023) to generate summaries of wetland conditions, and provided technical input to researchers on the 'Adaptation of the South-eastern drainage network under a changing climate' project. The project also explored the potential use of Sentinel-2 data to monitor chlorophyll-a levels in water bodies.

The project's main findings include the provision of updated DEA Water Observations datasets for the Limestone Coast Landscape Board region (Auricht, 2024). Key discoveries include significant correlations between surface water extent and groundwater levels, indicating reduced surface water persistence post-2000 likely due to climate change and extraction impacts. The project also applied the Wetland Insights Tool and generated surface area inundation extent and duration plots. Additionally, the project highlighted the potential for using Sentinel-2 data for Chlorophyll-a analysis and demonstrated the scalability and automation of methodologies for adaptive water management. The surface area inundation duration plots were hyperlinked to corresponding wetlands (SAWID) enabling the user to click on a wetland of interest and bring up a plot of inundation frequency and extent as a graphical pop-up (Figure 5). A separate layer was created from the SAWID data containing only the wetlands with corresponding plots (SAWID_Wetlands_WOFS_Plots.lyr).

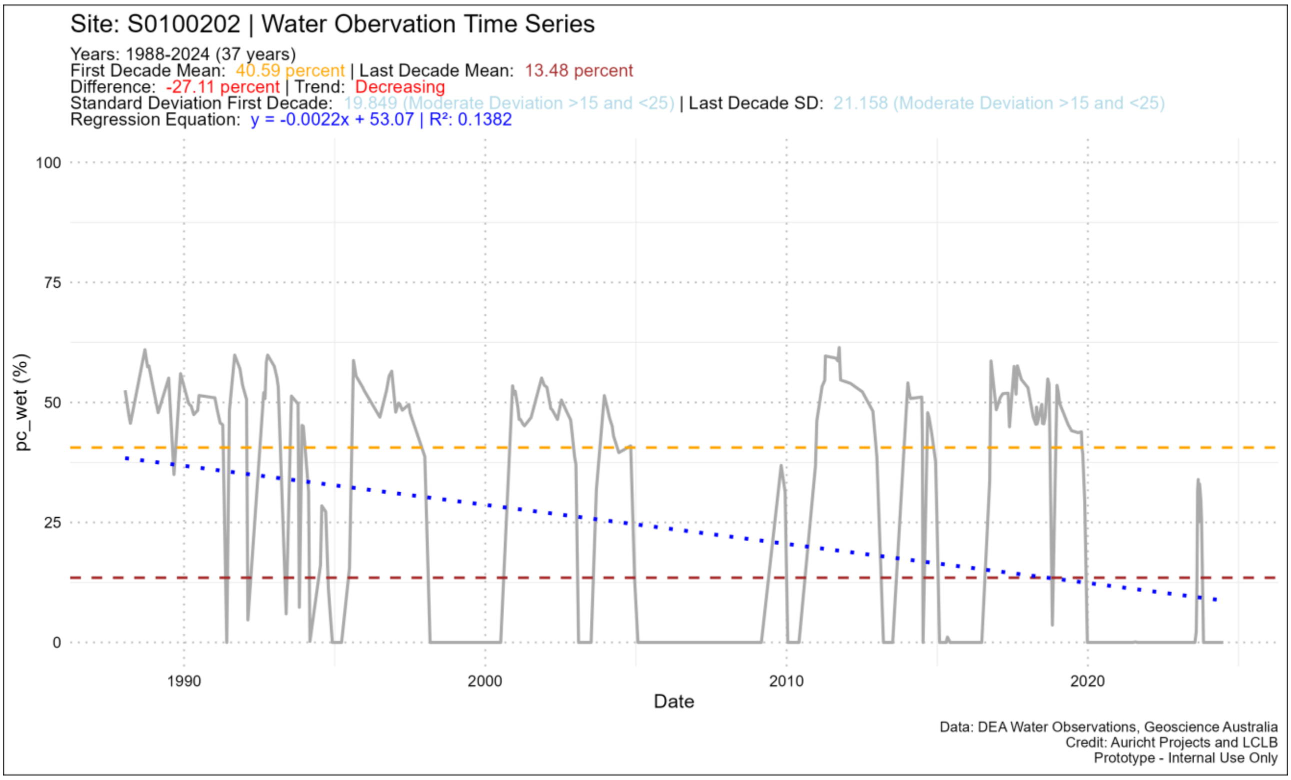

Figure 5 Example of an inundation surface area plot as percent of wetland with water cover over time.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\WOFS_CAuricht\WObs_Plots

4.5 Priority wetlands

The Limestone Coast Landscape Board provided a spreadsheet listing wetlands according to the prioritization classes determined by the Drainage and Wetland Strategy (DWS) (South Australian Government, 2019) and a shortlist of wetland complexes identified by the Limestone Coast Landscape Board for testing methodologies in this project. Attributes were joined to wetland spatial data (SAWID) based on the AUSWETNR identifier (Figure 6) to create 4 layers:

1. DWS Protect – Tier 1 priority to maintain the condition of the site by managing the water levels and quality to protect existing values
2. DWS Improve – Tier 2 priority to improve the condition of sites by managing threats
3. DWS Restore – Tier 3 priority to restore the hydrology of sites fringing riparian habitat
4. Shortlisted wetlands – a group of 23 wetland complexes for testing methods in this study

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\commondata\gde_shapefiles

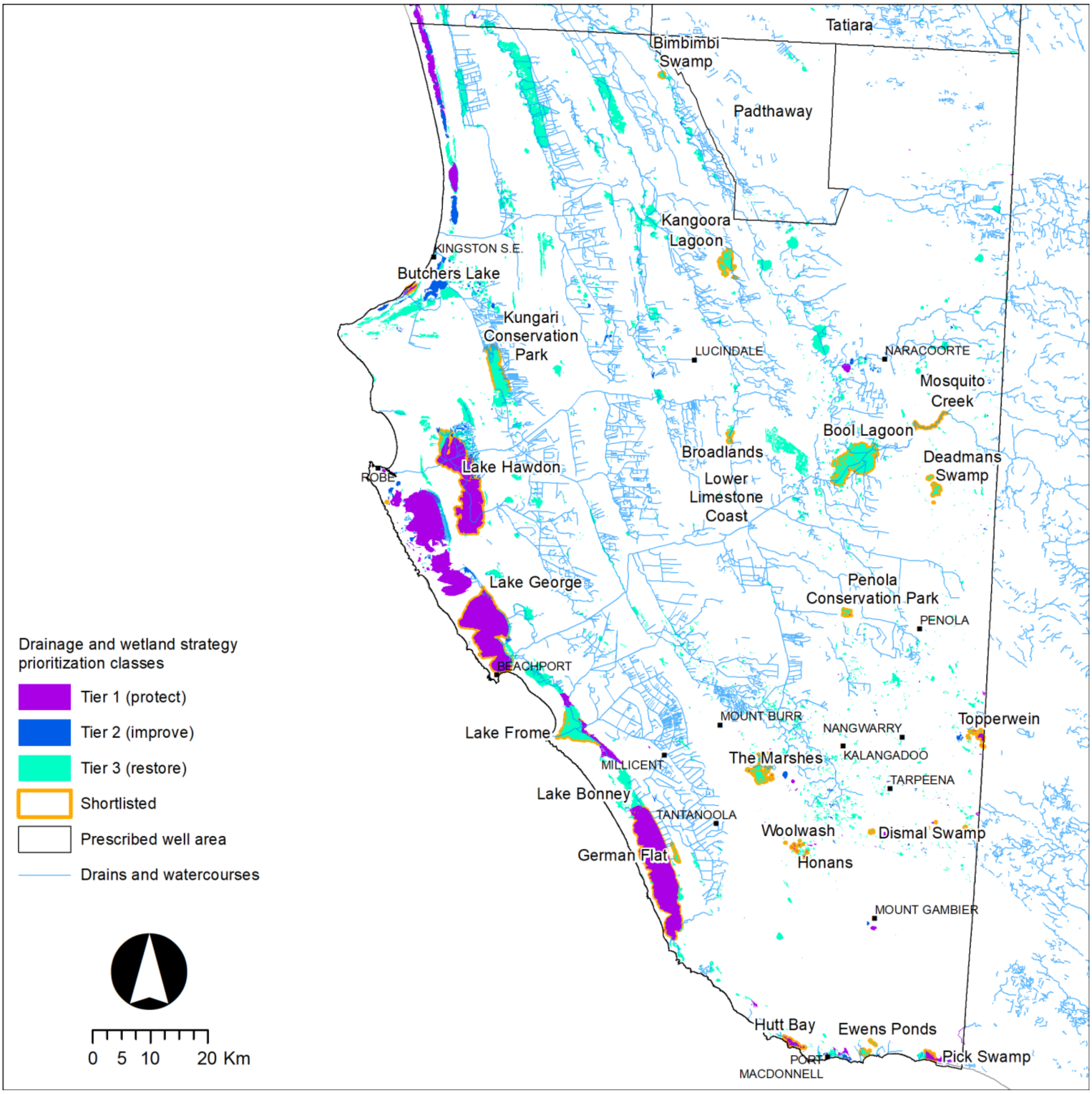

Figure 6 Drainage and Wetland Strategy wetland prioritization (South Australian Government, 2019) and shortlisted wetland complexes for testing methods in the current study.

4.6 Drains and wetlands groundwater-surface water interaction

A groundwater-surface water interaction dataset from the Drainage and Wetland Strategy was provided to the project and the metadata are summarised here for completeness. The dataset analysed the changes in groundwater-surface water interaction in managed drains in South Australia's South-East region over the past 30 years, based on a project and report by (Cranswick and Herpich, 2018) that investigated 30 years of change in groundwater-surface water exchange in the region. A dataset of drain features was extracted, filtered, and buffered by 20m. The 2m Digital Elevation Model was then clipped to the buffered feature class. Groundwater levels were interpolated for each 5-year epoch from 1985 to 2018, and the minimum DEM surface was subtracted from the average interpolated groundwater elevations to estimate depth to water. Finally, models were run to apply likelihood classifications for gaining conditions, losing conditions, and wetland types, based on the estimated depth to water figures. These data are displayed in Figure 7. Metadata statements are held in a subfolder alongside the data.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\DrainageWetlandStrategy

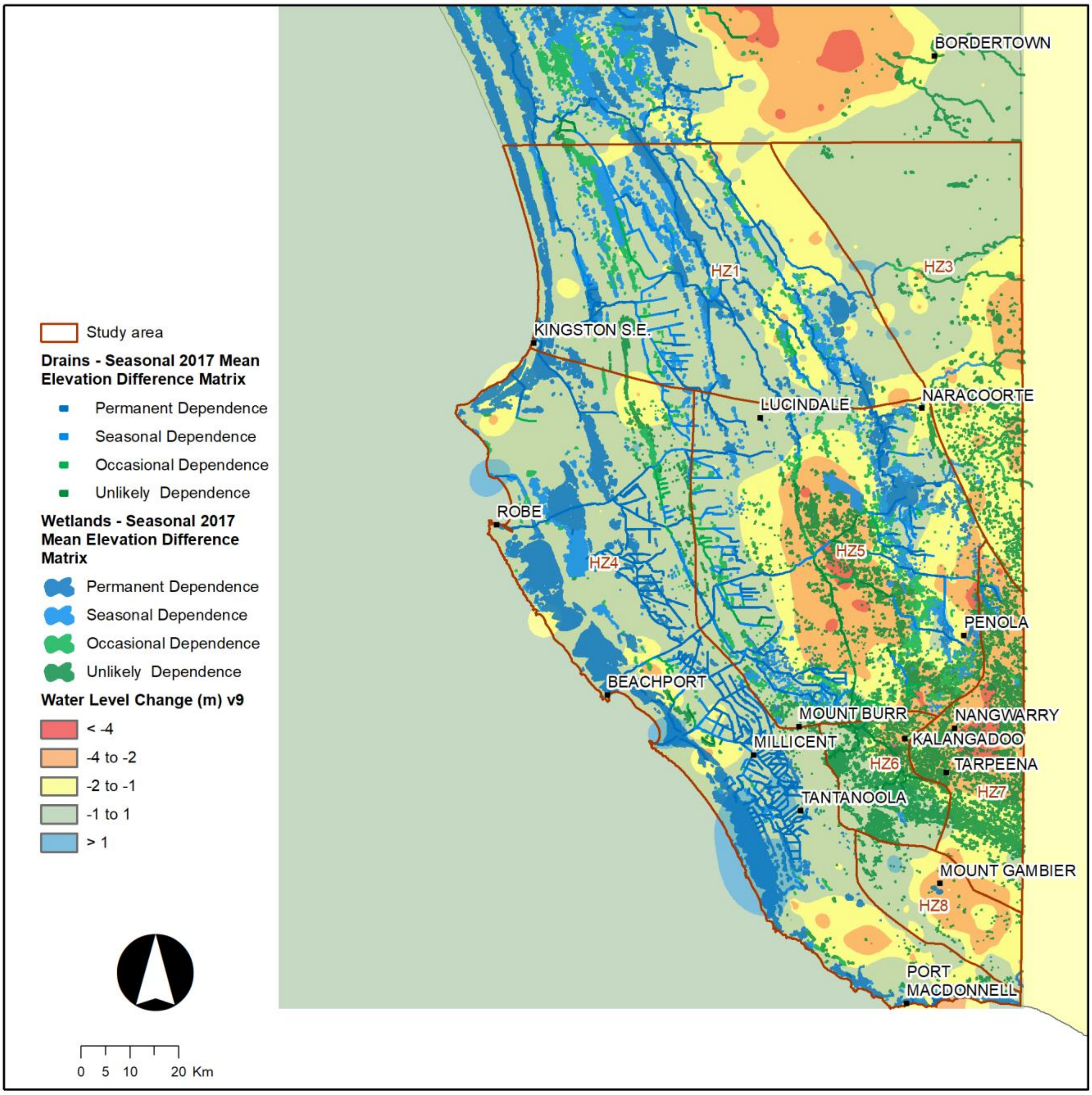

Figure 7 Drain and wetland groundwater dependence and groundwater level change 1985-2018 (Cranswick and Herpich, 2018).

