Port Phillip Bay Coastal Hazard Assessment

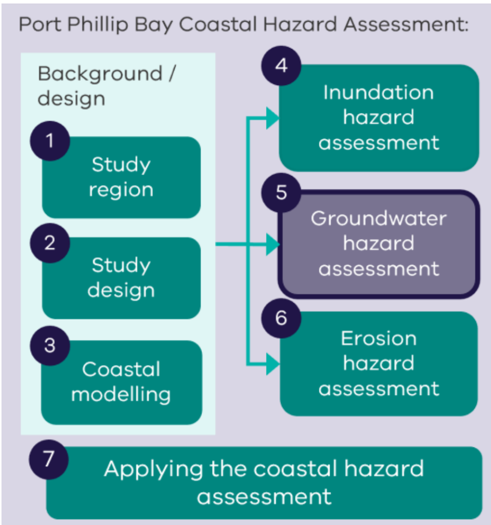
Summary #5: Groundwater hazard assessment

(Photo: Alluvium)

Overview

The Port Phillip Bay Coastal Hazard Assessment (PPBCHA) looks at likely coastal hazard impacts around Port Phillip Bay. This includes data analysis and modelling for a range of future climate change scenarios. Results will help land managers and the community to consider climate change in their future planning.

This summary provides an overview of the groundwater hazard assessment. This is the fifth in a series of summaries providing an overview of the PPBCHA technical work



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Groundwater is important for ecosystems, waterways, and lakes. It is also used for agriculture, industry and home use.

Coastal processes and sea level rise can impact on groundwater depth and salinity. These changes can impact the many values and uses of groundwater.

What is groundwater?

A large amount of water flows beneath the Earth's surface. Known as groundwater, it fills and flows through the spaces between soils and rocks. Groundwater plays an important part in our natural water cycle. Over time, water from rain and rivers moves down through the ground to be stored between soils, sands and rocks. Groundwater can also come to the surface again through springs or near the coast. Like estuaries, tides and waves influence groundwater.

Although an unseen resource, the groundwater of the Port Phillip Bay region provides many critical services and functions. These include:

- Baseflow to rivers, streams and swamps.
- Environmental water flows to ecological systems.
- Water sources to support commercial industries and agricultural production.
- Irrigation for gardens, parks and golf courses.
- Cultural and heritage features such as mineral springs.

With many values and uses, it is important that we conserve and properly manage groundwater systems.

Altona coastal park (Photo: Alluvium)

Some key terms useful for understanding groundwater are defined below.

Key terms	
Watertable	A "boundary" or interface between water-saturated ground and unsaturated ground. Often beneath the ground surface, the watertable is located at the top of the saturated zone, rising and falling based on the groundwater conditions.
Aquifer	Underground permeable (porous) layers of soil and rock that contain useable quantities of groundwater. Aquifers lie beneath all parts of Victoria.
Recharge	Water from rain and snow or rivers and lakes that moves downward from the surface and is added to an aquifer
Discharge	Where groundwater becomes surface water and flows out from underground aquifers. This can occur naturally in lakes, streams, springs, wetlands and oceans. People can also discharge groundwater through bores and pumping.
Permeable	Permeable surfaces or materials have spaces where water can flow through. The speed groundwater moves depends on the size and connectivity of these spaces. Permeable rocks include sands, gravels and limestone.
Impermeable	Impermeable surfaces or materials do not have spaces or only have small, disconnected spaces, limiting the flow of water. Impermeable rocks include slate, marble and granite.
Saline intrusion	The long term / permanent movement of sea water (saltwater) into freshwater areas, including groundwater aquifers, upstream waterways or water bodies. This means higher salt levels in previously freshwater areas.
Groundwater bore	A hole, well or excavation that is used to extract groundwater from underground aquifers.
Salt wedge	A layer of salt water that sits below a layer of freshwater, due to difference in water density. It can limit mixing between the fresh and salt water.
Response time	The time it takes for groundwater systems to adjust and stabilise to new conditions. Changing conditions could include in rainfall, evaporation, land use, extraction or sea level.

Braeside Park, Edithvale (Source: Alluvium)

Understanding groundwater

Groundwater systems are hugely complex. Occurring almost everywhere below the surface, they combine many different environmental processes.

To understand more about how groundwater systems work in our coastal areas, we first need to explain several key aspects of groundwater processes. Key terms are defined above.

Geology and groundwater

Local geology influences movement of water to and from the ground surface, and within groundwater systems. Water can flow through pores, spaces or fractures in soils and rocks. Some materials are more porous (bigger spaces and gaps) which make them more **permeable** to water.

Natural events, such as rainfall, **recharge aquifers** as water moves downwards from the surface due to gravity. Water also moves within aquifers. Groundwater flows generally move much slower than surface water flows. Areas of **impermeable** rocks above and below aquifers can limit water movement. These rocks can 'confine' an aquifer or create multiple aquifers at different depths.

Groundwater recharge and discharge

The amount of groundwater recharge is influenced by changes in rainfall and evaporation. Seawater can also be drawn into aquifers. Groundwater **discharge** can occur naturally - in lakes, streams, springs and wetlands, and in coastal areas, near the sea. Humans also generate outflows by pumping groundwater in **bores**.

