OTWAY WATER BOOK
42 B

Remediation of the Big Swamp Wetlands, Yeodene,

“A Fresh Start.”

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August 2018
Malcolm Gardiner
Email: otwaywater@yahoo.com.au www.otwaywater.com.au

"*The new monitoring program will increase understanding of the Barwon Downs groundwater system in its normal state.*"
(SKM 2015)

"***No evidence was found that declining groundwater levels caused by groundwater extraction at Barwon Downs had a negative impact on vegetation health in the catchment.***"
(Jacobs 2016)

"***...water table drawdown occurs during pumping, but no long-term environmental impacts have been linked to borefield operation.***"
(Barwon Water, February 2012:
Water Supply Demand Strategy 2012-2062, Draft.)

"***It is becoming apparent that to protect groundwater resources as a sustainable source of drinking water requires the protection of natural ecosystems that support it***."
(Simons & Notenboom 2009)

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CONTENTS

INTRODUCTION.

There are many things wrong with the Technical Works Program[1] and plan for the remediation of the Big Swamp Wetlands, Yeodene, Victoria, Australia. Huge data gaps exist. Contingencies plan for unforeseen developments are not considered. Basic assumptions appear to be mis-founded and dangerous. Guesswork is viewed as scientifically and technically sound. Context regarding the problem is extremely narrowly focussed.

An ever increasing number of revelations indicate that the remediation plan for the Big Swamp Wetlands needs to be re-examined and a fresh start made.

BACKGROUND

At the November 2017 Barwon Downs Groundwater Community reference Group meeting, Barwon Water tabled a remediation plan for Boundary Creek. This 9 November 2017 report prepared by Jacobs, outlined the background and a PLAN of action for the remediation of the Big Swamp Wetlands. Appendix B and C were not included in the 9 November plan, both vital to gaining a full understanding on the recommendations and recommended plan of action. An informed understanding being difficult to gain.

The 9th November 2017 final draft, "2016-2017 Technical Works Program, Barwon Water, Yeodene Swamp Study" had been processed on two occasions by 5 people. This process involved writing, reviewing and passing the 2017 document. The recommendations made in this study were regarded as sound enough to proceed with the infilling of the fire trenches and blocking of the agricultural drain at the east end of the swamp. This work was anticipated to be done in April 2018.

An initial response and review (Otway Water Book 42) of this 9 November 2017 work was written in December 2017[(2)] indicating there were numerous data gaps and that the report was far from being prepared along sound scientific and technical lines.

Meetings

In 2018 as part of the remediation program for Boundary Creek, Barwon Water set up a Boundary Creek Remediation Working Group. It was planned that over the 2018 year the group would meet 3 times. The first meeting was held in Colac in May 2018. Copies of the remediation plan[(1)] and Otway Water Book 42[(2)] were made available at this meeting. The remediation plan still did not contain Appendix B or C.

At this first meeting of the Boundary Creek Remediation Working Group, community group members recommended expert specialists be appointed to review the 9 November 2017 options for remediation as proposed by Jacobs.

6 June 2018 Meeting

Another outcome of the first meeting prompted an additional meeting that was held on 6 June at the Barwon Water offices in Geelong. Audio of this meeting was made.[(4)] Roger Blake tabled and presented a document[(3)] (see Appendix one). Charley Kohout and Malcolm Gardiner also tabled a document (see Appendix Two).

This meeting was recorded and is available on the Barwon Water web site. Appendix four covers some of the discussion and the following points were covered on the day.

- Drainage of the Gerangamete Swamp has little to no relevance or impact on the Big swamp Wetlands.
- The fire trenches have not altered the drainage regime.
- There are numerous data gaps regarding the knowledge of the swamp within the swamp boundaries.
- Missing reference and use of Government guidelines and experts' studies and research.

Mis-information Not Dealt With.

Mis-information presented in the 9th November 2017 study as pointed out in Otway Water Book 42 December 2017, had not been dealt with by the time the three expert specialists presented their written and verbal presentations in July 2018.

Expert Specialists Presentations (See Appendix Five for written submissions.)

At the 25 July 2018 Remediation Working Group meeting the reviewing specialists presented their work. Unfortunately, the 9 November plan had not been modified and still contained the mis information. As a consequence the reviewing specialists based some of their comments on assumptions, speculation, guesswork and suggestion contained within Barwon Water's remediation plan.

Despite this the three specialists' reviews of the 9th November study pointed out critical and extensive data gaps necessary to be filled if any degree of successful remediation is to be achieved (see Appendix Five). Many of these data gaps had already been recognised for some time by local community members (For written examples see Appendix One and Two. On numerous occasions over the four years of deliberations at the Barwon Downs Groundwater Community Reference Group, similar gaps were discussed and not resolved).

The reviewing expert specialists also warned of the possibility of creating unforeseen hazards and or outcomes when attempting remediation, and that contingencies arrangements must be made. The 9th November plan had oversimplified how easy it was to conduct a remediation of the swamp.

Narrowness of the Brief

Unfortunately, the demise and predicament of the Big Swamp Wetlands is only one symptom of a much larger problem. And, the cause of so many negative

impacts is the mining of groundwater at the Barwon Downs Borefield. Ceasing the mining of groundwater and allowing the Lower Tertiary Aquifers to recover should be the major consideration and the first step to be taken in any form of remediation of the area. Then a multitude of problems; actual acid sulfate soil sites; groundwater dependent wetland destruction; dwindling supplies of stock and domestic water; detrimental impacts on the Gellibrand River system; aquifer contamination and fish kills have some chance of being fixed (see Appendix Ten). Crucial to the success of these problems is the adoption of the recommendations the Barwon Water Groundwater Community Reference Group (CRG) made to the Barwon Water Board (see Appendix Eleven).

THE BOTTOM LINE.

There seems little doubt that a fresh start to the project needs to be made and that the context be broadened to involve the problems arising throughout the area of groundwater drawdown influence. That Jacobs not be given the lead role, and an independent ***Director of Project Management and Research*** be employed to carry out this project.

The brief given to the ***Director of Project Management and Research*** should, as a minimum:

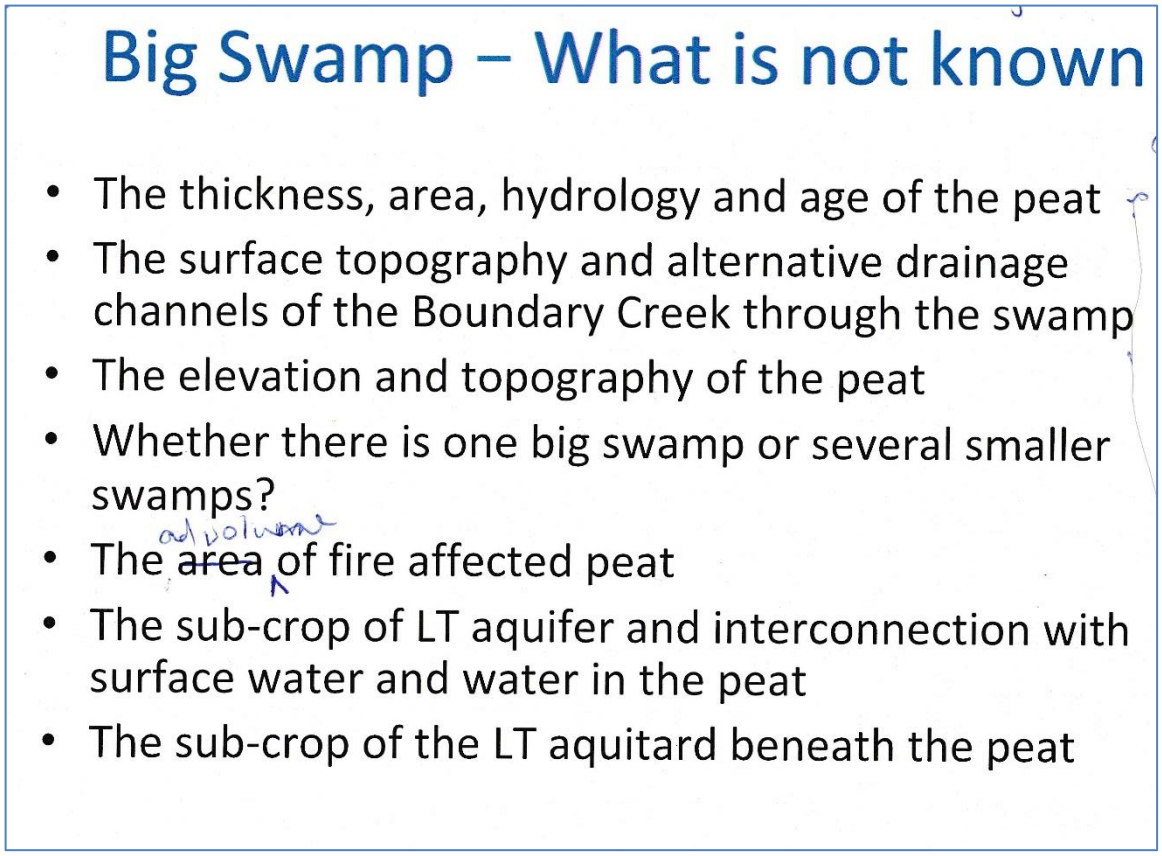
- Ensure comprehensive documentation of the entire process
- Develop a Resource Management Procedure.
- Implement a Clearly Defined and Documented Adaptive Management Approach applicable to the situation.
- Establish clearly defined assumptions
- Establish a knowledge base that includes:
  - Literature search
  - Following of National and State guidelines, procedures
  - A determine of what expertise and skills are required
- Source this expertise
- Establish methodologies known to work
- Make contingency plans
- Define a resource base
- Establishment a Broad Context that is ongoing, adaptive and dynamic.
- Prepare and plan for risk factors.
- Describe the current situation based on observable validated data
- Establish data Gaps
- Gather data to fill these gaps

An Important Part of the Fresh Start.

When considering and making a fresh start, Charley Kohout's methodology suggestions should be taken into account (see Appendix Seven).

APPENDIX ONE

Roger Blake Written document presented to Barwon Water 6 June 2018.

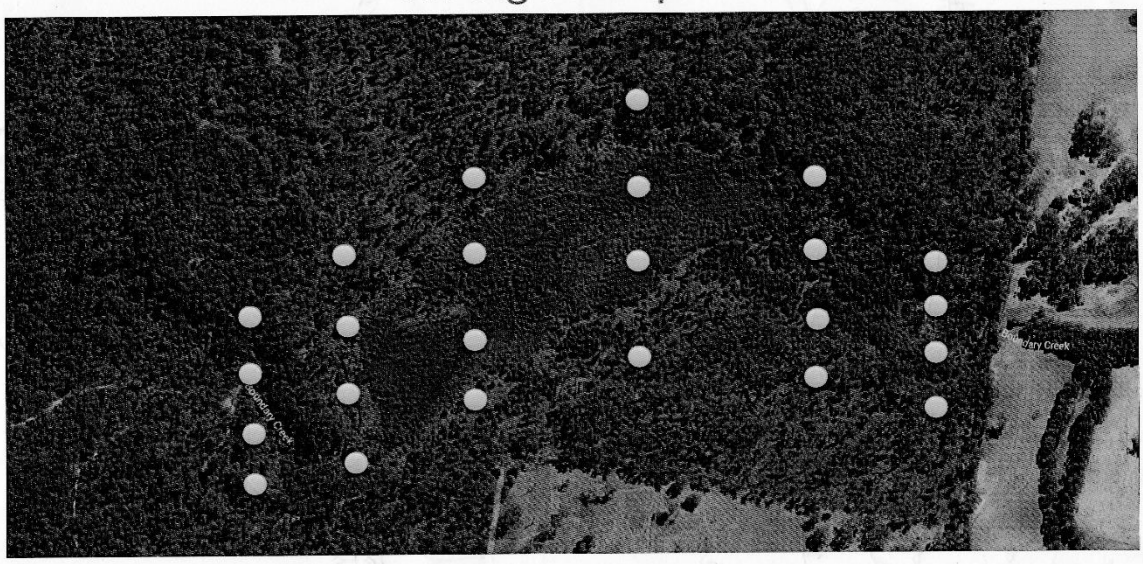


Note: I included the words "*and volume*."

Minimum Investigation program required before remedial Engineering works commence

- Survey the area of Big Swamp with contour interval 0.25 m
- Drill at least 24 holes (core or piston core), geologically log top and base of peat, LT Aquifer and Aquitard
- Establish at least 12 Piezometers in LT Aquifer and peat, sample chemistry, pH
- Record water levels, salinity and pH through peat
- Generate Geological structure contour maps of top and base of peat
- Construct Isopach map of peat and calculate volume of peat and volume of acid sulphate water contained

Recommended minimum survey area and drilling program for Big Swamp



Big Swamp Drilling program – 24 bores 15 m deep = 360 m

Survey and contour area with 0.25 m contours

APPENDIX TWO

Charley Kohout and Malcolm Gardiner. Written document tabled at Barwon Water/Jacobs 6 June 2018 meeting.

Charley Kohout has asked me to present a brief summary (pages 1-3) of the Process and some of the Project Management issues he has found with Jacobs' Big Swamp Remediation work.