5 Ecology

5.1 Listed flora and fauna records

Point records of fauna and flora species whose status is listed under National and State registers (e.g. rare, endangered, vulnerable, critically endangered etc.) located in the Oracle Enterprise Geodatabase were clipped to the study area and exported as shapefiles in the project coordinate system for drawing efficiency. These are symbolised based on status code (NPWACTATCODE) using the schema in the Oracle layers.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\sde_shp_lyr\fauna_rated_sites_state.shp

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\sde_shp_lyr\flora_rated_sites_state.shp

5.2 Vegetation mapping

Vegetation mapping for the region was sourced from the DEW Oracle Enterprise Geodatabase layer (VEG.SAVegetation_SE_Floristic.lyr), clipped to the study area and exported as a shapefile saved in the project folder for drawing efficiency. This dataset contains several levels of classification from broad descriptions to species-level descriptors, identifiers and data source/capture information. The data are symbolised following the Oracle layer schema using the SA_VEG_ID1 field.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\sde_shp_lyr\veg_saveg_se_floristic.shp

5.3 Species of National Environmental Significance

The Species of National Environmental Significance Database maps the distribution of species listed under the *Environment Protection and Biodiversity Conservation Act 1999* using modelling software and environmental data. The data are indicative and serve as a starting point for further investigation, not as a definitive scientific assessment. The polygon shapefile data are sourced from public grids (https://fed.dcceew.gov.au/) representing species distributions mapped at different spatial scales.

The Species of National Environmental Significance (SNES) database was utilised to extract the distributions of listed species within the designated study area. A preliminary assessment was undertaken to ascertain the proportional coverage of listed species across the 23 wetlands shortlisted by the Limestone Coast Landscape Board for initial scrutiny. An illustrative example of this analysis, showcasing the aggregate area occupied by species categorised as conservation dependent, vulnerable, endangered, or critically endangered, is depicted in Figure 8. This type of spatial query can be run for any wetland or feature of interest within the study area.

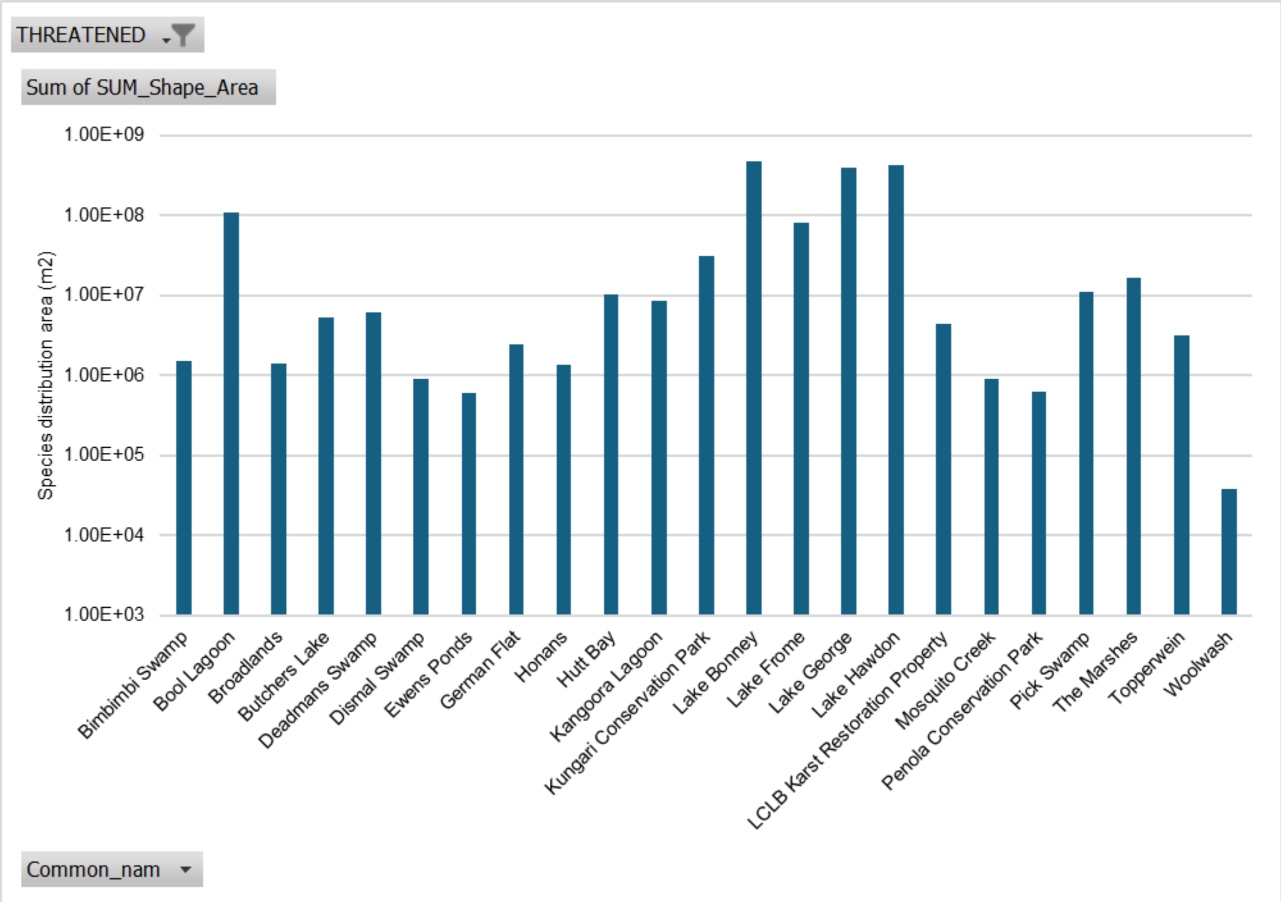

Figure 8 Total area of species distributions listed as conservation dependent, vulnerable, endangered, or critically endangered within the 23 wetlands of interest.

These data offer the flexibility to delve deeper into various taxonomic groups and provide species-level summaries. For instance, they allow for the examination of specific details such as the total area occupied by critically endangered species known to inhabit the 23 wetlands of interest, as depicted in Figure 9. In the Tool, these data are symbolised on a combination of the THREATENED and TAXON_GROUP attributes.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\commondata\species_of_national_environmental_significance_distributions\SNES_SE_HZ.shp

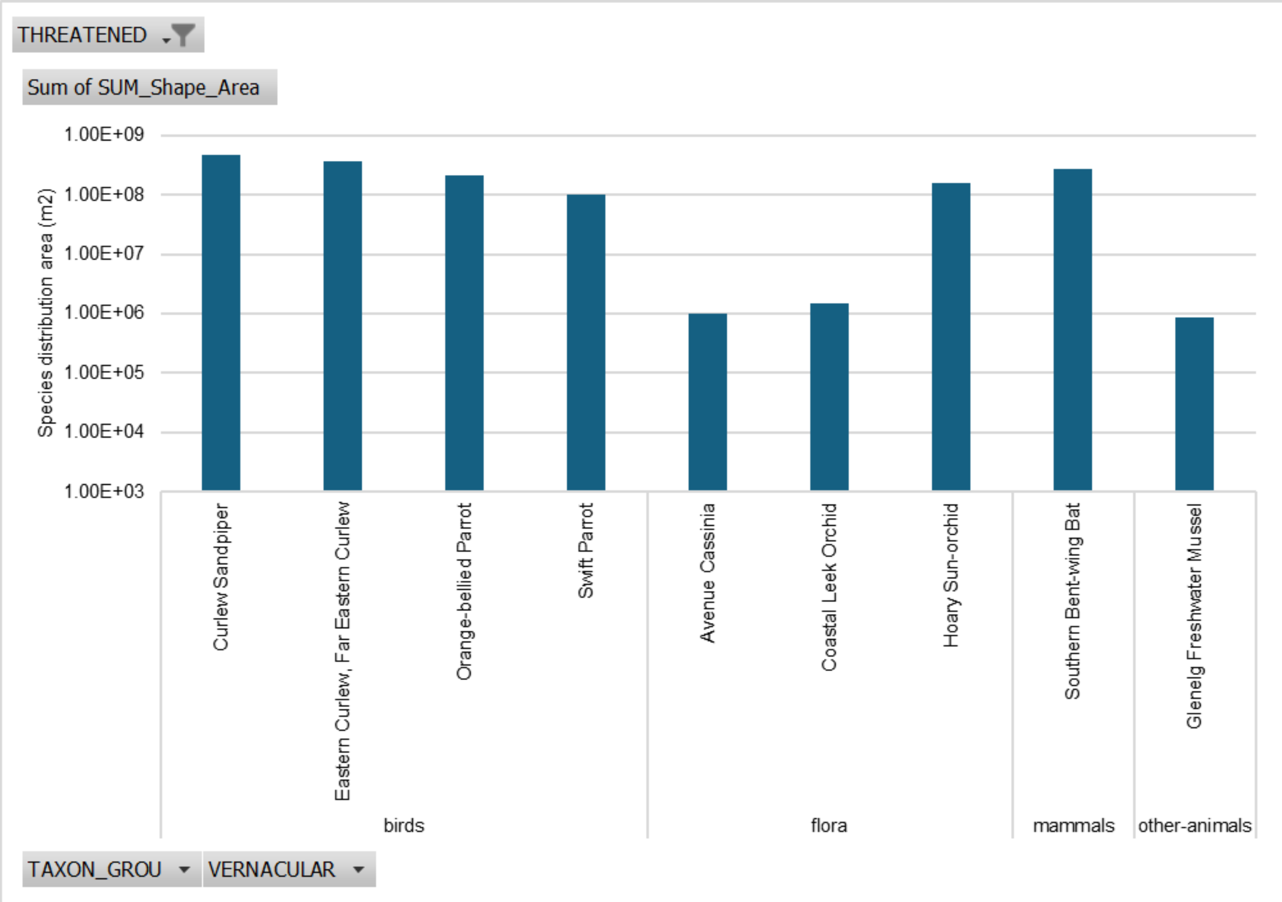

Figure 9 Total area occupied by critically endangered species with known distributions across the 23 shortlisted wetland complexes.

5.4 Bool Lagoon vegetation

The Friends of Bool and Hacks Lagoons, along with BirdLife Australia, provided Lynker Analytics with aerial photography and ground truth points for Bool and Hacks Lagoons. Using these data, Lynker manually annotated images into eight target classes: tussock, tree, sedge, reed, grasses, open water, ground, and aquatic floating. They employed a supervised learning process to train a machine learning model, achieving a classification accuracy and mean F1 score of 0.965. The sedge class was the lowest performing, often confused with grasses or ground, while the aquatic floating class was the highest performing, with perfect prediction accuracy. Further metadata and links to the data source are found at https://data.sa.gov.au/data/dataset/bool-and-hacks-lagoons-landcover-model-output-2022.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\commondata\cleaned_polygons_020523\Bools_polygons_2m.shp

5.5 Wetland Vegetation Component conceptual models

Wetland Vegetation Component (WVC) conceptual models summarize the ecological characteristics and environmental water requirements (EWR) of vegetation communities in the South East (Harding, 2018). These conceptual models describe species presence, regional distribution, and habitat functions, incorporating information from previous studies. The conceptual models include occurrence maps indicating their prevalence in catchment management units, based on the South Australian Wetland Identification Database. The EWR hydrograph shows variations in water depth and duration under typical and above-average rainfall. Conceptual models illustrate the relationships between hydrological conditions, salinity preferences and plant/fauna functional groups (Table 3). These models identify target EWRs and transition states for varying water levels, supported by species data. The models also include information on plant functional groups and their water regime needs (Gehrig et al., 2015), as well as key fauna species associated with the WVC models, with species noted for breeding or nesting.

