

# **OTWAY WATER**

## **Book 57 B**

### **“Otway Basin - Gas Exploration, Extraction & Groundwater Impact.”**

## Disclaimer

This book may be of assistance to you, but there is no guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaim all liability from error, loss or other consequence that may arise from relying on any information in this book.

This book has been prepared, and supporting documents used, with diligence. Statements within this publication that originate from groups or individuals have not been evidentially tested. No liability is accepted from any action resulting from an interpretation of this book or any part of it. The data in this book is arrived at from information sourced and available in the public domain at the time. The passage of time, manifestation of latent conditions or impacts of future events may necessitate further examination and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this book. This book has been prepared in accordance with care and thoroughness. No warranty or guarantee, whether expressed or implied, is made of the data, observations and findings expressed in this book. This book should be read in full. I accept no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this book by any third party. However, I do sincerely hope this book encourages you to enquire about and or further evaluate the material presented and diligently follow up on any aspect of Otway Ranges water resource management that may have been aroused in your mind but not answered.



November 2020. Revised May 2021.

Malcolm Gardiner

Email: [otwaywater@yahoo.com.au](mailto:otwaywater@yahoo.com.au) [www.otwaywater.com.au](http://www.otwaywater.com.au)



[www.stopgroundwatermining.com.au](http://www.stopgroundwatermining.com.au)



[www.otwayrangessubterraneanationalpark.org.au](http://www.otwayrangessubterraneanationalpark.org.au)

# CONTENTS

<b>Introduction</b>	<b>5</b>
Location maps - Otway Basin	6-7
<b>PART ONE. Gas Extraction in the Otway Basin.</b>	<b>8-14</b>
• Maps of onshore/offshore gas fields	8-9
• Beach Energy	9
• Reach Drilling	10-13
• Ministerial permission to pass under/through a Coastal park	13-14
• Assurances given there would be no impact	14
<b>PART TWO. Comparison between Gippsland and Otway Basin.</b>	<b>14-16</b>
• Summary of the Gippsland Experience	14
• Depressurisation of aquifers	14
• Is the Otway Basin different to the Gippsland Basin?	16
• Comparison between the two Basins	16-17
<b>PART THREE. The Victorian Gas Program.</b>	<b>18-48</b>
• Site Specific Investigation Data Required	18
• What is already known about the Otway Basin?	19
• Stygofauna	19
• CSIRO Phone Survey summary & Social Engineering	19
• Minimum Environmental Plan	19
1. Workplace Environment/Not natural Environment	19
2. Ecosystem Adjoining the Gas Wells Only	20
• Value and Strive for High Environmental Values	20
• Concerns with the VGP Conceptual Model	21-27
1. Hard to read Figures	21
2. Selective Use of Data	21
3. Only LTA and UKSD bores used for gas extraction comparisons	21
4. All Aquifers Trending Down	22
5. Poor Correlation with Rainfall	21-22
6. Impacts to be listed BUT aren't	23
7. Findings to be used if onshore gas extraction follows	23
8. All Variables Need to be Considered	24-27
Recharge, Salinity Intrusion, Temperature, Leakage, Fault Lines, Aquifer Recovery, Recharge after wet winters, Buffering Capacity of Aquifers under Natural Conditions.	
• Key Word Search for Risks, Benefits and or Impacts	27
• Scant Environmental Studies	27

• <b>THE THREE STAGES of the Victorian Gas Program</b>	<b>28-31</b>
1. Not Completed Yet	28
2. Ban on Onshore Gas Exploration lifted before Part One Completed	29-31
3. Fracking Ban Remains	29
4. VGP based on Science	30
5. No risks would results from Exploration	30
• The Numerical Model	30
1. Not yet done and to be based on the Conceptual Model	
• Data Gaps and Misinformation	31-42
1. Correlation between Rainfall & Water Levels	31
2. Groundwater Extraction for human use <sup>3</sup> is Extensive	
3. Rainfall & Groundwater decline Co-incident	33
4. Groundwater extraction a Better Fit	34-36
5. Rainfall Stations and Bores locations a Doubtful Connection	37
6. Better Rainfall Data could be collected	37-40
7. Rainfall isohyets	39-40
8. Stock and Domestic water extractions not included	41
9. Historical Water Levels Critical	41
10. Early 1990's very wet skewing the Cumulative residual rainfall	42
• The Impact on Groundwater from Gas Extraction	43-47
1. State as No Impact	43-44
2. Gas Extraction Data not Included	44
3. Comparison with Lower Level Hydrographs	45-47
4. 80% of LTA Bores Investigated had a downward Water level trend	47
• Onshore/Offshore Connectedness	48
1. Been Recommended for 17 years for onshore And offshore models to be combined	
• State Government NOT Fully Informed	48
1. Conned	
Double Check Information Provided	49
What would a CSIRO Report on the Otway Basin Say	49
Finally Fire	50
<b>CONCLUSION</b>	<b>50</b>
Appendix One	51-52
Appendix Two	53-54
Appendix Three	55-57
References	58-59

## **INTRODUCTION.**

Otway Water Book 57 covers the onshore impact that the offshore extraction of gas is having in Gippsland. It also discusses the possibilities that offshore and onshore gas exploitation elevates the risk and increase in the intensity of wildfire in the Gippsland and Otway Ranges region. Unlike Gippsland there has been very little investigation into the impacts of offshore gas extraction on onshore subterranean ecosystems in the Otway Ranges. This is especially so from a groundwater perspective. Otway Water Book 57 B makes an attempt at drawing together data that could be a relevant factor relating to the interaction between offshore extractions and onshore impacts.

As with many “*citizen science*” research attempts the extractive industries are sometimes very guarded at providing information. This more often than not complicates efforts to gain a clear picture of what is actually taking place.

Other confronting elements include poor research and investigation leading to doubtful conclusions. These things can lead to community confusion, suspicion, mistrust and conflict.

Part One of Otway Water Book 57 B looks at Beach Energy’s gas activities in the Otway Basin.

Part Two Compares the Gippsland and Otway Ranges Gas Extraction Experiences.

Part three reviews the Victorian Gas Program’s report on Groundwater Impact Assessment relating to gas extraction in the Otway Basin region.

## Location Maps.



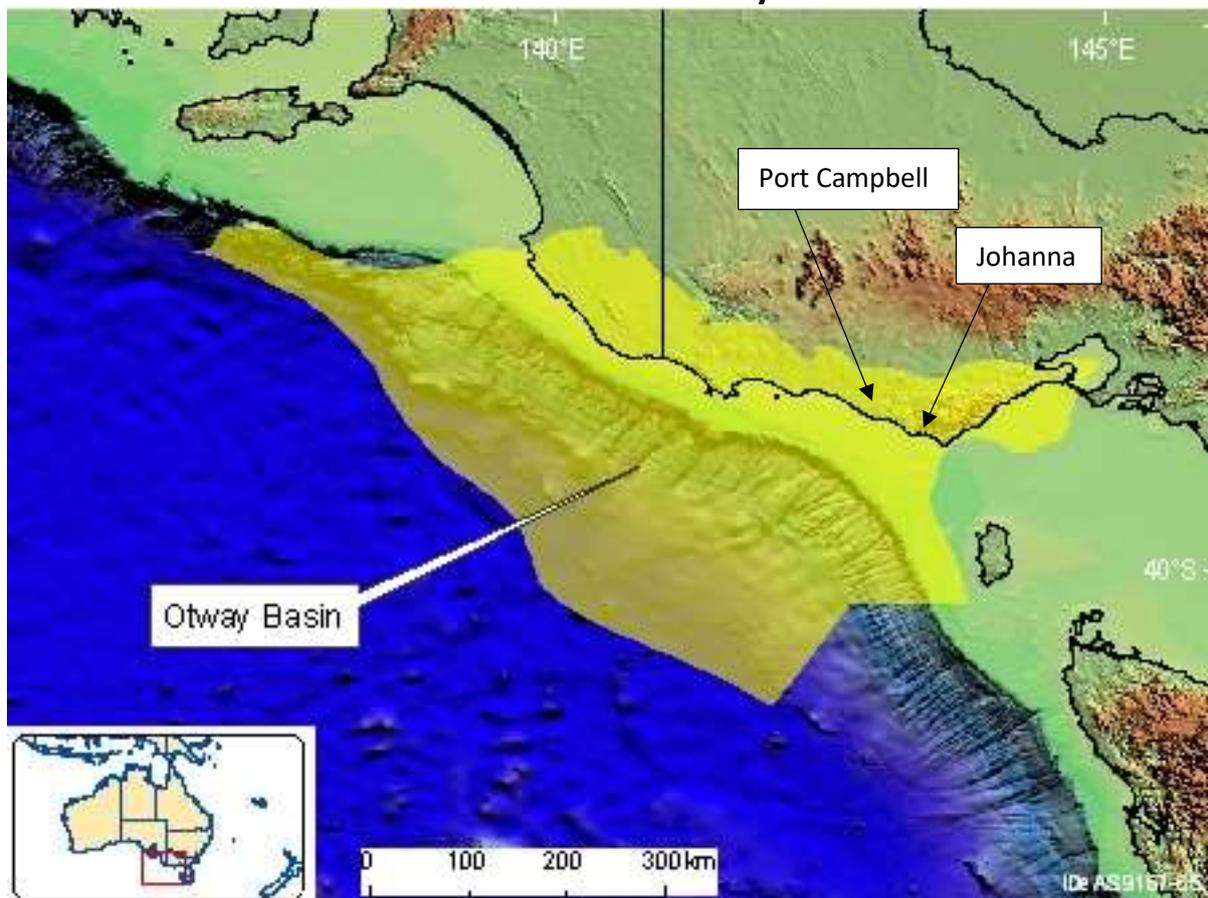
### The Otway Basin.

The Otway Basin is an onshore and offshore basin which extends approximately 500 kilometres from Cape Jaffa in South Australia to north-west Tasmania.



**The Onshore part of the Otway Basin in Victoria.** Map Source: Geoscience Australia

## The onshore and Offshore Sections of the Otway Basin.



Map Source: Geoscience Australia.

### The Otway Basin.

Several companies are involved in the gas extractive industry from the Otway Basin. This includes Victorian State and Commonwealth waters. No oil is extracted although condensate (light hydrocarbon liquids) can be produced.<sup>(13)</sup>

# PART ONE – Gas Extraction in the Otway Basin.

*“The gas industry has operated in the Otway Basin since the early 1960’s.”<sup>(2)</sup>*

Extraction takes place both on and offshore. There are “...**20 production bores**...”<sup>(6)</sup> in the area.

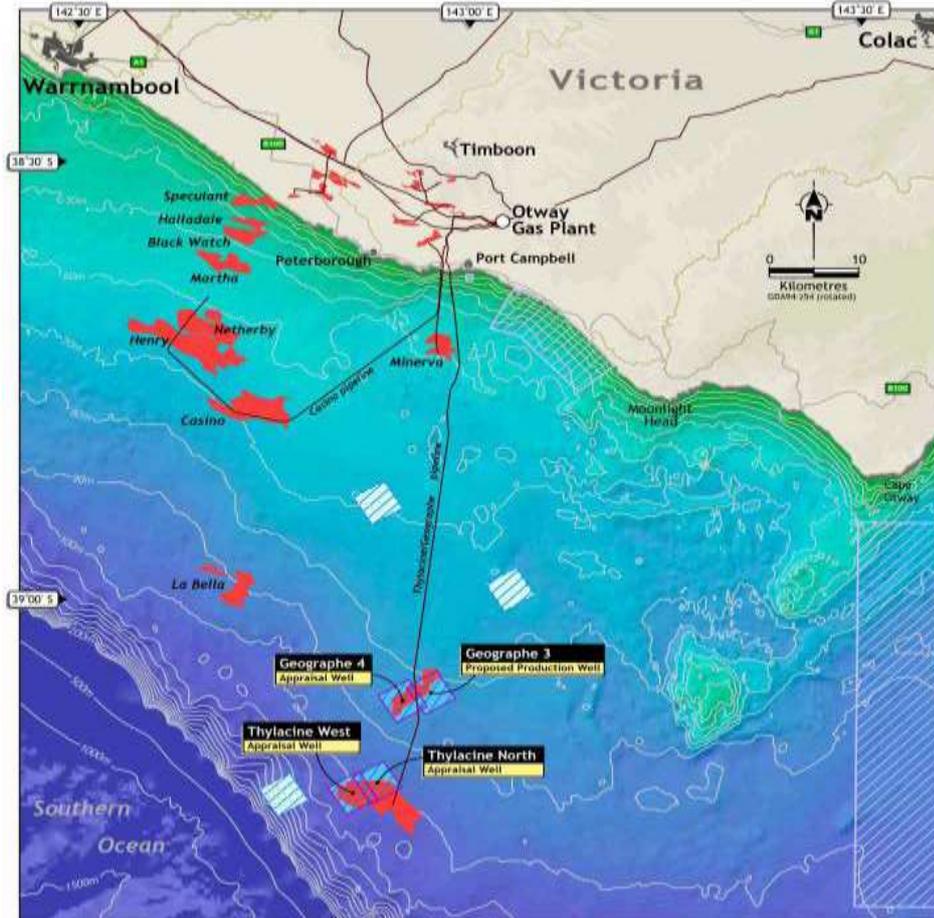


Figure 3.43 Onshore and offshore gas fields in the Port Campbell region (Origin Energy, 2017).

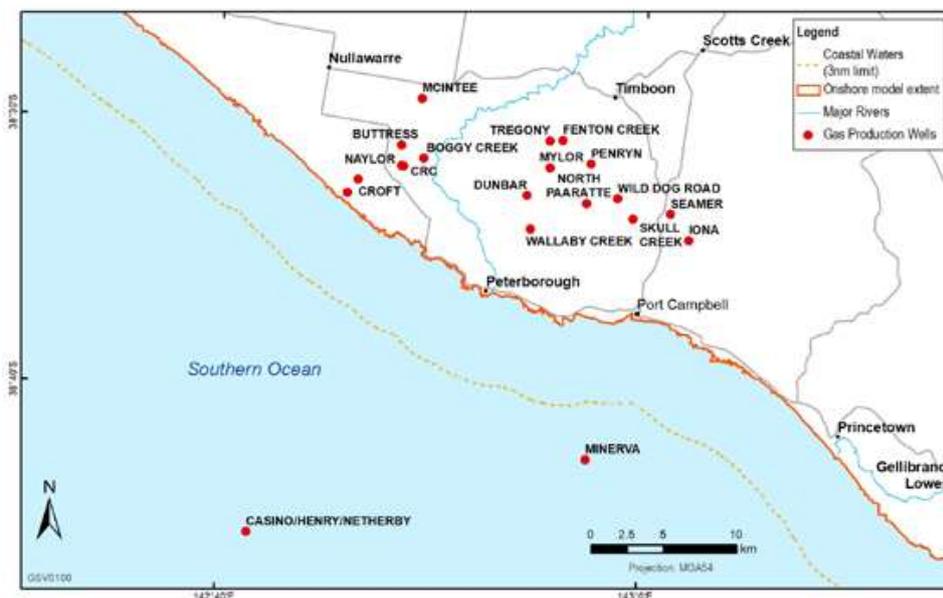


Figure 3.56 Historic and currently operating gas production wells<sup>(6)</sup>

## Beach Energy In the Otway Basin.

Beach Energy first discovered commercial quantities of gas off Port Campbell in 1979. Beach Energy permits extend from 32 to 80 offshore.

## Offshore and Onshore Licence Areas.

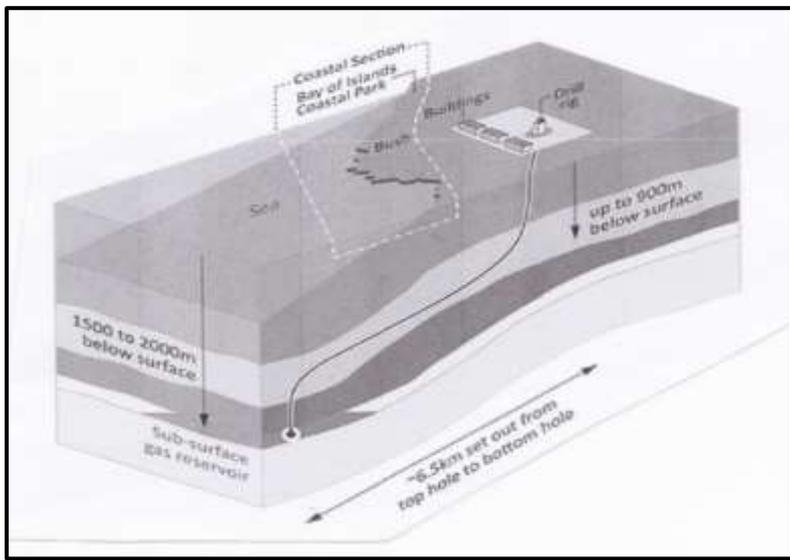


## Offshore Gas Fields.



Beach Energy operations in the Otway Basin involve natural gas production from offshore natural gas fields. The natural gas is piped onshore and processed at the Otway Gas Plant near Port Campbell.

**Onshore Extended Reach Drilling.**



Reach drilling is drilling a well horizontally from a borehole that is begun as a vertical bore. In 2015 the record for horizontal length of extended reach drilling was 12 km. When writing Otway Water Book 57 I was under the impression that Beach Energy was operating its reach drilling from offshore. This is not the case as can be seen in the diagrams above and below. The Beach Energy extended reach drilling is land based. The bore head begins its vertical shaft onshore and then is directed horizontally to the offshore gas field site.

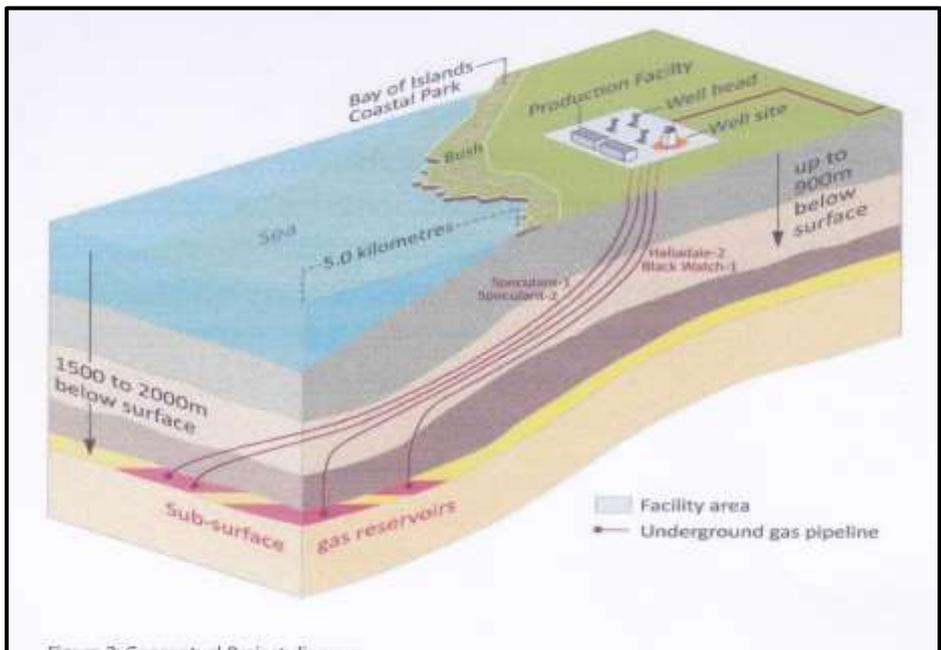
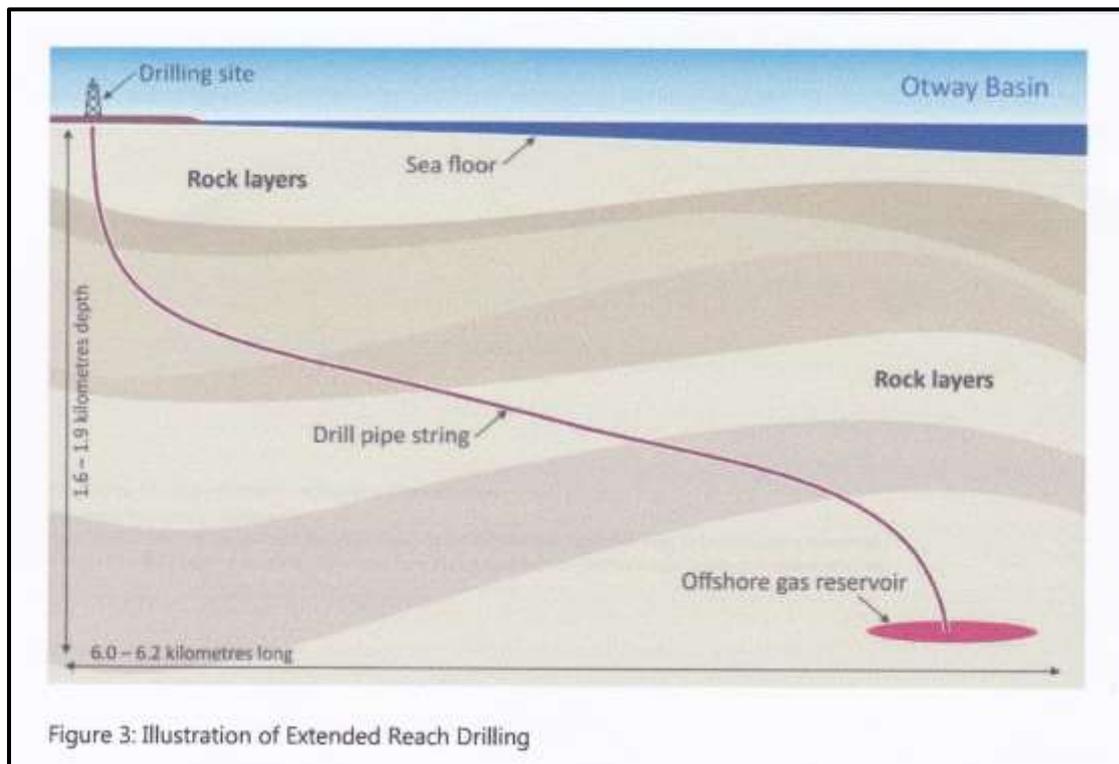


Figure 2: Conceptual Project diagram

**SOURCE:** Beach Energy.<sup>(15)</sup> 4 wells at Niranda.

The Black Watch 1 onshore extended reach drilling program has several wells at the site.