Background Material Provided by email before the First Big Swamp Remediation Meeting included…

Under the Introduction heading…

"***The Barwon Downs borefield is operated under a licence from Southern Rural Water. The licence is due for renewal by July 2019 in line with the expiry of the existing 15 year licence.***"

Under the heading Technical findings this was stated…

Recent technical work has confirmed that Barwon Water's pumping from the Barwon Downs borefield over the past 30 years is the main cause of a reduction in baseflow (groundwater contribution to streamflow) in the lower reach of Boundary Creek increasing the frequency and duration of no flow periods.

Lack of flow, especially during summer months has caused:

- ***Big Swamp to dry out,***
- ***The activation of naturally occurring acid sulphate soils in the swamp.***
- ***The release of acid water (pH less than 4) and heavy metals downstream of the swamp.***"

His clearly shows that Barwon Water has accepted that groundwater extraction at the Barwon Downs Borefield is the main cause for the Big Swamp drying out.

This acceptance lead to the development of a remediation program. This task was given to Jacobs.

The "Yeodene Swamp Study" 9 November 2017 by JACOBS.

This Study has been prepared by 3 people; reviewed by one and approved by another on two occasions (page i). A final copy was to follow in the new year 2018). The copy handed out at the 2018 May meeting still did not contain Appendix B nd C.

Under the heading "***Important note about your report***," on the second page marked "i," it states…
"Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of his report."

The sole purpose of the report is described as… "***The sole purpose of this report is to present the findings of a desk top and filed investigation carried out by Jacobs for Barwon Water ("the Client") in connection with the Yeodene Swamp ("the site"). This report was produced in accordance with and is limited to the scope of services set out in the contract between Jacobs and the Client.***"

There is a possibility that the "scope" given to Jacobs is at fault, but despite this
there is considerable doubt that the process and project management as quoted in the underlined statement above, has been followed.

1. National and State guidelines, standards and procedural practises have not been referenced and some doubt exists that they have been used.
2. Most notable is the omission of the AusCASS inland acid sulfate soil guidelines.
3. "Risk factors" as outlined in the Victorian EPA guidelines have not been mentioned.
4. References fail to include relevant studies by highly qualified scientists.
5. These nationally recognised scientists culd have been used in the planning stage, scientists such as L. Sullivan and R. Fitzpatrick. Why Richard Bush was not actively involved after his initial discussion with SKM some years ago is an oversight and shows a lack of thoroughness. Bush and Phil Hirst have extensive experience with the Big Swamp issue.

A Few Basic Process Issues.

1. Quality documentation is a key success factor.
2. Resource management including knowledge base and personnel is another key success factor.
3. Monitoring and review during the project is also a key success factor.
4. Problem identification following thorough data collection and data analysis is a key success factor.
5. Complexity of problems that are evident and as seen in ASS research demand a contingency plan to help deal with unexpected developments.

Examples of a few Basic Process Failures.

1. The main cause leading to this study is groundwater extraction over 30 years. However, no objective has been stated to address this main causal factor. Also, there are no quantified objectives. One wold expect a prioritised list of objectives related to this cause.
2. A plan has been devised where there is no definition of data. e.g. AHD relevant to Boundary Creek, contaminants, soil analysis, hydrology, hydrogeology. Definition of data also requires identifying data that is not readily accessible and needs to be included. Means of collecting missing data has not been defined.
3. There is no documentation describing how data has been analysed.
4. Detailed and prioritised problem identification has not been stated or included in project plans.
   1.1.1. There is an obvious need for a prioritised list of risk factors.
   1.1.2. The extent of surface water contamination has not been defined.
   1.1.3. Neither has the extent of groundwater contamination been defined.
   1.1.4. Groundwater contamination is a known risk factor excluded from this study.
   1.1.5. Historical significant timeline event have been omitted.
5. Jacobs' work has been reviewed by Jacobs and Barwon Water and none of thee above failures have been identified. Limitations and assumptions have been excluded at every stage.
   Due process and project management has not been followed.

An external review of the project is mandatory before any plans can be finalised.

No mention of remediation of degraded Groundwater Dependent Ecosystems along tributaries of the Boundary Creek Catchment.

The brief of the "Boundary Creek remediation working group" included the remediation of Boundary Creek. This has not been addressed as yet.

Charley would like a chance to discuss the full extent of his concerns regarding the planning of and the project process.

My Concerns.

Drainage lines impacting on the Boundary Creek Catchment.

Regarding Jacobs statement, page 18, in the 9 November 2017 Yeodene Swamp Study and presentation by Prof. Webb.

"***The Boundary Creek catchment has undergone significant modification over the last century. In 1886 the Gerangamete drain was completed, followed by a series of adjacent drains inn 1888 (Jennings, 2008). These drains claimed low lying land for agricultural production, and resulted in the removal of large sections of low land forest and grassy woodland, as evidenced by Ecological Vegetation Class mapping (Figure 2-1). The drainage of these areas is likely to have lowered the groundwater level near the drain and increased runoff, while reduced forest coverage may have increased groundwater recharge in these areas.***"

There are numerous mistakes and assumptions in this particular statement that require some comment.

1. Figure 2-1 found in the Jacobs report (copied below) contains a map dating back to 1750. This map is based on a massive amount of speculation and guesswork. The map also predates Captain James Cook's exploration of the east coast of Australia by 20 years and the arrival of the First fleet by 38 years.
2. The Boundary Creek Catchment does not form part of the Gerangamete Swamp.
3. The Gerangamete Drain does not drain the Boundary Creek Catchment.

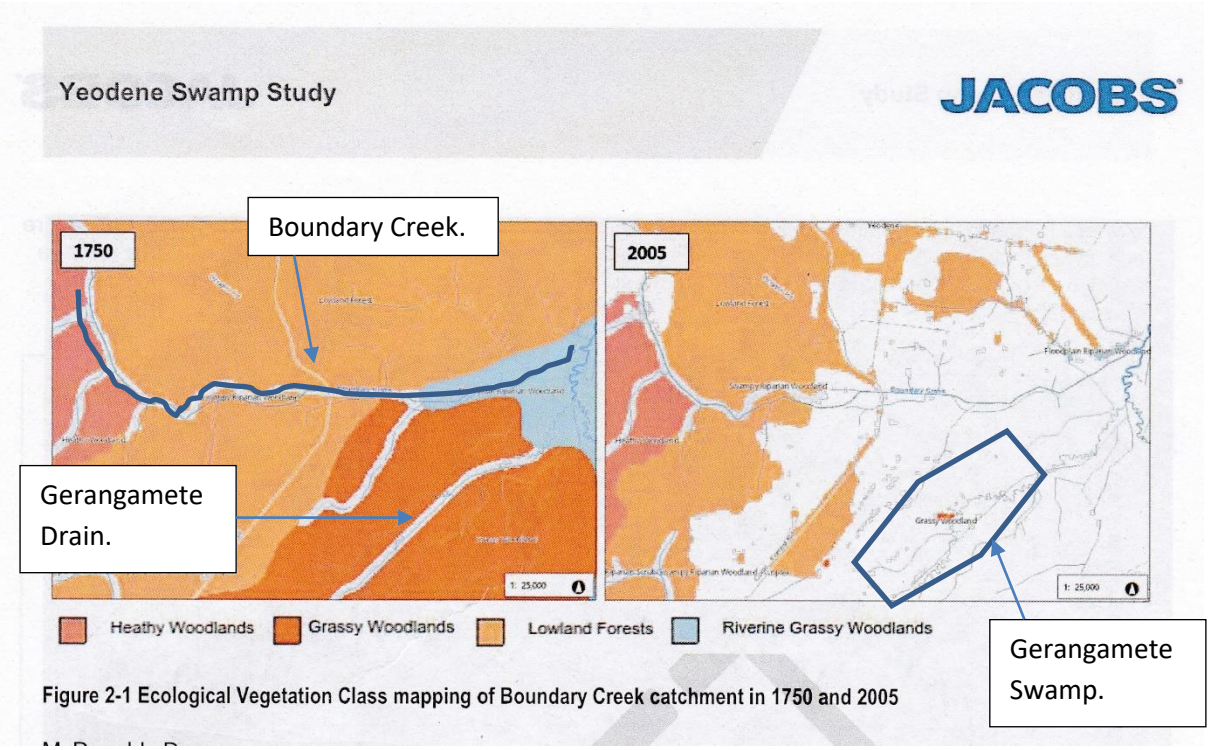


Figure 2-1 Ecological Vegetation Class mapping of Boundary Creek catchment in 1750 and 2005

4. John Callahan, descendent of original selectors of some of the swamp area, the Callahan Brothers, insists that the Gerangamete Swamp has nothing to do with the Boundary Creek Catchment.
5. John believes there was an ill-defined course that the west branch of the Barwon River through the Gerangamete Swamp area and this is why a straight drain was dug.
6. The following page taken from the Jennings 2008 document was the only reference that could be found in this book to the Gerangamete Swamp and or Gerangamete drain.

GERANGAMETE

Gerangamete district was opened up for selection at Colac Land Sales on Wednesday 20th December 1865, with the swamp area reserved for public purposes. Twenty years later, on 27th January 1885 the Gerangamete Swamp was opened for selection and those who purchased were:

G.ARMYTAGE	***CALLAHAN Bros.***	***W.S.ANDERSON***
T. HANCOCK	***A.CHILDS***	***T.DAVIS***
W.PRICE	***S.H.REID***	***H.BUCKLEY***
D.THOMAS		

"The holders of land fronting the Gerangamete swamp are grateful to the Minister of Lands for the very lenient manner in which he treated them in connection with the sale of that area. The land in the hands of resident holders and the conditions under which they ultimately obtain their grant is of such a stringent nature that the scheme of drainage approved of by the government must be faithfully carried out by the licencees. There is no question the swamp can be perfectly drained and I believe at a less cost than is generally supposed. The land when thoroughly drained will be equal to any grazing land in the colony but being subject to floods it will not be extensively cultivated".[3]

By 1886 the Gerangamete drain had been nearly completed by David Irvine, the contractor. Draining this land relieved about 800 acres of some of the richest land in the district which was periodically submerged by the overflow of the Barwon River. The humid climate of the district was admirably adapted for cultivation of oats, maize and many other cereals and it was hoped "the outlay incurred by the landowners interested will be amply rewarded in due course".[4] In 1888 the marshes adjoining the watercourses were drained.[5]

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3 Colac Herald 13.2.1885
4 ibid 28.5.1886
5 ibid 20.1.1888

7

I have another 27 items of data that I believe need to be collected to facilitate the remediation of the Big Swamp.

I also believe these will overlap with Roger Blake's submission and would like Roger to present his thoughts before dealing with mine.

Basic Data Gaps Still to be Collected and Questions to be Answered pre PLAN preparation.

1. What impact did the 160m AHD potentiometric level of the LTA have on the Big Swamp wetlands pre groundwater extraction?
2. What impacts are likely if the potentiometric level is returned to a level above the Big Swamp?
3. Is the Big Swamp actually a series of disjointed wetlands displaying different characteristics that require different management decisions to be made?
4. Where exactly does the aquitard peter out in relation to the Big Swamp Wetland area?
5. Complete transects across the Big Swamp Wetland in both a north south and east west directions.
6. Determine how deep the peat and burnt peat is throughout these transects.
7. Identify the depth of the oxidising peat in these transects.
8. Determine what compounds are found in the various areas of the swamp, including those that have been created as a result of the fire episodes.
   e.g. arsenopyrite, pyrrhotite etc
9. Determine how will these compounds react to rehydration.
10. Do the "new" compounds as a result of fire require different treatment?
11. Are there other reactions other than the one Prof. John Webb outlined ($Fes_2 + 15/4O_2 + 7/2H_2 = Fe(OH)_3 + 2SO_4^{2-} + 4H^+$) that need to be considered?
12. Are any other acids being produced e.g. nitric acid?
13. Has the CFA report that brown coal had caught fire during the 2010 fire, been investigated?
14. Flows through, under, into or across the wetlands need to be determined.
15. And, the impacts caused by the hydrophobic state of the soils and the slumping due to oxidation and or burning.
16. What impact is ET having with the changed conditions prevailing in the wetlands?
17. To what degree has the opportunistic vegetation changed conditions and functions within the impacted area?
18. Explain how putting a NSL or one metre high clay barrier at the eastern end of the wetlands, will saturate the wetlands all the way back to the western edge when there is an estimated 8m to 10m elevation difference.

19. What is the rationale to this option, even taking into account capillary action?
20. What is the analysis suggesting that an increase of 1 ML/d in the Artificial Supplementary Flows will be enough water to flood the swamp?
21. What is taking place in the riparian areas in the verges of the Big Swamp Wetlands of Boundary Creek?
22. Where do the Artificial Supplementary Flows disappear to?
23. Why do these flows disappear?
24. How much contamination of the groundwater is taking place?
25. What impact has happened to or will impact on groundwater biota?
26. When the borefield is operating air is sucked down into the void being made as the water is extracted. Even without this fan of air flow, peat can spontaneous combust at around the 40% moisture level. Have these two facts been considered when attempting to inundate the swamp wetlands?
27. Why hasn't the EPA, DELWP, Colac Otway Shire and Southern Rural Water been involved in the remediation process?