Lookup tables relating WVC models to wetlands (SAWID) were created that contain hyperlinks to corresponding descriptions (Harding, 2018). This enables users to query (using the identify tool) a wetland feature and click on the link that displays a PDF of the corresponding model description. WVC models were also related to point records at the species level using the Atlas of Living Australia database described in Section 5.6.

Table 1 Environmental water requirements target hydrograph reflect variations in depth and duration due to average rainfall conditions (Annual) and above average rainfall conditions (e.g. 1 in 3 years) (Harding, 2018).

	Surface Water Level (m)	J	F	M	A	M	J	J	A	S	O	N	D
Annual	0.2												
	0.1												
1 in 3 years	Water logged												
	Dry												
Max. depth	Maximum depth threshold (m)												
	Dry phase required	Yes or No											
Max. continuous inundation	Maximum duration inundation threshold												
	Max. continuous dry	Maximum desiccation threshold period											
Surface water salinity	Target surface water salinity and known thresholds (where available) of dominant species.												

Other:

Groundwater: Typical groundwater interaction and/or salinity thresholds

Soil: Typical soil types.

5.6 Atlas of Living Australia WVC model classifications

Wetland Vegetation Component (WVC) conceptual models identify key plant and fauna species that inhabit a range of wetland types in the South East (Harding, 2018) that vary with the depth, salinity and seasonality of the water bodies. Each flora and fauna species as listed in the WVCs were checked for presence/absence in the Atlas of Living Australia (ALA) database. Where flora or fauna groups but not specific species were listed for WVCs, the ALA database was searched for all species that fit the group within the South East (e.g. for the group “rails”, the following species were included: Eastern Australian Lewin's Rail; Buff-banded Rail; and Lewin's Rail). Name checks were carried out on all species that were not initially found in the ALA and appropriate synonyms were found.

All key flora species within WVCs were classified (Table 2) to identify which were unique to specific WVCs and which were common across many. This was to identify whether specific species could be considered diagnostic of specific WVCs and used to spatially map the extent of WVCs. All key fauna species and groups were categorised for each WVC based on whether they were known to use the habitat for breeding, or whether they were simply observed within the habitat.

Table 2 Classification of uniqueness of flora species with each WVC

Classification	Flora species
1	Must have this species to be considered this WVC
2	Likely to have this species and not listed in other WVC
3	Likely to have this species, but common to 1 or 2 other WVCs
4	Likely to have this species, but common to many other WVCs
5	Likely to have this genus and not listed in other WVCs
6	Likely to have this genus but listed in other WVCs
7	Likely to have this species in a drier state

Table 3 Wetland Vegetation Component (WVC) Conceptual Models in order of increasing broad salinity group (colour-coded) and increasing maximum target water depth (Harding, 2018).

Salinity Group		WVC Model	
Fresh	Increasing maximum water depth	1.7	*Callistemon rugulosus* shrubland (under *Eucalyptus leucoxylon* woodland)
		1.1	Shallow seasonally inundated *Eucalyptus camaldulensis* woodland
		1.5	*Leptospermum continentale* wet heathland
		1.6	*Leptospermum lanigerum* tall wet shrubland
		2.16	*Melaleuca squarrosa* wet heathland
		1.9	*Gahnia trifida* tussock sedgeland
		1.11	Freshwater emergent sedgeland
		2.17	Typha/Phragmites tall aquatic grassland
		2.20	Freshwater open aquatic herbland
		2.18	Karst rising spring – open water component
Brackish	Increasing maximum water depth	1.4	*Melaleuca halmaturorum* (Swamp Paperbark) tall shrubland
		1.4	*Melaleuca brevifolia* (Swamp Honey-myrtle) low shrubland
		1.8	*Gahnia filum* tussock sedgeland
		1.2	Seasonal brackish low aquatic herbland
		1.13	Semi-permanent deep fresh-brackish open water
Saline	Increasing maximum water depth	1.12	Inland Samphire saltmarsh
		2.15	Seasonal saline low aquatic bed
		2.19	Permanent brackish to saline deep open water
		1.14	Hypersaline wetlands

Flora and fauna point records classified and symbolised according to corresponding WVC models are held as shapefiles with associated layer files for symbology in ArcGIS layer package files. A layer package created for fresh, brackish and saline WVC models. Location data are held as shapefiles (.shp) and symbology as layer (.lyr) files in the subfolders located in the Packages folder.

Data path: file:\\J:\GISWorkspace\LimestoneCoast\Water\ALA_WVC\Packages

6 Water allocations and use

6.1 Allocations and extractions

A Python 3.9 script was written to create polygon shapefiles representing annual groundwater allocations and extraction volumes for the period 2015-2024. A spreadsheet was sourced from DEW via request by the Limestone Coast Landscape Board. Several notes and caveats apply to these data:

- Data are provided for the purposes of the contracted project and not to be used for any other purpose.
- Number of licences with an allocation in 2023 = 3008.
- Number of licences which have had an allocation during the life of the current plan = 3824, includes 8 licences which were surrendered in the period between the Plan being adopted (Nov 2013) and implemented (1 July 2014).
- Land Property List and Source Listing (bore and meter location) contains all available data. There are many licences for which this information is not complete and some for which it is incorrect. Both lists also contain information on licences surrendered in 2012 and 2013, which are not included in either the allocation or use worksheets.
- All licences are assigned to a management area. For some water (taking) licences, the licence includes wells in two different management areas. The specific management areas for each well are listed in the Source Listing, where it is known. There are only a few and they mainly cross the Zone 5A / Hynam East boundaries.
- Licences for forestry may cover multiple management areas but are designated a single management area on the licence. Where these occur, it may be possible to split the data using the Land Property List (use Parcel ID not Vol/Folio) and applying some logic (e.g. if a licence has both hardwood and softwood and the management areas are Hindmarsh and Coles, the hardwood will be in Coles and the softwood in Hindmarsh).
- Data includes all licensed allocations since the implementation of the current plan to the end of the 2022/23 water use year.
- Types of allocation components in each year varies (e.g. no bridging volumes after 2016).
- Carry-over included for transparency but overall creates a complication in any approach to interpreting data. There are specific rules around which components can accrue carry-over. Preferable to not to include carry-over as an allocation as it is a portion of the previous year's allocation and should only be used if relevant to the specific assessment.
- Data includes all extractive licensed use since the implementation of the current plan to the end of the 2022/23 water use year.
- Forestry water use data were not available for 2015-2017, or 2023. Table 4.4 in the Water Sharing Plan sets out 2011 areas of hardwood and softwood by management area and these figures equate to the Water Account set out in Table 1 in the appendices of the Plan.
- Forestry water allocations apply on a calendar year while extractive uses apply to a financial year. DEW Licensing advise that they consider water allocations at a point in time, amalgamation of data is only used for reporting purposes and where that occurs the forestry data are backdated to the previous water year, e.g. use for the year 2022 is reported in January 2023 and is included in the 2021/2022 figures.
- Forestry data have been included with water (taking) use data but are also provided separately in the worksheet.

- There were occurrences of negative water use. These are likely corrections to previous years' data, e.g. correction where temporary trades occurred. Traded volumes were accounted for against licences.

Scripts processed the spreadsheet provided accordingly to write shapefiles representing annual allocations and use performing the following key functions:

- Annual 'holding' allocations (2015-2023) were summed according to corresponding Groundwater Management Area (GMA).
- GMA polygon shapefile for unconfined and confined zones were merged and exported as a single shapefile (Unconf_Conf_MA_MGA54.shp).
- Holding allocations for GMAs were joined to the merged GMA shapefile (llc_holding_alloc_2015_2023.shp).
- Annual 'carry over' allocations (2016-2023, noting none in 2015) were joined to land parcels (DCDBID) based on relationship with licence number, licenced volumes associated with multiple land parcels were divided equally across associated parcels, shapefile exported (llc_carryover_alloc_2015_2023.shp).
- Annual 'active' allocations (2015-2023) were joined to land parcels (DCDBID) based on relationship with licence number, licenced volumes associated with multiple land parcels were divided equally across associated parcels, shapefile exported (llc_active_alloc_2015_2023.shp).
- Annual 'softwood forestry' allocations (2015-2023) were joined to land parcels (DCDBID) based on relationship with licence number, licenced volumes associated with multiple land parcels were divided equally across associated parcels, shapefile exported (llc_softwood_alloc_2015_2023.shp).
- Annual 'hardwood forestry' allocations (2015-2023) were joined to land parcels (DCDBID) based on relationship with licence number, licenced volumes associated with multiple land parcels were divided equally across associated parcels, shapefile exported (llc_hardwood_alloc_2015_2023.shp).
- Annual licenced 'groundwater use' (2015-2023) representing reported extraction volumes were associated with land parcels (on unique parcel identifier, DCDBID) based on relationship with licence number. Licenced volumes associated with multiple land parcels were divided equally across associated parcels, the shapefile was exported (llc_gw_use_m3_2015_2023.shp).

Data path:
file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\commondata\alloc_use_20240912

7 Economics

7.1 Residual values of agricultural land uses

The residual value of water is the economic value of water after all other costs of production have been accounted for. It is calculated by subtracting the costs of all non-water inputs, such as land, labour, fertiliser, and energy, from the value of the output produced (Cooper et al., 2025). Summary statistics of the residual values of water used for five agricultural land-use classes across the region were provided by the Task 1 project team. These data were spatially represented based on the ABARES Catchment Scale Land Use of Australia grid at a 50 m resolution (update December 2023 version 2). Units are in Australian Dollars per megalitre (AUD/ML). This national grid was clipped to the project study area and residual value statistics (minimum, median, maximum) were written to corresponding land-use areas and exported as separate spatial grids with a script written in Python 3.9 (Figure 10).

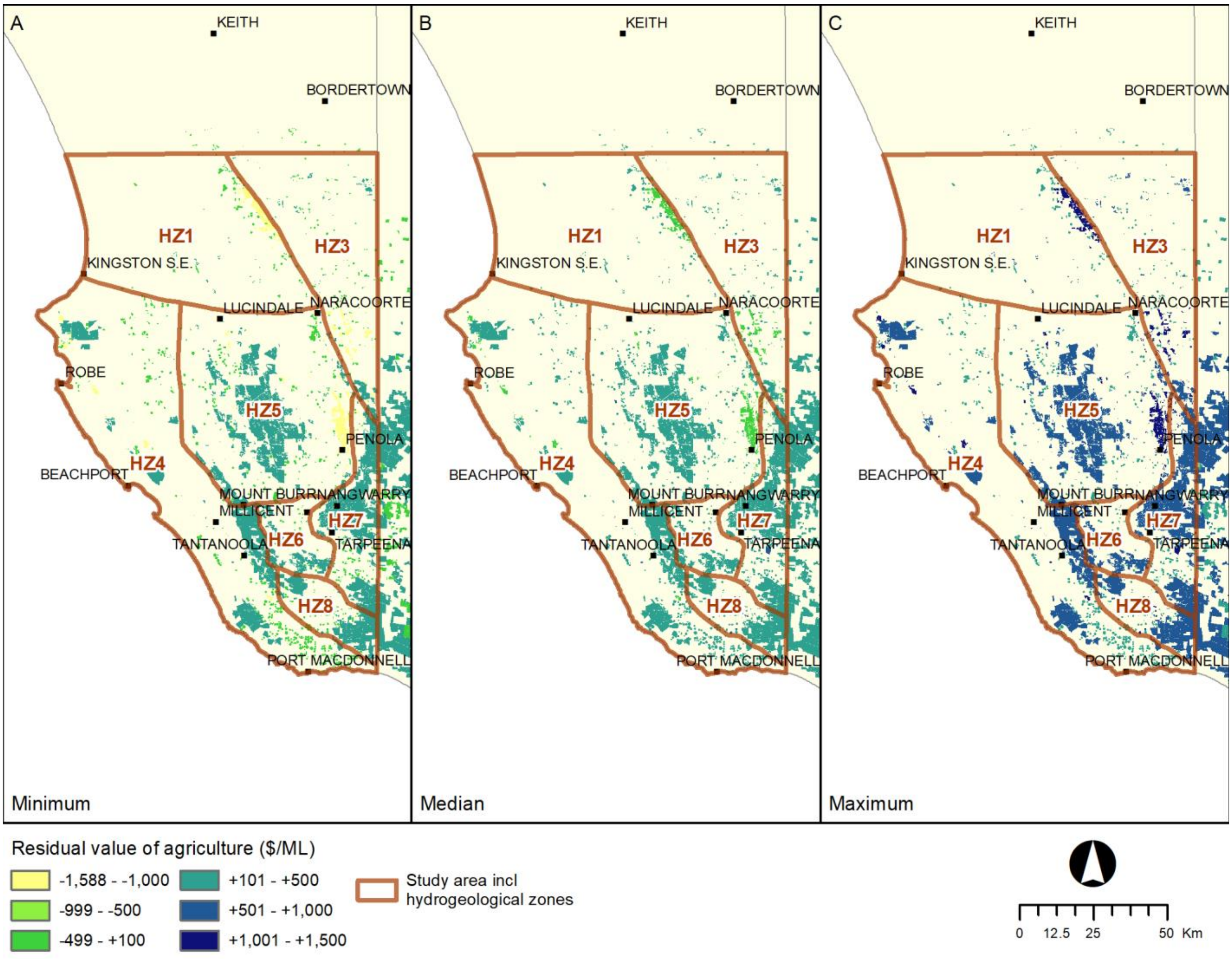

Figure 10 Estimated residual values of agriculture, A: minimum, B: median, C: maximum.