From what can be ascertained there are two onshore extended reach drilling sites. One site being west of Peterborough (see page 12) and the other to the east between Peterborough and Port Campbell (see page 12).



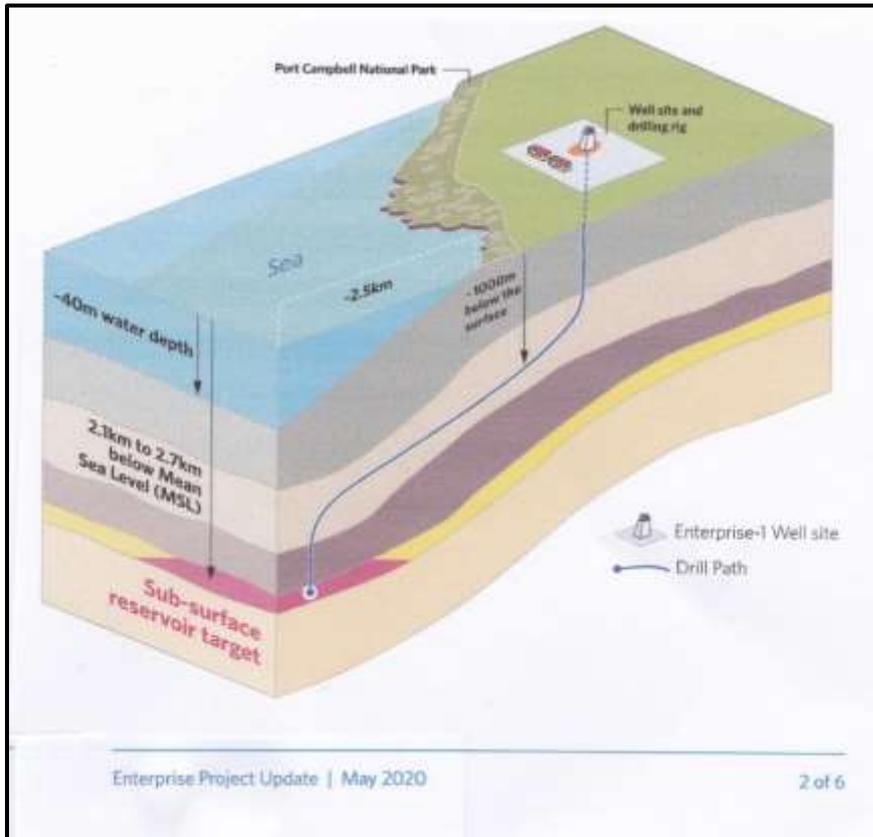


Map showing Halfodale, Black Watch and Speculant well site.

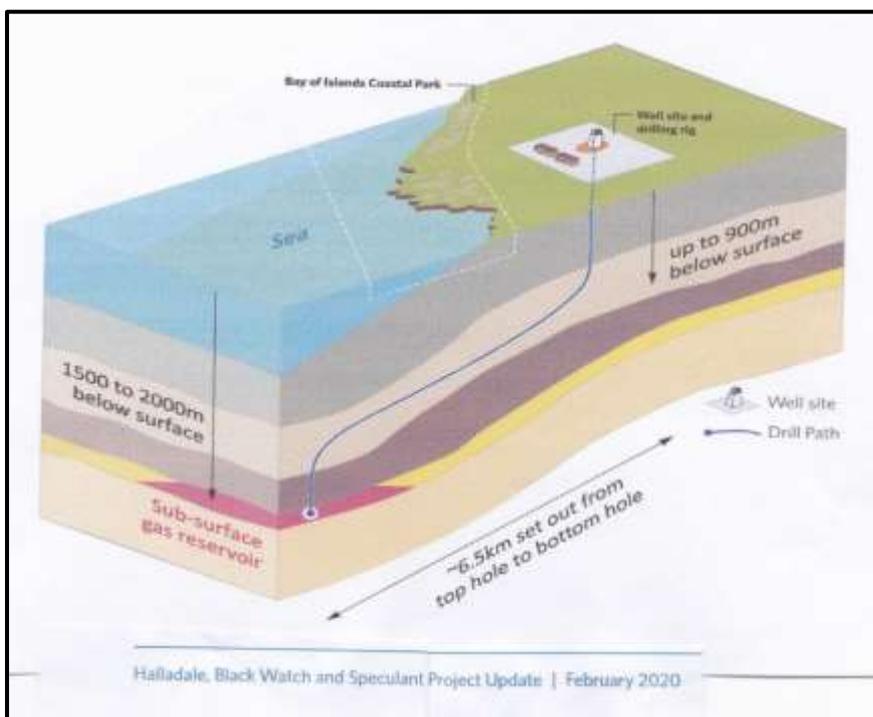
**Map Source:** Beach Energy.



Map showing vicinity of onshore project area, adjacent offshore exploration permit VIC/P42(V).



SOURCE: Beach Energy. Halladale, Black Watch and Speculant Project Update | February 2020



**Ministerial Permission Needed to Drill Through a National Park.**

Beach Energy when reach drilling under the Bay of Islands Coastal Park had to gain Ministerial approval. By law National Parks extend to the centre of the

earth, therefore Ministerial consent is required. Part of the approval process included Beach Energy asserting that the drilling “...*is not expected to have any impact on the surface flora and fauna, nor on geological stability within the park.*”<sup>(2)</sup> No mention of subterranean ecosystem disruption/impacts.

#### **Beach Energy Assurances Regarding the Environment..**

*“For Beach Energy, the safety of our people and the local environment are the highest priorities for our operations and projects.”*<sup>(4)</sup>

*“Beach operates within a highly regulated industry and must meet stringent environmental and safety standards.”*<sup>(4)</sup>

In a Q & A type forum Beach Energy wrote, when the question was posed, will drilling impact aquifers. *“No. Proven drilling technologies will be used to ensure sensitive zones, such as aquifers, are protected.”*

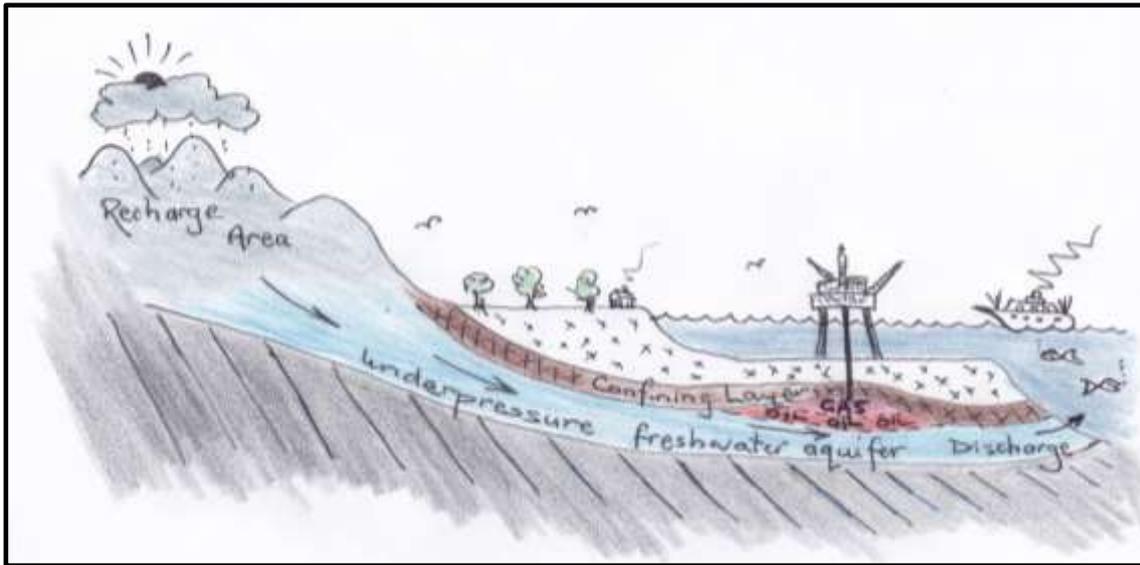
## **PART TWO – Comparing the Gippsland and Otway Ranges Gas Extraction Experiences.**

### **Summary of the Gippsland Experiences.**

It has been established and accepted beyond any doubt that offshore extraction of gas has had a profound impact on onshore groundwater levels along the Gippsland coastal regions.<sup>(7)</sup>

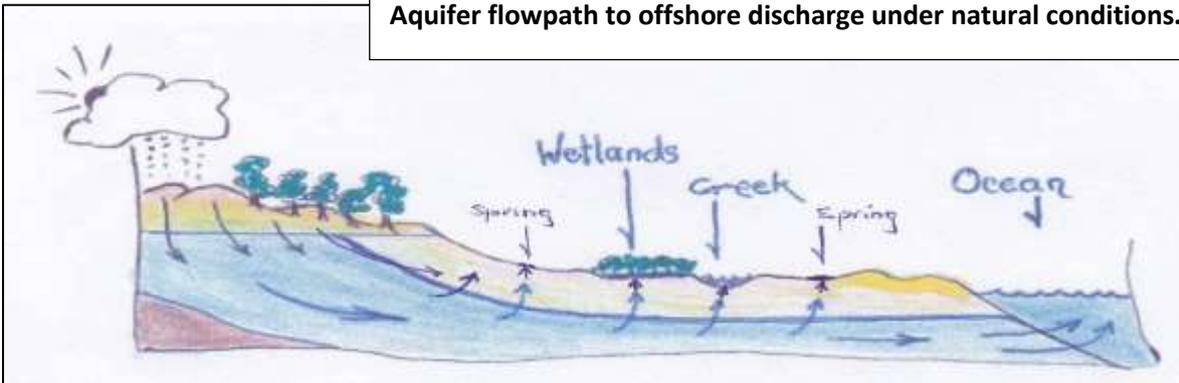
### **Depressurisation.**

The subterranean gas along the coast of southern Victoria is under enormous pressure, as is the water and any oil. Tap into the gas offshore and the pressure from the water forces the gas to the surface. The fluid extracted is a combination of gas and water. This expulsion of fluid is water driven. As water is blown to the surface with the gas the water level in the aquifer rises into the space left by the gas. As this happens the water pressure in the aquifer drops. Expel enough gas and the normal outflow of water into the ocean will stop. Extract more gas and the interface with salt water will move back into the fresh water aquifer’s flow path. At the other end of the aquifer at the onshore recharge points, the water table will drop as the depressurisation of the aquifer progresses.

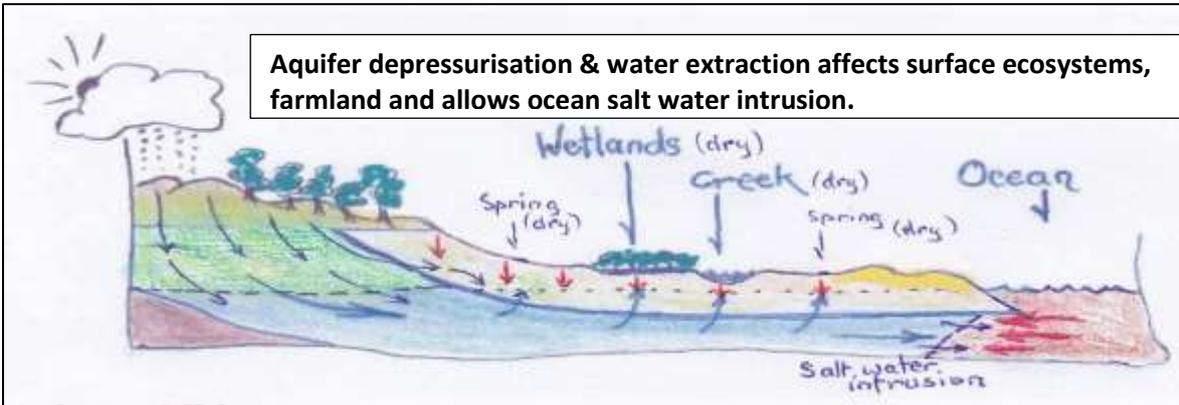


Extracting the gas and oil offshore depressurises the aquifer(s) and as a consequence water tables onshore suffer with falls to unprecedented levels. The CSIRO case proving this in the Gippsland scenario was so convincing that farmers in the Yarram/Seaspray region were given a 5 million dollar compensation package.

**Aquifer flowpath to offshore discharge under natural conditions.**



**Aquifer depressurisation & water extraction affects surface ecosystems, farmland and allows ocean salt water intrusion.**



Unfortunately, as a result of continued offshore extractions the water table is still being lowered by a metre a year.<sup>(8)</sup>

And, as at 2015 “...*offshore oil and gas production extracts a water equivalent volume of approximately 100 000 ML per year.*”<sup>(27)</sup>

## **The Question? Is the Otway Basin Any Different to Gippsland.**

Why would offshore gas extraction from the Otway Basin be any different to the extractions off the Gippsland coast? Finding any sort of answer has been difficult to obtain other than the ones stating there would be no impact. For some time verbal discussion with State Government people was based on the notion that the two areas are quite different and therefore cannot be regarded as having the same type of risks and impacts.

With:

- different modes of gas extraction,
- taken from a deeper level,
- not involving aquifers and aquifer depressurisation, and
- the continental shelf is much closer to the shoreline, and so on.

However, as seen in Appendix Two (page 52), things do not appear to be so different between the Gippsland and Otway Basin gas extraction activities.

**Gippsland** – The gas flows from the extraction bores under pressure from groundwater. The extraction method is water driven.<sup>(5)</sup>

**Otway** – “...*the extraction method is the same.*”<sup>(13)</sup>

**Gippsland** – water flows into the space that the gas occupied.<sup>(5)</sup>

**Otway** – “...*the water continuously flows into the space as the gas flows out.*”<sup>(13)</sup>

**Gippsland** – as a result the groundwater is depressurised.<sup>(5)</sup>

**Otway** – as a result the groundwater is depressurised.

The bottom line is any subterranean extraction of water, gas or oil has an impact.

*“All forms of natural gas development have the potential to impact groundwater users, surface water users and ecosystems as a result of aquifer depressurisation.”*<sup>(14)</sup>

**Gippsland** – onshore aquifers discharge from the ocean floor into the sea. However, over the decade 1994-2004 discharge of freshwater from the aquifers to the continental shelf is assumed to be nil due to the depressurisation of aquifer flow. Fresh water is no longer discharging into Bass Strait.<sup>(7)</sup>

**Otway** – onshore aquifers from the Otway Basin discharge from the ocean floor into the sea. *“Groundwater that does not reach the surface (onshore) is discharged into other aquifers, and eventually into the marine environment via seabed springs.”*<sup>(6)</sup>

*“Some aquifers, such as the LTA, extend beyond the coast to many kilometres offshore.”*<sup>(6)</sup> (LTA – Lower Tertiary Aquifer)

Present status of these offshore springs and discharge points is unknown.

**Gippsland** – being water driven, water is extracted with the oil and or gas. The following extract is taken from Otway Water Book 57.

*Long time onshore drilling contractor with 37 years on the offshore rigs, Mick Osborne, retells some of his offshore experiences. “Initially the offshore wellfield extracted close to pure oil and surfaced under enormous pressure at around 3300 pounds per square inch at 215<sup>0</sup>F. This came from 3-4 km down. As time went by the ratio of oil to water decreased. Even at around 99% water and 1% oil it was profitable, although this has nearly come to an end. Around 1985 100 ML/day of water was being processed 365 days a year and dumped into the sea after processing.”*

**Otway** – As stated earlier because the extraction methods are the same for both gas fields it is reasonable to assume water is extracted as part of the process in the Otway Basin. “...*so the extraction method is the same.*”<sup>(13)</sup>

## **PART THREE – The Victorian Gas Program (VGP)**

### **Site Specific:**

When reading the Victorian Gas Program, Technical Report T34 September 2020: Groundwater Impact Assessment – Conceptual report. Onshore Otway Basin , Victoria,<sup>(6)</sup> it stood out that much of the data used was very broad ranging in it use. It appeared to be concentrating on generalities glossing over and to the detriment of specifics found in various localities.

Using this broad brush approach when trying to make sense of what is happening throughout the Otway Basin (49,000 km<sup>2</sup>) would appear to be inputting misleading data into the model. Not all parts of the Otway Basin can be categorised in such general terms. There needs to be site specific investigation. The Conceptual Model report<sup>(6)</sup> hints at the value of site specific requirements but does little to address this. “*The effects of particular faults can be more realistically modelled in site-specific, localised numerical models constructed at a later stage.*”<sup>(6)</sup> This is the only reference made to site specific consideration – to be dealt with at a later stage.

The following dot points highlight things that should have been more site specific:

- having rainfall graphs within a close proximity to the bore hydrograph it is being compared with,
- which leads to the locating and use of rainfall stations that are pertinent to the area being discussed,

- accounting for huge groundwater extractions like at the Barwon Downs Borefield and then providing better explanation using site specific happenings should be done (see page 36),
- classifying the Mepunga Formation in some cases as part of an aquitard and in other sections of the Conceptual Model report as an aquifer, is confusing.
- In the Barwon Water Borefield documentation the Pember Mudstone is regarded as an aquitard not an aquifer as the Conceptual Model states. Have these discrepancies happened because of a broad brush stroke approach?
- Groundwater recharge and discharge areas would vary across the basin and need to be site specific to draw any satisfactory conclusions on how the water balance plays a part in water level trends.

The final word on this is captured in this quote. *“In reality, not all of the features are necessarily present at any one location or area, or along any single line section. These variations are more accurately captured in the detailed numerical model.”*<sup>(6)</sup> Unfortunately this model has not been completed or at least not available.

### **What Is Known about the Subterranean In the Onshore Otway Basin and Offshore?**

From an environmental ecosystem, groundwater and subterranean perspective the answer appears to be very little. If past experience and present day reports are anything to go by there is much to be learnt. Take the Barwon Downs Borefield extraction experience and the surface environmental impacts. Dead fish, platypus colonies wiped out, acid levels elevated off the scale, toxic heavy metals released, wetlands decimated, fire risk increased, streams dried up. With all of this in mind Barwon Water still applied for a 12,000 ML/year extraction licence as late as 2019. The above impacts resulted from less than 12,000 ML/year extractions. And, the Victorian Gas Program recommendations presented to the Victorian Government to go ahead with onshore gas exploration are based on no better information. Arguably the VGP environmental scientific and technical work is worse.

#### **The VGP Stygofauna Investigation.**

Otway Water Book 57 debunks in detail the VGP stygofauna survey<sup>(1)</sup> as nothing more than a poor and wishful piece of imaginative thinking. To claim that this report is based on scientific and technically robust principles is astounding. To assert... *“Currently there are no known subsurface GDEs across Victoria.”*<sup>(1)</sup> gives a glimpse into the absurdity of this report.