APPENDIX THREE
"Assumptions"

In the 9 November 2017 Yeodene Swamp study[1] under the heading "**Important note about your report**,"
it states…

"***Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of his report.***"

There can be no doubt that the remediation of the Big Swamp Wetlands requires scientific and technical robust thoroughness including applicable standards, guidelines, procedures, practices and expertise.

The Book title "Assumptions" examines the appropriateness of this statement. The following pages have been taken from this book, "Assumptions."

INTRODUCTION TO THIS BOOK

The focus of this book deals with dangerous assumptions which have led to a failure to identify serious risk factors. Our intention is to provide observations that we consider necessary for a better outcome in the remediation of Boundary Creek and the Big Swamp.

The first step in any problem solving exercise is the examination of assumptions that have been or need to be made.

Specific assumptions have been examined and documented. It is expected that this book will be used to start the process of examining and documenting assumptions made in this Boundary Creek remediation project.

In Chapter 1 HELPFUL ASSUMPTIONS are listed. These are then linked to dangerous assumptions in…

Chapter 2: HELPFUL v DANGEROUS ASSUMPTIONS.

This Chapter compares these two very different categories of assumptions.

A proper examination of assumptions will enable progress towards the documentation of limitations and a scope which is able to include prioritised risk factors, costs and benefits. Dangerous assumptions lead to the failure to identify serious risk factors.

Chapter 3: OBSDERVATIONS and QUESTIONS.

In this Chapter each dangerous assumption is stated and is then accompanied by observations that can be readily verified. The observations naturally lead to questions and risk factors which clearly show that dangerous assumptions have been made in this project.

It is expected that further observations, questions and actions will be added by highly skilled people to assist with the examination of assumptions.

Chapter 4: CONCLUSIONS.

A summary of failures that have been observed lead to a strong case for a detailed examination of assumptions before more damage is done in this project.

CONCLUSION

Jacobs and Barwon Water HAVE FAILED TO:

- **RECOGNISE FAILURES IN 2004 LICENCE PROCESSES which have resulted in the need for the Boundary Creek remediation.**

- **USE NORMAL PROJECT PROCEDURES**
  designed for complex projects.

- **HEED WARNINGS FROM EARLIER RESEARCH RESULTS**
  on Boundary Creek dating from the 1980's.

- **DOCUMENT AND SET PRIORITIES FOR**
  DETAILED PROBLEM IDENTIFICATION.

- **DOCUMENT THE EXTENT OF**
  THE MAJOR IMPACTS OF
  GROUNDWATER MINING FOR 30 YEARS.
  Groundwater pumping for 30 years has been described as the main cause of the problems in Boundary Creek Big Swamp.

- **USE AUSTRALIAN STANDARDS**
  definition of groundwater mining
  by using the term groundwater pumping.

- **IDENTIFY THE LEVEL OF COMPLEXITY inherent in the project.**

- **IDENTIFY THE RESOURCES NEEDED for the project.**

- **FOCUS ON 'THE TRUTH, THE WHOLE TRUTH AND NOTHING BUT THE TRUTH'**
  as the main principle behind all project work.

- **FOCUS ON 'THE INTENTION TO DO NO HARM'**
  as a key intention behind remediation work.

- **Develop the vision to**
  SEE THE CONSEQUENCES OF ACTIONS TAKEN.

- **UNDERSTAND THE RISKS INVOLVED**
  when taking actions without appropriate
  assumptions,
  limitations,
  realistic contexts,
  problem identification,

problem solving and planning.

- **USE GUIDELINES designed for this type of project.**

- **COMPLY WITH STATE ENVIRONMENT PROTECTION POLICIES.**

- **USE THE JACOBS MODEL TO PREDICT IMPACTS at Boundary Creek which have been evident to locals for 20 years and were formally communicated to Barwon Water and the Board in 2008.**

- **STATE ANY ASSUMPTIONS OR LIMITATIONS of the Jacobs model or this remediation project.**

- **Investigate the 2010 VICTORIAN AUDITOR GENERAL REPORT on GROUNDWATER to find out how auditors could arrive at such a conclusion as...**

VICTORIAN WATER AUTHORITIES
DO NOT KNOW WHAT THEY ARE DOING ...

UNTIL PROJECT MANAGEMENT PRACTICES

ARE DRAMATICALLY IMPROVED,

IT IS REASONABLE TO EXPECT THAT

DISASTERS WILL CONTINUE TO ESCALATE AND

REMEDIATIONS WILL FAIL.

APPENDIX FOUR

Following is a summary of some of the discussions that were recorded at the meeting, Ryrie Street office of Barwon Water, 6 June 2018.

1. Drains and Gerangamete Swamp development of 1885-86 as outlined in the 9 November report have little to no relevance to the present condition of the Big Swamp.
2. It was agreed the notion that "***The construction of fire trenches in Yeodene swamp has altered the swamps drainage regime. Currently significant volumes of water are drained from the swamp via these trenches and their connection with existing drainage lines.***"(1)(page57) is not the case. The fire trenches have not altered the drainage regime.
3. Remediation is not to commence until a final copy of the report is completed. The meetings planned for this year are part of this process.
4. It was agreed that the swamp must be remediated.
5. Barwon Water accepts this responsibility.
6. The report itself has fallen short of many of the "normal" scientific procedures as per Charley Kohout's concerns (See Appendix Three).
7. Stewart Anderson(Colac Otway Shire rep) voiced that the Shire often does not require a report to contain the type of detail Charley has identified as missing.
8. There are many gaps in the knowledge of the Big Swamp as tabled by Roger Blake and Malcolm Gardiner.
9. Basically option 6 is a "suck and see" operation.
10. No consideration has yet been given to amelioration of toxic slugs coming out of the swamp.
11. Contamination of the LTA has not been examined and is seen as a side issue.
12. The Yeodene CFA branch moved and accepted a motion supporting Prof. Webb's option 6.
13. It was stated the swamp was far too wet to carry out any detailed inspection as per Roger's recommendations.

    Note:

    Andrew McLennan and Malcolm Gardiner visited the swamp on 12 June 2018. A considerable flow was passing down Boundary Creek just above and below the Big Swamp Wetlands. At two transect points Andrew and Malcolm walked from one side of the swamp to the other on dry land. The water was travelling underground. The swamp and Boundary Creek had no flowing water at these transects.

APPENDIX FIVE *Experts Review of 9 Nov. 2017 Remediation*

Dr. Vanessa Wong

MONASH University

REVIEW OF THE CONCEPT DESIGN IN THE YEODENE SWAMP STUDY REPORT

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CRICOS Provider No. 00008C ABN 12 377 614 012
2018

Review of the Concept Design in the Yeodene Swamp Study Report

Background
The Barwon Downs borefield licence is due for renewal in June, 2019. In preparation for the licence application, a series of studies and monitoring programs have been completed by Barwon Water over the past five years to improve understanding of impacts caused by groundwater pumping which has been a concern of the local community. Recent technical work confirmed that historic use of the borefield has had an adverse impact on flows and drying of a peat swamp in the Boundary Creek catchment which has been the main contributor to a deterioration of water quality and acid water events. A remediation plan has been designed and implemented to improve water quality and flows and reduce the risk of future acid events.

This study reviews the proposed remediation plan under the following themes:

- The design, constructability and confidence of rewetting the swamp
- The confidence in the chemistry and chemical reactions
- The influence of the hydrogeology
- If there is a benefit in completing an options assessment, and
- Identify the information gaps

Yeodene Swamp
Yeodene Swamp, also known as Big Swamp, is a peat swamp with known acid sulfate soils, located in the Boundary Creek catchment to the south of Colac and east of Yeodene. The flow of water in to the Swamp is affected by McDonald's Dam upstream, which is subject to licence conditions including the passing of flows.

Reduction in base flow of Boundary Creek has largely allowed Yeodene Swamp to dry out, oxidising the underlying sulfidic sediments to form acid sulfate soils and allow for acidic water and high concentrations of heavy metals to discharge downstream. Furthermore, Yeodene Swamp was also affected by fires in 1997, 1998 and 2006.

It is agreed that the reduction in baseflow has largely been caused by a combination of lower than average rainfall and extraction of groundwater during drier periods to supply water for Geelong and the surrounding townships.

Remediation Plan
The aim of the remediation plan is to address community concern regarding poor water quality due to the presence of acid sulfate soils and to improve water quality by increasing the pH and decreasing the transport of heavy metals.

The options reviewed in the remediation plan include:
i) do nothing
ii) direct treatment of soils with neutralising agents in Yeodene Swamp
iii) in-drain water treatment with limestone in Reach 3 of Boundary Creek
iv) diluting acidic discharge in Reach 3 of Boundary Creek
v) revising flow release location to Reach 3 of Boundary Creek and isolating the swamp from the creek
vi) inundating Yeodene Swamp

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2018

1. Do Nothing
This option is the status quo. The acid sulfate soils have already oxidised due to the low water levels and are generating acidity which is transported to Boundary Creek and further downstream. Current monitoring data suggests that water quality is likely to remain low and acidity will continue to discharge during dry periods.

Knowledge Gaps: An understanding of the spatial distribution of acid sulfate soils in Yeodene Swamp and depth to sulfidic layers is currently missing. The Jacobs study only sampled from 7 sites across the Swamp, which is estimated to be 11 ha and at depth increments of 1 m. These sampling points should not be used as representative of the swamp given their location, the few that are used, and the high variability of soil characteristics in these peat swamps. High variability in soil samples has also been seen in the Marshy Creek peat swamps in Anglesea in a current study by Wong et al (data not shown). The *Victorian Best Practice Guidelines for Assessing and Managing Coastal Acid Sulfate Soils* and the Victorian EPA suggest that samples should be taken every 0.5 m.

It is recommended that surface water levels, groundwater levels, water quality parameters and rainfall continue to be monitored to establish a longer term record such that step changes can be discerned from temporal variability. It is also recommended that an acid sulfate soil study should be completed to understand the variability in terms of depth to the sulfidic layer to prevent oxidation in future dry periods.
Feasibility: not feasible
Does groundwater level impact on outcome? Yes

2. Direct Treatment of Soils with Neutralising Agents
This option aims to neutralise the acidity that is present with application of a neutralising agent such as lime. The option presented only considers application of lime via a slurry. A previous study (Wong *et al.* 2016) has shown that direct application of lime to a degraded swamp environment can assist in remediation. The graphical abstract is shown in Appendix A.

Knowledge Gaps: Application of lime via means other than a slurry should be considered to reduce costs and identify potential methods and logistics to deliver lime for neutralisation.
Feasibility: low to medium feasibility if conducted in conjunction with inundation
Does groundwater level impact on outcome? Not directly. However, if groundwater levels remain low and sulfidic sediments continue to oxidise, then larger doses of lime with more frequent application will be required

3. In Drain Treatment with Limestone
This option aims to neutralise acidic water by installing a drain with a neutralising agent such that acidic water is neutralised as it flows downstream. However, particle size of the neutralising agent is an important consideration for efficiency and should be < 0.5 mm to be effective (Watling *et al.* 2010), which is then susceptible to mobilisation downstream under higher flow conditions. Larger particle sizes are likely to form a coating of either an iron precipitate or calcium precipitate which may render the lime ineffective.

Knowledge Gaps: The impact of channel construction on the hydrology and hydrogeology of Yeodene Swamp is unknown and can potentially exacerbate the problem in the swamp itself.
Feasibility: low feasibility
Does groundwater level impact on outcome? Potentially, but this is largely unknown as it is dependent on the design and location of the drain

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4. Dilution of Acidic Discharge

This option aims to decrease the effect of acidic water by increasing the volume of water flowing through the swamp via increased flow releases upstream to dilute acidity and heavy metals. However, as the data show, there is limited buffering capacity in the water that would be released upstream and the effect would be dilution alone. Furthermore, there is unlikely to be enough water during the periods when large volumes of water are required for dilution flows ie. during summer dry periods when water availability has been lower according to the monitoring data.

Knowledge Gaps: The impact of large volumes of water released on the physical environments downstream is unknown and not considered. As suggested, it is likely to result in flooding of downstream areas.
Feasibility: low feasibility
Does groundwater level impact on outcome? Not directly. However, the volume of water available for dilution may be dependent on availability of groundwater depending on the source.

5. Revising flow release location/swamp isolation

This option aims to hydrologically isolate Yeodene Swamp from Boundary Creek to reduce acidic discharges. However, during higher flows, it is likely that the two areas will be hydrologically connected, which may results in higher impact acid discharge events compared to what is currently experienced. This is because Yeodene Swamp is likely to continue to oxidise and accumulate acidity and acidic products in the swamp, which will be rapidly discharged to Boundary Creek during high flow or high rainfall events.