Table 4 Statistical summary of residual values of five commodity groups in the South East region.

Statistic	Softwood	Hardwood	Potatoes and onions	Dairy	Winegrapes
ABARES Land Use Codes	312, 412	311	440, 447, 450, 453	420, 424	449
Minimum*	159.98	176.39	271.76	-160.65	-1587.6
Maximum*	619.93	802.94	1332.72	410.51	1296.56
Mean*	320.2	319.38	687.51	136.49	-161.24
Median*	309.96	310.69	684.07	140.4	-178.77
Mode*	159.98	176.39	271.76	-160.65	-1587.6
Standard Deviation*	76.97	71.1	167.77	108.06	456.92
Variance*	5923.8	5055.22	28147.45	11677.15	208771.6
Skewness	0.67	1.11	0.19	0	0.17
Kurtosis	0.31	3.08	-0.07	-0.52	-0.17
25th Percentile*	264.41	268.39	567.61	55.5	-496.84
75th Percentile*	365.96	358.89	791.99	214.23	147.2

* Unit = AUD/ML

The residual value of water in primary production (e.g., agriculture and forestry) can vary depending on several factors, including:

- The type of crop or livestock being produced
- The efficiency of water use
- The availability of water
- The price of the output produced
- The cost of non-water inputs

The residual value of water can be used to estimate the potential benefit of additional water (e.g., from a new dam or a stormwater-based managed aquifer recharge scheme). This information can be used to make water allocation decisions, such as which crops to grow more of to get the highest return from the investment in additional water (Cooper et al., 2025).

A negative residual water value indicates that the costs of all non-water inputs (land, labour, fertilizer, energy, etc.) exceed the value of the output produced, suggesting that the water used in the production process is not adding enough value to cover the costs of other inputs at the current price of the product (Cooper et al., 2025). This could also reflect scope for improving water use efficiency to reduce the average cost of water, the high cost of other non-water inputs used in the production process, and/or a low output price.

Data path: file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\landuse_aud_ml_v02

8 Hydrology

8.1 Surface water data analysis

Python scripts were written that generated time series plots for discharge, water level, lake level, water temperature, and TDS for surface water stations within the study area using data from Water Data SA. Table 5 summarizes the statistics of surface water data within the study area. All data available were included without filtering according to data quality fields.

Table 5 Statistics of surface water data within the study area (Water Data SA).

Description	Count
Total surface water stations in the study area	78
Total surface water stations with best available discharge data	19
Total surface water stations with best available water level data	41
Total surface water stations with best available lake level data	6
Total surface water stations with best TDS* available data	29
Total surface water stations with best water temperature available data	40
Total surface water stations with manual discharge gauging data	4

*Based on corrected electrical conductivity.

Figure 11 to Figure 15 display examples of surface water time series plots. Each plot includes information such as the name of the station, the station ID (e.g., A2390506) and its status (active or inactive), longitude (“Lng”), latitude (“Lat”), elevation (“Elv”), the number of records (“Rec”), minimum (“Min”), maximum (“Max”), and the average (“Ave”) of corresponding data. Additionally, a map showing the station’s position within the study area is included in each plot. These plots are configured as pop-ups via hyperlinks that are clickable when viewing the attributes of the features. Figure 16 shows the locations of wells/stations associated with time series plots in the study area.

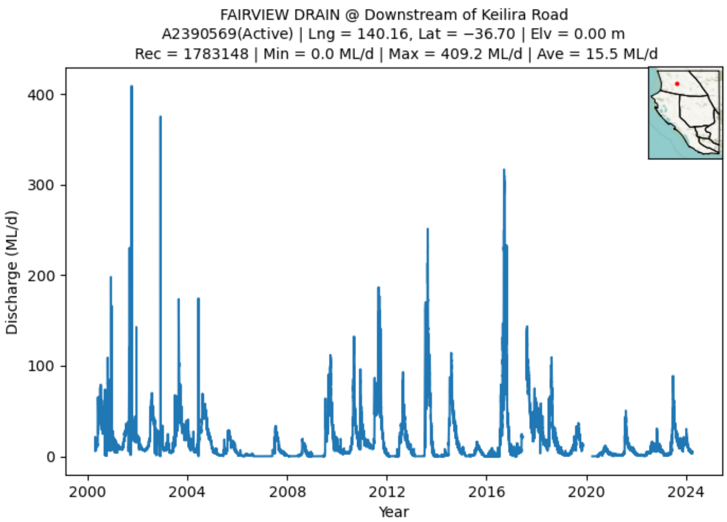

Figure 11 Discharge time series example for Fairview Drain.

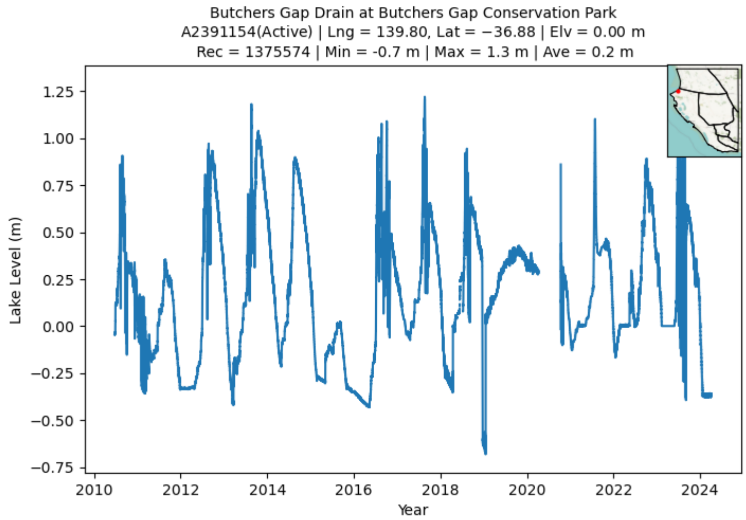

Figure 12 Lake level time series example for Butchers Gap.

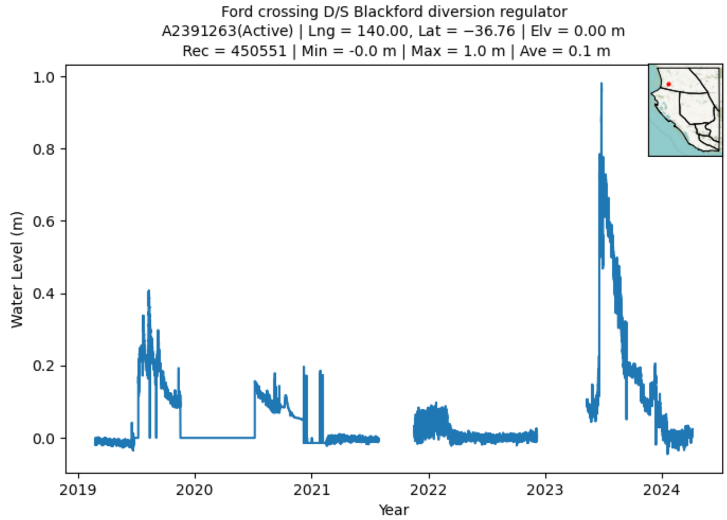

Figure 13 Water level time series example for Ford Crossing.

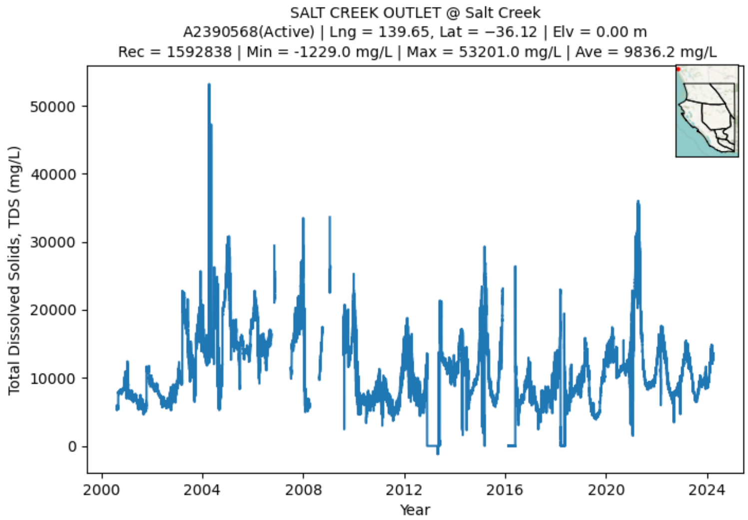

Figure 14 Total dissolved solids time series example for Salt Creek Outlet.

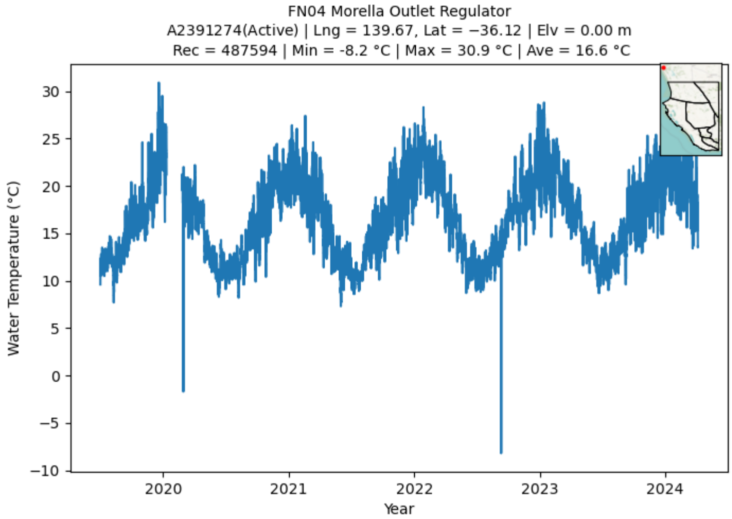

Figure 15 Water temperature time series example for Morella Outlet.

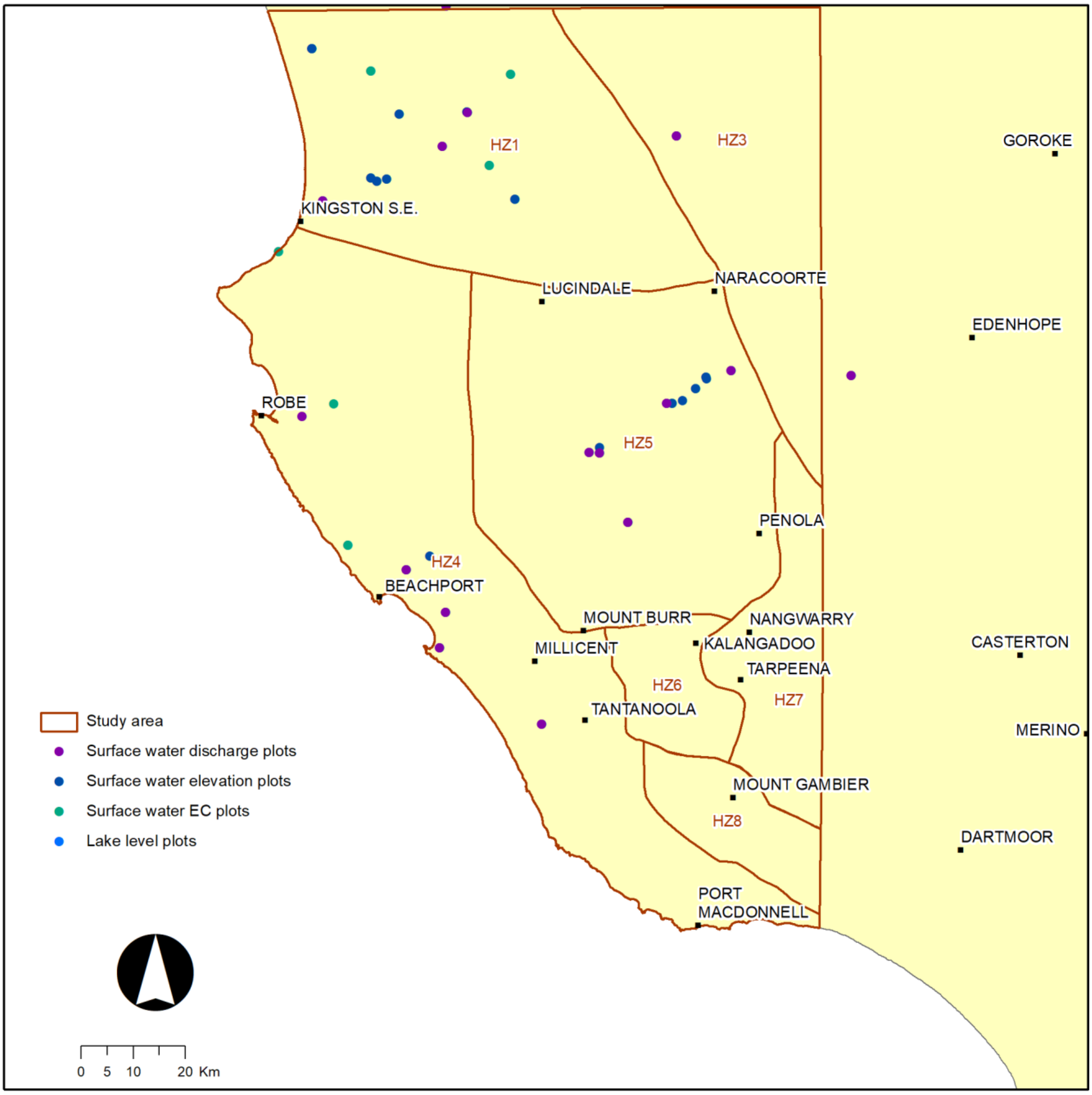

Figure 16 Locations of stations linked to times series plots of surface water parameters in the study area.