### **The VGP Phone Survey.**

Otway Water Book 57 presents a convincing case that a CSIRO phone survey was summarised by the VGP and used as nothing more than a convincing piece of social engineering aimed at giving the impression that the general population was in favour of onshore gas exploration.

### **The VGP Reference of a “Minimal Environmental Plan” not easily obtained.**

The quest to gain what the risks, benefits and impact of environmental considerations dealing with gas extraction from the Otway Basin are, has been like pulling teeth with a tooth pick. And, it has been a quest. There are at least two branches of the Victorian State Government involved and various exploration and extraction activities and companies involved. Add to that the joint involvement of Commonwealth and State waters makes for difficulties sourcing investigations and studies.

The Beach Energy report referred to in point 3 of Appendix One, page 51, took some finding and yes the report does deal with an environmental and some ecosystem’s consideration. However, only the human **working environment** and the **surface ecosystems** adjoining the onshore extended reach drilling plant are dealt with. Risk and impact from well site mismanagement and or accidents appears to be the major consideration here. No mention has been made of risk or impact on the subterranean ecosystems that could be affected from exploration, aquifer depressurisation and drawdown. No mention of subterranean ecosystems is even considered in this Beach Energy report.

### **The VGP states:**

*“Environmental impact investigations were conducted to assess the current and potential impacts of historical oil and gas drilling operations on groundwater and atmospheric conditions now and into the future. This investigation is the first of its kind undertaken in Victoria. The potential groundwater impact was considered in the Port Campbell Embayment (Otway Basin) and the Seaspray Depression (Gippsland Basin). Results found there is no evidence that the environment has altered as a result of these drilling activities over the past 100 years.”* <sup>(9)</sup>

Despite these assurances there appears to be few environmental impact investigations regarding the gas exploration of the Otway Basin. As for a lack of data supporting the statement that there is no evidence that the environment has altered as a result of drilling activities in the last 100 years, this seems incredible – considering the CSIRO Gippsland Basin report **found the exact opposite**. The CSIRO found substantial data supporting an opposite conclusion. A conclusion that was so convincing it resulted in a 5 million dollar compensation package to onshore farmers impacted from offshore gas extraction.

## **The Victorian Gas Program should be across all findings, studies, investigations and considerations.**

The VGP should also know exactly what Beach Energy have been doing as far as providing supporting documentation to statements such as the two below.

*“For Beach Energy, the safety of our people and the local environment are the highest priorities for our operations and projects.”<sup>(4)</sup>*

*“Beach operates within a highly regulated industry and must meet stringent environmental and safety standards.”<sup>(4)</sup>*

It would appear little environment ecosystem studies related to gas extraction have been conducted in the Otway Basin. The VGP cannot assume the things stated above have been or are being done. If they have then this documentation should be publicly available and easily accessed. It is not.

## **Other Concerns with the VGP Conceptual Model Report.<sup>(6)</sup>**

### **Some Graphs & Data Difficult to Read.**

The pdf of the Conceptual Model contains many figures that are difficult to read (see page 26 for such an example). This is frustrating and does not facilitate easy scrutiny. This increases the possibility that misinterpretation of the material will be made.

### **Selective Use of Data.**

The Conceptual Model report has used 36 hydrographs of the 1,367 state observation bores available in the study area, to highlight certain findings and conclusions. One of these findings being there is a high correlation between rainfall patterns and dropping hydrograph levels. I have chosen eight of these 36 hydrographs, demonstrating how easy it is to arrive at a different conclusion.

These 8 hydrographs have been taken from the Conceptual Model Report in an effort to demonstrate that graphs and figures can be manipulated to say many things. Maybe things that are not actually the way it is in natural life. In fact later discussion would suggest that a better correlation would be between groundwater extractions and falling hydrographs. However, there is every indication that there is even a closer correlation between offshore gas extractions and onshore groundwater decline.

**The 8 Hydrographs Chosen are taken from different depth levels.**

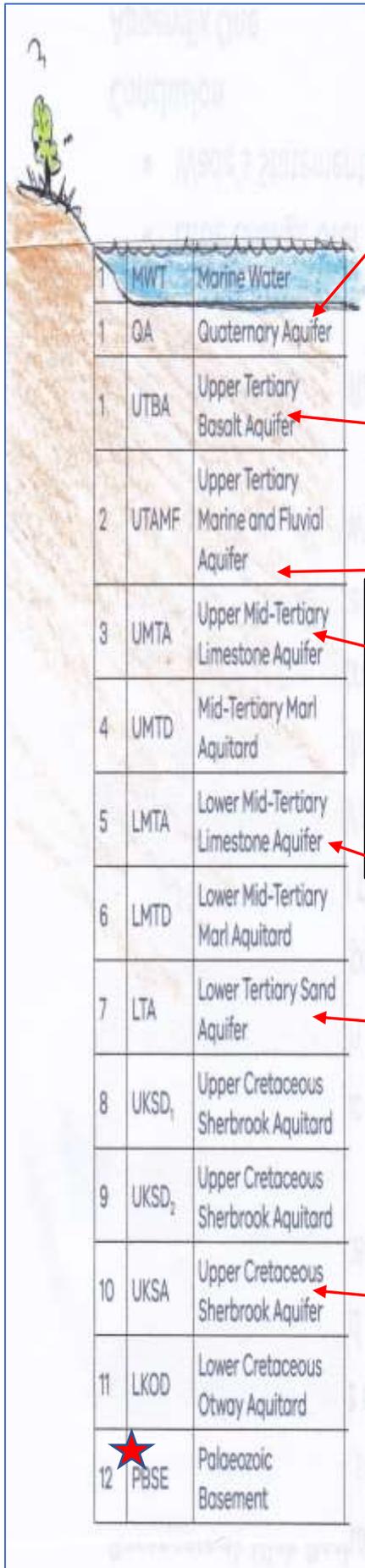
This part of Table 3.3 has been taken from the Conceptual Model report. This shows the earth structure and layers in relation to each other.

1	MWT	Marine Water
1	QA	Quaternary Aquifer
1	UTBA	Upper Tertiary Basalt Aquifer
2	UTAMF	Upper Tertiary Marine and Fluvial Aquifer
3	UMTA	Upper Mid-Tertiary Limestone Aquifer
4	UMTD	Mid-Tertiary Marl Aquitard
5	LMTA	Lower Mid-Tertiary Limestone Aquifer
6	LMTD	Lower Mid-Tertiary Marl Aquitard
7	LTA	Lower Tertiary Sand Aquifer
8	UKSD <sub>1</sub>	Upper Cretaceous Sherbrook Aquitard
9	UKSD <sub>2</sub>	Upper Cretaceous Sherbrook Aquitard
10	UKSA	Upper Cretaceous Sherbrook Aquifer
11	LKOD	Lower Cretaceous Otway Aquitard
12	PBSE	Palaeozoic Basement

Table 3.3 Aquifer parameters for hydrostratigraphic units used in the South-West region groundwater model (VAF Digital Raster Files; Hocking, 2007; Bush, 2009; Clarke et al., 2015)<sup>(6)</sup>

**Note** the LTA is low in the cross section of the earth's structure.

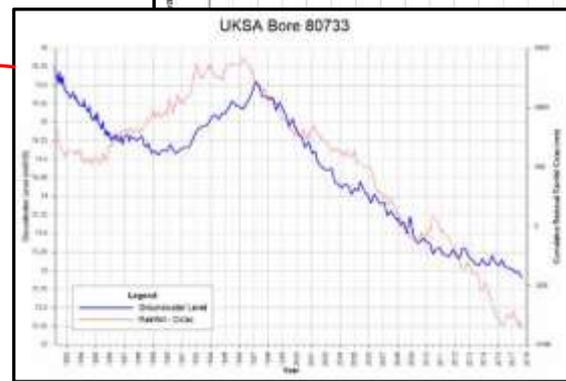
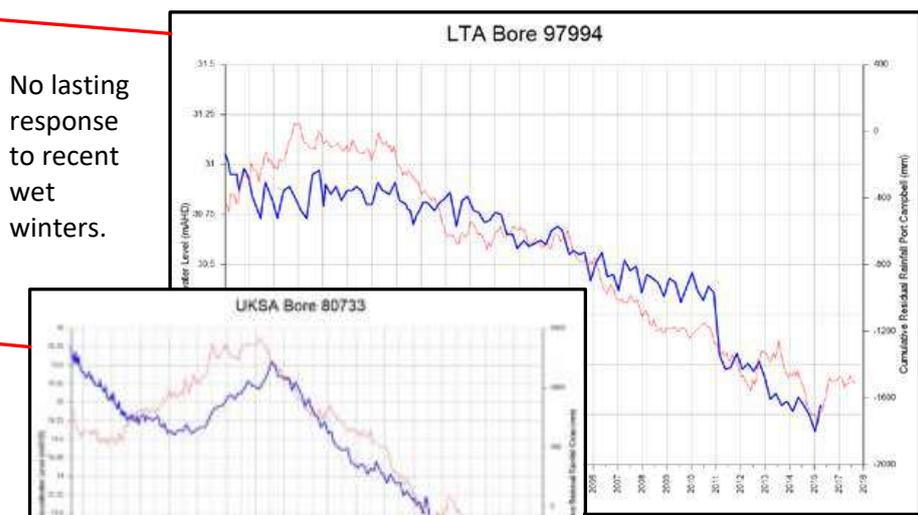
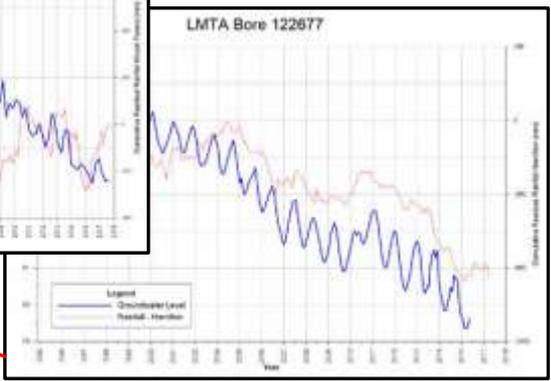
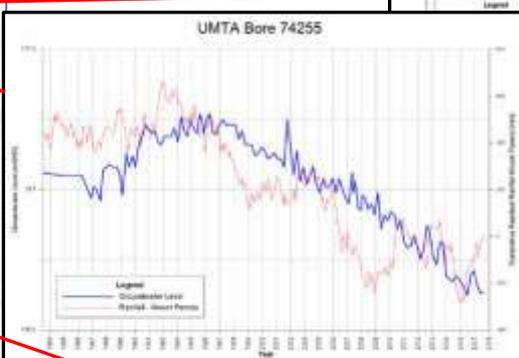
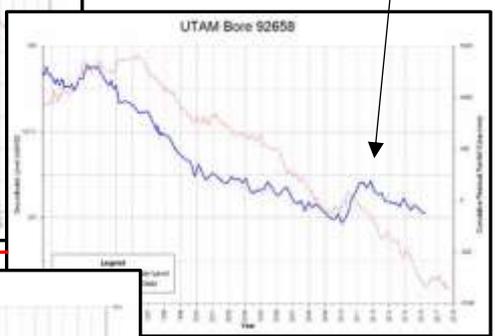
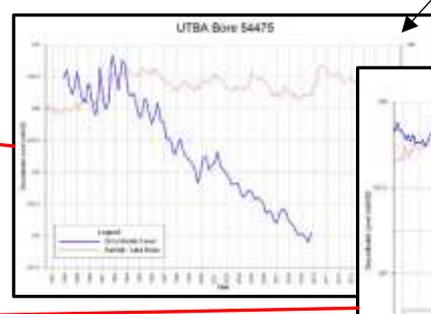
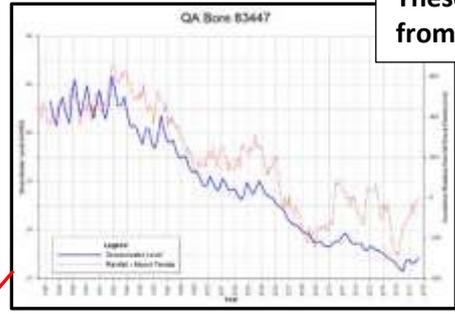
The Conceptual Model states the “*...water levels in the LTA show a distinct correlation with rainfall.*” Discussion on pages 26 and 27 below, throws some doubt on the suggestion that rainfall is the causal factor influencing the drops in the groundwater levels throughout the earth's structure. Graphs on the next page indicate a lack of rainfall to groundwater movement correlation. Under examination rainfall correlation is far from convincing. Unfortunately, the Conceptual Model output makes the suggestion that the correlation is quite distinct and leads the reader to draw a conclusion based on “dodgy” data presentation.



These hydrographs are from onshore bores.

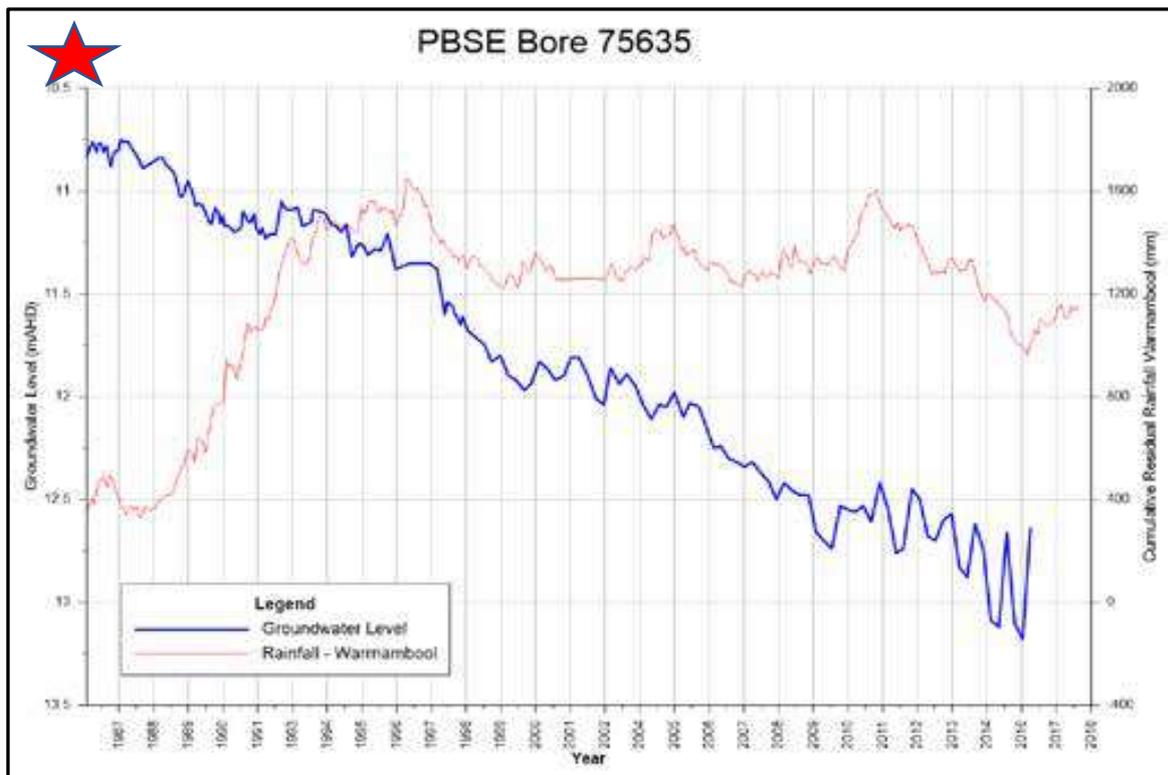
Why is this hydrograph trending down & the rainfall is steady?

Hydrograph upward trending & rainfall trending down.



No lasting response to recent wet winters.

Every one of these hydrographs is trending downwards.



This hydrograph is from the Palaeozoic Basement and is apparently one of the deepest bores investigated. With falling water levels in all the earth structures above Bore 75635, it is a distinct possibility that this downward vertical leakage from the layers above, is because the basement water level is being depressurised and or depleted. If this is the case there has to be some other factor other than rainfall causing this to happen?

### Is the Conceptual Model Good Enough?

Perhaps not. It is clearly stated that the Groundwater Impact Assessment Conceptual Groundwater Model “...*will be used to quantify groundwater and surface water impacts of potential onshore conventional gas developments in the basin. The model is required to quantify individual and cumulative impacts from potential developments, including changes to groundwater levels and pressures, and changes to river baseflows.*”<sup>(6)</sup> However, there is little evidence of this being done. The Conceptual Groundwater Model report sadly lacks this information. Little can be found in this report.

## Another Shortcoming of the Model.

### All Information Needs to be Considered when Feeding Data into a Model.

It is an accepted fact when attempting to gain accurate and functional results, accurate and all available information must be fed into the model. In the Conceptual Model these things have been left out.

**Recharge data:** *“Groundwater recharge is a complex variable that can change in time due to prevailing conditions and is the subject of many studies beyond the scope of this assessment.”*<sup>96)</sup>

Surely the recharge has to be included as an important variable in relation to water level trends.

**Density corrections for salinity and temperature:** *“It is therefore considered reasonable to omit density and temperature corrections in the South-West region groundwater model.”*<sup>(6)</sup> This omission was based on assumptions - difficulties and a lack of offshore data for these parameters. In the Gippsland scenario the 2004, CSIRO found over the decade 1994-2004 the offshore discharge of freshwater from the aquifers to the continental shelf to be nil due to the ceasing of aquifer flow from offshore gas extractions. Fresh water is no longer discharging into Bass Strait. This was 16 years ago and the gas extraction has continued. The likelihood of salinity intrusion back into the receding aquifer flowpaths is high. Is the same happening offshore in the Otway Basin?

**Fault lines:** Faults lines abound in sections of the Otway Basin and can be conduits facilitating vertical leakage (see pages 25-26, below). *“There is a lack of hydrological information available to enable the incorporation of fault structures into the regional model.”*<sup>(6)</sup>

### Vertical Leakage.

There is every possibility that the falling water levels in the LTA and UKSD is causing the upper aquifers to begin to leak downwards. This possibility has basically been ignored. Deep aquifers under pressure will leak upwards into layers above in a natural state and the reverse will happen if the lower aquifers become depleted and or depressurised.

### Nested Bores.

One of the most accurate methods of determining the degree of leakage between earth structures is to have nested bores measuring the water movement throughout the profile from the highest to lowest levels. However, there has not been one set of nested bore data included in the Concept Model report making it extremely difficult to determine leakage movement.

**Downward Vertical Leakage:** *“Some shallow formations are important transmissive units for underlying aquifers and can significantly*

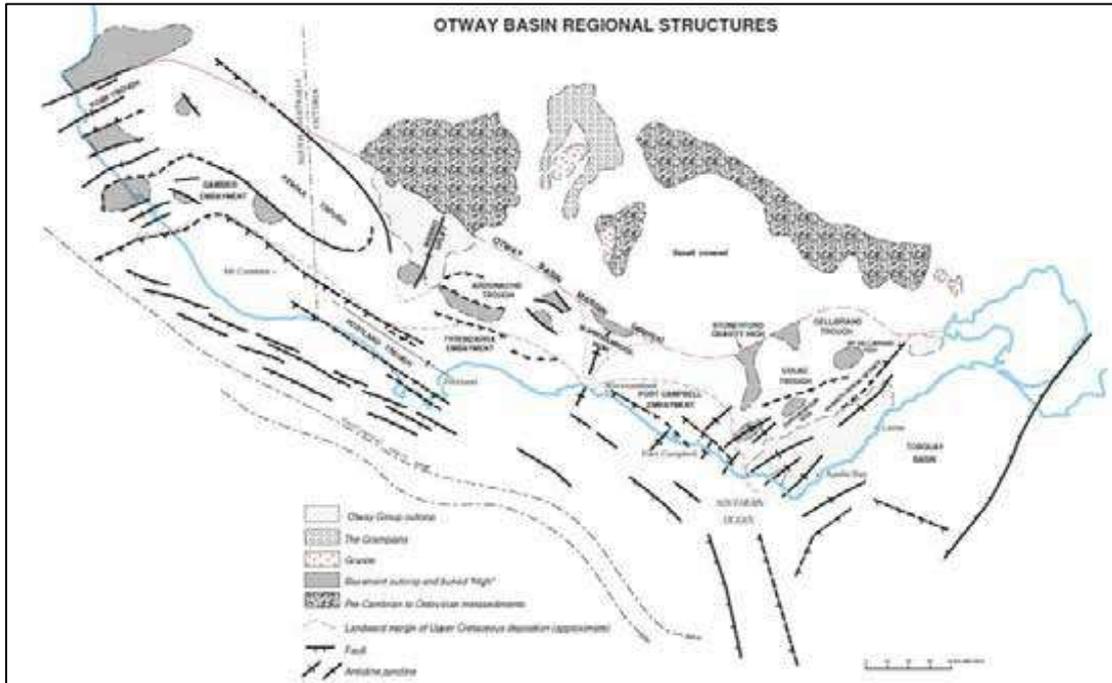
*influence the recharge characteristics of the area. In particular, the relatively thin QA, UTBA and UTAMF units host the watertable over large parts of the south west region and play a significant role in providing recharge to the deeper formations. In some cases, groundwater recharge is enhanced compared to areas where superficial units are absent (e.g. Figure 3.21), in others recharge is inhibited (e.g. Figure 3.17), and yet in others simply delayed in reaching the underlying aquifer (e.g. Figure 3.30), depending on their relative permeability.”<sup>(6)</sup>*

In the Barwon Downs Borefield area *“Leakage from the overlaying marls is likely to be the major source of the recharge under stressed conditions.”*<sup>(23)</sup> Higher earth structures play an important role recharging lower formations and in some cases this process takes some time.