Like rivers, gravity influences the movement of groundwater from high to low elevation areas. Coastal sea level defines the discharge boundary for groundwater systems across a region. Changes to sea level may change the movement of groundwater.

Watertable depths

Watertable depths vary across a region. They are dynamic and can rise and fall at different times. Seasonal and annual weather trends, tides, pressure, as well as land and water uses can cause watertable depths to change.

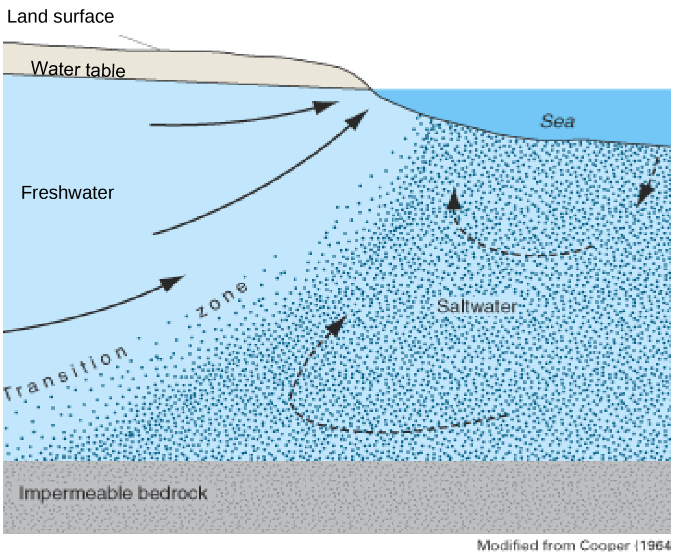
Groundwater **response times** are important for understanding how groundwater processes may change due to sea level rise.

Groundwater interactions on the coast

Near our coasts, interactions between surface water, seawater and groundwater are particularly complex. Groundwater is often discharging to the sea, while seawater sometimes recharges groundwater aquifers.

Freshwater and saltwater have different salinity levels (salt concentrations). Salinity influences the density of water, and interactions and mixing between fresh and salt water. Under natural conditions, fresh groundwater moves towards the sea in coastal areas. Discharging fresh groundwater tends to form a **salt wedge** with seawater along the coast. Saltwater is denser (“heavier”) and sits below fresher, less dense (“lighter”) water.

The amount of saltwater generally reduces with distance from the coast. The salt wedge will likely move further inland with rising sea levels or due to decreasing groundwater discharges.



Saltwater-freshwater interface (from Fetter, 2001).

Saltwater (saline) intrusion can also occur when coastal flooding (storm surges) or high tides flood low elevation areas. This can result in recharging aquifers with more saline water.

Groundwater around Port Phillip Bay

To assess some of the current and future groundwater hazards, we first need to understand more about the groundwater systems around Port Phillip Bay.

Watertable elevation

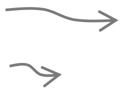
Just like water running off ground surfaces, groundwater flows downwards due to gravity. Port Phillip Bay acts as a groundwater "sink" with flows moving toward the bay. However, the total volumes of groundwater discharging to the bay remain unknown.

We use a watertable elevation model to map groundwater levels and flow directions. Many depth measurements from bores and ground surface elevations along with numerous other datasets help create this map of water table heights.

Watertable heights are measured from sea level and are beneath the ground surface. The model shows the complexity of groundwater flow patterns, particularly at a regional scale. Sea level influences flow patterns.

Reading the map

Arrows show groundwater flow paths from recharge areas (where water fills from the surface) to discharge areas (mostly the Bay). Known as hydraulic gradients, they represent the 'slope' of the watertable.