8.2 Water balance modelling

The integrated water balance results from the AWRA-L modelling are summarised across different components of the water balance, spatial boundaries representing different reporting zones (catchment boundaries and unconfined groundwater management areas), and the original 1 km grid model cells. Recharge is reported as gross recharge, as the total deep drainage reaching the groundwater store, and net recharge, the deep drainage minus evapotranspiration from the groundwater store. See Gibbs et al. (2025) for more details.

Columns in the spatial layers are:

- Gridcode/MNGTAREA/Name - identifier for the location of the output, for the grid cells, groundwater areas and surface water catchments, respectively.
- Shape_Area - area of the zone in m^2 (surface water and groundwater zones only).

The water balance results are average values in mm/year for the corresponding spatial unit (e.g. model grid, groundwater management area, catchment area). Average for "all" is over water years (March to Feb) from 1/3/1960-28/2/2020. Each decade is also over water years, e.g. 1960s is an annual average over the period 1/3/1960-28/2/1970. These results follow the format of Variable_scenario_period, where 'Variable' is one of:

- Rain: rainfall
- Q: surface runoff
- R_gross: Gross recharge
- R_net: Net recharge

'Scenario' is one of:

- HistoricalDyanmicHRUs - historical climate dynamic land use
- Historical2020HRUs - historical climate with 2020 land use constant over time. This assumption is also used for the climate projections
- 2060Dry - Dry 2060 SSP 2.4-5 scenario, represented by the EC-Earth 3-Veg GCM
- 2060Mid - Mid 2060 SSP 2.4-5 scenario, represented by the CanESM5 GCM
- 2060Wet - Wet 2060 SSP 2.4-5 scenario, represented by the EC-Earth 3 GCM

Some columns are of the form Variable_scenario_"change"_period. This represents a change (in %) from the long-term average. This is also the case for the decade values, e.g. Rain_HistoricalDyanmicHRUs_chanage_1970s has a positive % change, representing an above-average rainfall decade.

Water balance outputs are stored in three feature classes within a file geodatabase to preserve field names and for compatibility with ArcGIS. Outputs are represented at model grid scale and summarised for groundwater management areas and hydrological catchments. Each feature class contains the results of all variables and scenarios in separate fields. These are symbolised using layer files for rainfall, runoff and gross recharge using the corresponding file (e.g. water_balance_rainfall.lyr) in the folder directly above the file geodatabase path. The user can select the parameter of interest and symbolise using these layer files, e.g. average annual historical runoff with dynamic land use at model grid scale (Figure 17).

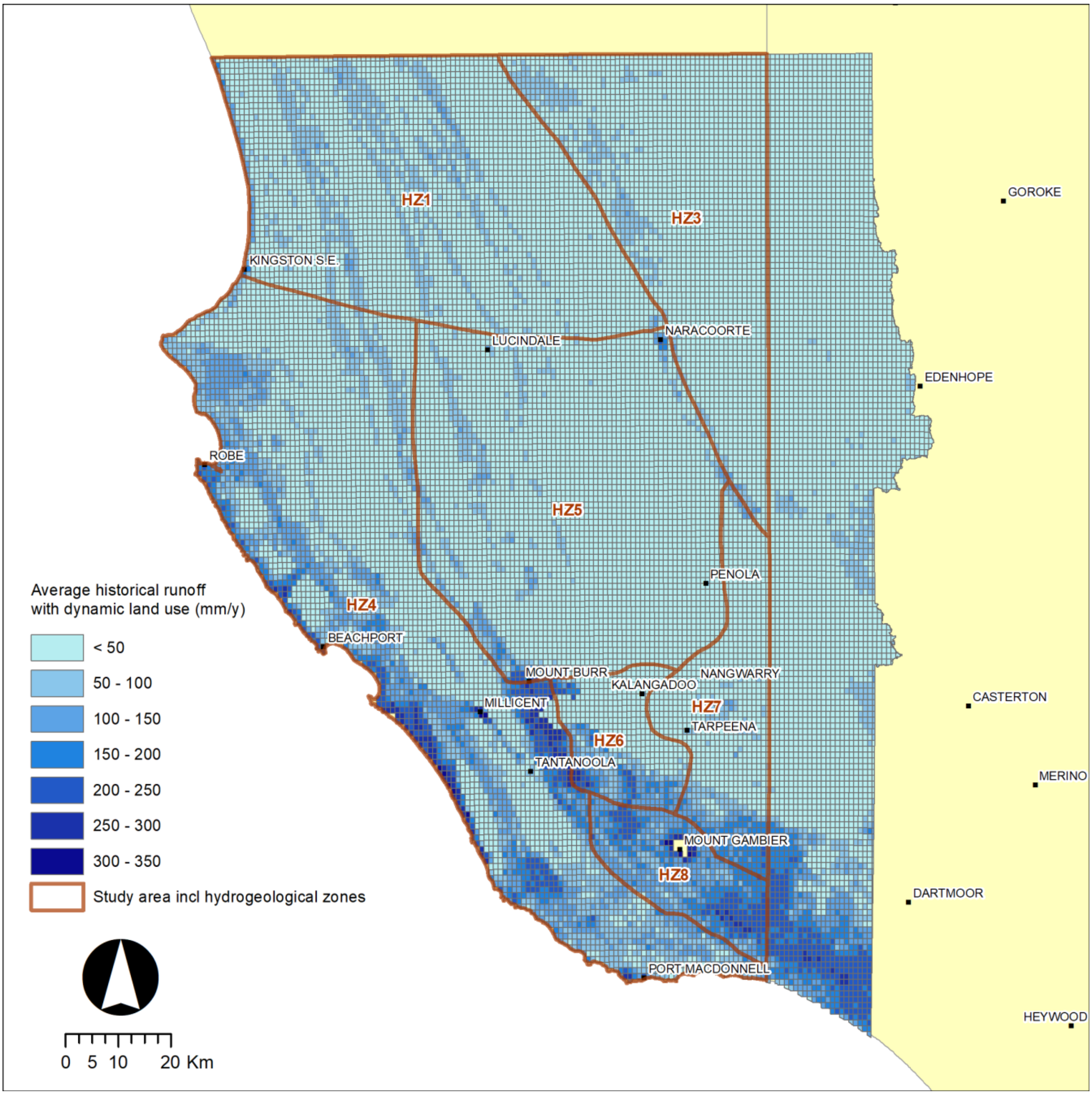

Figure 17 Modelled average annual historical runoff with dynamic land use.

Data path: file:\\J:\GISWorkspace\LimestoneCoast\Water\water_balance_outputs.gdb

8.3 Drain flow accumulation modelling

In these data, each point represents the discharge contributing to that location from the upstream catchment area, determined through the AWRA-L model. The upstream catchment was determined based on a digital elevation model then aligned to the 1 km resolution of the AWRA-L model, and points with a mean annual discharge greater than 500 ML/yr were retained with lower values discarded. Storage in Bool Lagoon and transmission losses in the drainage network downstream were included in the Drain M catchment only. Five scenarios were considered, see Gibbs et al. (2025) for details on the scenarios and application of losses. The scenarios and corresponding spatial files are:

- Historic climate scenario, 2020 land use constant over time (the same assumption applies for climate projection scenarios):
  - Historic_2020_gridcell_Accumulated_volume_MLyr.shp
- Wet climate scenario, 2060 SSP 2.4-5, represented by the EC-Earth 3 GCM:
  - EC-Earth3_gridcell_Accumulated_volume_MLyr.shp

- Mid climate scenario, 2060 SSP 2.4-5, represented by the CanESM5 GCM:
    - CanESM5_gridcell_Accumulated_volume_MLyr.shp
- Dry climate scenario, 2060 SSP 2.4-5 scenario, represented by the EC-Earth 3-Veg GCM:
    - EC-Earth3-Veg_gridcell_Accumulated_volume_MLyr.shp
- Historical climate with variable land use over time:
    - Gridcell_Accumulated_volume_MLyr_scale10.shp.

The relevant columns in the spatial layers are:

- Gridcode - identifier for the location of the point, aligned to the model grid cell IDs
- Mean - average volume accumulating to this location, in ML/year
- pcX – X is the percentile annual discharge, e.g. X=10 is 10th percentile with a discharge less than this in 10% of years, and X=50 the median. Units are ML/year.

Flow accumulation data are symbolised using graduated symbols. Symbology definitions are stored in a layer file (flow_accumulation_symbology.lyr), which can be selected to symbolise any of the flow statistics with a consistent schema.

Data path: file:\\J:\GISWorkspace\LimestoneCoast\Water\flow_accumulation_shps

9 Groundwater

9.1 Groundwater hydrographs, rainfall residual mass curves and salinographs

These analyses were based on groundwater data (provided by the Government of South Australia) and climate data (provided by Queensland Government) that are publicly accessible via WaterConnect (www.waterconnect.sa.gov.au) and SILO (www.longpaddock.qld.gov.au/silo/), respectively. All data available were included without filtering according to data quality fields. Table 6 summarises the key sources of data and provides links to access them.

Table 6 Data sources used in groundwater hydrographs and rainfall plots.

System characteristic	Description	Data source	Link
Groundwater			
Well summary data	A wide variety of information (82 fields) for a well, including drillhole number, network, aquifer, status, geometry, ground elevation, etc.	Groundwater Data	https://www.waterconnect.sa.gov.au/Systems/GD/Pages/Default.aspx
Water level data	Groundwater level data (21 fields) including drillhole number, standing water level (depth to water table), reduced standing water level water level, observation date, etc.		
Salinity data	Salinity data for a well (20 fields) including drillhole number, collect date, electrical conductivity (EC), etc.		
Surface water			
Discharge	Best available discharge data	Water Data SA	https://water.data.sa.gov.au/Data/Dashboard/53
Water level	Best available water level data		
Lake level	Best available lake level data		
Total Dissolved Solids (TDS)	TDS based on best available Electrical Conductivity (EC) data		
Water temperature	Best available water temperature data		
Discharge	Manual flow gauging data	Limestone Coast Landscape Board	-
Climate			
Rainfall	Gridded daily rainfall derived either by splining or kriging the observation data on grids with 0.05° longitude and latitude resolution	SILO – Australian climate data from 1889 to the current date	https://www.longpaddock.qld.gov.au/silo/

Scripts were developed in Python to extract groundwater information from the WaterConnect database and gridded daily rainfall data from SILO. The Python package *sa_gwdata*, available at the GitHub repository (https://github.com/kinverarity1/python-sa-gwdata), was utilised for accessing groundwater data. An Application Programming

Interface (API) was integrated into the scripts to directly retrieve daily rainfall data from the SILO website for the nearest grid point to each well's location. Only bores situated within the study area (Figure 1) and with repeated measurements (i.e., at least 50 water level or electrical conductivity (EC) measurements) were included for groundwater level and salinity analysis. The statistics of wells within the study area are presented in Table 7.

Table 7 Statistics of wells within the study area.

Description	Count
Total wells in the study area	45,680
Total wells in the study area with at least 50 water level measurements	1085
Total wells in study area with at least 50 salinity measurements	257
Total wells in the study area with at least 50 measurements for both water level and salinity	143
Total wells in the study area with logged water level data	190

The Python scripts also generated time series plots, comprising hydrographs (groundwater elevation and depth to water table versus time) and salinographs (EC versus time) for each well in the study area with at least 50 readings. This process yielded a total of 1085 water level plots and 257 EC plots.