**Upward Vertical Leakage:** In the extreme east of the Otway Basin gas exploration study area at the Barwon Down Borefield region, pre groundwater extraction, earth structures above the LTA were being recharged from the pressure of the LTA below. *“The immediately overlaying Narrawaturk Marl(aquitard) is up to 170 m in thickness and grades from silty sands to marl. It has very high storage capacity and within the borefield area is known to contain groundwater of good quality. Under undisturbed conditions an upward vertical, hydraulic gradient exists between the marl and the Lower Tertiary aquifer system and the marl is recharged (upward) with groundwater of good quality from below.”*<sup>(23)</sup>

In 2016 Jacobs<sup>(24)</sup> stated that when an upward hydraulic gradient exists *“This facilitates upward leakage from the aquifers into the overlaying aquitard and is a key discharge process for the aquifer.”*

**Leakage via faults:** The upward and downward vertical leakage can also be facilitated by faults in the earth’s structure. *“Structural geological features such as regional faults may influence groundwater processes via the displacement of hydrostratigraphic units, and by providing potential conduits for flow between separate aquifers.”*<sup>(6)</sup>



**Figure 3.1** The Otway Basin showing regional structures, faults and basin subdivisions (GSV, 1995).<sup>(6)</sup>

This Conceptual Model report figure shows faults in the Otway Basin. This figure is an example of the difficulty experienced reading what is being presented.

### **Aquifer Recovery After Wet Winters.**

Aquifers with a falling water level trend should begin to recover and show an upward trend with winter rains. Very few of the hydrographs presented shows signs of recovery in line with rainfall patterns. This suggests there is at least one other influencing factor. This factor could be gas extraction, farm and urban groundwater extraction, climate change and or a combination of all these things.

***Is it Coincidental?*** It could be that it is coincidental that the water tables are depleted when there is a lack of rainfall because this is the very same thing that triggers the anthropic need to extract groundwater.

***Buffering Capacity of the Aquifers.*** No attempt appears to have been made to determine what the hydrographs would have been like long before extraction of groundwater and gas took place. The historical evidence showing the stability of the aquifers pre fluid extraction has not been attempted. Under natural conditions did the aquifers have a normal oscillation that looked nothing like the huge dips and rises since human extraction has taken place. In a 1986 report the region of the two hydrographs found on pages 35 and 36 was shown to have very stable water table levels pre groundwater extraction. Otway Water Book 35<sup>(26)</sup> discusses in some detail the Dynamic Equilibrium Water Level Zone

whereby the aquifers had a natural buffering capacity against drought and climate change. Since significant groundwater extraction has taken place during the 1982-83 drought the aquifers in the extreme east of the Otway Basin region are anything but stable. In 1986 Farmar-Bowers reported that the water dynamics in the Barongarook High area had been relatively stable for some considerable time, *“Current water tables appear to be quite stable and there is little movement between seasons or years. (J. Leonard Pers.Com.)”*<sup>(25)</sup>

**Note:** little movement between seasons or *years*.

(John Leonard is a hydrogeologist with extensive experience and knowledge of the region.)

### **A Key Word Search.**

Completing a search of the report<sup>(6)</sup> using words in an effort to find what the predicted cumulative impacts from potential developments where, included the following:

**“Risk”** was mentioned 3 times - but no risks listed.

**“Baseflows”** 3 times; **“Baseflow”** 17 times with no changes predicted or mentioned.

**“Impact”** mentioned 109 times with the majority in the footnote on each page; **“Impacts”** 21 times and **“Impacted”** 5 times with no assessment of any potential impact.

**“Groundwater level changes”** yielded nothing.

**“Potential”** was mentioned 23 times regarding the finding of potential risks and what *will be investigated* but nothing was forthcoming.

No risks, benefits or impacts quantifying individual and cumulative impacts from potential developments, including changes to groundwater levels and pressures, and changes to river baseflows, could be found.

### **Scant Environmental Studies.**

Besides the stygofauna study, the Groundwater Impact Assessment Conceptual Groundwater Model report is apparently the best that the VGP can produce as an environmental study. Diligent searching has found no other environmental reports.

This Conceptual Model report<sup>(6)</sup> was released in September 2020. It is stated as the first of a series of three reports to be released.

*“This report presents the first stage, the construction of the conceptual groundwater model framework to simulate any impacts of onshore conventional gas development in the Otway Basin.”*<sup>(6)</sup>

## ***The Three Reports:***

1. Construction of a conceptual groundwater model (completed September 2020).
2. Development and calibration of a numerical groundwater model.
3. Application of possible gas development scenarios and potential impacts of groundwater conditions in the Otway Basin.

This is all very well but there are several problems with this.

- A. Parts 2 and 3 have not been completed. Maybe not even done (see pages 28-30).
- B. Parts 2 and 3 should be based on and follow the conceptual model (see page 30).
- C. The Groundwater Conceptual Model, has enormous data gaps and doubtful input data with misinformation (see pages 31-48).
- D. The connectedness between the offshore and onshore areas of the Otway Basin has largely been ignored (see page 48).
- E. The Victorian Government not fully informed and was “conned” into allowing the onshore gas program to proceed with the above limitations (see page 48).

**A.** One could consider the Victorian Gas Program results regarding the Otway Basin as half baked and difficult to swallow.

***“This report presents the conceptual basis for the groundwater environmental impact assessment in the Otway Basin (South-Western region). The numerical model development and calibration, and results of specific scenario modelling are presented in companion reports (Tarkzaban et al., in prep).”***<sup>(6)</sup> Part 2 - the numerical model, and part 3 - the potential impacts, are in preparation and still to be tabled – as at March 2021.

After repeated requests for this documentation and any other assessment documentation of risks, benefits and impacts of environmental consideration, the best that can be provided is the stygofauna report, an interpretation of the CSIRO phone interview on community thoughts (but not the actual report), and the Groundwater Conceptual Model report (see Appendix Two, page 52 & 53). But, where is the rest...

***“The VGP has also assessed the risks, benefits and impacts associated with onshore conventional gas exploration and development...”*** Where is this?

***“...which was used to inform the Victorian Government’s decisions for an orderly restart of the onshore conventional gas industry from 1 July 2021.”***

Isn’t this information in preparation as part of the Tarkzaban et al. work? Maybe it has been completed and only available for Victorian Government “eyes.”

The Victorian State Government lifted the ban on conventional onshore gas exploration some-time early in 2020 (see page the press below). This was around the time in March 2020 that the VGP Final Progress Report was released.<sup>(9)</sup> How decisions could be made so early in 2020 when Part One, the Groundwater Conceptual Model was not completed until December 2020, and Part Two, the Numerical Mode and Part Three the potential impacts reports are still in preparation.

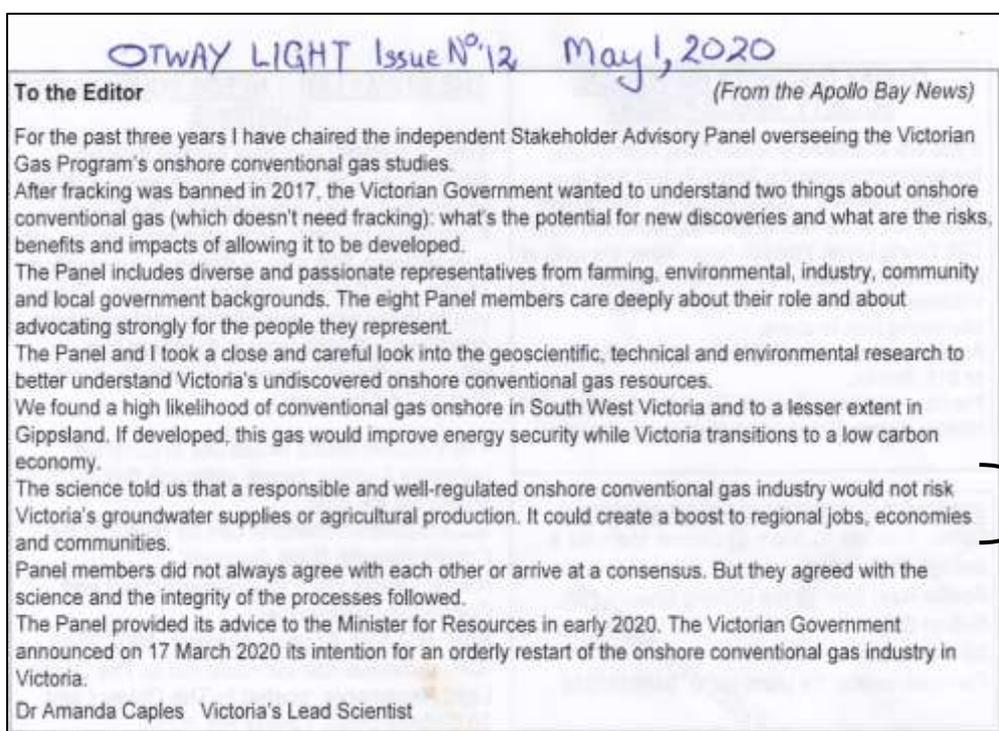
### Fracking Ban Remains.

Part of the Victorian Government's announcement was that the onshore fracking ban is to remain in place. It is my view, however, that the VGP supported this ban as part of a social engineering campaign. Otway Water Book 57 present the case for this view<sup>(5)</sup>



## Important Questions.

The article below includes a supporting statement for the Government's decision from the Chairperson of the Independent Stakeholder Advisory Panel. It also tells the story of the science that found responsible and well-regulated onshore conventional gas exploration would not place at risk



Otway Water Books 57 & 57B challenges this statement. The science or lack of it, tells us to be especially wary due to the massive data gaps. The science also indicates that the Precautionary and Intergenerational Principles should be adhered to as a matter of course.

groundwater or agricultural production. Does this include coupling the offshore and onshore reservoir and aquifer models? No. Does this mean evaluating the onshore impacts from offshore extractions? No. Was the CSIRO science regarding the Gippsland gas fields wrong? Perhaps, but any mention of the CSIRO report<sup>(7)</sup> in the VGP could not be located. And, once again where is the science and documentation supporting the notion that the groundwater supplies will not be affected? Nowhere. Where is the data and or reports made available so that risks and impacts can be scrutinised?

## B. The Numerical Model Follows the Conceptual Model.

A numerical Model is based on a conceptual model.

*"The construction of numerical models, or mathematical models, is based on the conceptual models."*<sup>(11)</sup>

As a result any problems with the conceptual model will be reflected in any numerical model. If a numerical model, Part Two, is ever completed.

### C. Data Gaps & Misinformation.

As with all models the output from the model is only as good as the input into the model. This Section **C.**, questions this input.

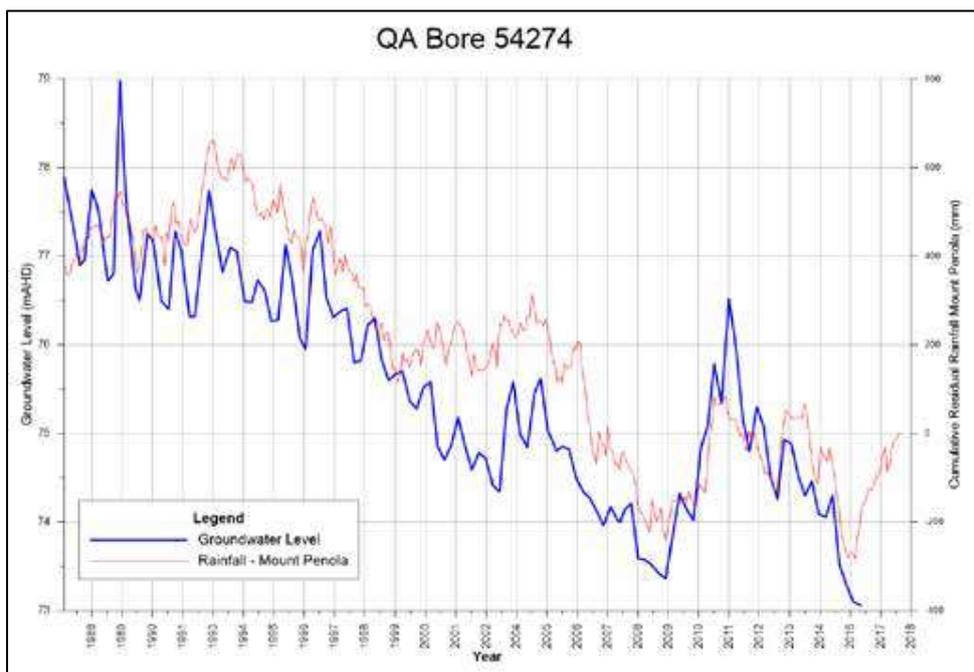
#### Hydrographs and Rainfall.

The Conceptual Report draws a high correlation between downward movement of water levels in the aquifers in the study area with rainfall decline. This correlation is emphasised and repeated in each of the numerous hydrographs taken from the study area.



Figure 2.1 Onshore conventional gas program study area and South-West region groundwater model extent.

In fact there are 36 such graphs in the report representing nine aquifers and one aquitard. For example – QA Bore 54274 below.



However, the correlation drawn between water table movement and rainfall can be extremely misleading. Especially so if notice is taken of the amount of dialogue written about each set of hydrographs in regard to human use.

**The Quaternary** “...*aquifers are extensively used by the agricultural sector.*”<sup>(6)</sup>

**The Upper Tertiary Basalt Aquifer** “...*can yield appreciable volumes of water ... and are also well-known as a groundwater resource*”<sup>(6)</sup> “*This aquifer is likely to be significant in providing indirect groundwater recharge to the deeper aquifers over a large area.*”<sup>(6)</sup>

**The Upper Tertiary Marine and Fluvial Aquifer** in the study comprise a collection of various formations highly variable in lithology. “*This aquifer typically does not produce high yields and is considered to be of local significance (SRW, 2011).*”

**The Upper Mid-Tertiary Aquifer** “...*is the most utilised aquifer of regional significance ... and provides reliable water supplies for numerous towns in the Otway Basin.*”<sup>(6)</sup>

**Lower Mid-Tertiary Aquifer.** “*Its variable lithology makes it an important aquifer in some areas.*” “*Yields from this aquifer are not well documented.*”<sup>(6)</sup>

**The Lower Tertiary Aquifer** “...*is the most important regional sandy aquifer in the Otway Basin, supplying several towns including Geelong, Port Campbell, Timboon, Peterborough, Port Fairy and Portland (SRW, 2011, Wannon Water, 2019).*”<sup>(6)</sup>

**The Upper Crustaceous Sherbrook Aquifer.** “*The formations are well known gas and petroleum reservoirs and are associated with high salinity formation water, therefore are not generally used for groundwater supply due to their depth and poor water quality.*”<sup>(6)</sup>

**The Palaeozoic Basement.** *They are commonly considered as having very low permeability, forming a no-flow lower boundary to groundwater. However, this assumptions not always valid, as there are many water supply bores constructed in Palaeozoic rocks, particularly for stock and domestic uses.*”<sup>(6)</sup>

This dialogue shows that the greater majority of the aquifers in the study area are utilised as a water supply for the numerous human activities. Agriculture, irrigation, Stock & Domestic and urban reticulated water. It just so happens that this will be during dry periods of low or lower rainfall. What should be compared is what the hydrographs looked like before and after human extractions of groundwater. For example before groundwater extraction the Gellibrand Groundwater Management Area, which is part of the Otway Basin study area, had a significant buffering capacity to counteract dry summers, drought and climate change. The hydrographs remained relatively level.

The following four hydrographs taken from the Conceptual Model report<sup>(6)</sup> appear to lack a consistent and plausible correlation between the water level and rainfall.

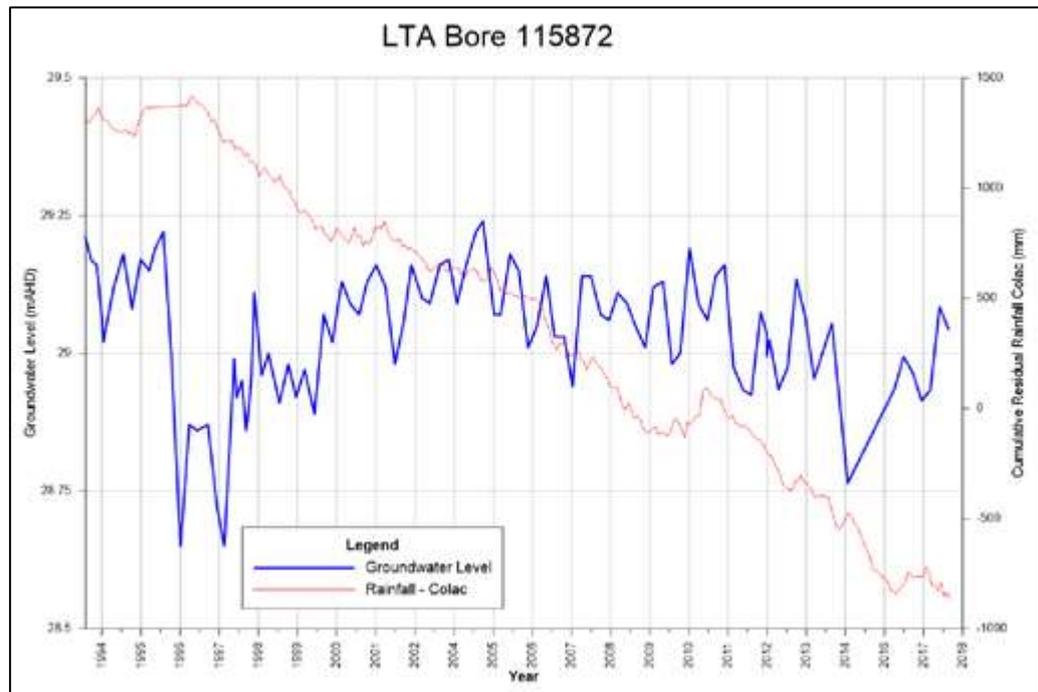


Figure 3.52 Groundwater levels and cumulative residual rainfall versus year at LTA Bore115872 (2 km northeast of Timboon, 12 km north-northwest of Iona site, screen depth416 m).