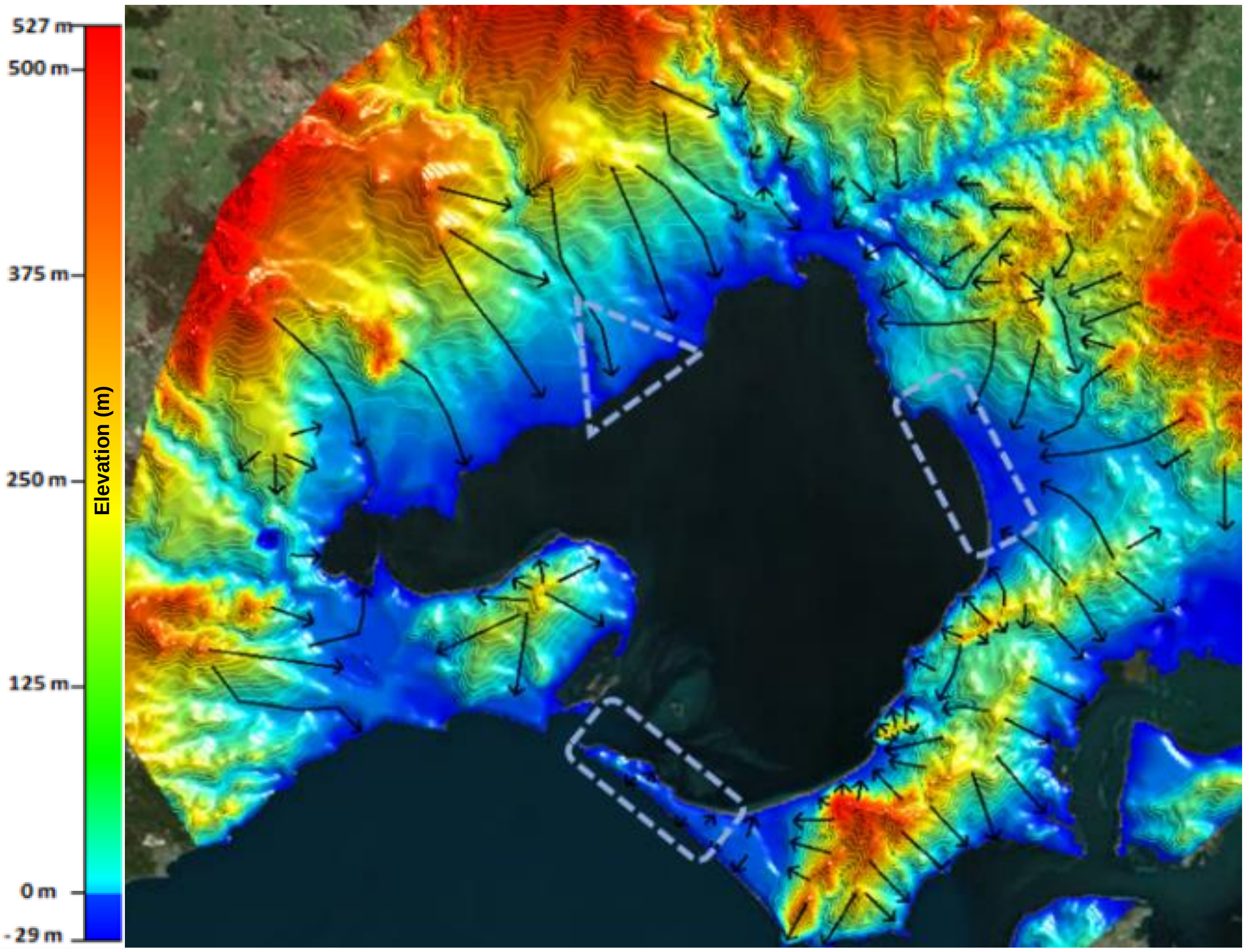


Long arrows show a flatter slope (low gradient), with slower moving flows.
Short arrows are a steep slope, with faster flows.

A flatter gradient near the coast means sea level rises impacts on watertable depth over a larger area. A smaller vertical rise in sea level affects a longer distance inland.

The slope, together with geology can influence how long groundwater systems take to respond to changes (response time). These changes could include sea level, rainfall, evaporation, land use or extractions.

Where hydraulic gradients are low (flat) and the local geology is highly permeable, the system will have shorter response times.



Watertable elevation (as colour) and generalised flow paths (as arrows) – dashed polygons focus areas for detailed analysis (Source: CSIRO)

Salinity

Most shallow groundwater is saline (salty) to some degree. Salinity of water influences what it can be used for. Salinity is measured at the water table and in milligrams of salt per litre of water (mg/l).

In the Port Phillip Bay region, groundwater salinity varies from 500 mg/l to more than 35,000 mg/l. The western half of the Bay has higher salinities. This includes:

- The Bellarine Peninsula, which is quite shallow and relatively saline
- Some areas north of Corio Bay, near to Point Wilson and surrounds are relatively saline
- Areas around Altona, Williamstown and Port Melbourne are relatively saline.