Rainfall residual mass curves (RRMCs) were incorporated into hydrographs to illustrate deviations of the rainfall record from the long-term mean values. RRMCs aid in visually identifying where changes in water levels are due primarily to climatic effects. An RRMC for time series *x* (in this case, daily rainfall extracted from the SILO) is defined as follows (Aitken, 1973):

$$C_t = \sum_{i=1}^{t} \left(\frac{x_i}{\bar{x}} - 1 \right) \qquad 1 \le t \le N \tag{1}$$

where C_t is residual mass and $\bar{x} = \sum_{i=1}^{N} x_i / N$ is the mean of the series. The quantity C_t represents a time series of the cumulative departure from the mean. Where the series *x* contains a sequence of lower-than-average values, the RRMC will trend downwards (a negative gradient), whereas above-average values of *x* produce an upwards trend. In this way, the RRMC allows for rapid identification of periods of above-average and below-average rainfall.

Python scripts produced hydrographs showing groundwater elevation and depth to water table time series for each well (1085 plots in total). The daily rainfall and RRMC (calculated based on Equation 1) were added to hydrograph plots, which include important bore information, including the drillhole number ("DHNO") and well status codes (e.g. ABD, OPR, etc.; the definition of well status codes can be find via this link https://www.waterconnect.sa.gov.au/Systems/GD/Pages/Code-Definitions.aspx), the longitude ("Lng") and latitude ("Lat") of the well, the ground elevation ("ELV"), number of records ("Rec"), average rainfall ("Ave rainfall") over the period of groundwater elevation measurement, and a location map showing the well's position within the study area. A sample plot is shown in Figure 18. These plots are configured as pop-ups via hyperlinks that are clickable when viewing the attributes of the features.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\WaterLevelSalinityPlots\LSE-WaterConnect\Shapefile\WaterLevel.shp

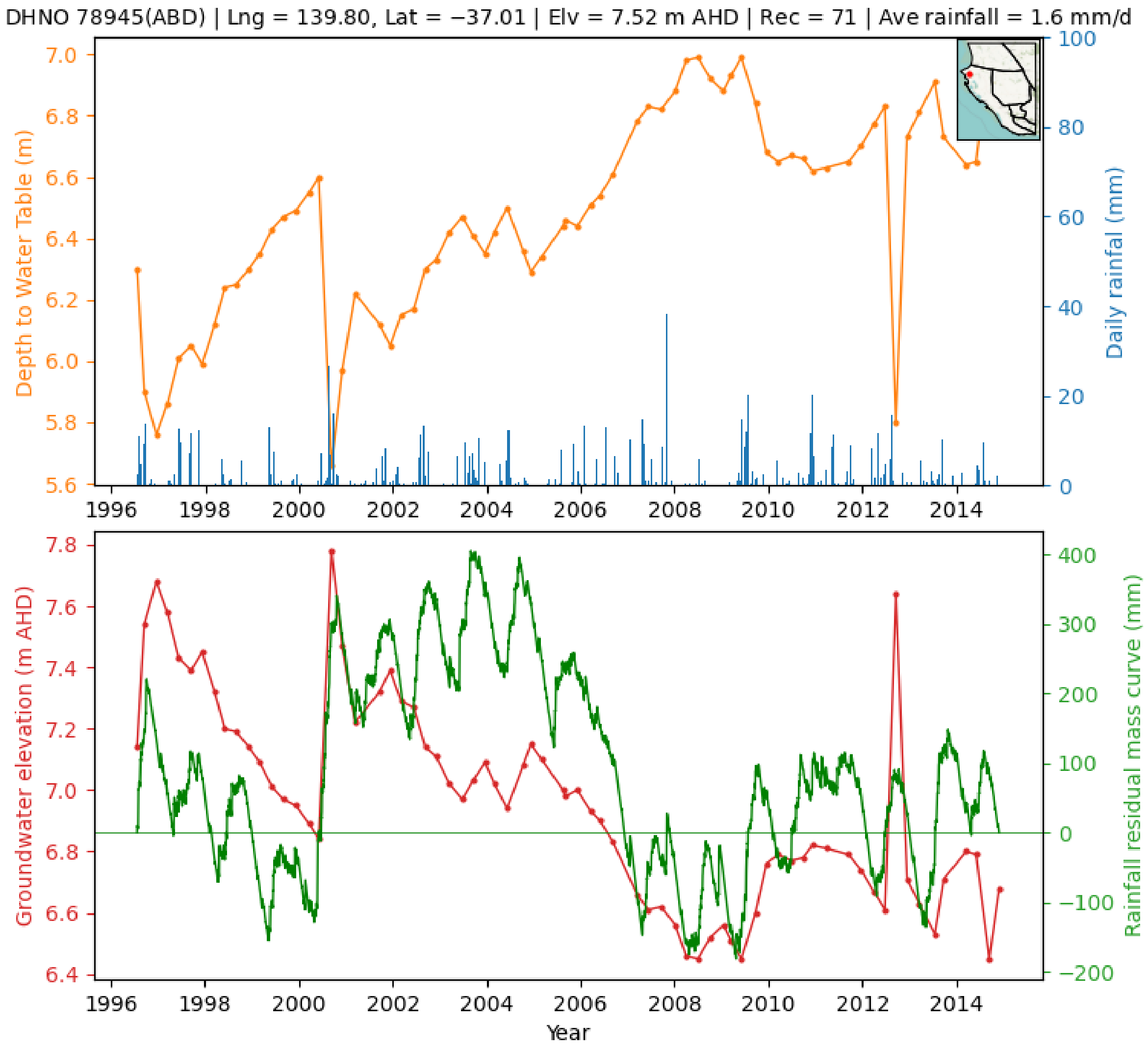

Figure 18 Example hydrograph and corresponding rainfall residual mass curve for one location in the study area shown in the inset box.

The Python scripts generated hydrographs displaying the depth to water table, accompanied by corresponding bar charts illustrating the frequency (number of days) in each year where the depth to water table is less than certain thresholds (i.e., ≤ 2, 1, 0.5, and 0 m). This process yielded a total of 190 depth to water table hydrographs, each paired with its corresponding frequency bar chart. These plots also provide important information about monitoring wells, including the drillhole number ("DHNO") and well status codes (Figure 19). These plots are configured as pop-ups via hyperlinks that are clickable when viewing the attributes of the features.

Data path: file:\\J:\GISWorkspace\LimestoneCoast\Water\LSE_WaterDataSA_GW\Shapefile\DepthToWaterTableFrq.shp

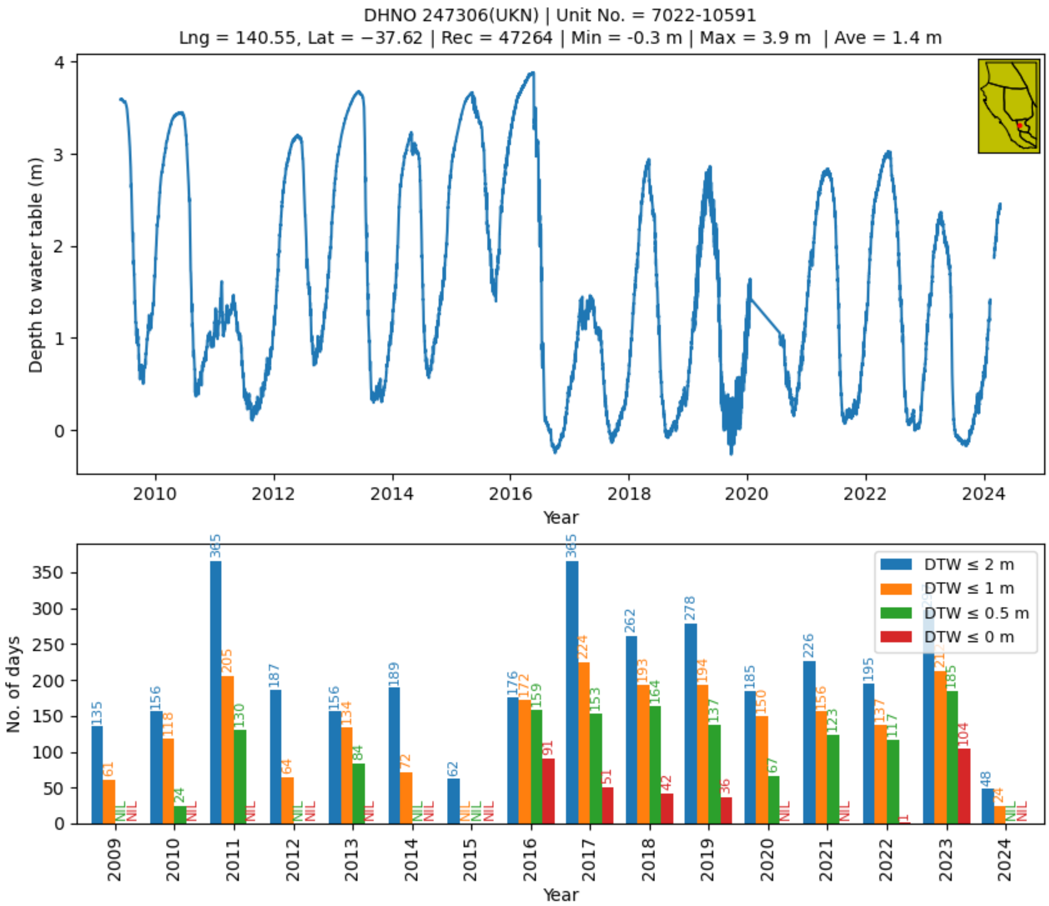

Figure 19 A sample of depth to water table time series and corresponding frequency bar chart.

Salinographs show the time variation in groundwater salinity, represented by the EC (electrical conductivity in units micro-siemens per cm; µS/cm). Salinographs were produced using Python scripts (257 plots in total for the various wells of the study area). Each plot also includes the drillhole number ("DHNO"), the longitude ("Lng") and latitude ("Lat") of the well, the number of records ("Rec"), and the location of the bore (shown in a small inset map). Figure 22 shows an example of a salinograph for one bore.

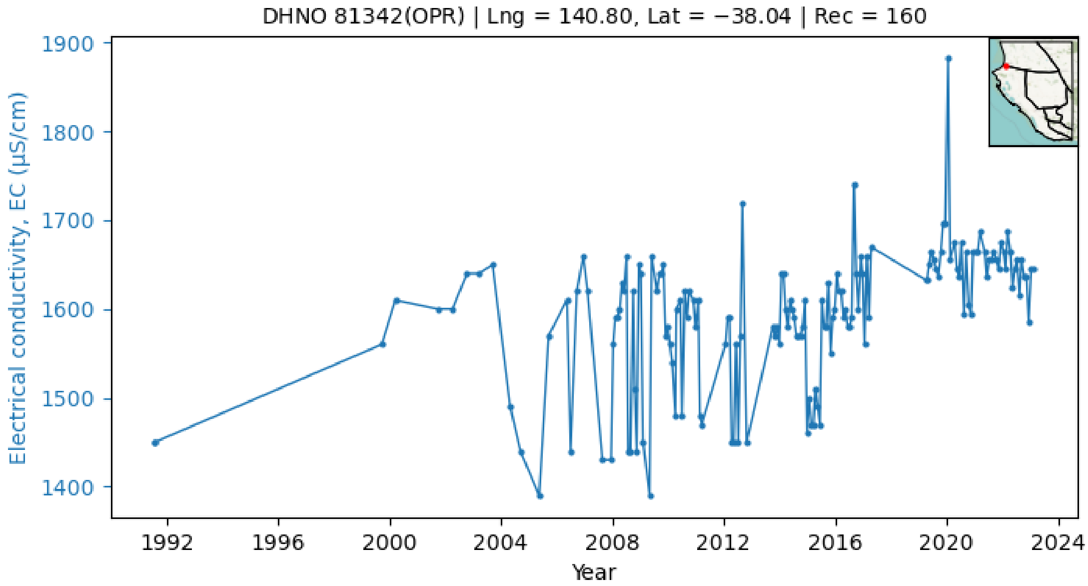

Figure 20 Example salinograph for a bore in the study area shown in the inset box.

Python scripts also generated a shapefile with two attribute fields, including drillhole number and the path to hydrographs and salinographs plots for each well. These plots are configured as pop-ups via hyperlinks that are clickable when viewing the attributes of the features (Figure 21).