Knowledge Gaps: A more complete understanding of the surface water-groundwater interactions in the Boundary Creek catchment is required.
Feasibility: low feasibility
Does groundwater level impact on outcome? Potentially. This would depend on the location and design of the flow release location

6. Inundating Yeodene Swamp

This option aims to reintroduce reducing conditions to neutralise acidity in Yeodene Swamp and reform sulfidic sediments to reduce the impact of heavy metals. This would take place by infilling the fire trench and the agricultural drain to prevent water draining to the base levels of these channels. This approach has been undertaken successfully at other sites, as identified by Jacobs. However, the impact of the changes in soil chemistry after the fires in 1997, 1998 and 2006 has not been considered and is likely to play a significant role in the success of this option. The soils are most likely dominated by hematite and maghemite following heating and burning of organic matter, which are likely to take a long time to react. It is also possible that inundation may result in pooling of a larger volume of acidic water as it appears that sulfate concentrations are low, which can also limit the formation pyrite.

Knowledge Gaps: The effect of fire-affected acid sulfate soils following inundation is unknown, and the rate of neutralisation is likely to be very slow, but is unknown. The absence of vegetation in the inundated areas of the swamp suggest acidic water, and this can potentially be exacerbated with inundation if the surface water is acidic. Despite these issues, this option is most likely the most feasible option
Feasibility: medium feasibility
Does groundwater level impact on outcome? Yes, because groundwater levels will need to remain high for oxidation to cease and reduction processes to occur

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Further Considerations
The effects of the three fires in 1997, 1998 and 2006 have not been considered in these management options. As mentioned previously, the fires have significantly altered the soil chemistry and therefore, it is unlikely that inundation will result in rapid reformation of pyrite and monosulfides as in prior studies. It is recommended that an investigation in to the effects of inundation on surface water quality and soil chemistry be undertaken.

Furthermore, the recommendation that the drainage regime of pre-1999 be re-established due to the decreased frequency in acidic discharges. However, again, the effects of the fires have not been considered as a large volume of acidity is likely to have been generated following each event. The soil properties and flow paths are also likely to have been irreversibly altered following these fires. Therefore, it is erroneous to assume that the pre-1999 surface hydrology and hydrogeology can be re-established.

Specific Questions
Will it rewet the higher end?
This question is difficult to answer without elevation data

Success criteria on reversal
The criteria will depend on the aim of the remediation plan. To improve water quality downstream, then the ANZECC guidelines can be used, with all of the caveats that have been discussed via email in the current discharge event. It is assumed, however, that success will be determined on decreased frequency of acidic discharge events and decreased oxidation of acid sulfate soils. However, as mentioned earlier, the effects of the fires may have irreversibly altered the hydrogeology and soil chemistry and therefore, a return to pre-1999 conditions is unlikely to be a useful criteria to measure success.

Design of the barrier/dam wall (and all questions therein)
There is not enough information provided in the report to answer this question. The critical information that is missing is the elevation data, however, a better understanding of the hydrogeology and surface water-groundwater interactions of the area is also required.

Options Assessment
See discussion of options above

Location of Lower Tertiary Aquifer
Jacobs has suggested that saturated peat and alluvial sediments in Yeodene Swamp are separated by an aquitard.

If water leaks from the swamp into the aquifer under the swamp, will extra supplementary water be required to maintain streamflow?
An investigation in to the hydrogeology and surface water-groundwater interactions would answer this question

Performance Evaluation Review Technique
There is not enough information provided to answer this question

Confidence the equation can be reversed
A controlled laboratory study focusing on inundation of these soils with water sourced from upstream could address this question

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Analysis of what is being neutralised
This can also be addressed with a controlled laboratory study

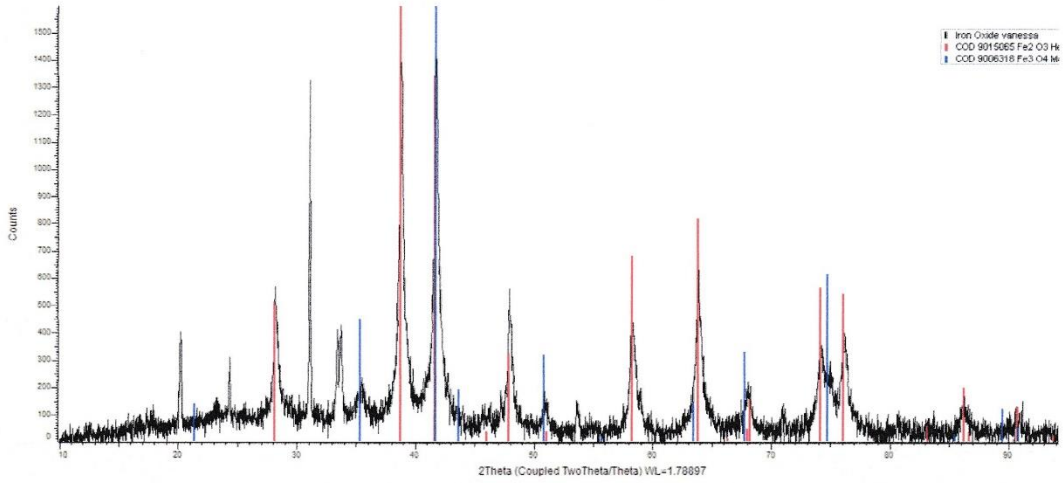
Data showing neutralisation process re. flooding
Additional surface water quality data loggers located in the swamp can potentially address this question

How much of the swamp might not be inundated?
This can be estimated with a GIS analysis providing a recent high resolution digital elevation model (DEM) is available

What could go wrong and what could happen?
Fire has already occurred and changed the soil chemistry. Dry peat swamps are a high fire risk in summer. An in depth desktop assessment of the geology will be a useful exercise to determine the likelihood of the presence of brown coal.

Approvals and permits
I suggest that Victoria EPA and local council would be the first organisations to contact

Core samples
Below is an X-ray diffraction spectra of a single sample collected from Yeodene Swamp with hematite and maghemite as the dominant minerals.



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References

Watling, K.M., Sullivan, L.A., McElnea, A., Ahern, C.R., Burton, E.D., Johnston, S.J., Keene, A.F., and Bush, R.T. Effectiveness of lime particle size in the neutralisation of sulfidic acid sulfate soil materials. In '19th World Congress in Soil Science: Solutions for a Changing World', 1-6 August 2010 2010, Brisbane,

Wong, V.N.L., McNaughton, C., and Pearson, A. (2016) Changes in soil organic carbon fractions after remediation of a coastal floodplain soil. *Journal of Environmental Management* **168**, 280-287.

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Appendix A

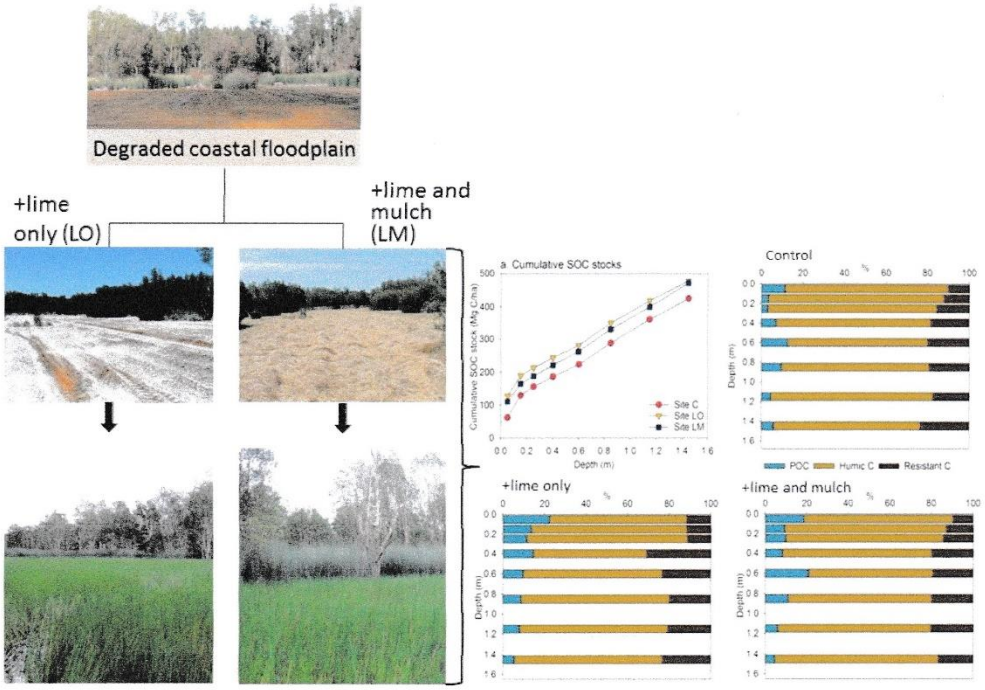

Figure A1. Effects of remediation of a degraded acid sulfate soil swamp after 3 years (Wong et al. 2015)

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Prof. Richard Bush

Independent Expert Review of the Acid Sulfate Soil Preferred Management Options for Yeodene Swamp

File note prepared for Barwon Water.

Date: 18th November, 2018.

Report Prepared by:

RICHARD BUSH

International Centre for Balanced Landuse

University of Newcastle, NSW, 2308.

Scope:

- To review the preferred concept design (management strategy) in the Yeodene Swamp study report.

Task:

- Complete a desk top review of the preferred concept design. This should include your expertise on whether the preferred management strategy put forward is appropriate to meet the objective of the remediation plan and for the environmental circumstances present.
- Propose additional management strategies appropriate for this remediation plan other than the six represented (this can include hybrids of the six presented).
- Preparation of a short file note.

Source Document:

- *JABOBS 016 - 2017 Technical Works Program, Barwon Water, Yeodene* Swamp Study. S191000-GW-RP-001, FINAL DRAFT 9 November 2017

Context:

Jacobs (2017) provide evidence that groundwater extraction over the past 30 years by Barwon Water has reduced streamflow in the lower reach of Boundary Creek.

The managed allocation of a 2 ML/day supplementary flow has not been adequate to prevent persistent drying of Yeodene Swamp (i.e. Big Swamp) and the consequent oxidation of naturally occurring acid sulphate soils and related release of acidic water (pH less than 4) and heavy metals downstream of the swamp.

A number of studies and reports have demonstrated that acid sulfate soil conditions impact the environmental condition within, and downstream of Yeodene Swamp. The impacts become evident in the early 1990's and have intensified over the past two decades. The acid sulfate soil impacts are chronic and without remedial land management intervention, can reasonably be expected to persist for decades.

The community is aware of the environmental degradation in Yeodene Swamp and more broadly, the extent of groundwater drawdown and the implications for

stream flow and water quality. They have raised issues about ecological impacts at various points along Boundary Creek, the potential to increase acid sulphate soil and fire risks at the Yeodene peat swamp, and the sustainability of current and forecast extraction limits and the current operational regime of the borefield.

Jacobs (2017) report differentiated groundwater extraction and climate effects on the groundwater system, predict water table and stream flow changes, and comments on potential ecological impacts. The investigation by Jacobs (2017) discusses:

- groundwater extraction versus seasonal climate variability on groundwater system
- potential risks of acid sulphate soils and whether that could change in the future
- if the current compensatory flow is effective at protecting Boundary Creek
- groundwater dynamics in the aquitard
- groundwater and surface water interaction along Boundary Creek.

From my review of Jacobs (2017), drawing on my experience over the past 20 years of investigating similar environmental systems, the evidence linking acid sulfate soil conditions and declining water quality in the Boundary Creek -Yeodene Swamp to groundwater extraction is compelling.

Remediation plan for boundary creek

The stated environmental objective of the remediation plan for Boundary Creek is to *"prevent – to the best of our ability –any further low pH (pH<4) events in the Barwon River"*. The objectives of the Yeodene Swamp Study by Jacobs (2017) were to:

1. Improve the conceptual understanding of the processes that affect the volume and quality of water between McDonalds Dam and the Barwon River.
2. Recommend future management options for Yeodene Swamp to improve the condition and water quality downstream of the swamp (i.e. Reach 3 of Boundary Creek).

Jacobs divide Boundary Creek into three distinct reaches based on the geology and groundwater setting as follows:

- **Reach 1** (upstream of McDonalds Dam): the creek flows over basement and receives minor groundwater inflows.
- **Reach 2** (downstream of McDonalds Dam to Yeodene Swamp): the creek flows over the regional aquifer (Lower Tertiary Aquifer). Yeodene Swamp is located at the downstream end of the Reach 2 and is considered to be losing water to the surrounding alluvial aquifer.

- **Reach 3:** The creek flows over aquitard and receives minor groundwater inflow.

Remediation options for Yeodene Swamp presented by Jacobs (2017)

Potential management strategies to improve the quality and volume of water flowing in Reach 3 of Boundary Creek were considered. Six options were reviewed and summarised in Table 0-1-2:

1. Do nothing
2. Direct treatment of soils with neutralising agents in Yeodene Swamp
3. In-drain water treatment with limestone in Reach 3
4. Diluting acidic discharge in Reach 3 of Boundary Creek.
5. Revising flow release location to Reach 3 of Boundary Creek and isolating the swamp
6. Inundating Yeodene Swamp (Preferred Option)

Option (6) - "Inundating Yeodene Swamp", is presented as the preferred concept. The working premise is that inundation will neutralise the acid in the swamp by reversing the chemical reactions from oxidising (acid generating) to reducing (acid consuming) by limiting oxygen in the soil profile. The design involves the construction of a low bundwall to raise groundwater in the Big Swamp and increased supplementary flow from 2ML/day to 3 ML/day to effectively inundate the lower end of the swamp.