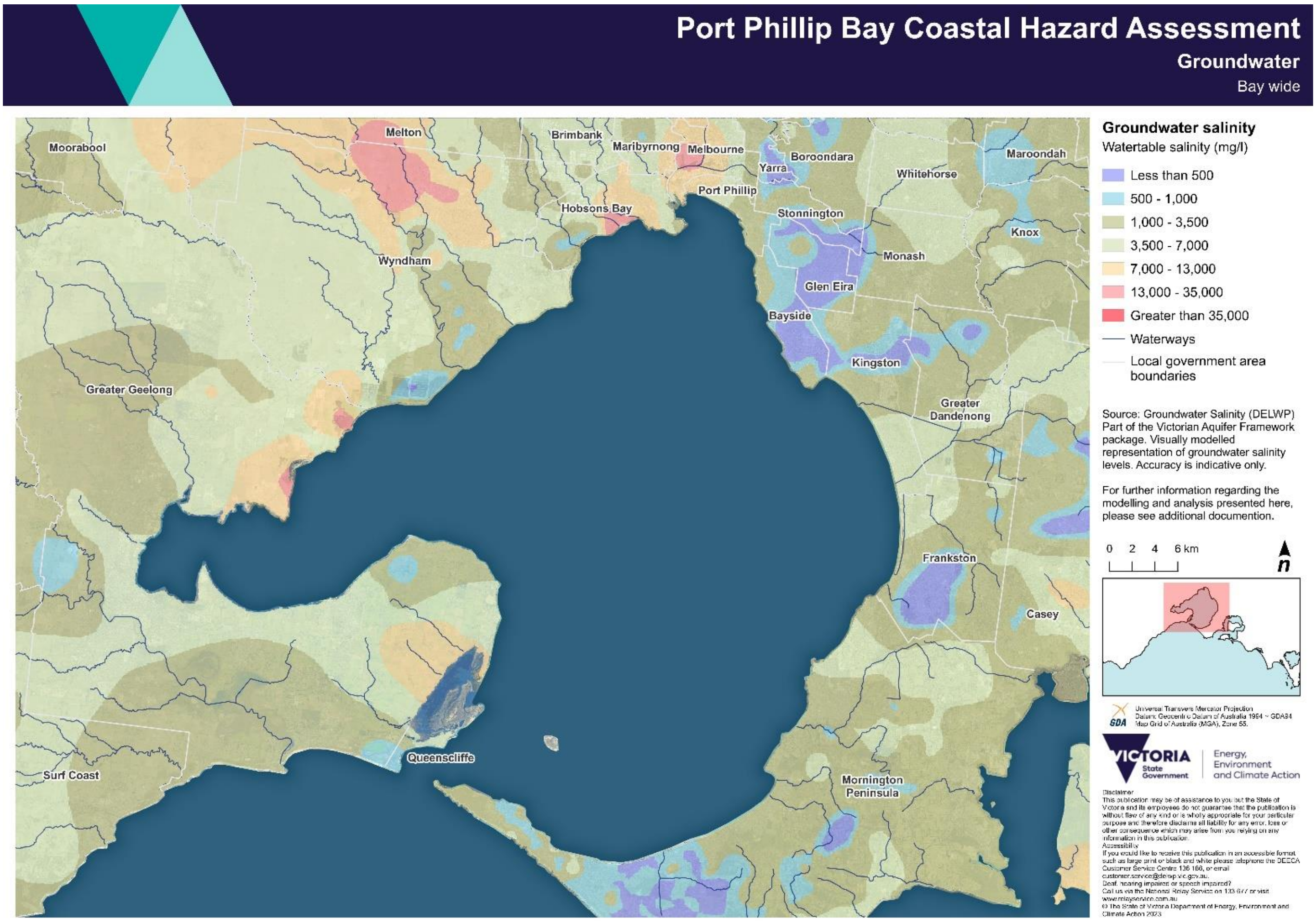
Other areas around the bay have fresher groundwater, meaning it can be readily used for commercial and domestic irrigation purposes.

Typical salinity values and uses

Salinity (mg/L)	Description and use
Less than 500	Fresh water for drinking and irrigation
500 to 1,000	Marginal water for some irrigation. Impacts on freshwater ecosystems
1,000 to 3,500	Brackish, suitable only for certain irrigation crops, useful for stock
3,500 to 7,000	Saline, useful for most livestock
7,000 to 13,000	Very saline, limited use, only for certain livestock
13,000 to 35,000	
More than 35,000	Brine or very saline marine water, some mining and industrial uses

Groundwater extraction is common in the Werribee Delta, the southeastern bayside suburbs and Nepean Peninsula. The water table depths in these areas are generally less than five metres below the surface and the water quality is relatively fresh.

The figure below maps watertable salinity across the Port Phillip Bay Region.



Watertable salinity in the Port Phillip Bay region (Source: DEECA). Salinity data layers obtained from state's Victorian Aquifer Framework Package by Centre for eResearch and Digital Innovation (CeRDI).

What are groundwater hazards?

Groundwater systems experience change in watertable depths and salinity in response to many factors. When these changes impact on our use of groundwater or cause inundation (flooding) of land, these are considered hazards.

Watertable depths and groundwater salinity provide a measure of potential groundwater hazards. A watertable less than two metres below the natural surface in urban areas is usually considered a hazard. Watertable depths are predicted to shift due to changes in groundwater recharge (inflows) and discharge (outflows) rates.

Groundwater hazards can become apparent in many ways. Increased salinity and rising groundwater can impact on:

- Drinking and domestic water supply
- Irrigation, agriculture and other industry water supply
- Underground and near surface infrastructure and assets such as building foundations, pipes and services
- Coastal ecosystems and habitats such as wetlands and marshes
- Previously fresh-water environments
- Groundwater-dependent ecosystems

To understand groundwater hazards in the regions around Port Phillip Bay, we looked at:

- changing watertable depth/levels
- shallow groundwater becoming surface water
- changing groundwater quality (such as salinity).

These changes may increase coastal erosion hazards (through changes to groundwater discharge) and inundation hazards (due to shallower watertables).

Groundwater dynamics in a changing climate

Climate change along with changing land uses and groundwater management result in changes to the groundwater systems around the Bay. These can impact on services that groundwater provides.

They can include:

Natural changes

- Reduced rainfall and higher temperatures (and evaporation) - less water is available to recharge groundwater systems.
- Sea level rise – more saline water enters groundwater systems at the coast causing groundwater levels to rise and become surface water.