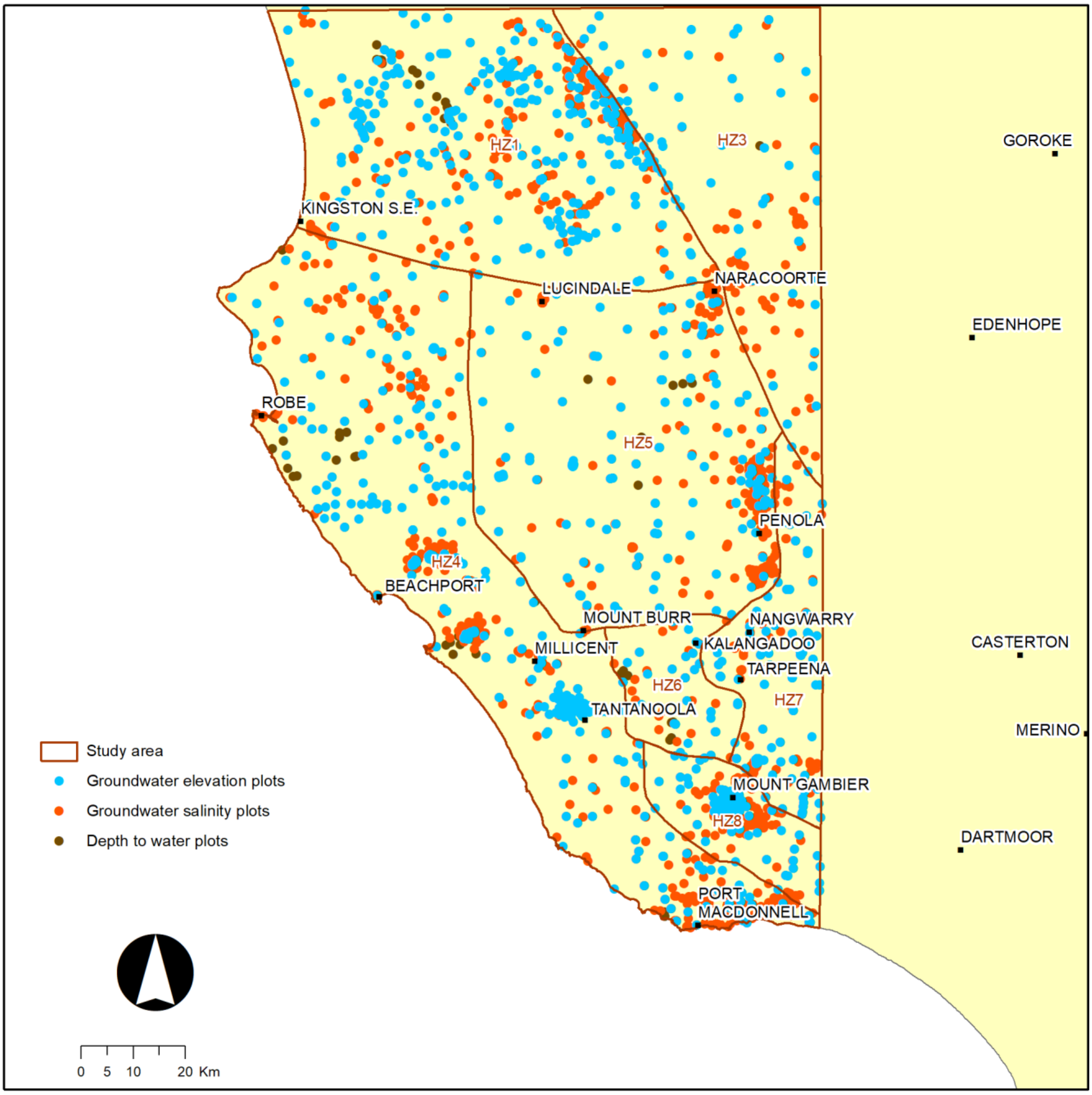

Figure 21 Locations of observation wells linked to times series plots of groundwater parameters in the study area.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\WaterLevelSalinityPlots\LSE-WaterConnect\Shapefile\Salinity.shp

9.2 Long-term groundwater level trends and decadal statistics

Bore depth to water table (DTW) data for the South East region were accessed from the National Groundwater Information System (NGIS) Version 1.7.1 (BOM, 2023). Outliers were removed based on bore mean levels ±3.1 standard deviations across the dataset. An annual DTW time series for each bore was constructed using bores with a minimum of two observations per year in at least 35 out of 51 years for the period 1971-2021. The minimum DTW for each year (annual recovered level) was used in the trend analysis. A two-period comparison method was used to analyse long-term trends across the time series (Fu et al., 2022). The two-period difference in means (minimum annual DTW) was used to determine statistical differences and magnitudes of change. Trend magnitudes were spatially interpolated across the region using Empirical Bayesian Kriging. Two extreme outliers were excluded based on an examination of a normal quantile-quantile plot of standard errors. The interpolated surface was estimated based on 294 samples with an overall root-mean-square error of 0.023 m/y. Mean predictions and standard error of predictions were exported as grids at a 1 km resolution. Standard error was higher in some areas, particularly in the north of the region where data were relatively sparse. Within the study area, prediction errors were relatively low. Figure 22 illustrates the long-term groundwater level trends in the study area.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\dtw_trend_50y\se_trend_beta_y35_minann_dtw_ebk.tif

file:\\J:\GISWorkspace\LimestoneCoast\Water\dtw_trend_50y\se_trend_beta_y35_minann_dtw_se_ebk.tif

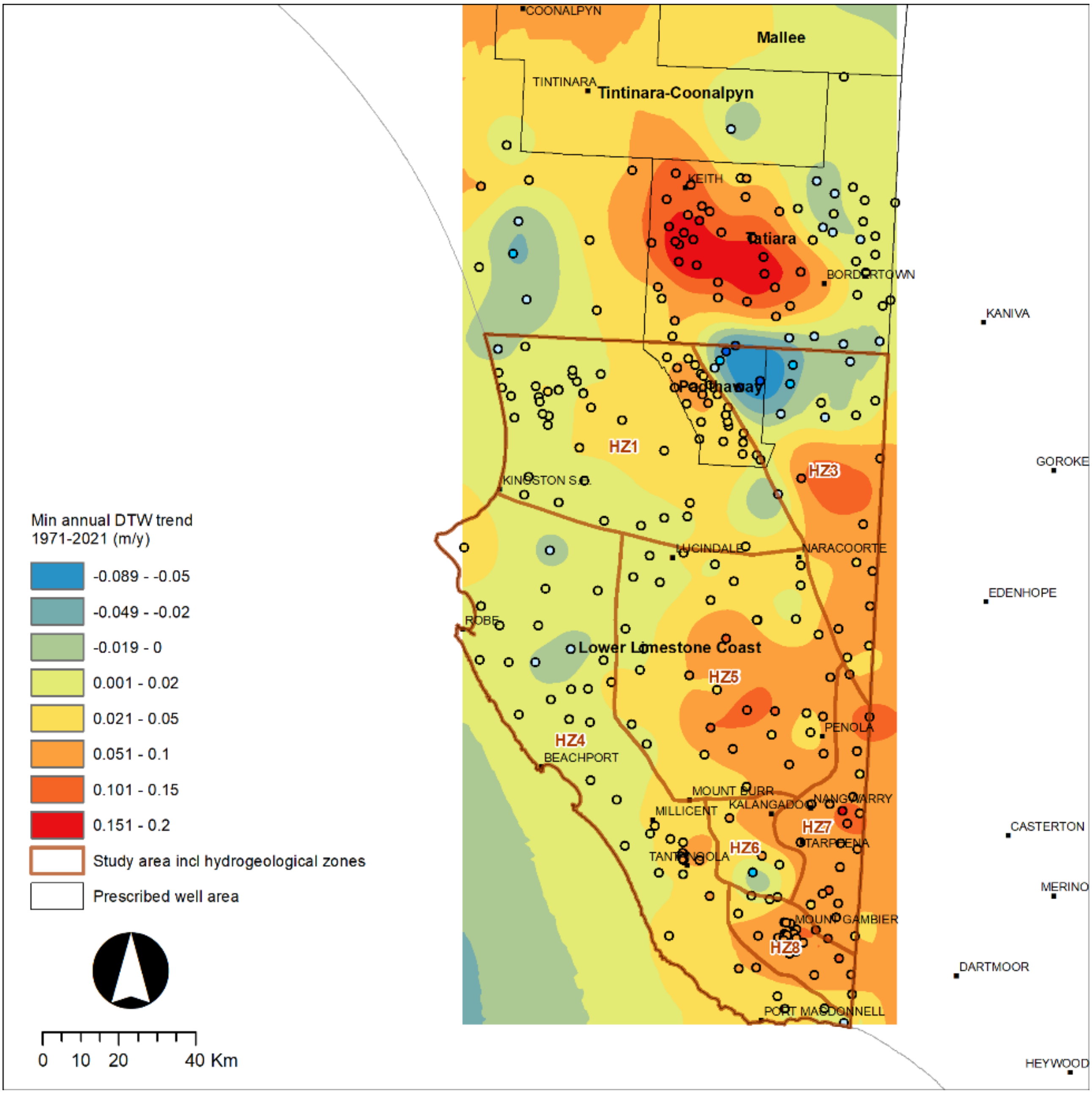

Figure 22 Long-term depth to water (DTW) trends (1971-2021) in the study area, positive DTW trend magnitudes indicate long-term groundwater level declines.

A decadal analysis of groundwater levels was conducted using data from the National Groundwater Information System (NGIS) Version 1.7.1 (BOM, 2023). Bore locations and water level observations were extracted for records within the study area. Outliers were removed based on bore mean levels ±3.1 standard deviations across the dataset. Bore coordinates and water level observations were spatially joined based on the ‘hydroid’ identifier. Two functions were defined to process the data, one to filter the data to only include records with a minimum number of observations per year, and a minimum number of years with those observations, and another to calculate percentile values for each decade, ensuring that each decade has a minimum number of records. Records were filtered to include only those with ≥2 observations per year and ≥10 years with those observations. Mean, minimum, and maximum annual groundwater levels for each bore were extracted and the median values for each decade were then calculated. The results were output as three shapefiles, one for each of the mean, minimum, and maximum annual, decadal median groundwater levels.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\commondata\swl_decadal_q50

9.3 Average annual groundwater recharge estimates

A grid of average annual groundwater recharge estimates for the study area were sourced that used a water balance method to estimate groundwater recharge, incorporating remotely sensed evapotranspiration data over a 29,000 km² area (Crosbie et al., 2015),. The raw recharge estimates were compared to 190 independent recharge values from the water table fluctuation method (2001–2010), revealing a 45 mm/year negative bias. A simple offset was applied to correct this bias. The corrected estimates were then compared to 99 historical recharge values, showing no significant difference but large residuals, indicating imprecision. The study also examined the relationship between water table depth, net recharge, and vegetation types, particularly under pastures and plantation forestry. The bias-corrected, 2001-2010 average annual recharge data are shown in Figure 23.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\Goyder_SE_Drainage_GIS_Tool_Package_671ff1\commondata\cmrset_10y_avg_recahrge_nobias.tif

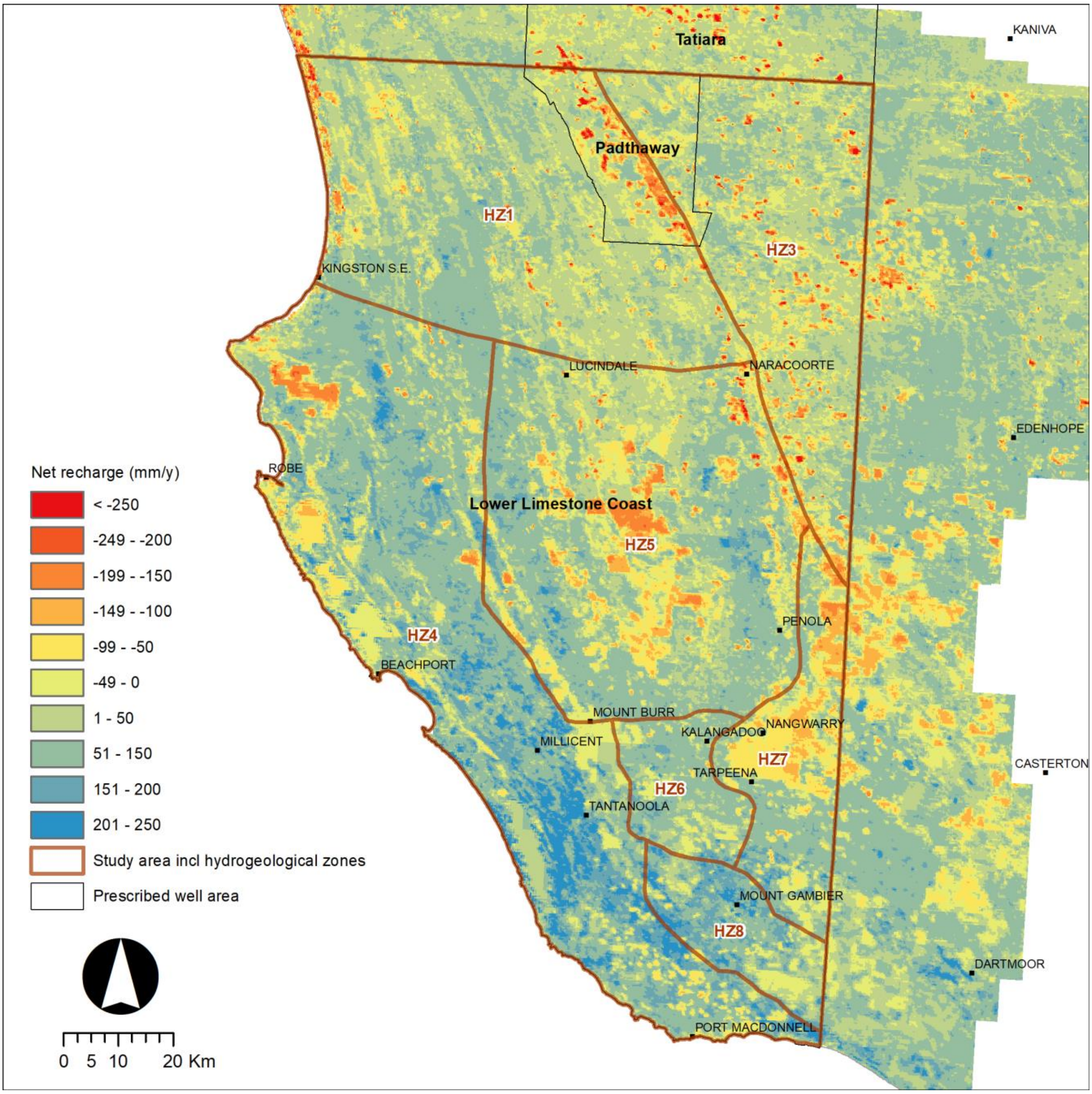

Figure 23 Bias-corrected net recharge estimates as an average of 2001–2010 (Crosbie et al., 2015).