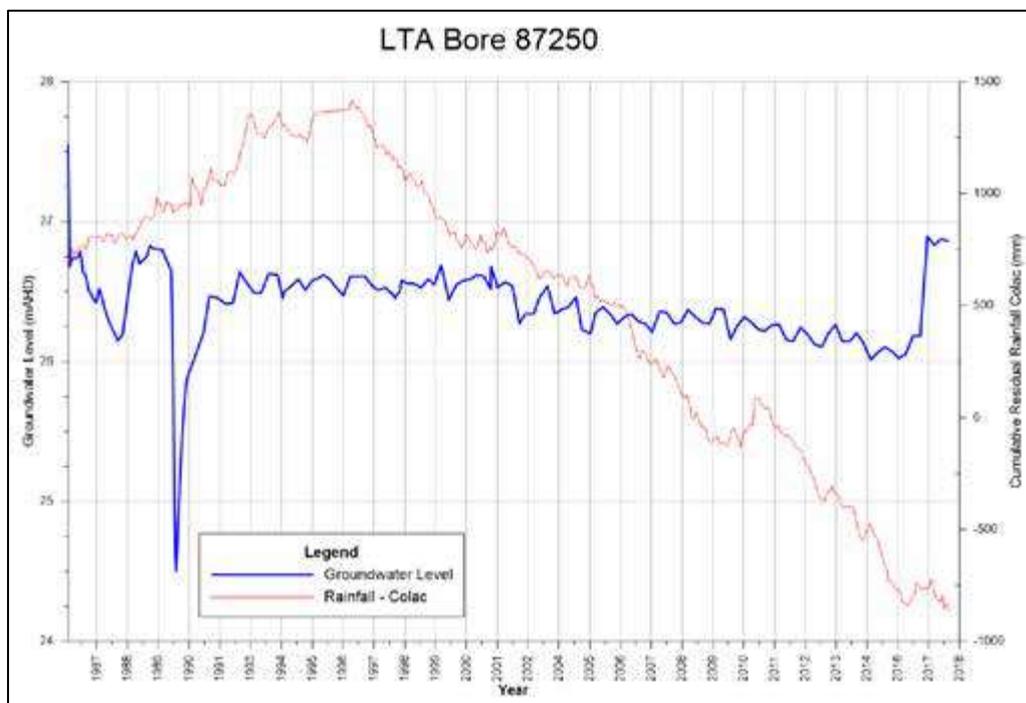


Figure 3.49 Groundwater levels and cumulative residual rainfall versus year at LTA Bore 87250 (7 km north of Port Campbell, 3 km northwest of Iona site, screen depth 659 m).



Figure 3.13 Groundwater levels and cumulative residual rainfall versus year at UTBA Bore 54475 (3 km northeast of Streatham, screen depth 15 m).

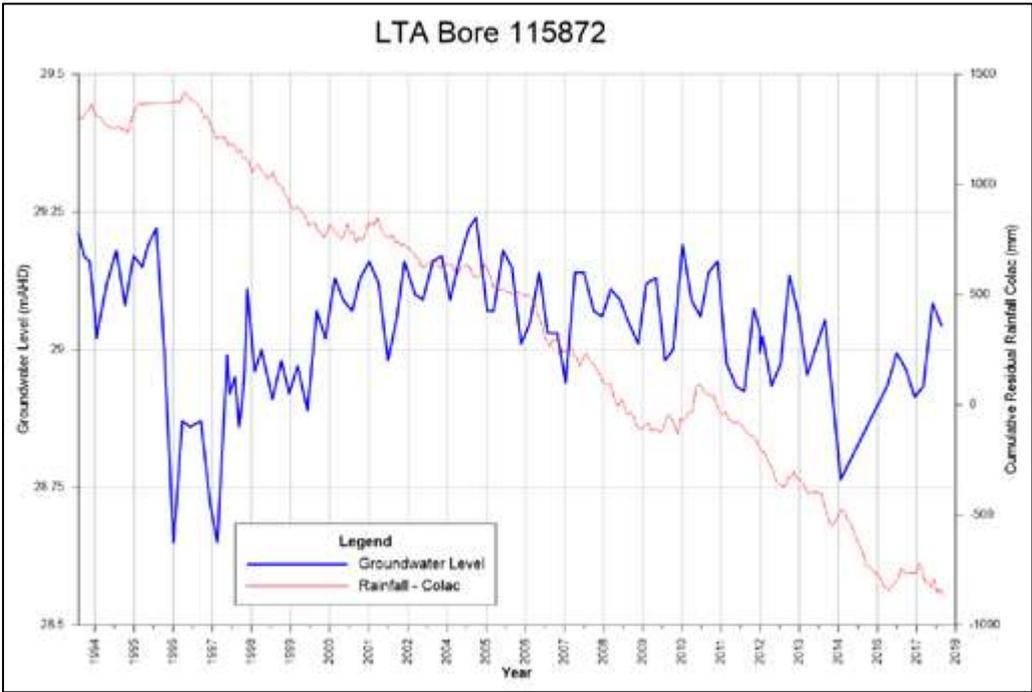


Figure 3.52 Groundwater levels and cumulative residual rainfall versus year at LTA Bore 115872 (2 km northeast of Timboon, 12 km north-northwest of Iona site, screen depth 416 m).

The highest demand period for groundwater extraction is when there is little rainfall. Perhaps a better correlation comparison would be groundwater extraction volumes against the bore hydrographs. At the very least there would appear to be more factors driving the hydrograph changes than rainfall.

**Perhaps Groundwater Extraction, NOT Rainfall, Drought, Land Use Change or Climate Change is responsible for the Downward Hydrograph Trends.**

Two bores that graphically highlight this are PBSE Bore 64230 and LTA Bore 64233. The rainfall correlation is coincidental. When investigating these two bores from a site specific angle the hydrograph movement is critically related to groundwater extraction.

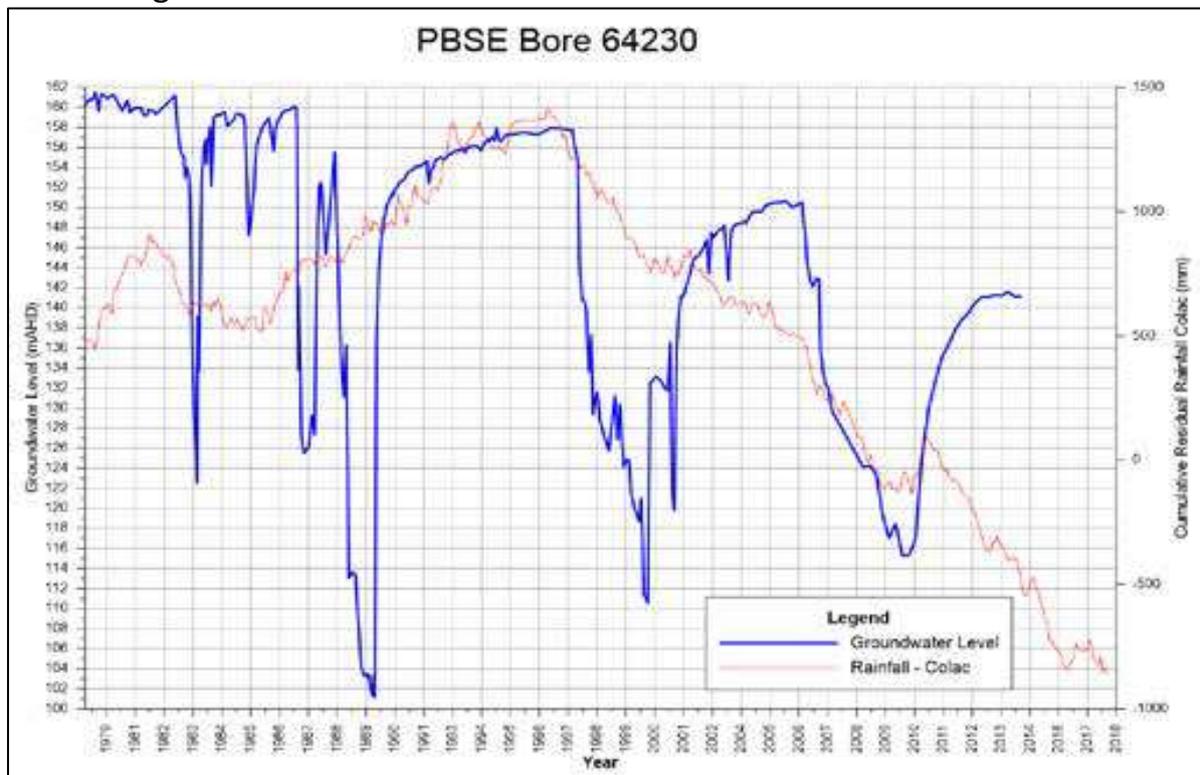
**Map location of Bores 64230 & 64233** can be seen on page 37.

PBSE Bore 64230 is approximately 13 km south east of the Colac rainfall used for comparison. Is this comparison relevant with such a distance difference? No. Maybe, it could be argued the Colac rainfall is relevant to this bore's recharge intake area. However, it would be a difficult argument to claim the same for LTA Bore 643233 that is approximately 32 km from the Port Campbell rainfall gauge that has been used for correlation.

These two graphs are worth some examination and highlight three things.

1. Groundwater extraction is a better fit for the hydrograph rises and dips and downward trending.
2. Without the groundwater extraction the pressure head in this aquifer would have maintained a relatively flat line trajectory close to pre groundwater extraction levels.
3. The rainfall comparison as appropriate seems doubtful.

Observation bores 64230 (on this page), and Bore 64233 (next page) are well inside the residual drawdown area influenced from the Barwon Downs Borefield groundwater extractions.



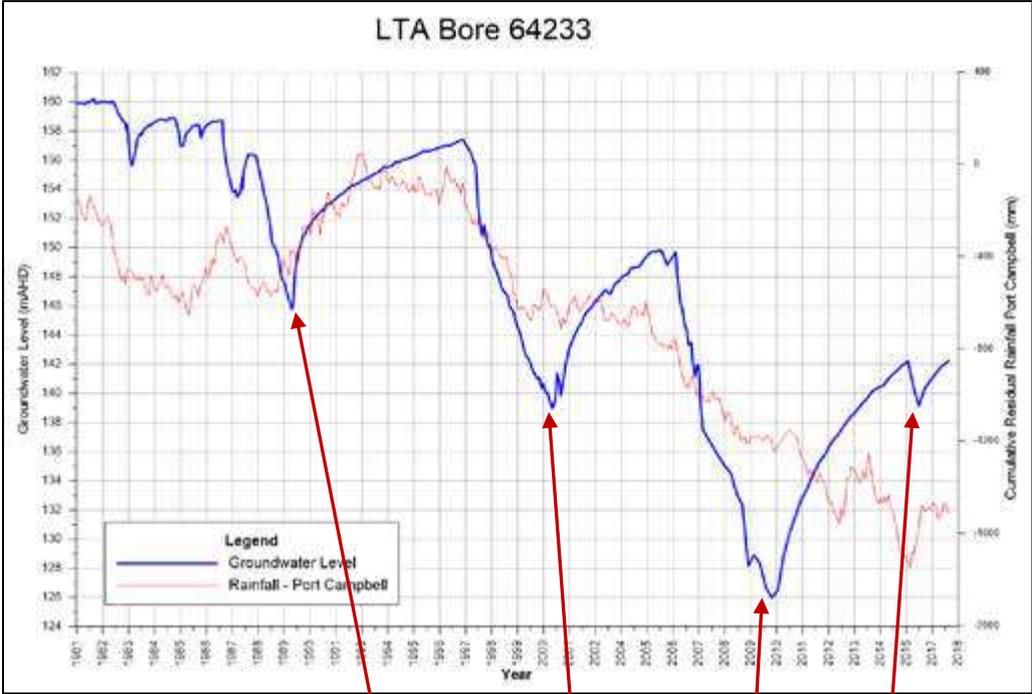
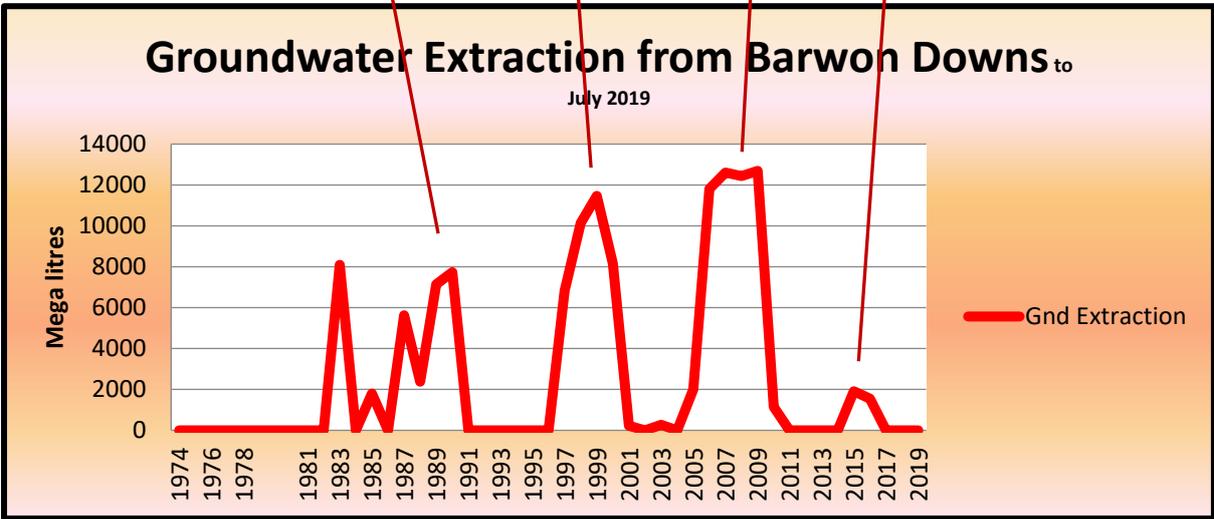


Figure 3.29 Groundwater levels and cumulative residual rainfall versus year at LTA Bore 64233 (15 km southeast of Colac, screen depth 154 m).

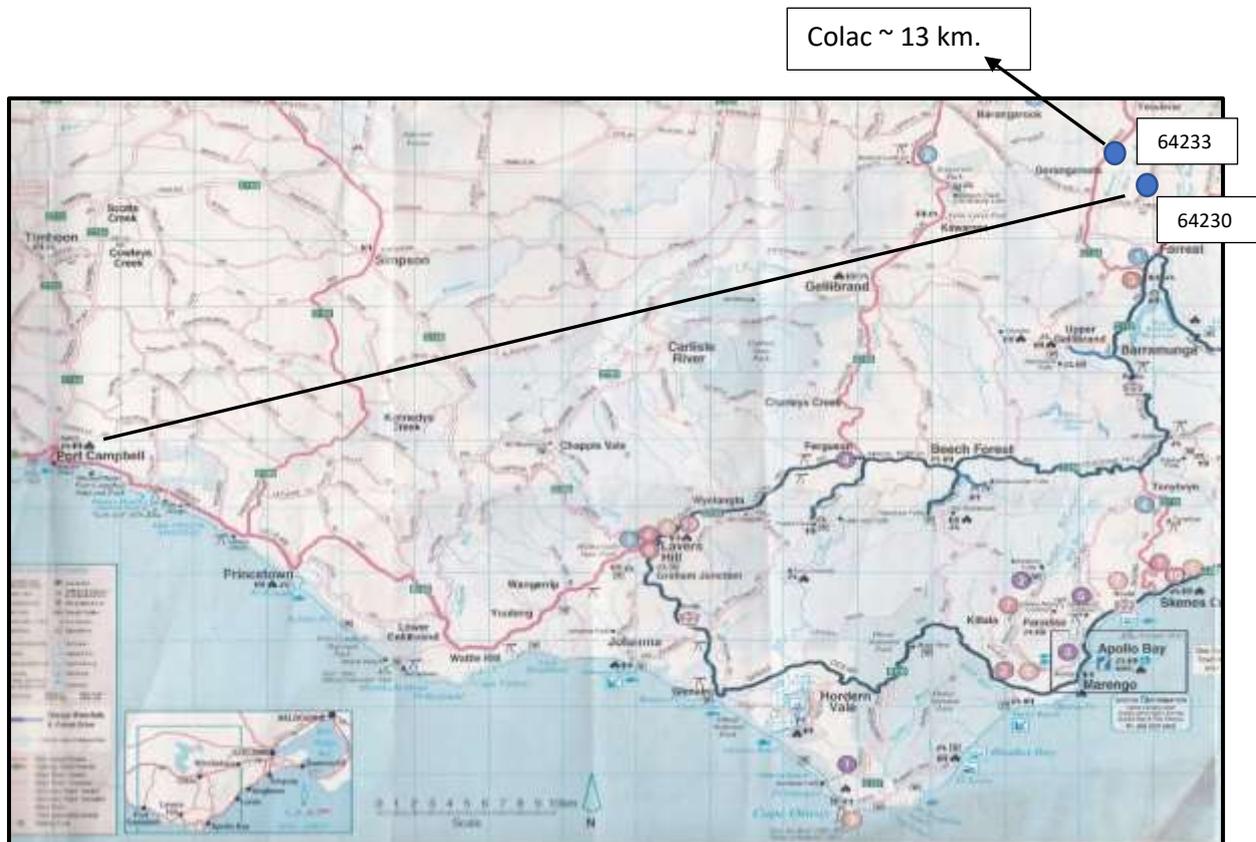


The correlation between groundwater extraction with the bore hydrographs in Observation Bores 64230 and 64233 is a far better match than the rainfall as a causative influence on the water level graph movements.

As the Conceptual Model report states ***“Steep declines are consistent with intensive nearby groundwater pumping.”***<sup>(6)</sup> With this in mind why hasn’t groundwater extraction rates, rather than rainfall, been used as the major correlating factor graphed against groundwater decline?

It has been shown that groundwater extraction at the Barwon Downs Borefield is by far the major reason for the severe fluctuations in these two hydrographs and other Observation Bores within the residual drawdown impact area.

### Site Location of Observation Bores and Rainfall Gauging Stations linked by the VGP to these bores.



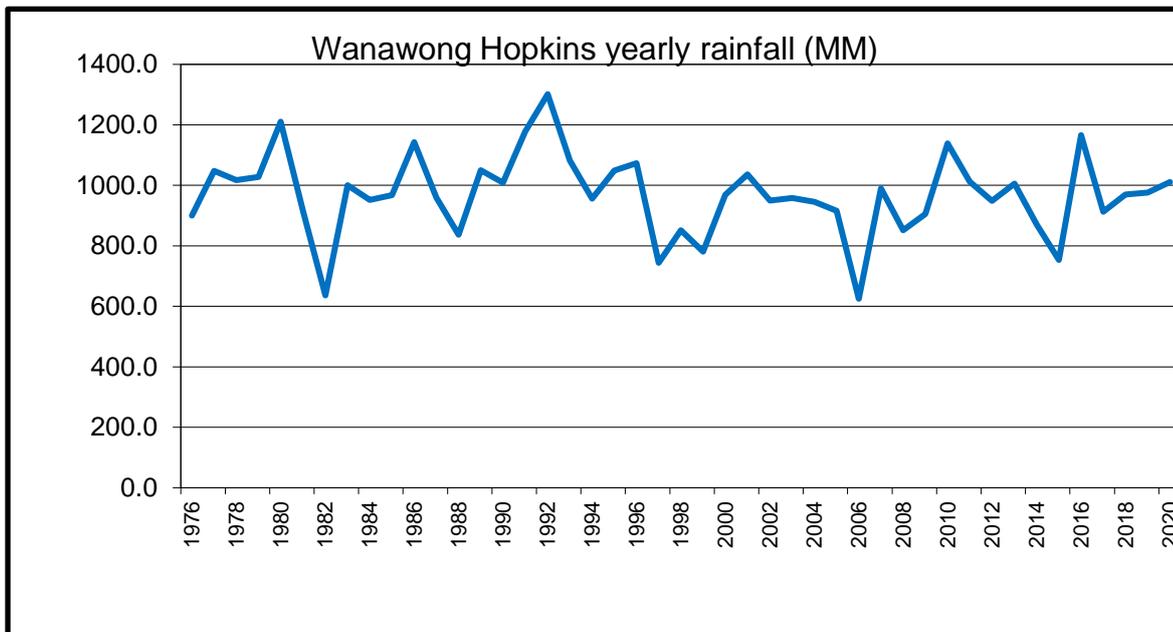
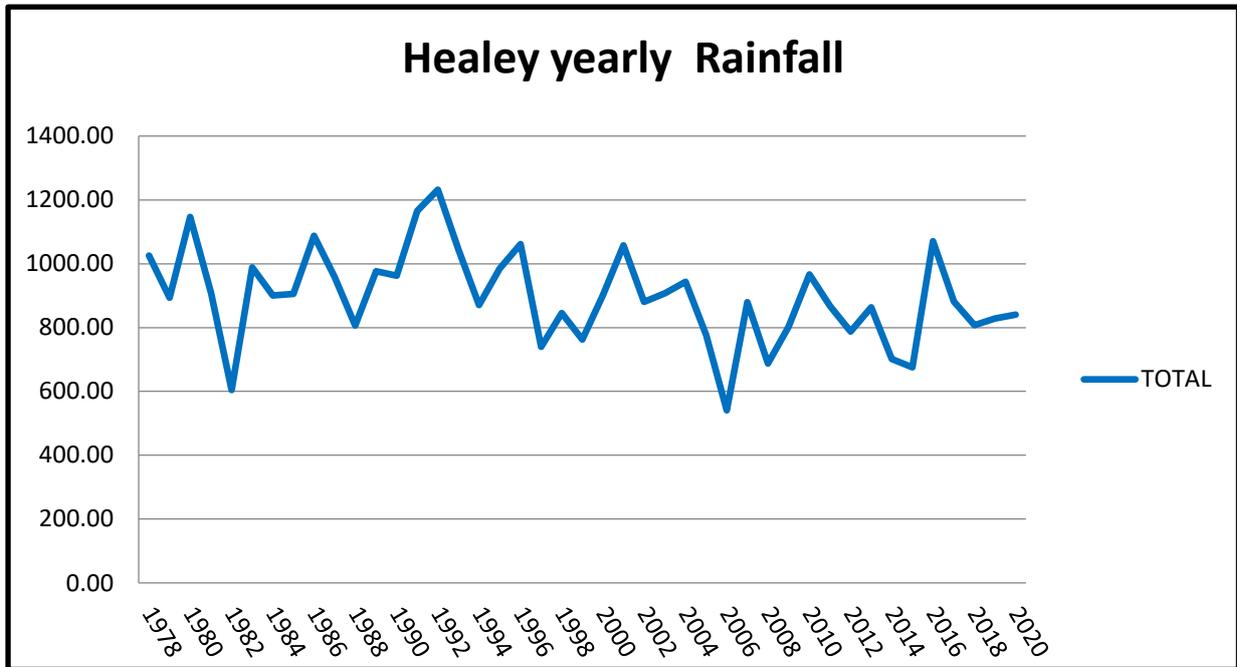
### Rainfall Comparison.