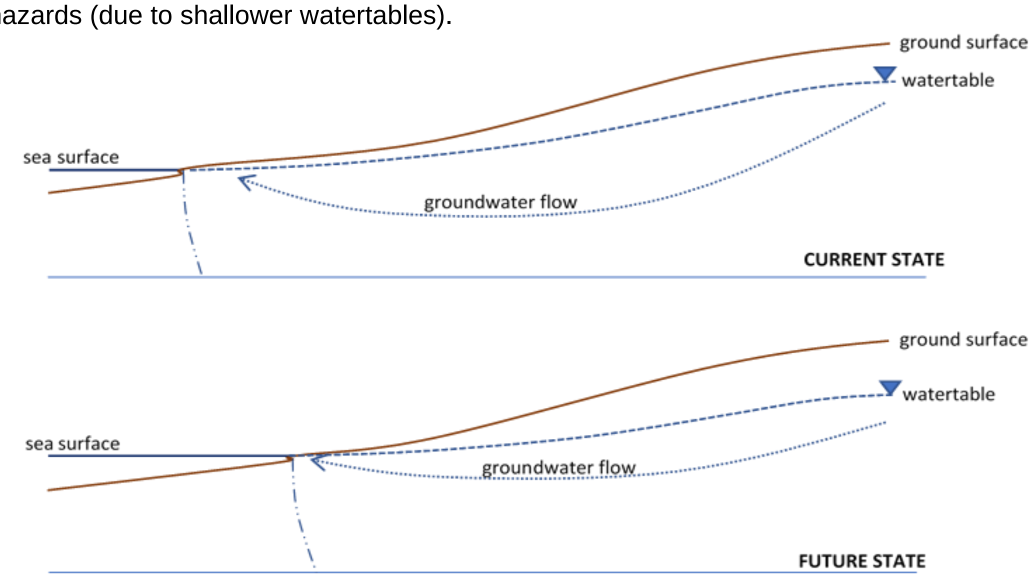
Human induced changes

- Increased urbanisation - water cannot flow into and through the ground to recharge groundwater levels and instead flows as surface water
- Increased use of groundwater – water is taken quicker than it is recharged, meaning an overall decline in groundwater levels

Sea level rise changing the watertable

As sea levels rise, watertables in discharge zones at the coast rise. This may lower the watertable slope (hydraulic gradient), reducing discharge rates of fresher groundwater in coastal areas.

This can alter how the seawater and groundwater interface behaves. This interface may move further inland, also shifting saline conditions further inland.



Sea level rise impacts on the watertable (Source: CSIRO)

Modelling groundwater hazards

General trends in groundwater movement and processes are understood. However, there are data and knowledge gaps for groundwater processes in Port Phillip Bay. Understanding of the impacts of climate change and rising sea levels on groundwater is also limited.

We used conceptual modelling as the most appropriate way to explore groundwater systems in the region. We developed a method to approximate how changing conditions, including sea level rise, might affect watertable depths and the groundwater system.

Our models and assessment were based on previous research, data and information, including:

- Previous visualisations, such as the Visualising Victoria's Groundwater (VVG) portal
- Monitoring data from groundwater bores
- Geological surveys
- Studies undertaken for major infrastructure projects such as the Westgate Tunnel Project and the Level Crossing Removal Project.
- Other stakeholder databases (e.g. Melbourne Water, Port of Melbourne, Southern Rural Water)

Design conditions

Decreasing rainfalls and increasing evaporation may affect groundwater systems. However, rising sea levels are considered to have a greater effect on groundwater at and around the Bay. We focussed on this for our groundwater hazard assessment.

Our study centred on the impact of sea levels on depth to watertable. The assessment looked to:

- Understand existing conditions for whole of the Bay
- Explore where the depth to watertable is likely to change due to sea level rise.

The design events for our groundwater hazard modelling include:

- multiple planning horizons (sea level rise scenarios): present-day (0.0 m), 0.2 m, 0.5 m, 0.8 m, 1.1 m, and 1.4 m

Modelling approach

We developed conceptual (simple) models of groundwater depth and salinity. These covered:

- The entire Bay
- Three focus regions:
  - The Werribee region
  - The Mentone to Frankston sand belt
  - The Nepean Peninsula

The three focus areas have high groundwater use and good data availability. This allows more detailed analysis.

Point Nepean (Photo: Alluvium)

Modelling outputs

Our groundwater hazard assessment provides us with estimates of watertable depths for each sea level rise scenario. We can use these results to examine:

- What groundwater hazards might look like for a single sea level rise scenario, including shallow groundwater areas
- Where and how much the watertable depths change between different sea level rise scenarios

Mapping groundwater hazards

Groundwater hazard results for each design event are arranged into grids. This allows us to map groundwater hazards (watertable depths) and visualise where hazards are located, both now and in the future.

For the PPBCHA, groundwater depths have been classified as:

Watertable depth	Description
Sea	Surface water
Shallow	Up to 2 metres deep
Intermediate	Between 2 and 5 metres deep
Deep	Greater than 2 metres deep

These maps show the watertable depth as colour-coded depth bands. We show shallow watertables (high hazard) to deeper watertables (low hazard).

We can think of the shallow watertables areas as “groundwater hazard extents”.