10 Airbourne Electromagnetic Survey

10.1 Conductivity-depth profiles from airborne electromagnetic surveys

Task 4 aims to assess the risk of seawater intrusion to irrigated agriculture by developing site-specific cross-sectional models and through an airborne electromagnetic (AEM) survey aimed at imaging salinity variability within Limestone Coast aquifers (Davis et al., 2025). The former modelling efforts contribute to the broader objective of developing numerical modelling tools to investigate historical and future seawater intrusion scenarios under various land-use and hydrological conditions.

Task 4 has developed key steps for investigating coastal aquifer hydrology in the Limestone Coast region. These include:

- Developing regional-scale groundwater flow models and extracting cross-sectional models
- Refining cross-sectional models to simulate vertical variations in flow and salinity
- Incorporating offshore aquifer characteristics and extending models to account for offshore sediments
- Running preliminary models to estimate seawater extent in aquifers
- Refining models to reduce spatial area and improve accuracy.
- Comparing numerical models to AEM survey results.

A more complete explanation of data collection, interpretation and calibration of the AEM survey is provided in a companion report (Davis et al., 2025). Interpreted cross-sections of AEM results were plotted for transects along the coastline. In addition to the flight line transects, a point shapefile (conduct_depth_sect_pts.shp) representing the start location of each of these transects was written with hyperlinks to cross-sectional plots. Users can click on a point of interest and view the corresponding plot as a pop-up, e.g. Figure 24.

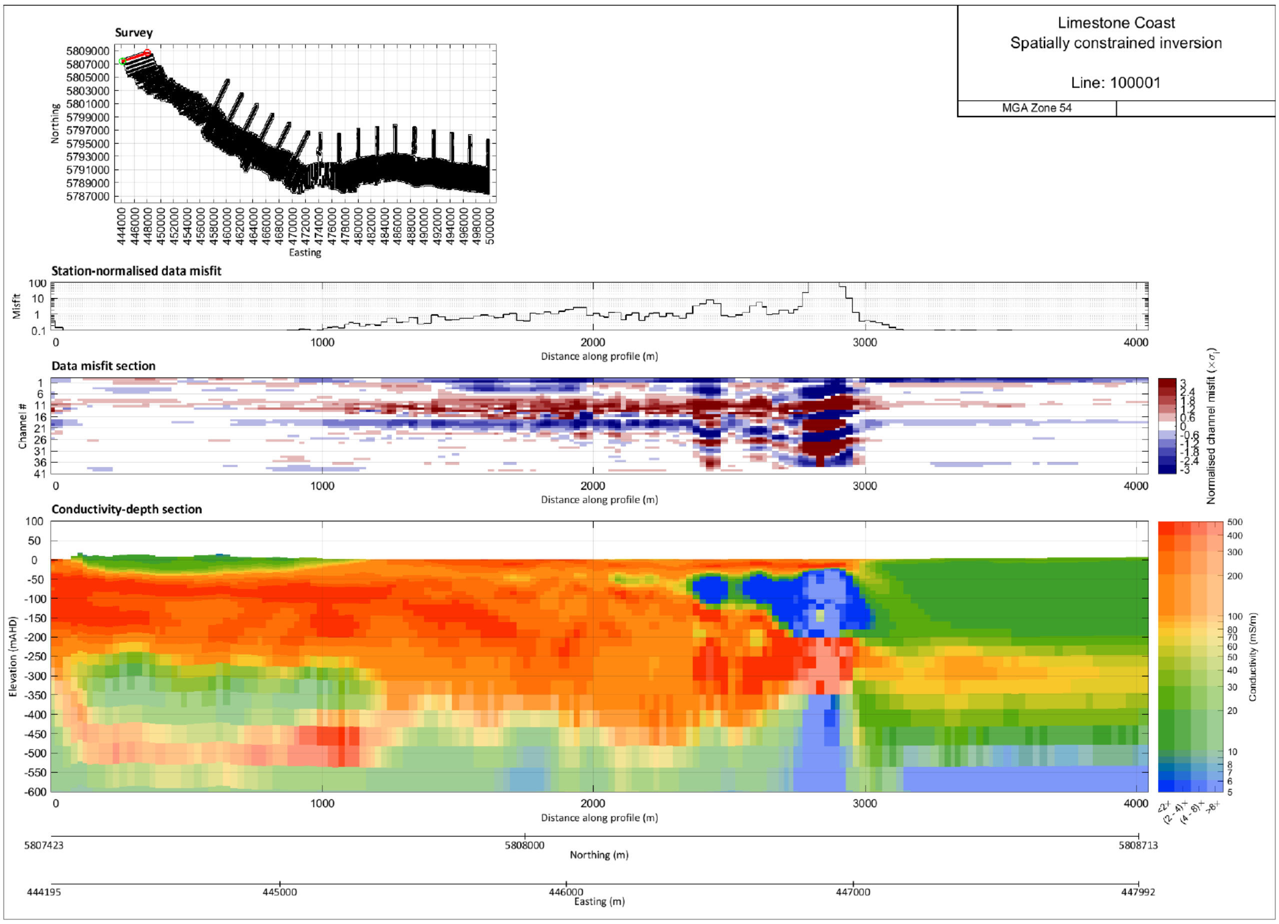

Figure 24 Conductivity-depth profile example for one transect interpreted from AEM data.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\ConductivityDepthSections

11 Soils

11.1 Flooding susceptibility

Classes are based on an interpretation of soil landscape map units which are classified according to the proportion of the area susceptible to flooding. This feature layer was sourced from the DEW Oracle Enterprise Geodatabase.

Data path:

file:\\V:\GISTools\LayerFiles\EGIS_PRD2020\LANDSCAPE.SALAD_Flooding.lyr

11.2 Recharge potential

Recharge potential (i.e. capacity for water to access groundwater systems via the soil) is estimated from soil profile water holding capacity, substrate porosity and rainfall. Classes are based on an interpretation of soil landscape map units, within which recharge potential can vary significantly. Each map unit is classified according to various proportions of high and moderate recharge potential, estimated from field observations. This feature layer was sourced from the DEW Oracle Enterprise Geodatabase.

Data path:

file:\\V:\GISTools\LayerFiles\EGIS_PRD2020\LANDSCAPE.SALAD_Recharge.lyr

11.3 Soil group

The map depicts the distribution of up to 15 generalised soil groups and is based on an interpretation of soil landscape units which invariably comprise several soils. The most commonly occurring soil group in each landscape is delineated on this map. This feature layer was sourced from the DEW Oracle Enterprise Geodatabase.

Data path:

file:\\V:\GISTools\LayerFiles\EGIS_PRD2020\LANDSCAPE.SALAD_Soil_Group.lyr

11.4 Subgroup soil

The map depicts the distribution of up to 61soils plus three miscellaneous categories, which are representative of the range occurring across the agricultural districts of South Australia. This feature layer was sourced from the DEW Oracle Enterprise Geodatabase.

Data path:

file:\\V:\GISTools\LayerFiles\EGIS_PRD2020\LANDSCAPE.SALAD_Soil_Subgroup.lyr

11.5 Surface soil texture

Classes are based on an interpretation of soil landscape map units which may have components with different surface textures. Map units are classified according to their most common surface texture category. Where this accounts for less than 60% of the map unit, a qualifier is used to indicate whether the majority of other soils have coarser or finer textured surfaces. This feature layer was sourced from the DEW Oracle Enterprise Geodatabase.

Data path:

file:\\V:\GISTools\LayerFiles\EGIS_PRD2020\LANDSCAPE.SALAD_Soil_Texture.lyr

11.6 Waterlogging susceptibility

Classes are based on an interpretation of soil landscape map units which may have variable waterlogging characteristics. Map units are classified according to the most susceptible component of the landscape, provided that it accounts for at least 30% of the area. An additional class identifies land where limited areas are susceptible to waterlogging. This feature layer was sourced from the DEW Oracle Enterprise Geodatabase.

Data path:

file:\\V:\GISTools\LayerFiles\EGIS_PRD2020\LANDSCAPE.SALAD_Waterlogging.lyr

12 Conservation areas and Native Title

12.1 Conservation

The boundaries outlined in the 'CONSERVATION.Npwsa.Reserves' dataset mark the land in South Australia dedicated to conservation. These protected areas preserve diverse fauna and flora species, serving as a crucial biological reservoir. The dataset provides the accurate legal boundaries of reserves established under key Acts, including the National Parks and Wildlife Act and the Wilderness Protection Act, within South Australia.

The 'CONSERVATION.Ramsar.Reserves' dataset outlines the boundaries of six internationally significant wetland areas in South Australia, as listed under the Ramsar Convention. These protected areas, including Bool Lagoon and the Coorong, are recognized for their global importance and are safeguarded by the Convention to conserve their unique ecosystems. These datasets were sourced from the DEW Oracle Enterprise Geodatabase.

Data path:

file:\\V:\GISTools\LayerFiles\EGIS_PRD2020

12.2 Native Title

Native Title Determination areas (ADMIN.NativeTitleDeterminations) and claims (ADMIN.NativeTitleClaimsBnd) boundaries represent land subject to native title claim or court determination of native title rights and interests on the land. These boundaries were sourced from the DEW Oracle Enterprise Geodatabase.

Data path:

file:\\V:\GISTools\LayerFiles\EGIS_PRD2020

13 Aerial imagery and digital elevation models

13.1 Aerial imagery

An aerial image mosaic dataset at 25 cm resolution captured in March 2024 covering the study area across the South East region is included. This dataset is pathed from the DEW image server and is not duplicated in the project directory due file size limitations.

Data path:

file:\\V:\Samba_ImageServices\Ortho_Imagery\Aerial_Ortho_Mosaics\SouthEastNRM\2024_SouthEast_25cm\GDA2020_LCC\SouthEast_15-31Mar2024_25cm_LCC.ecw

13.2 Digital elevation models

A digital elevation model (DEM) at 2 m resolution captured in 2024 covering the study area across the South East region is included. Another DEM at 1 m resolution captured in 2018 covering the coastal region of the study area is also included. These datasets are pathed from the DEW image server and are not duplicated in the project directory due file size limitations.

Data path:

file:\\V:\Samba_ImageServices\Digital_Elevation_Models\SouthEast_NRM\2024_SouthEast_2m\GDA2020_MGA54\SouthEast_15-31Mar2024_DSM_2m_MGA54.tif

file:\\V:\Samba_ImageServices\Digital_Elevation_Models\SouthEast_NRM\2018_SouthEastCoastalLiDAR_1m\MGA\SouthEastCoastalLiDAR_22May-24Aug2018_DEM_1m_MGA54.tif

14 Updating data, scripts and outputs

Data held in the project directory can be updated by either editing directly in ArcGIS, or by adding a new data source and redirecting the project file (ArcMap or ArcPro) to the new data source. The ArcMap (.mxd) and ArcPro (.aprx) GESWAT project files are set to READ ONLY. The user needs to copy and rename their working project file (.mxd or .aprx) to save changes. For optimal loading and drawing efficiency, the working file should be located within the project directory.

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water

Python scripts written and used by the Task 5 project team to process data are marked up and saved in a separate folder for ease of reference. To update data sources and generate new outputs, these scripts can be rerun. To rerun scripts, relevant directories will require updating and the user will need to ensure the required Python packages and libraries are installed (e.g. via pip or Conda install procedures). The scripts were written in the Python 3 environment (Van Rossum and Drake, 2009).

Data path:

file:\\J:\GISWorkspace\LimestoneCoast\Water\python_scripts

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