The Conceptual Model report<sup>(6)</sup> gives a strong impression that reduced rainfall across the Otway Basin is the reason for downward trending hydrographs. In the narrative of the various aquifers the word “*correlation*” is linked with “*strong*” twice, “*distinct*” once, “*stronger*” once, “*clear*” twice, “*broad*” once, “*moderate*” by 2, “*weak*” by 1, “*some*” by 1 and “*little*” by 2. The emphasis on this rainfall correlation is consistent and to the exclusion of other variables. This leads the reader of the report to conclude rainfall has the biggest influence on the behaviour of the bore hydrographs.

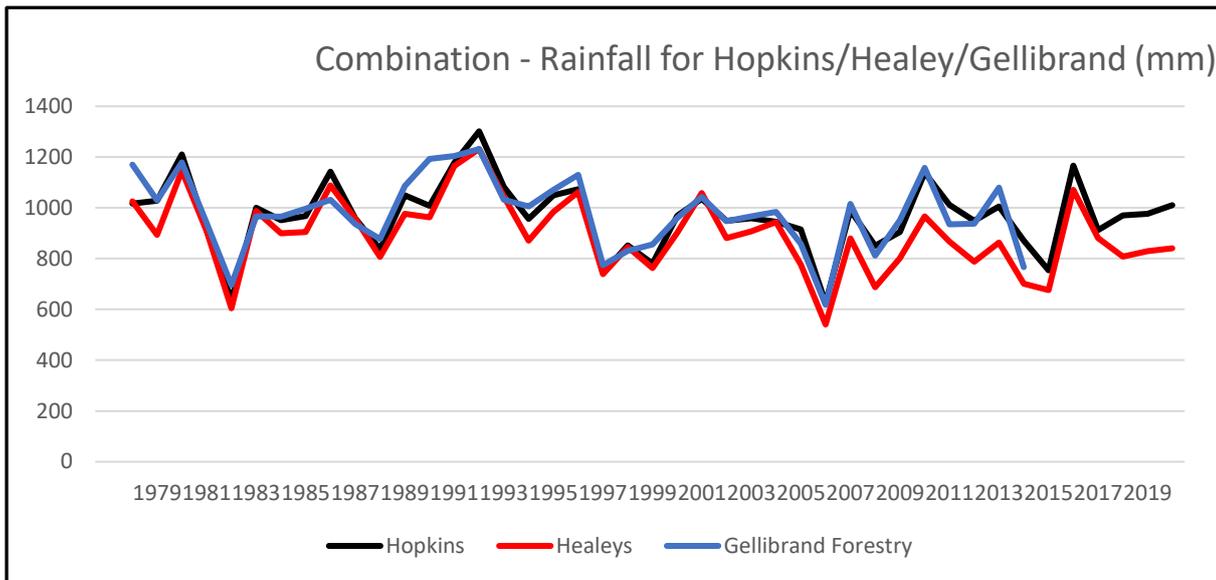
LTA Bore 64233 is located approximately 32 km from Port Campbell. And, PBSE Bore 64230 is located approximately 13 km from Colac. If rainfall was the best way to determine why the aquifers are behaving in the way they are, then using rainfall data close to the recharge regions for the bores would appear to be a much better match. Both the rainfall data for these bores is most definitely not taken from the aquifer recharge areas.

The recharge area for Bores 64230 and 64233 is the Barongarook High area south of Colac.<sup>(17)(18)(19)(20)(21)</sup>

The following two rainfall graphs are the Healey rainfall station that is on the Barongarook High and the Hopkins gauge that is on the southern edge of the High.



On the next page these two graphs have been placed on the same graph with the Gellibrand Forestry rainfall. See page 40 for the location of these sites.



From the Barongarook High and south to the coast the rainfall has varied very little over the years,<sup>(16)</sup> and this does not match the map of the rainfall bands (isohyets) found in the Conceptual Model report.<sup>(6)</sup>

This is the rainfall bands (isohyets) map taken from the Conceptual Model report.<sup>(6)</sup>

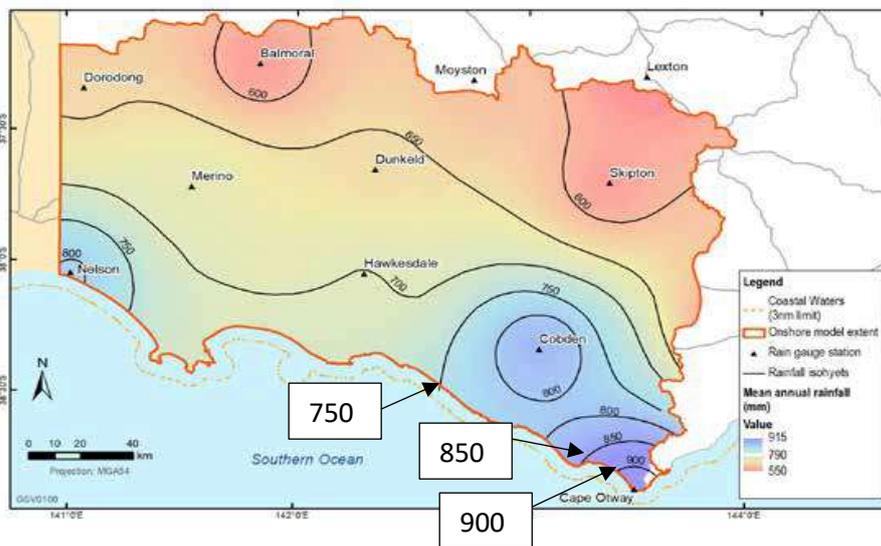
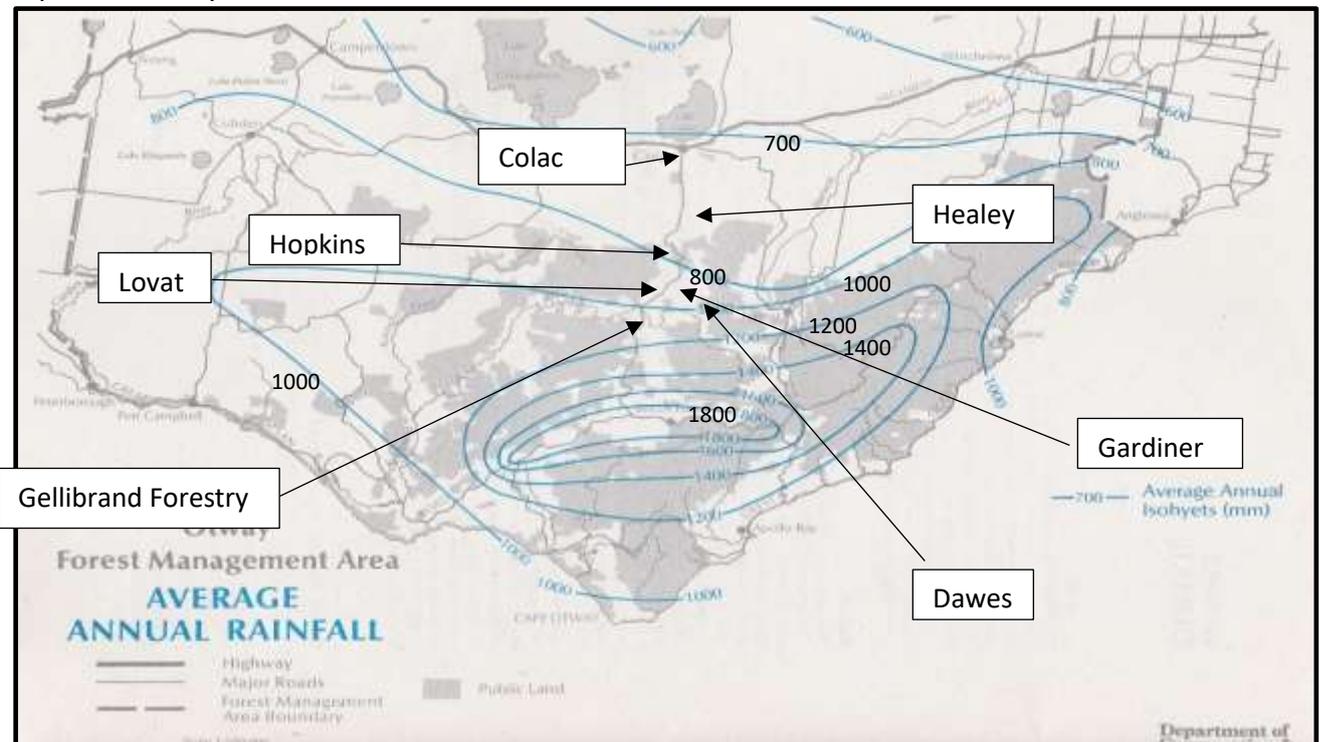


Figure 2.4 Distribution of mean annual rainfall across the south west region (1950–2017) (BOM, 2018).

This map has markedly different average rainfall distribution isohyets to those found in the 1990’s Otway Forest Management Area, Forest Management Plan.<sup>(22)</sup> The 1990 isohyets and the location of several rainfall gauging stations has been taken from Otway Water Book, February 2021, Book 21 B.<sup>(16)</sup> This book shows that the isohyets over recent years are extremely close to those indicated for the 1990’s. Rainfall data showing this similarity have been taken

from the records of the rainfall gauging stations at Colac, Healey's, Hopkin's, Gardiner's, Lovat, Dawes's and the Gellibrand Forestry.

Map taken from Otway Water Book 21 b.



SOURCE: 1990 Otway Forestry Management Plan, Victorian State Government.

It would appear that the Conceptual Model<sup>(6)</sup> has used a broad paint brush style approach for data representation. Comparing such diverse areas and range of data loses site specific focus. Rainfall data should be closer linked to the recharge areas for the various aquifers and then related to the bores monitoring those aquifers. Then there may be some relevance between rainfall and water table levels. Not haphazardly matched in such a disjointed fashion. Up to this part of the discussion aquifer drawdown would be better compared with licenced groundwater extractions. But, there may be better data for comparison and consideration.

However with 1,367 groundwater production bores in the study area, groundwater extraction influence cannot be discounted. ***“The south west region contains 40% of all licenced groundwater bores in Victoria (SRW, 2011).”***<sup>(6)</sup> The south west region includes the Otway Basin.

Also, ***“Approximately 100 ML/year is the typical irrigation licence volume.”***<sup>(6)</sup> From the Tertiary aquifer formations ***“Approximately 30% of current groundwater licence holders abstract up to 10ML/year, and 72% of licence holders abstract up to 200ML/year...”***<sup>(6)</sup> If calculated this would add up to a sizeable amount of water. An amount worth considering as the major reason for water level drawdown across the Otway Basin.

### **Stock and Domestic**

S & D extractions do not have to be licenced and have not been accounted for as part of data input into the Concept Model. These extractions should be taken into consideration. The following quotes are the only two references made of Stock & Domestic water in the Conceptual Model<sup>(6)</sup>. *“Some hydrograph patterns from the QA are influenced by pumping for stock and domestic water supply.”*

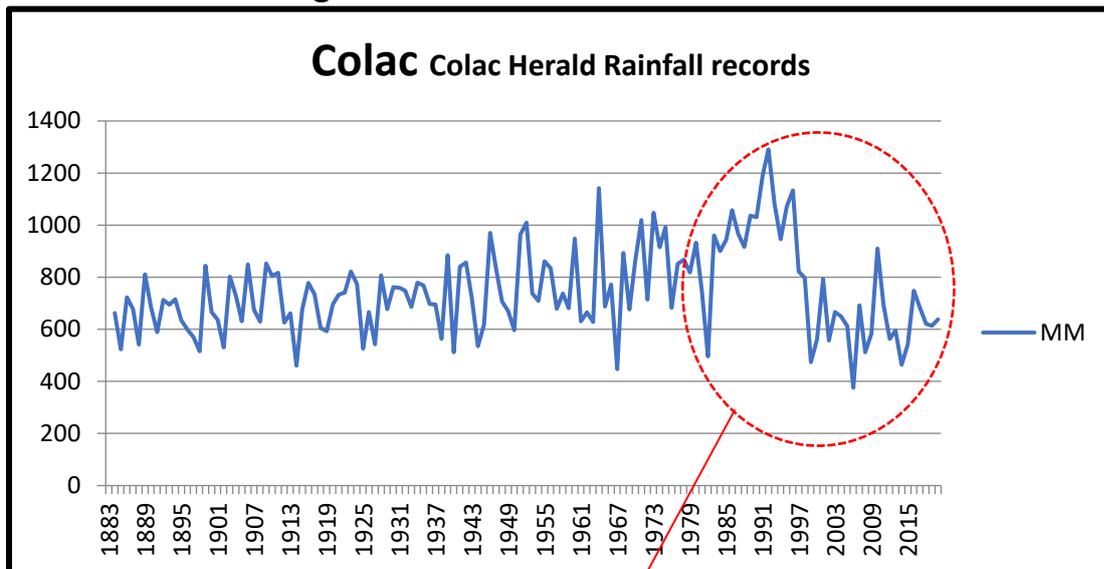
*“However, this assumption is not always valid, as there are many water supply bores constructed in Palaeozoic rocks, particularly for stock and domestic uses.”* Models are only as good as the quality and amount of input. With S & D groundwater extractions included the model output would be even better.

### **Historical Water Levels Critical.**

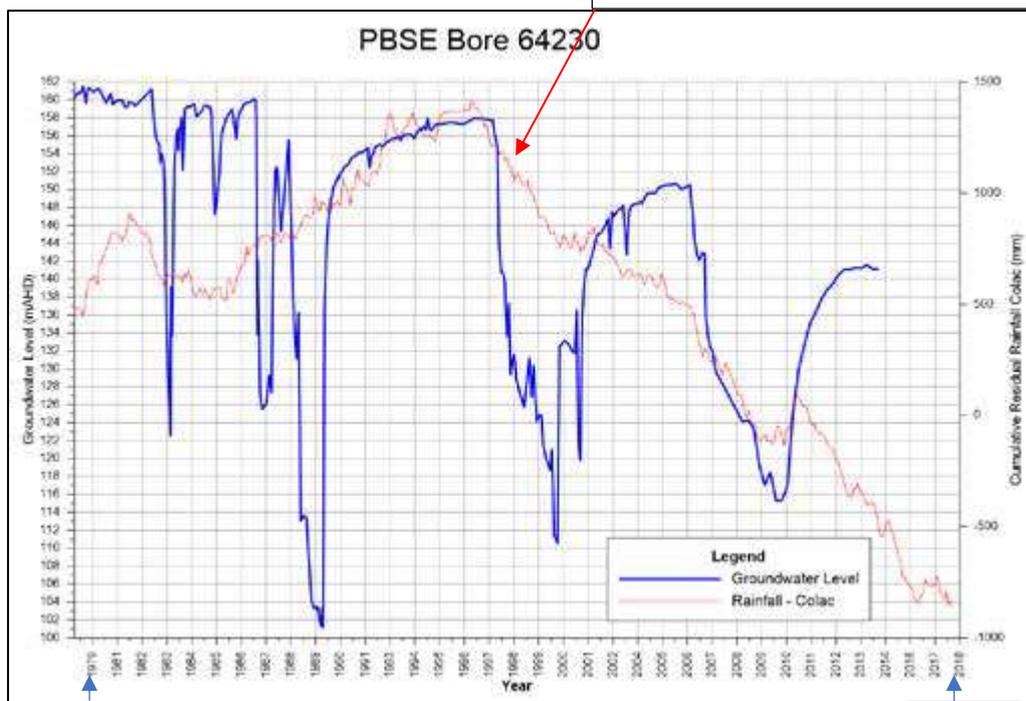
Determining historical pre groundwater extraction water levels is critical. Pre groundwater extraction level comparison with the onset of extraction would indicate the degree of impact and should be taken into account in the modelling. This does not appear to have been undertaken.

The longer this is left the greater the chance of being able to garner any information especially at a local landholder experience and knowledge.

1990s Rainfall Data gives a skewed cumulative residual rainfall results.



Very wet period in the early to mid 1990's.



1979

2017

Comparing the natural rainfall with the cumulative residual rainfall used in the Conceptual Model<sup>(6)</sup> is interesting.

**“Overall. There was an increasing trend from the 1950s to the 1990s, followed by a distinct downturn to the present day.”** Has the cumulative residual downward rainfall trend come about because of an unusually extremely wet period during the early 1990's that has an unusually higher cumulative residual rainfall drop when rainfall returned to pre 1990 levels? A skewed result. Possibly. **Rainfall impact needs to be revisited.**

# The Impact on Groundwater from Gas Extraction.

## Onshore Fields:

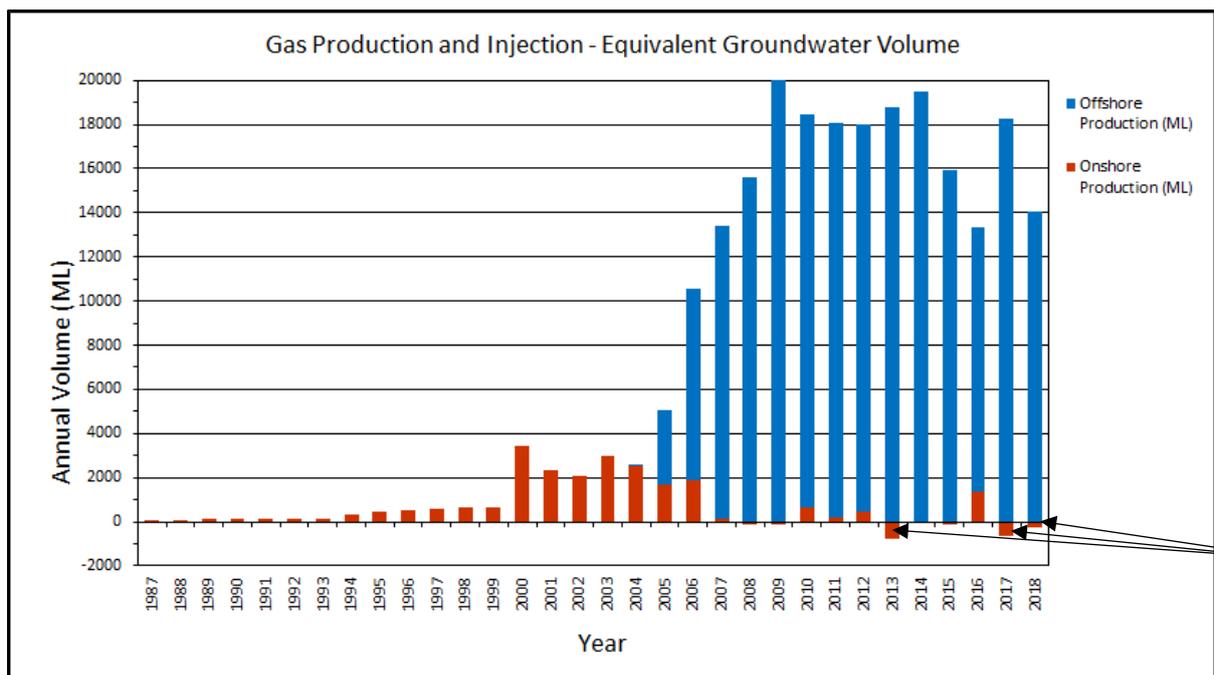
*“Gas production commenced onshore in 1987, increased in 2000 and further increased with offshore production in 2005...”<sup>(6)</sup>*

*“Onshore conventional gas reserves to the north and north-west of Port Campbell were in commercial production between 1987 and 2005 (Clarke et al., 2015; DPI, 2007)...”*

*“All of these fields are now depleted; however, some continue to be used for gas storage and recovery by reinjection via the Iona gas facility, with product sourced from Moomba in South Australia (Moe, 2017).”<sup>(6)</sup>*

*“No hydrographs show clear trends in parallel with gas production or re-injection volumes.”* Wow.