In addition to the increased supplementary flow, the fire trenches and agricultural drain that are present on the eastern end the swamp will be infilled to further minimise water losses by drainage.

Jacobs (2017) expect their preferred strategy will reinstate the acid generation profile of the Swamp to pre-1999 conditions. I am not certain this has been fully considered and is justified based on the information presented. The 1999 condition also would be difficult to benchmark. Is this simply referring to surface water quality in Boundary Creek for just pH, or will it consider the broader, and potentially more critical impacts.

Comments on Conceptual Understanding and utility of the report by Jacobs.

Point 1: *In my opinion the Jacobs (2017) report provides an adequate characterisation* of the basic soil, hydrological, terrain and groundcover conditions in the Yeodene Swamp-Boundary Creek Catchment for the purpose of interpreting

the landscape architecture and processes. Sufficient data and interpretation is presented to identifying the severity and extent of acid sulfate soil conditions at this location, its spatial relationship to the shallow and deeper groundwater systems, conceptual hydrological processes and variability in surface and groundwater water quality.

Point 2: In my opinion Jacobs (2017) *provides sufficient information to implicate the* compounding effects of groundwater extraction and seasonal drought conditions in the progressive lowering of the regional groundwater system.

Point 3: In my opinion the soil assessment undertaken by Jacobs (2017) **do not** adequately quantify parameters relevant to predicting biogeochemical response and implications of inundation. The testing regime is adequate to demonstrate the occurrence and severity of acid sulfate soils and related metal contaminants in the peat soils of Yeodene Swamp. The soil sampling, array of analytical tests and acid-base accounting approach to characterise the acid sulfate soil hazard (Refer to Appendix C) are consistent with national guidelines for estimating lime requirements to treat acid sulfate soil and assess potential environmental hazards.

Point 4: I find the report provides insufficient information to understand sufficiently the ecological and environmental condition and values of Boundary Creek and Yeodene Swamp to evaluate the potential merit of the management design concepts (Options 2-6). Although a vegetation survey was undertaken (as described in Section 3.7 and reported in Section 4.7), the environmental attributes and their significance to the local terrestrial and aquatic ecology is not clearly defined.

Without a clear understanding of the environmental attributes that include ecological function and environmental condition, it is difficult to consider the appropriateness of management objectives and concept designs for Yeodene Swamp-Boundary Creek.

Point 5: Jacobs (2017) acknowledge that a robust understanding of the water balance through Reaches 1-3 is a key knowledge requirement for understanding the drivers to water quality, acid sulfate soil degradation and potential management concepts. Quantifying water movement and budgets accurately is a complicated task, generally requiring sophisticated approaches (including tracers and saturated and un-saturated hydraulic assessment) to assess exchange and preferential flow-paths, and intensive continuous monitoring of surface and ground water conditions over timeframes sufficient to generate enough data to satisfy statistical testing rigour across the spectrum of climate and management variability.

Point 6: I am satisfied with the general soundness of methods use to assess the water budget, yet it is apparent that considerable uncertainty remains in the interpretation of water balance. This is as expected when the detailed study includes only two detailed field spot measurements (May and Aug), and field based detailed investigation extends only to 7 months. Similar studies can

take 2-4 years in my experience. For example, is Section 4.6 "Surface and Groundwater Interaction", there is uncertain about the sources and flow paths of surface water and reasons behind the large variability of losses between 2.1ML/d to 9.9ML/d in Reach 2 are inconclusive.

Point 7: Jacobs (2017) acknowledge that soil hydraulics are a major factor governing the dynamics and processes for shallow ground water re-charge/discharge and the movement of acidity and related materials vertically and horizontally within the acid sulfate soil profile and its discharge from Reach (2) 'Big Swamp' to Reach (3) 'Boundary Creek'. The results as described in Table 7-3 indicate hydraulic conductivity of the sediments in Yeodene Swamp and Reach 3 ranged between 0.02 and 0.2 m/day and falls within the range of hydraulic conductivities given for silty material. The exception to this range was YS05 which recorded a hydraulic conductivity of 1.5 m/day. This type of variability can have significant impacts on water movement and the mobilisation of contaminants, essentially acting as preferential flow pathways.

Point 8: High (i.e. 1.5m/day) conductivity observed in parts of the catchment may be the result of soil macro structure or charcoal layers, and not higher sand content as suggested by Jacobs (2017). The conventional displacement method used to measure hydraulic conductivity as described by Jacobs (2017) (see Appendix D) does not necessarily represent the behaviour of acid sulfate soils. Water movement in acid sulfate soils is mostly through macro-pores and fissures (Cracks) (Wilson et al 1999). Jacobs (2017) considered the microstructure and porosity based on particle size. Furthermore, fire and the presence of vertical cracks that penetrate deep into the sub-soil and charcoal layers in the subsoils of Reach (2) at the Big Swamp will have a marked effect on hydraulic conductivity and implications for water management.

Point 9: The effects of fire on the physical, chemical and biological characteristics of the Big Swamp, have not been fully considered by Jacobs (2017). When considering the causes for the observed step-change in Boundary Creek water quality around 2000, (see Figure 2-12 Number of cease to flow days in Boundary Creek at Yeodene vs monthly pH at Yeodene). The long-term stream water quality data indicates that pH declined below 4 from about 2000 onward as a result of no/little stream flow. Jacobs (2017) discount the potential influence of peat fire in Reach (2) on the drop in base flow and chronically low pH. The effect of fire may have been under-estimated in thgis instance, having personally seen the transformative effects of fire on the soil profile at the Big Swamp.

Point 10: Peat fires have the potential to significantly affect both water balance and water quality in peat acid sulfate soils. Peat layers in wetland environments can markedly influence water balance through the capacity to store and slowly release water. The peat acts as a massive sponge, protecting subsoils from drying out and providing resilience to streams by maintaining base flow conditions during dry periods. In my opinion formed from working on peatlands over the past 20 years, even small disturbance to the upper peat

layers can substantially diminish the capacity of peats to provide a resilient baseflow during dryer periods, directly leading to the loss of flow in downstream reaches. Fire also renders the soils prone to accelerated oxidation and leaching of acidity and metals.

The effects of fire may not have been fully estimated in the Jacob's investigation, or consideration in the management concept designs, based on the information provided in the report.

COMMENTS ON MANAGEMENT OPTIONS

Point 11: Summary comments provided in Table below

TABLE 1

OPTION	DESCRIPTION - JACOBS	COMMENT – R Bush	Feasibility
(1) Do Nothing	• Yeodene Swamp will continue to release acidic water in Reach 3. • This is considered unacceptable.	• This is not an acceptable option based on the likely persistence, and possible exacerbation of the environmental hazard. • Yeodene Swamp will continue to release acidity, metals and impact the environment for potentially *decades. The impacts* could also be exacerbated by predicted climate change scenarios. • One significant hazard is the risk of fire and further loss of peat coverage, causing a deepening of the oxidation process and generation of more acidity. The hazard is likely to increase under this option	**Not Feasible**
(2) Treatment of Soil	• Significant works would be required to access the entire swamp to distribute neutralising agents, which will be very disruptive to existing flora and fauna.	• There is insufficient data in the report to exclude the use of neutralising agents on the grounds of feasibility and risk-reward assessment.	**Unresolved**

	• Significant costs associated with first application and subsequent applications are likely to be required.	• More details explanation given below.	
(3) Installation of a lime drain	• A limestone drain has the potential to improve water quality during low flow periods, however there would be limited benefit during high flow events. • Significant capital costs would be required which would result in major modifications to Reach 3 and ongoing maintenance would also be necessary. Furthermore, water quality in Yeodene Swamp would not improve. • This option is more fixing the symptom rather than the problem.	• There is insufficient data in the report to justify the exclusion of limestone drain on the grounds of feasibility and 'risk-reward' assessment. • While acknowledging the limitations highlighted by Jacob's (2017), these structures can assist in protecting and improving downstream environments as part of an integrated solution, most commonly as an intermediate intervention.	**Unresolved**
(4) Diluting acidic discharge	• Volumes of water required for dilution cannot be sourced in this region and would increase flooding and adversely impact Reach 3: 250 ML/day during low flows / 1,200 ML/day during high flows	• The modelling and field based observations demonstrate that dilution is ineffective at protecting downstream (Reach 3) from acidic events. • Furthermore, the dilution strategy does not address the source of acidity and environmental conditions within Reach (2)	**Not Feasible**
(5) Revising flow release location	• Require the hydraulic isolation of Yeodene Swamp from Boundary Creek. • This is likely to cause adverse impacts on water quality under high flow conditions when the swamp floods as pent up acid would be flushed out in high flows • This would increase drying in the swamp, which would exacerbate the acid sulphate soils in the swamp.	• There is insufficient data in the report to justify the exclusion of revising flow release locations on the grounds of feasibility and 'risk-reward' assessment. • Hydraulic diversion can provide an opportunity to minimise the chronic discharge of acidity under conditions of low-moderate flow.	**Unresolved**

		• When considered as part of an integrated approach, this intervention can potentially deliver significant benefits to Reach (3). • Other management activities could mitigate the potential for increased drying.	
(6) **Inundating the swamp**	• Key indicator for low pH events is "cease to flow" conditions at the Yeodene Swamp. This objective of inundating the swamp is to prevent cease to flow events at Yeodene. • Technically feasible and cost effective option to inundate swamp by increasing supplementary flows and infilling fire trenches and agricultural drain at eastern end. Approach to complete this would involve: • Infill the fire trenches and block the agriculture drain, ideally before April 2018 (pending approvals) to allow the swamp to retain more water over the winter months. • Minimum flow required initially is 3 ML/day as measured below McDonald's Dam. • Low flow requirement of 3 ML/day is a best estimate based on a detailed assessment of the historical data. It is possible that more water could be required for short time periods during very dry conditions. Equally	• The conceptual description, operation and assumption underlying this option provide insufficient information to consider the merit of the approach and assess the risk-reward. • Explained in more detail below.	**Unresolved**

	it's also possible that this volume could be reduced to 2 ML/day within 2-3 years as the swamp remains saturated. • Ongoing adaptive management is required that involves regular monitoring and site visits are recommended to ensure the minimum flow requirement is meeting the objective.		

Point 12: In isolation, options (2), (3), (5) and (6), may not deliver the stated objective of sustainably preventing acidification (pH< 4) under variable seasonal conditions.

Point 13: With specific reference to **Preferred Option (6) "inundation"**, there is a need for more detail on aspects of both management, design and land conditions to adequately consider the feasibility and effectiveness of this strategy.

The concept based on inundation although simple on first principles, raises may questions about the environmental processes and potential remediation outcome/s. I will address the key issue below:

- Jacobs (2017) refers to several acid sulfate soil wetlands where re-wetting strategies have been used to improve environmental conditions. These include the Lower Lakes (SA), Bottle Bend (NSW), Partridge Creek (NSW), Maelup (WA) etc. I can add several others including East Trinity National Acid Sulfate Soil Demonstration Site (QLD) and Seven Oaks (NSW). It is important to recognise that a reasonable comparison of these wetland systems with the Big Swamp on important soil and landscape factors would be required to make a relevant comparison for the purpose of indicating the potential benefits and likely outcomes of inundation.

- Even on a superficial level, most of the wetlands being used as a guide have soils of differing properties such as the availability of reactive organics for biogeochemical reactions, physical, chemical and biological properties that affect mineral transformations, stores of acidity, geochemistry, hydrological and climatic settings. It is over-simplistic and potentially unreliable, to anticipate the outcome of inundating the Big Swamp, based on studies and data highlighted by Jacobs, as the Big Swamp is by comparison, unique in the Australian context.

- Inundation (or re-wetting) strategies have proven effective at triggering the onset of chemical and microbe-driven reactions that consume organic

matter, transform minerals and generate alkalinity in acid sulfate soils. But it is important to recognise these processes can, and do, occur at vastly differing rates, and can result in an unexpected impacts during the on-set of reduction. They can even create new hazards that need to be managed. For example, The East Trinity re-wetting/inundation process caused a massive accumulation of reactive iron on the soil surface, loss of all vegetation, mobilisation of acidity, mobilisation of metals, nutrients and fine floc (suspended sediment), and the formation of a highly reactive potential acid sulfate soil layer at the upper – most soil layer.

- Multi-million dollar investment in capital works and operations was required that included active management intervention such as lime dosing of waterways to prevent off-site impacts, lime application on soil surfaces to accelerate biogeochemical reduction, installation and maintenance of sedimentation traps, targeted re-vegetation and the construction of water retention basins flow diversion structures to partition parts of the wetland (Luke 2016). Inundation of acid sulfate soils in principal appears simple. In practice, the consequences, short and long term, are ill defined and difficult to predict without considerably more information that provided in the Jacobs (2017) report.

- A simple decision flow diagram for inundation in acid sulfate soils is provided in Appendix A. Elements of this outline have not been fully addressed in the conceptual design of Option (6) at this point in time.