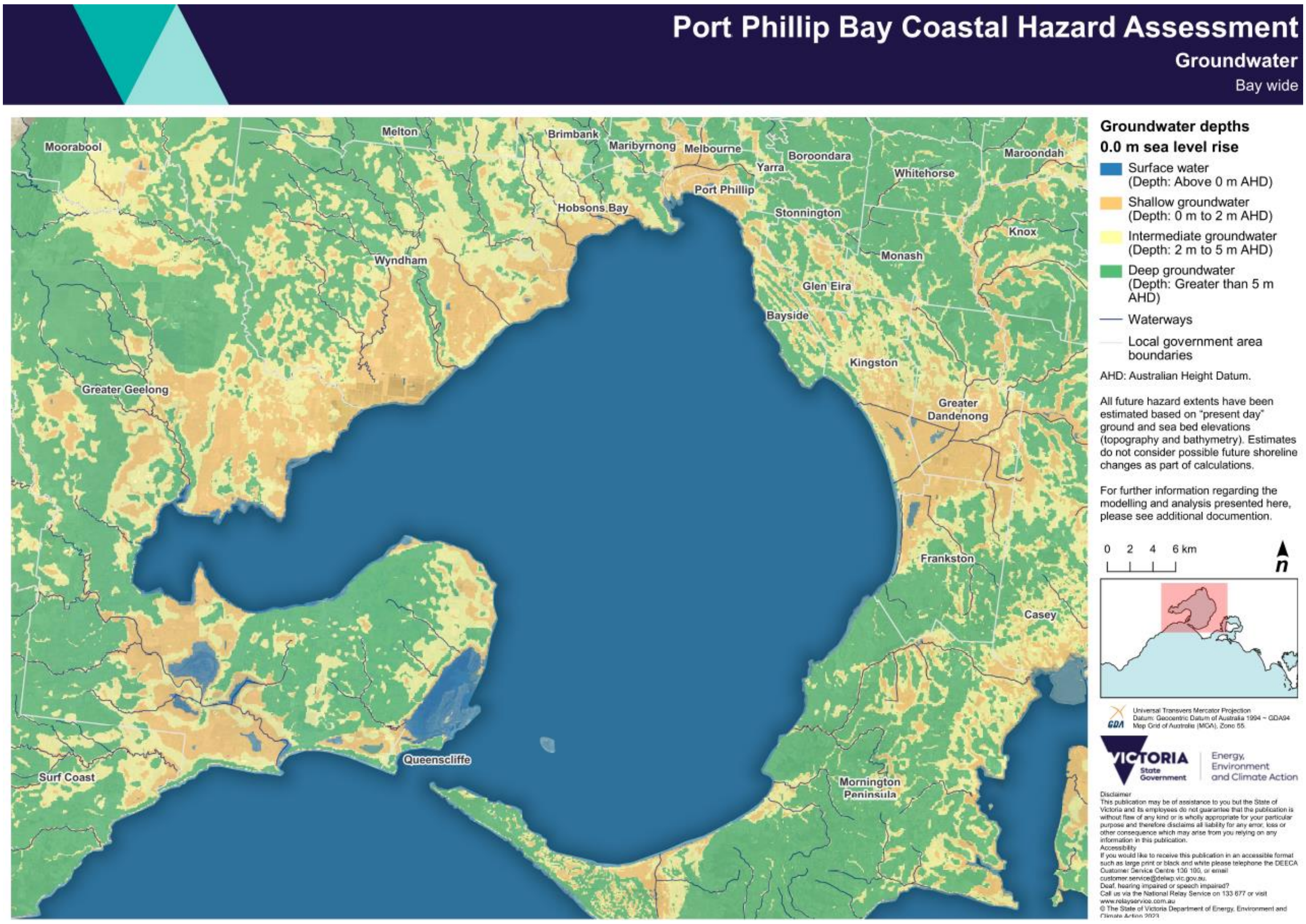
The **Hazard mapping supplement** provides more information on the coastal hazard maps and how to interpret them.

Our groundwater hazard maps have the following convention:

Depth below the ground surface	Colour
Above 0 m (surface water)	
Ground surface to 2 m	
2 m and 5 m	
Deeper than 5m	

Mapping also helps us explore **vulnerability** and **risk.** We do this by considering the values, uses and infrastructure located in hazard areas. Vulnerability and risk can differ for different hazard types, weather events, conditions and over time.

Improved understanding of hazard processes from these mapped results allows better management decisions.



Present day (0m SLR) groundwater depths

Using mapped extents

Mapped model results help us understand groundwater conditions along the Port Phillip Bay coastline.

This allows us to examine how coastal areas might respond if these conditions were to occur. By mapping results, we can compare extents of different sea level rise scenarios.

We can also explore how hazard extents vary for different hazard types (groundwater compared to inundation and erosion). We use mapping to assist us in identifying focus areas for adaptation.