This last statement is strongly challenged on pages 44 – 47.



*“After 2007 there was also cyclic re-injection and withdrawal of gas stored in some of the onshore gas fields, which would be expected to produce a fluctuating pattern if it impacted on the overlying aquifers.”<sup>(6)</sup>*

In comparison to gas volumes extraction the re-injection amounts seem miniscule and it is doubtful that a fluctuating pattern would immerge as a result.

### **Data not included – not available.**

1. The graph of natural gas production above does not contain the *“...production data for the Iona field for 1998/99 and 2007/08 financial years, as well as an absence of condensate data from 2002/03 to 2004/05.”*<sup>(6)</sup>
2. The Boggy Creek field data used does not have production condensate from 2007/08 to 2010/11.<sup>(6)</sup>
3. *“There is no available production data (gas or condensate) for the Buttress and CRC fields as well as the Naylor field after the 2004/05 financial year.”*<sup>(6)</sup>

The graph of gas production would be markedly different if the data from these periods was included.

## **Claims of No Impact on Groundwater from Gas Extraction.**

The Groundwater impact Conceptual Model report, Onshore Otway Basin, Victoria,<sup>(6)</sup> concluded that gas production from the Otway Basin has had no impact on groundwater.

*“Groundwater monitoring data has provided no evidence to suggest that historic gas production in the Port Campbell area (onshore and offshore) has impacted the overlying groundwater aquifers.”*

**Were the LTA and UKSD the only aquifers investigated for gas extraction impacts?**

Bores from the Lower Tertiary and the UKSD aquifers were the ones monitored with the specific aim of determining whether there was gas extraction impact. Aquifers above these two lower aquifers did not appear to come into the calculations.<sup>(6)</sup> *“The trends evidenced in the available groundwater level data for the LTA and UKSD1 in the Port Campbell region do not show any historic impacts from the gas industry...”* What about the higher aquifers? Or the lower aquifers? Were they discounted out of hand? With a result that concluded...*“Groundwater monitoring data has provided no evidence to suggest that historic gas production in the Port Campbell area (onshore and offshore) has impacted on the overlying groundwater aquifers.”*<sup>(6)</sup>

However, there would appear to be little data and or discussion within the report that *supports* this notion. In fact the data provided shows the opposite. It would also appear that other than the aquifers of the LTA and UKSD1, none of the other aquifers were even considered. The emphasis and causal reason for the hydrographs downward trend has been projected as declining rainfall. With hints that groundwater extraction may be a contributing factor.

## Denial.

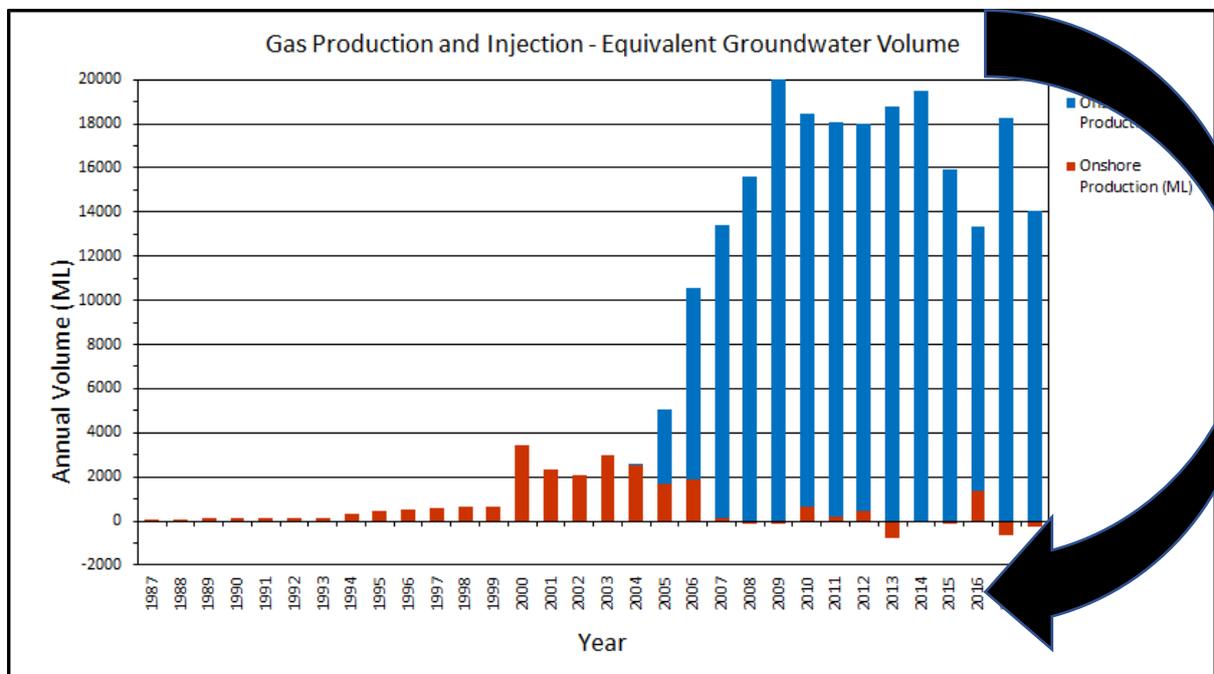
### The Statement Denying Impact from Gas Extraction.

*“The trends evidenced in the available groundwater level data for the LTA and UKSD1 in the Port Campbell region do not show any historic impacts from the gas industry and are likely to have been influenced by processes of natural recharge-discharge and groundwater pumping.”*

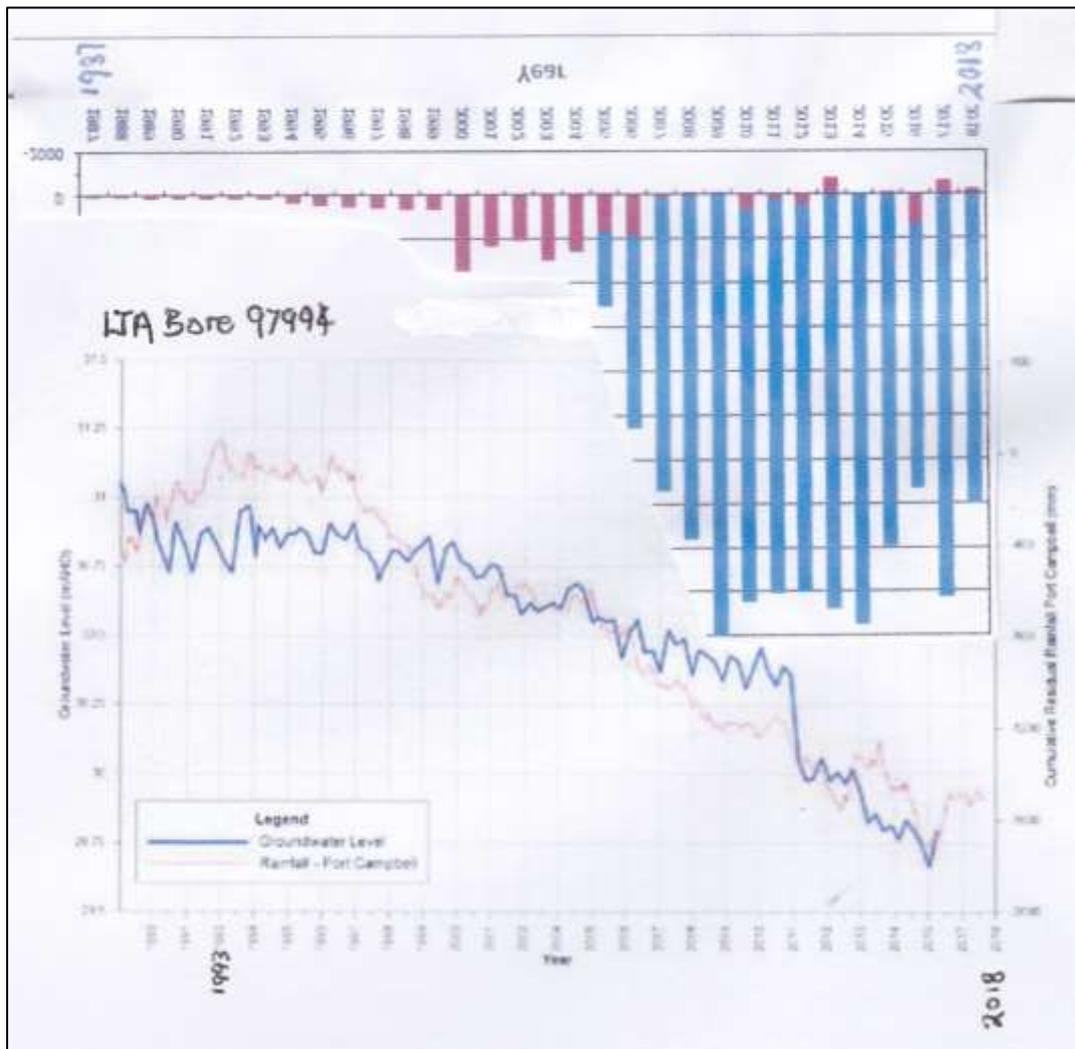
The correlation between rainfall and the trends of aquifer water table movement has been presented throughout the Conceptual Model report. No other graphic detail or clear possibility has been presented. There is this narrative that groundwater extraction could be a possibility but is left up to the reader’s imagination to join the dots. Perhaps groundwater extraction and rainfall are partly responsible of downward trending hydrographic levels, but there appears to be a bigger contributor.

### Gas Extraction.

However, there is graphic data available to compare gas extractions with bore hydrographs. In an effort to do this and show a correlation between gas extraction and downward trending hydrographs, the following table taken from the Conceptual Model report showing gas extractions has been flipped horizontally and then placed against three bore hydrographs also found in the Conceptual Model report.<sup>(6)</sup>



An extremely strong graphic correlating pattern emerges.



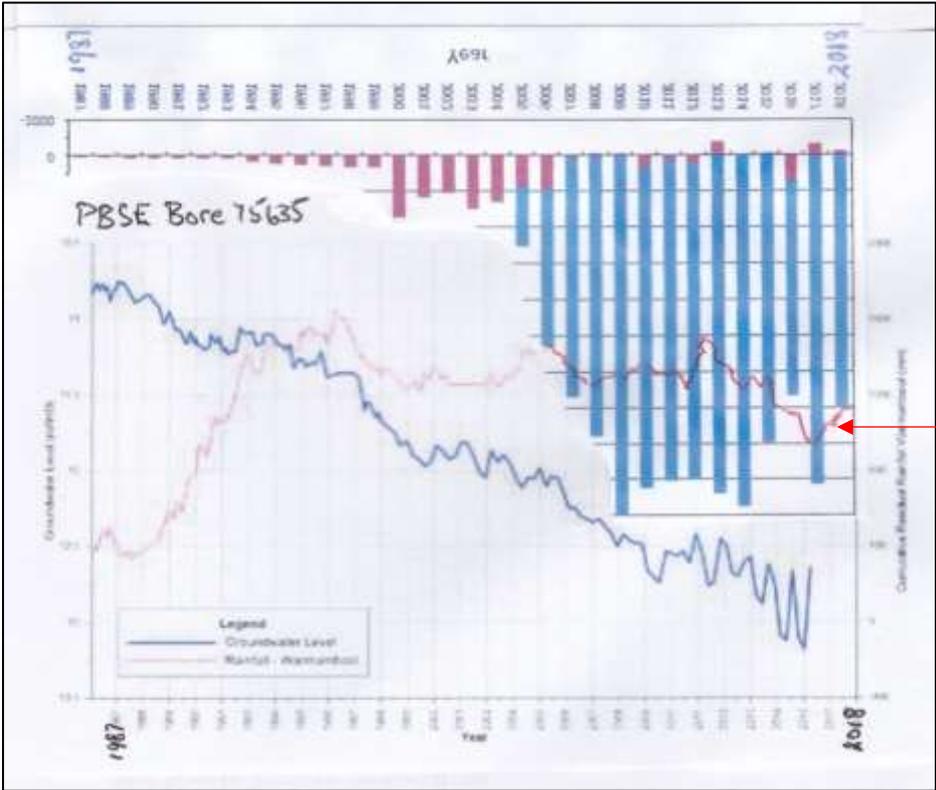
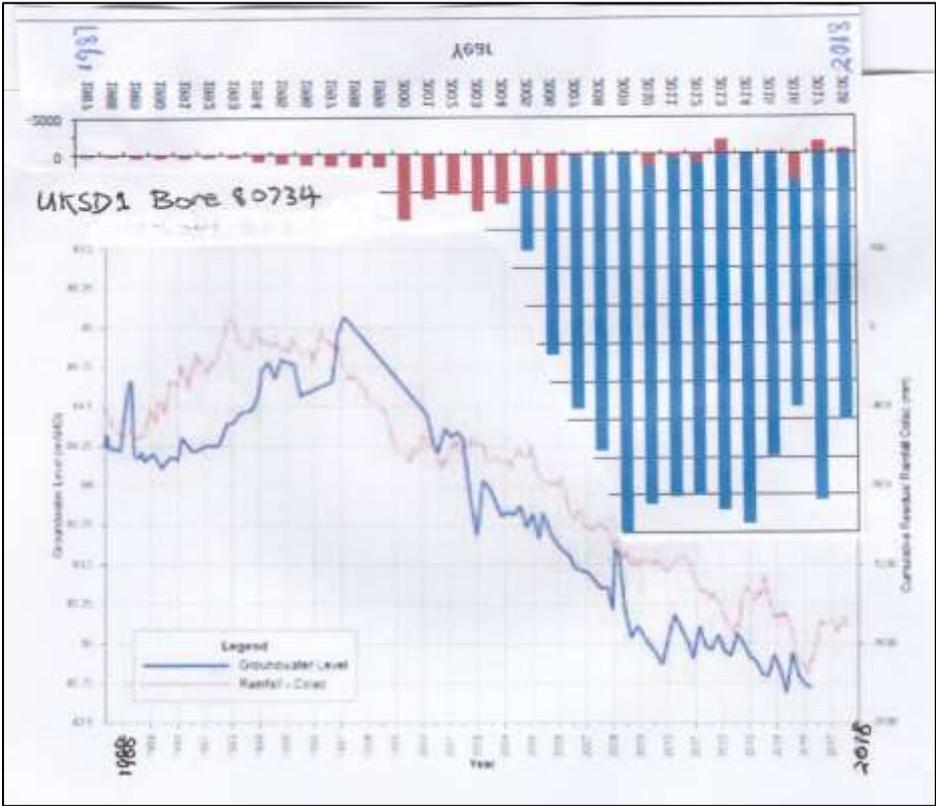
Out of 185 LTA bore hydrographs referred to in the Conceptual Model report, it is stated that 159.1 groundwater level trends were falling, with 20.35 levels stable and 5.55 rising.

In other words 80% were falling and this supports the argument that there is significant impact at the Lower Tertiary Aquifer level.

***Could it be gas extraction?***

***Yes. Most definitely.***

Without exception the gas extractions correlate with the falling water tables used in the Conceptual Model report.



Rainfall trend.

The gas extraction figures certainly show a close correlate with the bore hydrographs much better than the rainfall ones. If the missing data sets from

production wells as mentioned on page 44 above, were included, then this correlation would be so much more convincing.

#### **D. Onshore offshore Connectedness.**

Throughout the VGP process the onshore and offshore regions have been treated as two distinct systems. If nothing else it should have been learnt from the 40 years of offshore Gippsland extraction of gas and oil, that the onshore and offshore ecosystems are intricately interwoven. Especially when the onshore aquifers discharge out to sea and that the offshore extractions depressurise these very same aquifers. Perhaps the VGP has come to realise this in some small degree when in the 3<sup>rd</sup> VGP report,<sup>(10)</sup> page 27, it states that a refined 3D geological framework model will “...*seamlessly join the new onshore map with the existing offshore Gippsland Basin 3D geological model.*”

Not that this instils a great deal of confidence in the Victorian Gas Program. This very thing was muted 17 years ago in the 2004 CSIRO report<sup>(7)</sup> recommending a “...*coupling the offshore and onshore reservoir and aquifer models...*”<sup>(7)</sup> This was seventeen years earlier and still nothing had been done. If done, this would go a long way to better defining exactly how the system was working and better inform correct decision making. A clearer picture of the sustainability of local water supplies and impact on the environment would be reached. Not done 17 years ago, and there is no evidence that it has been done as at February 2021. Especially in the Otway Basin Conceptual Groundwater Model dated December 2020.<sup>(6)</sup>

#### **E. State Government Not Fully Informed.**

To my knowledge and from numerous requests for final documentation of the Victorian Gas Program investigations, the final documentation has not been completed. Part Two, the numerical model and Part Three the risk scenarios. Yet, the State Government was given assurances that onshore gas exploration in the Otway Basin would cause few if any problems. As a result permission was given last year to proceed with onshore exploration. Unfortunately, the results of this incomplete work also suggests that after exploration, extraction would be as acceptable.

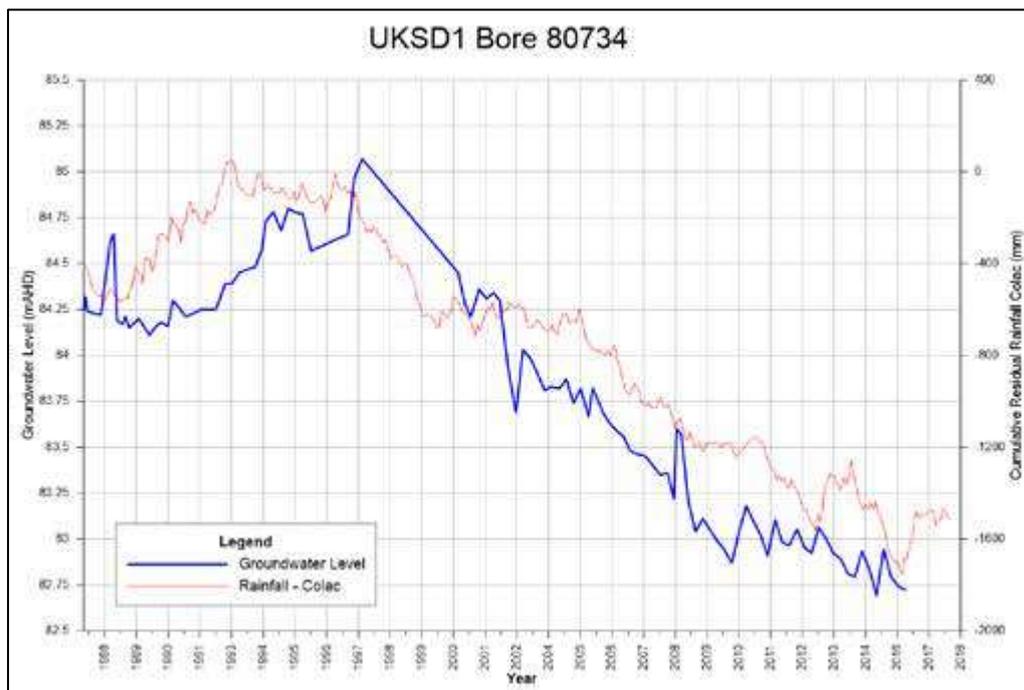
***But, then again maybe this no impact scenario was not so hard to accept, considering a gas lead recovery from the COVID 19 impacts has a certain ring to it.***

### Double Check Statements.

When making statements and drawing conclusion it is critical that there is a review process. On page 45 of the Conceptual report in table 3.5 this statement is made.

**“80734 UKSD1 (Paaratte) Semi-Confined 153 +2x Steady 38 E.”**

The 2019 Bore 80734’s water level trend has been classed as steady. Not falling and not rising. However, on page 48 of the same report the hydrograph for Bore 80734 is shown as follows.