Point 14: Questions arising:

A) Will the inundation at Big Swamp result in a static free standing water, or will it be fluctuating in depth and circulating? Each scenario will create different effects.

B) Is the Option (6) strategy targeting the remediation of sub-soil, surface soil, the entire soil profile?, or the entire profile?

C) Are the soil conditions conducive to reductive geochemistry on a scale and rate that will consume? Or will some amendment of the soil be required to enable the soils to respond in a positive way?

D) Will the bund be sufficient to provide a favourable hydraulic gradient across the entire wetland, or will a series of bund walls be needed to achieve suitable inundation? What is the flood hazard of the bund and what will be the predicted water quality during a major flood event?

E) Is waterlogging the sub-soil, or permanent inundation of the topsoil and therefore wetland, likely to create different ecological/environmental outcomes and how could this be assessed?

F) What will be driving the biogeochemistry underpinning the recovery of the soils at Big Swamp, and how will this change over the short-medium and long-term? What is the major limiting factors and will be the implications of the shifting biogeochemistry for the environmental condition and will this create an on-going water quality management issue for Boundary Creek? Will the biogeochemistry need intervention to kick-start the process?

G) It is possible the hazard of potential acidity will increase as a result of inundation through the reformation of pyrite? Could cycling between wet and dry conditions mitigate the hazard and yet treat the issue. What sort of water management infrastructure and plans would be needed to achieve this outcome, and could it be feasible at the Big Swamp?

H) Acidity is one aspect of the impacts that follow from the draining and oxidation of acid sulfate soils. Others include irreversible soil shrinkage and physical changes to the soil, emissions of greenhouse and toxic gases, changes to soil biota, changes soil nutrient cycles and soil erosion. Have these aspects been considered, as they are not explained in the report?

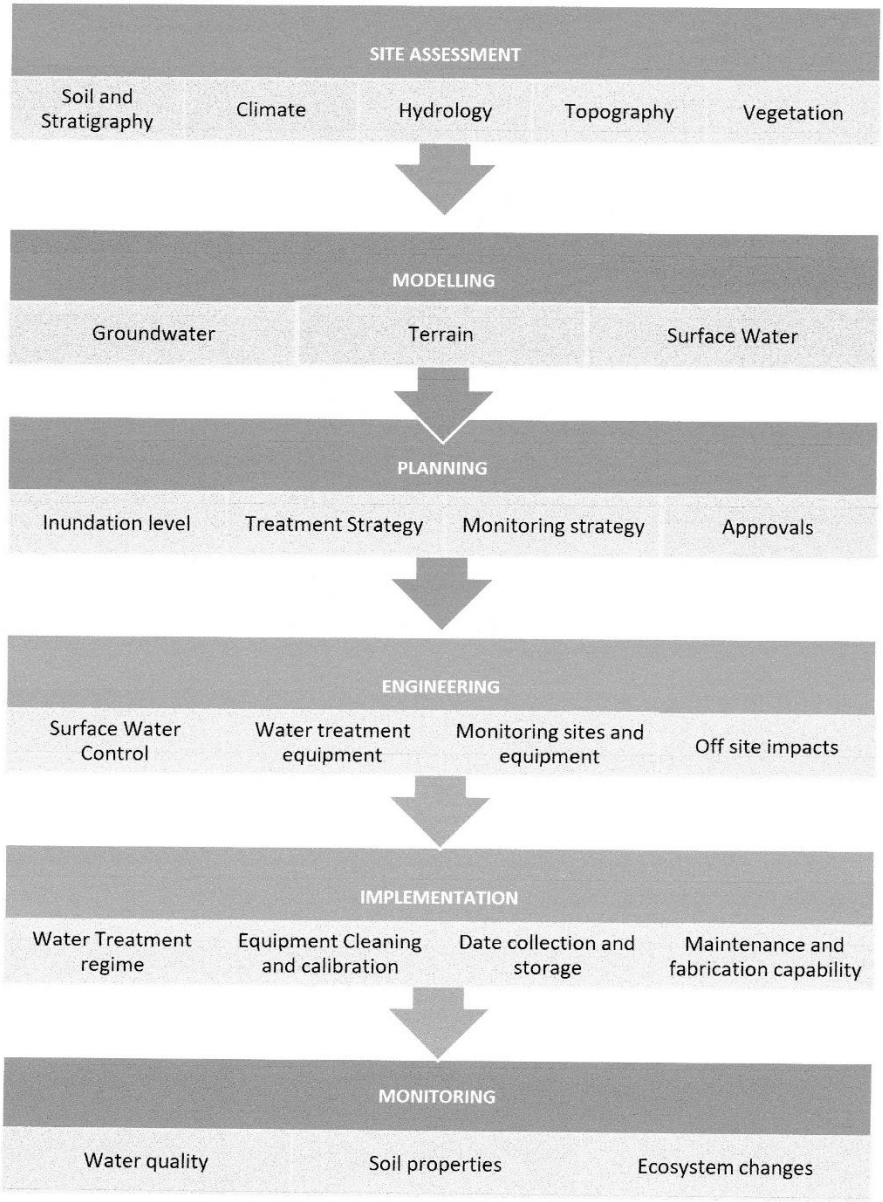
I) The potential for 'black-water' events, hyper-deoxygenation and the release of certain metals known as metalloids are particularly problematic for acid sulfate soils that become inundated (e.g. arsenic, are major issues. Have these been considered? What would be the cost of intervention and management if these issues were to develop as a result of inundation? Can they be avoided through different hydrological manipulation, and would this require a different capital investment for water management and monitoring?

References

Luke, H 2016, 'East Trinity remediation and rehabilitation after acid sulfate soil contamination, north Queensland', *Ecological Management and Restoration*, viewed 8 September 2016, https://site.emrprojectsummaries.org/2016/03/13/east-trinity-remediation-and-rehabilitation-after-acid-sulfate-soil-contamination-north-queensland/

Wilson, BP, White, I & Melville, MD 1999, 'Floodplain hydrology, acid discharge and change in water quality associated with a drained acid sulfate soil', *Marine and Freshwater Research*, vol. 50, pp. 149–157.

APPENDIX A (Luke et al 2016)



Dr. Darren Baldwin

Expert Panel for the Boundary Creek remediation plan: Review of the preferred concept design

Rivers and Wetlands

Prepared by: Darren S. Baldwin
Rivers and Wetlands

July 2018

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Expert panel for the Boundary Creek remediation plan: Review of the preferred concept design

A report prepared for Barwon Water

This report was prepared by
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Summary

1. Consensus must be reached on the purpose of the rehabilitation project - protecting downstream environments, improving the ecological condition of Yeodene Swamp, or both.
2. Drying of the swamp exposed acid sulfate soils, creating acidity.
3. Shifts in the hydrology and hydrogeology of Yeodene Swamp were caused by climate change, lowering of the Lower Tertiary Aquifer through groundwater extraction, and the operation of McDonald's Dam - all often acting together during periods of drought.
4. Re-flooding will stop any additional acid formation, but it will mobilise any acid in the peat profile. A more accurate assessment of the current store of acid in the swamp is recommended.
5. Simply re-flooding the swamp, without adding additional alkalinity, will not completely solve the problem. More acid will be produced in the next drying event.
6. There is some question of whether or not re-wetting Yeodene will actually result in a re-introduction of sulfate reduction. This needs to be tested in small scale experiments prior to installing the barrier.
7. It is possible that the barrier will need to extend below the shallow aquifer to the aquitard below Yeodene swamp.
8. Reversibility of changes that occurred to the peat on drying and being burnt should be explored.
9. Adding more alkalinity (as lime) is strongly recommended both in the swamp, and downstream, to manage acidification events in the short-term.
10. Trying to promote other anaerobic reactions, other than sulfate reduction, that can create alkalinity should be explored.

Review of Concept Design

1. A "wicked" problem

There are a number of legitimate competing interests for the water in question. Water for Geelong, water for McDonald's Dam, water for Yeodene Swamp and water quantity and quality downstream of Yeodene Swamp (including the Barwon River). The issue at hand has the hallmarks of a 'wicked problem'.[1] One aspect of wicked problems is that, because of complex interdependencies, the effect to resolve one aspect of a wicked problem may reveal or create other problems. Because of their nature, it is rare that wicked problems are actually solved, rather any 'solutions' are often, by their nature, compromises between legitimate competing outcomes.

2. A clear statement needs to be made about the purpose of the rehabilitation.

There doesn't seem to be a clear consensus on the overall goal of the project. If it is to stop pulses of acid reaching the Barwon River, then the approach taken may be entirely different to processes for rehabilitating or even restoring Yeodene Swamp.

The "*National guidance for the management of acid sulfate soils in inland aquatic ecosystems* (2011)"[2] outlines a framework for assessing the options for remediating inland acid sulfate soils (ASS). The framework starts with an assessment of risk followed by a clear statement of management objectives and the activities that will achieve those objectives. The activities can be grouped into five broad classes:

- No intervention;
- Minimising the formation of ASS in the first instance;
- Preventing oxidation;
- Protecting connected ecosystems;
- Controlling or treating acidification through neutralisation or bioremediation.

Yeodene Swamp contains ASS, and the ASS have been oxidised, so the potential activities in those two classes don't apply to the Swamp in its current condition. If the objective of the project is to minimise impact below Yeodene Swamp ('protecting connected ecosystems') the activities undertaken will be different than if the objective is to rehabilitate Yeodene

[1] A 'wicked problem' is a problem that is difficult or impossible to solve because of incomplete or contradictory knowledge, the number of people and opinions involved, changing requirements that are often difficult to recognise and, the interconnection with other problems. The use of the term "wicked" denotes resistance to resolution, rather than evil intent. See https://www.wickedproblems.com/1_wicked_problems.php for an introduction to the concept.

[2] See: http://www.environment.gov.au/water/publications/quality/guidance-for-management-of-acid-sulfate-soils.html

Swamp. For example, in their report, Jacobs (2017; at page 49) dismissed liming downstream because it wouldn't impact on water quality in the swamp, but clearly would impact on water quality in the Barwon River.

3. Promoting sulfate reduction ('reversal of reaction') to mitigate the effects of acidification

Life exists in the absence of oxygen. There are bacteria that use the chemical compound sulfate (SO_4^{2-}) the same way we use oxygen. Instead of producing carbon dioxide, they produce another chemical called sulfide (S^{2-}). Sulfide can react rapidly with metals, mostly iron, to produce metal sulfides. Metal sulfides are the active ingredient in ASS. When metal sulfides are exposed to oxygen they revert back to sulfate, in the process creating acid.

The conversion of sulfate to sulfide and back to sulfate is pH neutral. The conversion of sulfate to sulfide creates the same amount of alkalinity as the amount of acid produced when the sulfide is converted back to sulfate. It is the conversion of sulfate to sulfide (in the process creating more ASS) which the proponents are relying on to 'rehabilitate' Yeodene Swamp.

Will it work? The answer is maybe. Firstly, re-inundation will significantly slow, if not completely stop, the production of any more acid. This is because there isn't a lot of oxygen that can be dissolved in water - typically 10 parts per million. It will, however mobilise any retained acidity in the swamp which will need to be managed in the short term. I haven't been given sufficient information to determine exactly how much acid will be immediately mobilised, therefore I don't know how much lime needs to be deployed to neutralise the first flush. Jacobs (2017) only took 3 cores during their assessment. The Victorian guidelines[3] suggest 2 cores per hectare (ha) for sites larger than 4 ha to assess the risk posed by ASS. I estimated the area of Big Swam to be about 9 ha, meaning that the appropriate sampling effort would be closer to 18 cores rather than 3. *I believe a more detailed sampling program needs to be undertaken to quantify the amount of ASS and acid that is currently stored in the wetland.*

Whether or not re-inundation will re-ignite sulfate reduction (the conversion of sulfate to sulfide) depends on a number of factors. Sulfate reduction requires:-

- A zone without oxygen;
- A source of sulfate and;
- A source of bioavailable carbon (a food source for the bacteria).

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[3] EPA Victoria (2009) *Acid Sulfate Soil and Rock*. EPA publication 655.1; Also see Department of Sustainability and Environment (2010) *Victorian Best practice guidelines for assessing and managing coastal acid sulfate soils*, Melbourne Victoria.