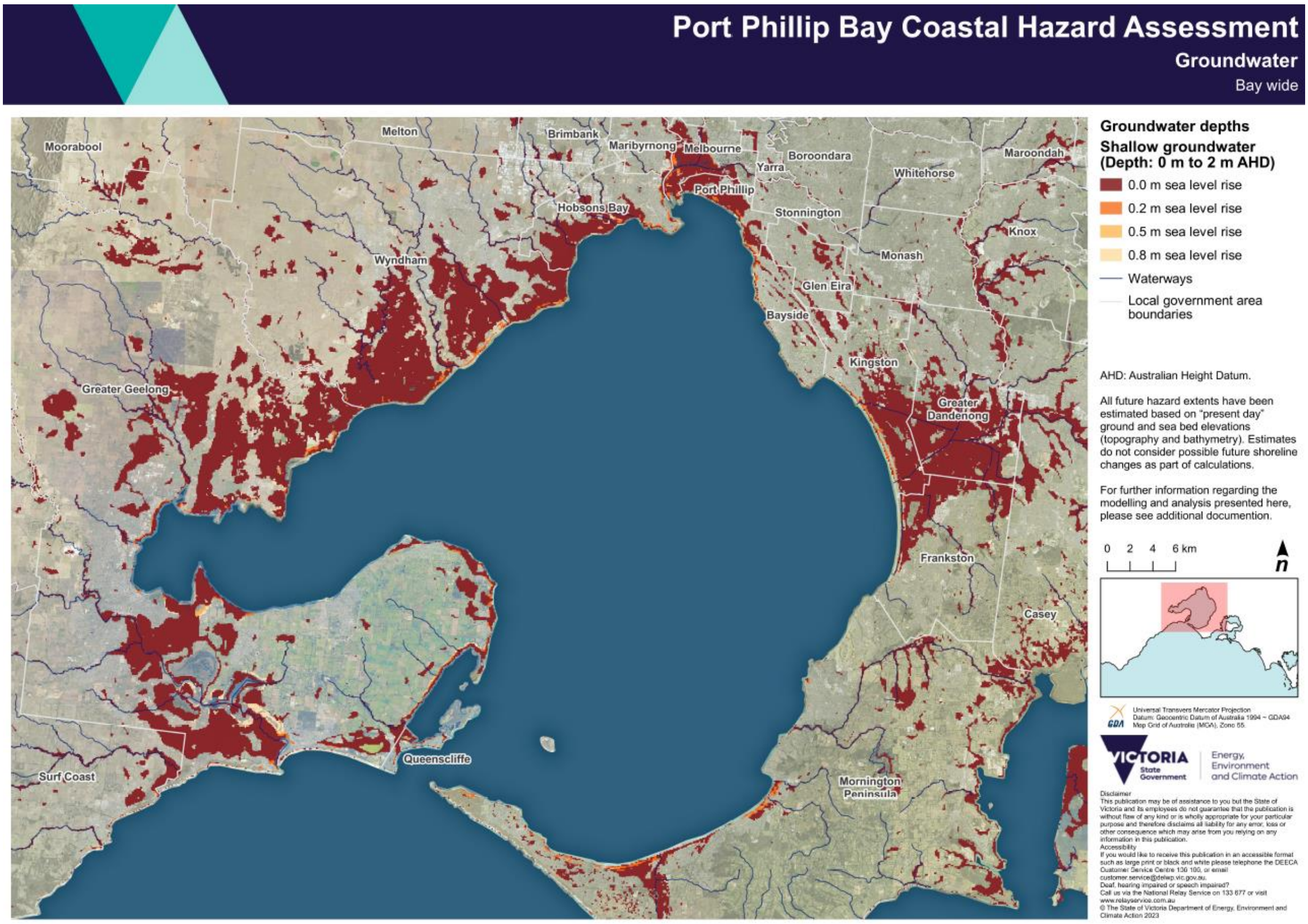
Several map sets accompany this summary, with both Bay-wide and more detailed maps. These represent a selection of scenarios considered for groundwater conditions.

Understanding potential hazard areas provides a starting point for hazard adaptation planning. Knowing the locations where groundwater might become a hazard allows us to prioritise these areas for further analyses.

We know that close to the Bay's shoreline watertables are very shallow (less than 2 metres below ground surface). This means groundwater processes here are likely to be influenced by rising sea levels.

Our maps show groundwater depths around the whole bay – for present day and each sea level scenario. We already have significant areas groundwater in less than 2 metres from the surface. These shallow areas are projected to increase as sea levels rise.

What do the results tell us?



Shallow groundwater depths (0 m to 2 m) by sea level rise scenario - Bay wide (Source: DEECA)

Bay wide analysis

We studied the groundwater depths and increasing shallow areas for the entire Bay and for three focus areas.

Bonbeach Beach (Photo: Alluvium)

Projected future groundwater hazards and considerations for Port Phillip Bay and some of its regions