This hydrograph water level is anything but steady. More on a steady decline, but most definitely not steady in the context setting of falling, steady or rising.

### What Would a CSIRO Report on the Otway Basin Say?

Both the Otway Basin gas and the Gippsland Basin gas is water driven. Land holders in the Yarram/Seaspray area were told pre the CSIRO report that offshore gas extraction could not possibly be the cause of onshore impact to groundwater levels. The CSIRO report concluded that offshore extraction was in fact the cause of onshore impacts. Despite climate change, drought, land use change, irrigation and Stock & Domestic groundwater use, the major cause for the depletion and impact on onshore groundwater levels was the offshore extraction of gas.

Is the Otway Basin any different? Does this mean irrespective of the variables of rainfall, climate Change, landholder and urban utilisation of groundwater, that gas extraction from the Otway Basin is causing the aquifers in that basin to be on a downward trending pattern? The graphs and data presented on pages 40 to 42 would tend to suggest the very same thing is happening in the Otway Basin as is happening in the Gippsland Basin. Forest, farmland and recharge areas severely impacted.

### **Finally – Fire.**

Whatever the causes of the depressurising and dropping of water tables in the aquifers of the Otway Basin, there is a resulting heightened level of fire risk, intensity and duration.

By dropping the water tables in the recharge areas, the area begins a slow drying out and the vegetation is put under stress. Unfortunately this goes undetected as rainfall creates a Green Belt Delusion<sup>(26)</sup> at the surface.

Everything appears to be normal. But when fire takes hold fire activity is intensified, durable and much more difficult to control. Perhaps, lessons can be learnt from the East Gippsland experience.

## **CONCLUSION**

It has been proven beyond any doubt that the major reason for the depressurisation and dropping of groundwater levels in the Gippsland region is the result of offshore gas extraction. This offshore gas extraction is water driven and there is also little doubt that the gas extraction in the Otway Basin involves exactly the same water driven processes. At this stage however, impacts from gas extraction in the Otway Basin and on the Otway Ranges have not been recognised and or attributed to any degree to gas extraction.

After sketchy and poor scientific and technical research, the Victorian Gas Program recommendations to the Victorian State Government facilitated the lifting of the moratorium on onshore gas extraction and encouraged the continued offshore gas extraction as a gas lead COVID 19 recovery strategy.

Unfortunately, the Victorian Gas Program has taken selected data; ignored other data; accepted certain assumptions; generalised and drawn conclusions that verge on, if not sitting directly in, the realm of epistemic theory. And, resource management decisions arrived at in this way are fraught with wrong decision making, and can, more often than not, end in catastrophic situations.

Otway Basin gas extraction has not had its risks, benefits or impacts determined. All gas extraction should be halted until this is done. The biggest possible loser is the depressurising and dropping of onshore potable

groundwater resources across the Western District including the Otway Ranges.

## APPENDIX ONE.

From: Mal Gardiner <[otwaywater@yahoo.com.au](mailto:otwaywater@yahoo.com.au)>

Sent: Friday, 8 January 2021 10:44 AM

To: \*\*\*\*\* (DJPR) <\*\*\*\*\*@ecodev.vic.gov.au>

Subject: Otway Basin queries.

Hello \*\*\*\*,

Hope you had a Merry Christmas and a good start to the New Year.

I have a few queries that you may be able to help me with.

1. Is Beach Energy the only company exploring and extracting gas/oil from the Otway Basin?

There are no companies exploring for onshore conventional gas in Victoria until the end of the moratorium on 30 June 2021. There are a number of companies exploring for and extracting gas in the offshore component of the Otway Basin, both in Victorian state waters and Commonwealth waters. The Otway Basin appears to be a gas resource region. No oil is being extracted – although condensate (light hydrocarbon liquids which are dissolved in the gas while it is underground) can be produced.

2. Is gas being piped from the Gippsland gas fields and being stored in the Otway Ranges?

There are no underground gas storage facilities in the Otway Ranges and the geology of that area is not appropriate for gas storage. Lochar Energy manages an underground gas storage plant near Port Campbell. Once gas enters the distribution network there is nothing stopping it travelling great distances if it's not used up along the way. It is possible that gas from multiple locations has found its way to the Port Campbell underground gas storage plant.

3. Do you know what the "minimal environmental impact" that the onshore research drilling at Niranda South is having - as described by Beach Energy?

The Geological Survey of Victoria is separate from the compliance function. Compliance of a drilling operation with the Act and regulations is carried out by the Earth Resources Regulation, within the Department of Jobs, Precincts and Regions. The Regulator is responsible for assessing a company's environmental management plan for a project. I note that the Environment Plan Summary for the Blackwatch project at Nirranda South is available on the Earth Resources website [https://earthresources.vic.gov.au/\\_data/assets/pdf\\_file/0005/489110/Beach-Energy-Black-Watch-1-Drilling-Environment-Plan-Summary.pdf](https://earthresources.vic.gov.au/_data/assets/pdf_file/0005/489110/Beach-Energy-Black-Watch-1-Drilling-Environment-Plan-Summary.pdf). It discusses the Environmental Impact, Risk Assessment and Controls, including the Environmental Risk Assessment Summary.

4. Is the the gas from the bores water driven like it is in the Gippsland Basin or is it extracted in another way?

These are all water-driven reservoirs, so the extraction method is the same.

5. Where does the water come from that fills the void created by the extracted gas?

Gas extraction does not create a void in the reservoir - the water continuously flows into the pore

space as the gas flows out. The water comes from the porous and permeable rock below the original contact between the gas and the water and the depth of that contact becomes shallower as the gas field is depleted. Normally this water is saline and not suitable for potable water supply.

6. What amount of volume of water does this amount to?

This depends on the volume of gas and condensate produced, and the depth of the reservoir below the surface. Because gas is highly compressible, one cubic metre at the surface occupies a much smaller volume underground (and the deeper the reservoir, the smaller the volume). Work that groundwater modeller Saeed Torkzaban did a couple of years ago, while working for the Geological Survey of Victoria, assumed that 1 m<sup>3</sup> of gas at surface conditions was equivalent to 0.0064 m<sup>3</sup> in the reservoir. Depending on how much condensate is in the mixture, the volume occupied in the subsurface will increase, but will always be less than the volume at surface temperature and pressure.

If you can help with answer to these question that would be great.  
Kind regards,  
Malcolm.

*Malcolm Gardiner*  
1805 Colac Lavers Hill Road  
Kawarren  
Vic 3249  
ph +61 0475 358 747  
[www.otwaywater.com.au](http://www.otwaywater.com.au)

\*\*\*\*\*

Government of Victoria, Victoria, Australia.

This email, and any attachments, may contain privileged and confidential information. If you are not the intended recipient, you may not distribute or reproduce this e-mail or the attachments. If you have received this message in error, please notify us by return email.

\*\*\*\*\*

## APPENDIX TWO.

# Environmental studies

---

### **1.1 Scientists from the State Government’s Geological Survey of Victoria (GSV) are conducting groundwater sampling and atmospheric monitoring across the Otway Basin in Victoria’s south west and the Gippsland Basin in the south east.**

As part of the Victorian Gas Program, a mobile water science team is testing 100 State Government-owned groundwater bores to determine groundwater chemistry, identify traces of natural gas (methane) and provide a benchmark of existing environmental conditions.

The team is also conducting atmospheric monitoring, looking at varying concentrations of methane and carbon dioxide.

#### **1.1.1 Why sample groundwater?**

Groundwater chemistry sampling looks at the mix of chemical elements that naturally exist in groundwater.

This program will test for elements such as bromine, chloride, fluoride, sulfate, calcium, magnesium, sodium, potassium, nitrate, dissolved organic carbon, methane, ethylene and ethane.

This analysis can be used to determine the unique chemical profiles of each groundwater system. It also provides a benchmark of local environmental conditions.

#### **1.1.2 The sampling program**

The groundwater sampling in the Otway Basin is occurring between August 2017 and May 2019. The team will start near Colac and move west towards Casterton, passing through the local government areas of Corangamite, Moyne, Warrnambool, Southern Grampians and Glenelg.

The Gippsland groundwater sampling program is taking place between February 2019 and June 2019. The bore well sites are located between Port Welshpool and Lakes Entrance. The team will pass through the local government areas of South Gippsland, Wellington and East Gippsland.

The volumes of water taken from the bores will generally range between 50 – 200 litres, depending on how long it takes for the water chemistry to stabilise and be representative of the aquifer.

The sampling work will have no impact on local water tables, flora or fauna.

#### **1.1.3 How are groundwater and natural gas connected?**

Natural gas accumulations only exist in certain circumstances in geological basins. Where gas does exist, it seeks to rise through geological layers unless it is trapped by impermeable rock. This migration of gas includes natural movement through aquifers.

By analysing the chemistry of a groundwater bore, scientists can detect signs of gas migration, which could indicate the presence of a natural gas accumulation.

#### **1.1.4 Stygofauna**

In addition to trace chemical analysis, the groundwater studies are also sampling for stygofauna. Stygofauna are minute subterranean aquatic animals that live in groundwater. The presence of stygofauna is an indicator of groundwater health. This will be the first regional groundwater fauna assessment undertaken in Victoria.

#### **1.1.5 Atmospheric monitoring**

A regional atmospheric survey was also conducted in 2018. This survey measured atmospheric changes across south-west Victoria and Gippsland to identify sources of methane and carbon dioxide. This provides a baseline to enable an assessment of any future environmental change.

#### **1.1.6 Victorian Gas Program**

The environmental studies are part of GSV's Victorian Gas Program (VGP), which is conducting scientific research into the potential for new discoveries of onshore conventional gas.

The onshore conventional gas studies are designed to provide an evidence-based gas resource estimate and identify the risks, benefits and impacts of onshore conventional gas exploration and production.

The main focus of the VGP is the Otway Basin, which GSV considers as having the highest potential in the state for new discoveries of onshore conventional gas.

The information from the groundwater sampling program and atmospheric monitoring will provide a baseline of environmental conditions.

Local communities and water authorities will have access to the results and all information will be publicly available via the Earth Resources website: [www.earthresources.vic.gov.au/gasprogram](http://www.earthresources.vic.gov.au/gasprogram)

The environmental studies will not need to access private land for this program.

#### **1.1.7 Stay in touch**

Information about the Victorian Gas Program can be found at:

[www.earthresources.vic.gov.au/gasprogram](http://www.earthresources.vic.gov.au/gasprogram)

Regular progress reports about the scientific studies can also be found on the website.

To be added to the Victorian Gas Program emailing list, please send a request to:

[vgp@ecodev.vic.gov.au](mailto:vgp@ecodev.vic.gov.au)

## APPENDIX THREE.

Colac Herald 26/2/21

Objection to Otway gas plan

BY BILLY HIGGINS

Local climate campaigners have backed an Australian Senator's rebuke of a planned gas project that could impact Apollo Bay fishers.

Tasmanian Senator Peter Whish-Wilson called on the federal regulator NOPSEMA to raise its threshold for approving new gas explorations after concerns that proposed seismic testing west of King Island could damage the region's rock lobster industry.

King Island and Apollo Bay fishers both harvest southern rock lobster populations found off the Otways coast, and the Apollo Bay industry has raised fears of the damage that seismic testing causes to crayfish colonies.

Senator Whish-Wilson's motion comes shortly after a Senate inquiry into the commercial and environmental impacts of seismic testing was again delayed, with its findings now due in May.

The Otway Climate Emergency Action Network is among a host of local groups that have rallied against offshore gas drills in recent years. OCEAN's Lisa Deppeler said the Parliamentary debate represented progress for the cause.

"This is a significant step in the campaign to prevent any further exploration for offshore gas in the Otway Basin," she said.

"We are running this campaign because there is no need for this exploration given the poor future for gas in Australia."

Sen Whish-Wilson spoke out against a planned 4089-square-kilometre proposed gas exploration project from Texas-based energy company ConocoPhillips, which starts about 23 kilometres west of King Island.

The Green Senator called on the Senate to recognise a "knowledge gap" regarding the impacts of seismic testing on local industries and their communities and called on NOPSEMA to take a cautious approach to its permit approval process.

"ConocoPhillips must address these fears with evidence-based answers, and if ConocoPhillips cannot prove there will be no impact on local fishing livelihoods then the seismic testing should not go ahead," Sen Whish-Wilson said.

One Nation Senator Malcolm Roberts indicated his party would support the motion to prevent international companies from profiting from Australian gas reserves.

Assistant Fisheries Minister, Senator Jonathon Duniam, said in reply that the Federal Government had "effectively regulated" gas activities alongside fisheries industries, and that the government was working with fishers and resource companies on a "voluntary national approach".

The Parliamentary inquiry into seismic testing is now likely to be more than a year late, after its had its reporting date extended to May 21 earlier this month.

It's the third extension after the report was originally due in May last year.

Apollo Bay fishers and environmentalists were among public submitters to the inquiry by its end date of December 2019.

Colac Otway Shire Council formally opposed seismic testing in July last year to Federal and State MPs, following similar stands from other councils with coastlines bordering the Otway Basin.

Medal this year.

# Drill thrills company, frustrates activists

BY BILLY HIGGINS

**Beach Energy has reported more than double its expected yield at a gas exploration well offshore at Port Campbell and expects to use the supply by the end of next year.**

The resources company said the gas discovery provided encouragement for it to further explore nearby drilling options off the Otways coast, frustrating climate activists who demand a fast shift to renewable energy.

Beach last week announced that its Enterprise gas field – within three kilometres of the Port Campbell National Park shoreline – had found 97 petajoules of sales gas and 211 kilotonnes of LPG in undeveloped gas reserves. The figures account for estimated reductions in yield as the reservoir depletes.

One petajoule equals one million billion joules or 278 gigawatt hours, and translates to the heat energy content of 29 million litres of petrol.

Beach managing director and CEO Matt Kay said the energy company aimed to supply the nearby Otway Gas Plant during the first half of the 2022-23 financial year.

"The material Enterprise discovery helps to ensure a continued pipeline of gas to the Otway Gas Plant – a key supplier to the east coast gas market," he said.

"The liquids content in the field is more than double our pre-drill expectation, significantly increasing the value of the discovery.

"Ultimately, Beach's investment in the region with our joint venture participant is helping to meet the shortfall in supply that is forecast for the east coast gas market in the near future, as well as

providing an economic boost to the region and creating jobs through the supply chain."

But local environmental group OCEAN, which has heavily campaigned against Otways gas drills in recent years, said further exploration had potentially devastating long-term consequences.

"OCEAN concedes that Victoria will require gas supplies in the short term while we move to sustainable energy sources," OCEAN's Lisa Deppeler said.

"On the face of it, Beach Energy's onshore exploration seems innocuous and the lesser impact on the environment, but it still involves destructive seismic exploration over fragile, shallow waters and there is not enough science on how this will impact the Otway Basin water table by contamination or further drops in level.

"Natural gas, which is basically methane, is not a transitional energy source and is much worse for global warming than coal and oil."

OCEAN also objected to Beach's claims that the discovery would lead to reduced energy prices for Victorians considering the high proportion of exports from Australia's resources.

It also claimed an ongoing commitment to gas would hurt jobs in the long term as Australia risked falling behind other countries in developing its renewable industry.

The Enterprise project is based at an onshore, 55-metre-high rig that drills underground to reach the gas reserve near the shore.

It is separate to an offshore exploration venture underway at the Artisan well, using the Ocean Onyx rig, from 32km to 80km offshore near Port Campbell

# Drillers strike undersea gas

BY BILLY HIGGINS

**Ocean drillers have found more gas off the coast of Port Campbell.**

Beach Energy announced this week it had made its discovery at the Artisan-1 exploration well in the Otway Basin, about 32 kilometres off the Victorian coast.

But the energy company said that the yield fell below its pre-drill expectations.

Beach said it would earmark the well as a gas producer in coming years with a view to supplying the Otway Gas Plant near Port Campbell.

It comes after Beach also reported a substantial gas discovery at the Enterprise well, within three kilometres of the shoreline.

"Beginning our Otway campaign with two exploration successes is a good result for Beach," Beach chief Matt Kay said.

"While the Artisan discovery is at the lower end of pre-drill expectations, it is being cased as a future producer. Drilling operations have gone to plan and I want to commend the teams working on the Ocean Onyx for the successful start to the campaign."

Colac Herald 26-3-2021

## References.

1. Victorian Gas Program, Technical Report 13 February 2020: Regional baseline stygofauna survey, onshore Otway Basin Victoria. Bold, T, A; Servo, P; Iverach, C, P and Hocking, M.
2. Beach Energy. Halladale, Black Watch and Speculant Project Update February 2020
3. Victorian Gas Program, Technical Report 14 February 2020: Regional baseline stygofauna survey, onshore Gippsland Basin Victoria. Bold, T, A; Servo, P; Iverach, C, P and Hocking, M.
4. Beach Energy. Enterprise Project Update May 2020
5. Gardiner, M, November 2020: Are the Otway Ranges Threatened by Wildfire Resulting from Subterranean Water, Oil and Gas Extraction, Just Like Gippsland. Otway Water Book 57.
6. Victorian Gas Program, Technical Report 34 September 2020: Groundwater Impact Assessment – Conceptual report. Onshore Otway Basin, Victoria.
7. Hatton, T., Otto, C., Unterschultz, J. 13 September 2004: Falling Water Levels in the Latrobe Aquifer, Gippsland Basin: Determination of Cause and Recommendations for Future Work. CSIRO.
8. Southern Rural Water. 2018-2019: Yarram Water Supply Protection Area report. <http://www.srw.com.au/publications/>
9. Victorian Gas Program. March 2020: Progress Report, Report Number 4. Final. Geological Survey of Victoria.
10. Victorian Gas Program. October 2019: Progress report, Report Number 3. Geological Survey of Victoria.
11. Dahlhaus, P., December 2018: Barwon Downs Borefield: Review of literature and identification of issues. Prepared for Southern Rural Water.
12. See Appendix One, pages 50-51 of this book.
13. See Appendix Two, pages 52-53 of this book.
14. Department of Environment, Land, Water and Planning and the Geological Survey of Victoria, 2015: Onshore natural gas water science studies – Gippsland region synthesis report. Department of Environment, Land, Water and Planning and the Department of Economic Development, Jobs, Transport and Resources, Melbourne. June 2015.(2)
15. Beach Energy: Environmental Summary. Black Watch 1 Gas Field Development Project Drilling Plan, Environmental Summary. S4600AH718165.

16. Gardiner. M, February 2021: The Extremities, Borefield Drawdown Influence. Otway Water Book 21 B.
17. Leonard J., Department of Minerals and Energy. September 1984: Submission to Natural resources and Environment Committee Inquiry into Water resources Management, regional Water Strategy Plan for South-Western region of Victoria, Stage 1, Augmentation of Geelong's Water Supply to the Year 1995. Geological Survey of Victoria. Victorian Government.
18. Barwon Water 21 December 2012: Newlingrook Groundwater Investigation, Gellibrand River Streambed and Baseflow Assessment. Final 1. Prepared by Sinclair Knight Merz.
19. Jacobs 19 May 2015: Barwon Downs – Recharge and Climate Change. Presentation prepared for Barwon water as presentation to the May 2015 Community reference Group.
20. Sinclair Knight Merz, 21 December 2012: Newlingrook Groundwater Investigation, Gellibrand River Streambed and Baseflow Assessment. Barwon water.
21. Williamson R.J., 1982: Estimation of River Recharge Using regional watertable data. Gellibrand well field investigation. Unpublished Report Geol. Surv.Vic.1982/42
22. Victorian State Government. 1990: Forest Management Plan, Otway Forest management Area.
23. Witebsky S., Jayatilaka C. and Shrugg A. J., November 1995: Groundwater Development Options and Environmental Impacts, Barwon Downs Graben, South-Western Victoria. Department of Natural Resources and Environment.
24. Jacobs, 12 December 2016: Barwon Downs Technical Works, Integration Report. Prepared for Barwon Water.
25. Farmer – Bowers Q., October 1986: Environmental Issues Barwon Downs Groundwater. South Western Region Water Management Strategy.
26. Gardiner. M, Revised June 2020: Flowpaths, Drawdown, Recharge, Vertical Leakage and Perched Swamps within the drawdown influences of the Barwon Downs Borefield. Otway Water Book 35.
27. Department of Environment, Land, Water and Planning and the Geological Survey of Victoria, 2015: Onshore natural gas water science studies – Gippsland region synthesis report. Department of Environment, Land, Water and Planning and the Department of Economic Development, Jobs, Transport and Resources, Melbourne. June 2015.(2)