Re-inundation of Big-Swamp should create a zone of low oxygen. What is uncertain is the source of sulfate and bioavailable carbon. It is assumed that the source of sulfate to Yeodene Swamp, used to create the ASS in the first case, is from upstream. Specifically, where Boundary Creek intersects with an outcropping of the Lower Tertiary Aquifer (LTA). The data around this is uncertain, and requires further investigation. (There has only been at most one water sample analysed in the 30+ year history of the existing bores in the region)[4]. However, if we assume that groundwater from the LTA is the source of the sulfate to Yeodene Swamp, lowering of the water table means that there isn't an inflow of groundwater from the LTA into Boundary Creek, and therefore there won't be a new source of sulfate for sulfate reduction. If that is the case, then the source of sulfate for the formation of new ASS will be the sulfate that is currently stored in Yeodene Swamp; bearing in mind that a lot of the sulfate produced when the ASS in Yeodene Swamp were exposed to the air, has now been washed downstream. *I would suggest an investigation to accurately identify the source of sulfate to Yeodene Swamp, and the amount of sulfate currently stored in the swamp, be instigated.*

Sulfate reduction also requires a source of bioavailable carbon. When Yeodene Swamp was almost permanently wet, this would have come from the plant litter growing in the wetland. Especially the carbon that is leached from the litter (like tea from tea leaves). Now that the wetland has dried out, it is not certain that the peat that supported the vibrant plant growth in the wetland will return to its previous state. When peat dries out it undergoes a series of potentially irreversible changes. Peat is mostly made up of the structural polymers found in plants (cellulose, lignin etc). This material doesn't break down when it is saturated with water and has no or very low oxygen concentrations because the micro-organism that can break down this material (mostly fungi) can't live in zones without oxygen. When the peat is dried, fungi can colonise the peat and start to break it down (that is why you get subsidence). The peat loses its ability to store as much water as it did prior to drying and the surface of the peat is more likely to shed water than adsorb it (it becomes hydrophobic). Therefore, it remains to be seen if the plant community will return to the same condition as it was in prior to inundation. *A small-scale study should be undertaken to specifically determine if simply inundating peat will result firstly in anoxia and then promote sulfate reduction.*

The other issue with the proposed inundation strategy has to do with the differences in speed of the various chemical and biochemical reactions. As noted above, the conversion of sulfate to sulfide and then back to sulfate should be pH neutral. Sulfate reduction produces alkalinity (as carbonate or bicarbonate ions), sulfide oxidation produces acid. The two cancel each other out. The problem is that the precipitation of metal sulfides (the active ingredient in ASS) is rapid, so that they accumulate very close to where the sulfate reduction

[4] Bores 109108, 109110 - 109113, 109130 and 109143.

occurs. Conversely, for the most part, bicarbonate compounds are quite soluble and while some carbonate salts are insoluble in water, it takes time (months to years) for them to fall out of solution at the concentrations you would expect to see following sulfate reduction. This means that if the system isn't closed (hydrologically isolated), the alkalinity produced in ASS formation can be lost from the system (Figure1).

We have published some work on predicting the likelihood that alkalinity would be trapped in a system like Yeodene Swamp.[5] It depends in part on the calcium concentration in the source groundwater, the calcium to sulfate ratio in the source groundwater, the buffering capacity of the soil and the rate of groundwater movement in the system. In other words, alkalinity capture in these systems cannot be guaranteed. Because Yeodene swamp has acidified, it means that the system is not closed and alkalinity is being lost from the system.

Because Yeodene is an open system that does not retain all of the alkalinity produced during ASS formation, the approach of inundating Yeodene Swamp, and only relying on alkalinity created during new ASS formation to neutralise acidity produced in previous ASS formation events, is flawed. It creates a pool of ASS in the swamp that doesn't have any associated neutralising capacity associated with it, because this neutralising capacity has already been used up to neutralise previous acidity - a bit like robbing Peter to pay Paul (Figure 1). When the swamp dries out again, there will be another acidification event.

It is highly likely Yeodene Swamp will dry out in the future, notwithstanding the introduction of the proposed barrier and new flow rules downstream of McDonald's Dam. The drying of Yeodene Swamp will most likely be caused by three factors - a drying climate, lowering of the water table through groundwater extraction, and the operation of McDonald's Dam - all often acting at the same time during extended periods of drought.

[5] K.L Whitworth, E. Silvester and D.S. Baldwin (2014). Alkalinity capture during microbial sulfate reduction and implications for the acidification of inland aquatic ecosystems. *Geochimica et Cosmochimica Acta* 130, 113-125.

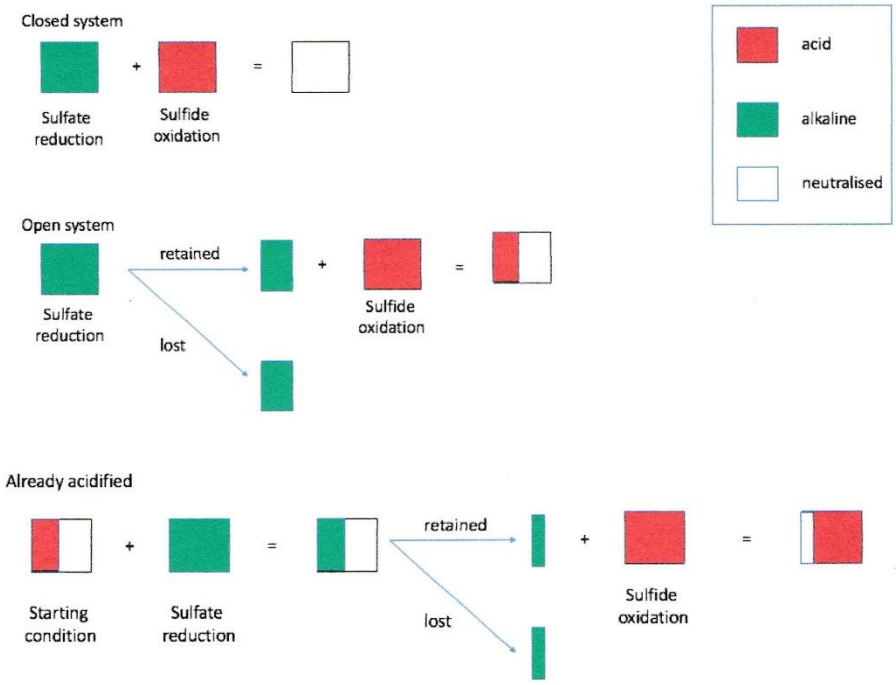

Figure 1: A schematic diagram representing the flow of acid and bases during a sulfate-reduction/sulfide oxidation cycle in a closed system (without any export), an open system where alkalinity can be exported downstream (like Yeodene Swamp) and re-introducing a sulfate-reduction/sulfide oxidation cycle in an open system that has already acidified (the preferred concept design).

4. Has the re-inundation approach been successful in the past for treating ASS in inland waterways?

Jacobs (2017) state "[t]his management strategy has been shown to be effective in a number of freshwater acid sulfate soils ..... [t]his includes Partridge Creek and Darawakah Wetland (Johnston et al, 2008), the Lower Murray Lakes (Baker et al, 2014), Lake Mealup (Jenkins and Appleyard 2014) and in Bottle Bend Lagoon" (at page 56).

This is not quite an accurate summary of the literature. For example, Johnston et al (2008)[6] state "while the reformation of reduced inorganic sulfur species (RIS) is partially responsible for the generation of alkalinity and wetland scale recovery from acute acidification, the fact that these species tend to be most abundant near the surface 0.2 m of the reflooded soils, presents a long-term management challenge. In particular, these near-surface stores are potentially vulnerable to atmospheric oxygen during the next ENSO induced drought episode. Such exposure may lead to pyrite oxidation and temporary re-acidification of surface sediments and waters with attendant risks for surface water quality degradation." The authors note that the period when the wetland was re-inundated was during the 4th wettest period on record.

Baker et al (2014)[7] indeed report an increase in soil alkalinity as a result of re-inundation; and subsequent re-formation of ASS. However, they also noted that some hotspots were still acidic 3 years after re-inundation; and the initial flushing resulted in the mobilisation of acid and metals through the sediment profile and into the water column. They didn't re-consider what would happen if the re-inundated sediments were exposed again.

I was unable to source the Jenkins and Appleyard 2014 paper, but an analysis of the restoration project suggests that at least some of the rapid change in alkalinity of the wetland was likely caused by decomposition of a large amount of bulrush (*Typha sp.*), that was mulched prior to the re-inundation of the lake. Lake Mealup is now managed as a permanently inundated system using drainage water. While there are plans to re-introduce a drying cycle, the Peel Harvey Catchment Council note that liming will be necessary because of exposure of ASS.[8]

Bottle Bend lagoon. I have done extensive work on Bottle Bend Lagoon. The lagoon was dry from 2002 to 2010. The initial drying was associated with lowering the Mildura Weir Pool. This resulted in a substantial lowering of the local ground water table, exposing sediments and causing acidification. Re-filling of the Mildura Weir Pool did not result in a re-filling of the wetland. The wetland was re-filled by the 2010 flood and the water replenished by floods in 2012 and again in 2016. To the best of my knowledge, the sediments in Bottle Bend Lagoon still contain ASS.

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[6] S. Johnston, E. Burton, T. Aaso and G. Tuckerman (2008) *Remediation of coastal acid sulfate soils by freshwater flooding.* Found at: www.coastalconference.com/2013/papers2013/Scott%20Johnston.pdf

[7] A. Baker, P. Shand, R. Fitzpatrick, AM Jolley, L. Barnett (2014) Neutralisation of soil acidity in re-flooded acid sulfate soil environments around Lake Alexandrina and Lake Albert, South Australia. http://scu.edu.au/nationalassconference/index.php/3/

[8] Annon. https://www.eianz.org/document/item/3153

5. An alternate approach to re-introducing sulfate reduction

An alternate option than promoting sulfate reduction and producing more ASS in the process, is to promote an alternate reaction - specifically nitrate reduction. This would require adding nitrate fertiliser (and possibly a source of bioavailable carbon) to the swamp. Before nitrate addition is considered as an alternate to re-instating sulfate reduction, it would be necessary to undertake a small-scale trial to determine whether or not this approach can be successful (e.g. whether or not the peat can return to a state to promote anoxic conditions, to what extent the added nitrate will oxidise any residual sulfides in the swamp, etc). The dose of nitrate would need to be carefully monitored because of the potential for nitrate export downstream leading to nuisance algal blooms.

6. Will the proposed additional water reach Yeodene Swamp?

It has been reported that the reach above Boundary Creek above Yeodene Swamp has gone from a gaining reach to a losing reach. That means instead of water going into the swamp, it is going in to refill LTA. Furthermore, Jacobs (2017) has shown that flows above McDonald's Dam are greater than flows downstream of McDonald's Dam at times (e.g. November 2015 to May 2016); which is not consistent with the dam's operating rules.[9] So the question remains of how much of the proposed 3 ML/day flow will reach the swamp.

7. How much did winter and spring flow add to the recharge of the LTA prior to the construction of McDonald's Dam?

If McDonald's Dam operates within its rules, it is able to harvest winter runoff. In the current state, with the reach above Yeodene Swamp being a losing reach to the LTA, winter and spring runoff unimpeded by McDonald's Dam should contribute to ground water levels. *I would suggest a study that modelled groundwater levels in the LTA and the shallow aquifers along Boundary Creek over the last several decades both with and without McDonald's Dam to see how large that effect actually would be.*

8. The peat's response to re-wetting

As mentioned above, I have questions as to whether or not the peat in the swamp will revert to its previous state upon re-wetting. Some of the peat in the swamp has been burnt. Some will have been broken down by fungi, which will lead to subsidence. In other peat swamps, peat drying has resulted in substantial changes to the peat. It can become hydrophobic (water repelling), which substantially reduces the amount of water the peat can hold. Reversal of this process can be slow. *A study should be undertaken to determine the extent that the peat will recover its physical properties (particularly water holding*

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[9] "*Unless otherwise directed by the Authority, water may only be harvested into the on-waterway dam during the period from 1 July to 31 October inclusive; at all other times, the entire stream flow must be passed downstream of the dam.*"

capacity) on re-wetting. This will affect the plant community that can grow in the swamp (the source of bioavailable carbon) as well as the soil microbial community.

9. Liming downstream of Yeodene Swamp

One of the options considered, and rejected, in Jacobs (2017) was the installation of a lime drain below the swamp. The lime would neutralise the acid produced in the swamp before it reached the Barwon River. One of the reasons for rejecting the lime drainage was because the process would modify the reach downstream of the swamp. This reach has already undergone significant modifications. The land around the reach has been extensively drained, and the lowest part of the reach appears to have been straightened at some stage. While I agree with the Jacob's report that this is only treating the symptom and not the problem, nevertheless acidification events will continue in Boundary Creek, at least in the short-term.

Dosing the reach below Yeodene Swamp with lime (calcium carbonate or $CaCO_3$) during acid events is feasible. A back of the envelope calculation[10] would suggest that it would take 50 - 75kg of lime per ML per day to neutralise pH 3 water. Therefore, installing a manual or automated liming station in Boundary Creek to neutralise acid events in the short term should be considered. *It is only a short-term solution though. This is not without its issue.* Permits would probably be required to dose a stream. Furthermore, neutralisation would result in the precipitation of any metals dissolved in the acidic water. The metal accumulation can be monitored and assessed against the Australian Sediment Standards. *As a preliminary action, the current status of surficial sediments in Boundary Creek downstream of Yeodene Swamp needs to be evaluated against the Australian Sediment Quality Standards.*

Response to the specific question raised

A. Confidence that the wall will sufficiently wet the swamp over the 8 - 10 m gradient.
I have been able to get a digital elevation model of the swamp. The last LIDAR data was collected in 2008 i.e. before drying, subsidence, the 2010 fire and the fire trench being dug. *It is recommended that new LIDAR data be obtained.*

Examination of the site using *Google Earth Pro* suggests the gradient is probably closer to 4 metres. Jacobs have stated that the purpose of the structure is not to totally re-inundate the site but to increase the height of the water table. If that is the case, then the structure

[10] pH 3 = 10^{-3} moles H^+/L. 1 ML of water at pH = 3 would contain (10^{-3} x 10^6) = 10^3 moles of H^+. One mole of $CaCO_3$ can neutralise 2 moles of acid therefore you would need 5 x 10^2 moles of $CaCO_3$ to neutralise 1 ML of pH 3 water. The molar mass of $CaCO_3$ is about 100g/mol. Therefore, you would need (5 x 10^2 x 100g) = 50 000 g = 50 kg of $CaCO_3$/ day. Using a safety factor of 1.5 would require 75 kg.

needs to be designed such that groundwater out-flows downstream of the structure are impeded. Google Earth images suggest that there are local expressions of groundwater downstream of Yeodene Swamp. *A hydrogeological investigation needs to be undertaken to see if the structure needs to extend all the way through the shallow aquifer to the aquitard to minimise groundwater outflows.* Minimising groundwater losses will also overcome the problem of alkalinity transfer from the swamp downstream.