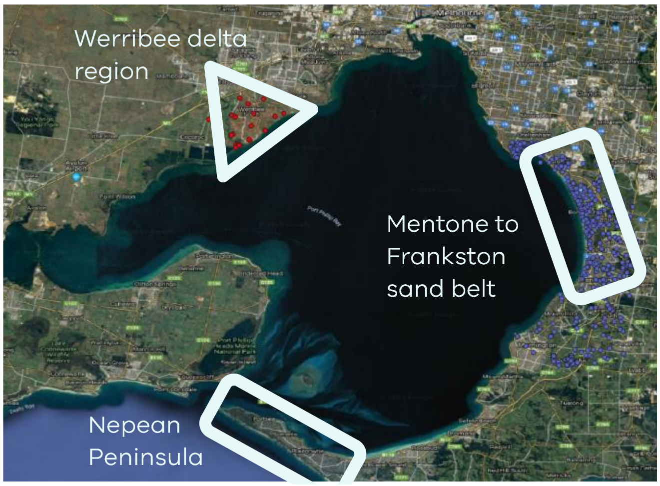
- Decreasing rainfalls and increasing evaporation may lower watertable depths over the next century.
- Rising sea levels are predicted to have a greater impact than changes in rainfalls for the region's groundwater.
- Rising sea levels will see the seawater-groundwater interface move further inland in some areas. This will likely take decades.
- Changes to shallow groundwater are mainly along and near to the Bay's coastlines.
- Northern areas of the Bay, Geelong, the Bellarine Peninsula and to the south of Safety Beach to Point Nepean are increasingly impacted by 0.2 m.
- Groundwater hazards (shallow areas) extend further inland as sea levels rises more significantly (1.1 m and 1.4 m scenarios). These increasing hazard areas include Queenscliff, Salt Lake near St Leonards, Moolap, Avalon, the Cheetham Wetlands and Altona coastal park.
- Many groundwater-dependent ecosystems close to the coast will be increasingly affected by groundwater hazards.
- The Bay's western shoreline – including Cheetham Wetlands, Altona Coastal Park, and Jawbone Flora and Fauna Reserve, as well as the Bellarine Peninsula Ramsar site may be increasingly impacted.
- Rising watertable hazards will also impact on built assets in the coastal areas. However, this is occurring over several decades, a rate at which allows us to plan towards their longer term management.
- We will likely need to revise how domestic and commercial groundwater usage is managed in the future.

Analysis of three focus regions

The three focus areas have high groundwater use and good data availability.

This allows more detailed analysis for:

- Werribee delta region
- Mentone to Frankston sand belt
- Nepean Peninsula



We have presented an overview of current and future groundward hazards for these regions.

Werribee delta region

Current conditions	Future conditions
• Groundwater sustains the agricultural (horticultural) industry for this region. • Watertable depth across the Werribee Delta is relatively shallow. • Recharge of this groundwater system depends on rainfall. • Groundwater management controls (triggers) help manage groundwater usage. • Triggers (limits), based on depth to watertable, help to manage possible seawater intrusion into the aquifer.	• Decreasing rainfalls and increasing evaporation may lower the watertable by up to 0.01 m over the next century. • Rising sea levels are predicted to have a greater impact for the region's groundwater. • Rising sea levels will see the seawater-groundwater interface move further inland, by up to 250 m for 1.4 m rise in sea level. • We will likely need to revise groundwater usage and management controls (triggers) in the future.

Mentone to Frankston 'sand belt'

Current conditions	Future conditions
• Watertable depth across the Mentone to Frankston sand belt is relatively shallow. • Longer, flatter slope (low hydraulic gradient), with slower moving groundwater flows. • Recharge of this groundwater system depends on rainfall.	• Decreasing rainfalls and increasing evaporation may lower the watertable by up to 0.04 m over the next century. • Rising sea levels are predicted to have a greater impact for the region's groundwater. • Rising sea levels will see the seawater-groundwater interface move further inland, by up to 100 m for 1.4 m rise in sea level.

Nepean Peninsula

Current conditions	Future conditions
• Groundwater usage for this region is highest of the Port Phillip Bay areas. Majority of this is for domestic usage. • Current usage volumes are right at the limit of amounts allocated for human use. • Watertable depth across the Nepean Peninsula is relatively shallow. • Recharge of this groundwater system depends on rainfall. • Groundwater flows both north into the bay and south into the ocean. • Low hydraulic gradient, with slower moving groundwater flows.	• Decreasing rainfalls and increasing evaporation may lower the watertable by up to 0.04 m over the next century. • Rising sea levels are predicted to have a greater impact for the region's groundwater. • Rising sea levels will see the seawater-groundwater interface move further inland, by up to 50 m for 1.4 m rise in sea level. • Bores located close to the coast will likely be more impacted. • We will need to revise groundwater usage.

How can we use this assessment?

Using the conceptual models, the groundwater hazards have been qualitatively analysed around Port Phillip Bay. This helps provide an understanding of possibly impacted areas close to the coast.

This may inform a more proactive approach towards managing increasingly impacted groundwater locations in the future. This includes ongoing monitoring and regular review of current groundwater management plans. Further research and investigations are needed to better understand how groundwater systems may be impacted by rising sea levels, and the potential hazard implications in coastal areas

What next?

These results allow us to consider when hazards may occur and how they change over time. This means we can better plan for the future and develop appropriate management response.

Using maps as the foundation, we can determine where to focus our next efforts. This might be analyses and obtaining extra information to aid decision making. Some areas may require local-scale studies, to better determine risk or adaptation planning.

To develop strategic approach to long term groundwater management, we need to:

- understand more on our reliance and uses of groundwater around the bay
- addressing some groundwater data and knowledge gaps (such as monitoring)
- learn more about climate change impacts on groundwater systems.

Stony Creek Backwash (Photo: Alluvium)

We acknowledge Victorian Traditional Owners and their Elders past and present as the original custodians of Victoria's land and waters and commit to genuinely partnering with them and Victoria's Aboriginal community to progress their aspirations.

Accessibility

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