B. Criteria to measure the success of the reversal of the chemical reaction
As noted above, I am not entirely sure that the approach will work in the current situation; and if it does it will not prevent acidification happening into the future. Again, I would suggest that the idea be tested in small scale experiments before embarking on an engineering solution.

Technically, for a true long-term solution, the criteria for success of the project would be that the acid neutralising capacity (ANC) of the sediment in the swamp exceeds the actual and potential acidity arising from oxidisation of reduced sulfur species in the sediments.

C. Is the proposed dam wall design the most appropriate?
As noted above (At question A), I think additional information is required regarding the structure's ability to retain groundwater - especially whether or not the structure needs to extend to the aquitard.

D. If the hydraulic barrier is only a metre above ground level at the downstream end of the swamp, while at the other end ground level is 15 metres higher, how can the swamp be inundated without leakage?
See answer to Question A (above).

E. How much water is retained and how much will flow over the barrier?
I can't answer this question based on the information supplied in Jacobs (2017).

F. What is the predicted amount of acid that will be flushed out following the inundation of the swamp?
It is difficult to answer based on the available data. Jacobs (2017) only took 3 cores during their assessment. The Victorian guidelines[11] suggest 2 cores per hectare for sites larger than 4 ha for assessing the risks posed by ASS. I estimated the area of Big Swam to be about 9 ha, meaning that the appropriate sampling effort would be closer to 18 cores rather than 3.

[11] EPA Victoria *Acid sulfate soil and rock* Publication 655.1 (2009); also see Department of Sustainability and Environment (2010) *Victorian Best practice guidelines for assessing and managing coastal acid sulfate soils*, Melbourne Victoria.

G. How much will remediation cost and how long will it take?

I cannot comment on cost or construction time. The question of how long reversal of acidity takes it will depend on:

- Whether or not other strategies in addition to the barrier being built are used
- How much sulfate (or other electron acceptors) and bioavailable carbon are present in the swamp
- How long it takes for the peat returns to a semblance of its previous condition
- Local hydrology and hydrogeology
- The temperature (microbial processes are temperature dependendant).

H. Site Visit

I agree with this comment; so that all stakeholders have an opportunity to explain what they 'see' in the landscape, what their values are and where they see solutions (see 'wicked problem' above).

I. Give the options a rating or weight.

Do nothing - Zero rating. While 'do nothing' is a legitimate management decision in some instances (e.g. in an unconnected wetland of little ecological or economic value), in the current situation, if no action is taken then there will be ongoing ecological harm to downstream ecosystems. Therefore, this is not an option.

Treatment of soils - Low rating if this is the only option; moderate to high ranking if done in conjunction with other activities. This isn't a long-term solution and, as pointed out by Jacobs (2017), it is highly impractical to inject the treatment to depth. However, as a short-term stop gap, it will help deal with the acidity, both in the swamp and downstream. In plot trials at Bottle Bend Lagoon, soil amelioration with lime or calcium hydroxide were the only activities that affected soil pH.[12] *At a minimum, a feasibility study of aerial application of fine lime to the swamp should be undertaken.*

Instillation of a lime drain in Reach 3 - Liming (in some form) has a medium to high rating in the short to medium term, but needs to be done in conjunction with other activities. I think the highest priority in the short-term is to minimise impact of acid events on the Barwon River, which means liming. Jacobs (2017) has suggested a lime lined drain, which will irreversibly impact on the nature of lower Boundary Creek. As noted at point 8 above, manual dosing of lime should also be considered.

Diluting acidic discharge - Zero Rating. There isn't enough water. pH is measured on a negative log scale. This means that a fall in pH by one unit means a ten-fold increase in acid

[12] M. Fraser, D. S. Baldwin, G.N. Rees, E. Silvester and K. Whitworth (2012) Rehabilitation options for inland waterways impacted by sulfidic sediments - Field trials in a south-eastern Australian wetland. *Journal of Environmental Management*, 102, 71-78.

concentration. So, to dilute 1 ML of water at pH 3, to pH 6, would require 1000 ML of water (assuming no buffering capacity in the dilution water).

Revising Flow Location - Low Rating. Isolation is a legitimate approach, analogous to triage in medicine if the objective of the study is to minimise impacts on downstream ecosystems. In this scenario the swamp is essentially abandoned as an ecosystem. Notwithstanding the societal ramifications of this approach, to be an effective strategy requires the site to be completely isolated from adjacent ecosystems. Given the substantial ground- and surface water connectivity in Boundary Creek, while this approach might be feasible, it certainly would be expensive.

Inundating Yeodene Swamp - High Rating in the long-term but needs to be done in conjunction with other activities (liming and soil treatment), and there are a number of caveats. As outlined in the first section of this report, there are still a number of knowledge gaps that need to be addressed. Acid will be mobilised on re-flooding, which will need to be neutralised (hence the soil treatment and downstream liming). Simply re-instating sulfate reduction (if that can actually be achieved) only postpones the problem until the next large drought - hence the idea of introducing other electron acceptors to compete with sulfate reduction.

J. Look at each remediation option - does groundwater level impact on outcome.

Do nothing - No
Treatment of soils - Yes, because the amount of ameliorant used will depend on how much unoxidised ASS (referred to in Jacobs (2017) as potential ASS) are in the system. As the localised groundwater level falls, more ASS will be oxidised, creating more acidity.

Liming (noting the expansion of the original proposal to include direct liming) - indirectly. It is based on expressed acidity, which in turn is based on groundwater level (as above).

Diluting acidic discharge - not relevant

Revising Flow Location - Yes, because, to be a successful strategy, the remnant ecosystem needs to be completely isolated from downstream ecosystems.

Inundating Yeodene Swamp - Yes, for the reasons outlined in the first part of this report.

K. Where is the LTA under the swamp?
Earlier modelling by Jacobs suggests that the swamp is lying over a shallow aquifer that is separated from the LTA by an aquitard. Direct contact between the LTA and Boundary Creek is upstream of the swamp.

L. If water leaks from the swamp into the aquifer under the swamp, will extra supplementary water be required to maintain streamflow in Boundary Creek downstream?
I have addressed this at point 5 in the *Review of Concept Design.*

M. Contamination of the LTA and understanding if the chemistry of the aquifer will be affected due to swamp (i.e. poor water quality extracted from the bore field as a result of acidic water leaking into the aquifer from the swamp).
I would expect little impact of poor water quality from Yeodene Big Swamp impacting on water quality extracted from the bore field except in the very long-term (millennia). Firstly, given the proposed connectivity (Question M, above) direct connectivity between the shallow aquifer below the swamp and LTA is through an aquitard, so movement will be very slow. Any acid produced would most likely be neutralised by dissolution of rocks forming the aquitard. While this would produce a plume of metals, the sheer volume of water in LTA would dilute the metal signal before it reached the bore field.

N. PERT chart for option 5
For reasons that I hope I have articulated clearly enough, I don't think the project is sufficiently advanced for a PERT analysis.

O. Confidence the equation can be reversed
This is addressed at Points 3 and 4 of the *Review of Concept Design.*

P. Analysis of what is being neutralised
This is also addressed at Points 3 and 4 of the *Review of Concept Design.*

Q. Data showing neutralise process re: flooding with the 8 – 10m rise front to back of swamp
I'm not entirely sure of the meaning of this question, but I believe I may have already addressed the key points.

R. How much of the swamp might be non- inundated (being elevated) and so fire prone
This was addressed at Question A.

T. What could go wrong and what could happen? E.g. identification of brown coal, ignition of fire
What could go wrong already has.

U. Does a process / legal requirement similar for that of a mine contamination need to be followed for Big Swamp?
This is a question for Barwon Water's legal advisors. Potentially relevant policy documents include:-

- Victorian *Industrial Waste Management Policy (waste acid sulfate soils) 1999;*
- EPA Victoria *Acid sulfate soil and rock* Publication 655.1 (2009);
- *Victorian Coastal Acid Sulfate Soil Strategy* and

- *Victorian Best practice Guidelines for Assessing and Managing Coastal Acid Sulfate Soils.*

V. Does the remediation concept design need to be submitted to obtain regulatory / statutory approvals?
This is a question for Barwon Water's legal advisors.

W. Please source core sample data from Professor Richard Bush / Phil Hurst
I haven't seen the results from Richard's Core samples. The relevance to the current discussion would depend on how long ago they were taken.

APPENDIX SIX *Barwon Water's Remediation Brief to Jacobs*

Hi Malcolm,

An action from the Jacobs meeting was for me to send through the brief we had prepared for the Yeodene Swamp study.

Please find brief attached.

Have a good weekend,

Jo

Joanna Lee

Senior Water Resources Engineer I Asset Planning

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Enabling regional prosperity through high quality, affordable and secure water services.

Stage 1_ Consultancy Brief.pdf

1. SCOPE OF SERVICES

The relevant tasks for the Yeodene swamp study are set out below:

Task 2: Additional calibration of the groundwater model to replicate drawdown responses in the Boundary Creek catchment	
Objective/s	• To improve how the Boundary Creek catchment is represented in the updated groundwater model. This is critical in understanding potential impacts of future groundwater extraction on environmental and social receptors.
Task description	• Desktop review to identify current gaps of the Boundary Creek catchment • Workshop with Barwon Water staff (Geelong office) to confirm key questions/issues that will require resolution prior to the submission of the licence renewal application • Update groundwater model at a localised scale in preparation of scenario modelling • Calibrate model to an accepted confidence level classification as per the Australian Groundwater Modelling Guidelines • Prepare a short report outlining the model update and calibration (including the desktop review)
Inputs	• Jacobs (2016) Barwon Downs numerical model revision and recalibration report • Jacobs (2016) Integration report
Outputs	• Workshop with Barwon Water including any necessary preparation • Workshop minutes • Calibrated groundwater model • Short report/memo

Task 5a: Study of Yeodene Swamp and its impact on the lower reach of Boundary Creek	
Objective/s	• To understand what functions drive the flow and water quality of the Yeodene Swamp and what may have contributed to the swamp reaching its current state • This information will then be used to assess the impacts of a potential supplementary flow release to Reach 3, downstream of Big Swamp.

Task description	• Prepare a conceptual site model to understand the functions of the Yeodene Swamp. This will need to include:
	  ○ The chemical and physical processes occurring in Yeodene swamp as it is today (for example, how the swamp is affecting stream flow and water quality, particularly to reach three of Boundary Creek)
	  ○ The role of peat soils and PASS
	  ○ The role of the swamp in the water balance for the Boundary Creek catchment, including potential surface water groundwater interactions
	• Consider the current condition of the swamp given the environmental changes that have occurred. This will need to include:
	  ○ Groundwater extraction
	  ○ Climate change/variability
	  ○ Peat fires
	  ○ The cutting of the trench to minimise the spread of fire
	• Make a preliminary assessment on:
	  ○ How much of the current supplementary flow is reaching the Barwon River
	  ○ How water quality is changing from the swamp to the confluence of the Barwon River
	  ○ Whether additional acid or metals would be mobilised by additional flow from the revised supplementary release point
	  ○ Groundwater surface water interactions in the reach, and whether the creek is gaining, losing or neutral
	• In accordance with previously discussed RFP, Barwon Water needs to assess

	whether there is benefit to providing an additional flow release point to reach 3 to maintain/improve stock and domestic flows to existing users in Reach 3 of *Boundary Creek. The RFP and proposal put forward by Jacobs proposed to* only consider Reach 3. This task builds on that proposal, however we would still like to understand this as part of our requirement for a lower Boundary Creek Masterplan. Lou Lennon's email dated 6/9/2016 "Boundary Creek Soils Study RFP" should be utilised to flesh out the additional actions in this task. • Prepare a draft report noting that this will be a public document and as such, needs to be written in plain English • Prepare a final report based on feedback from Barwon Water
Inputs	• Task 2 • Jacobs (2016) Barwon Downs numerical model revision and recalibration report
Outputs	• Conceptual site model • Draft report • Final report

Task 5b: Study of Yeodene Swamp and its impact on the lower reach of Boundary Creek (<u>to be delivered as a sub-consultancy</u>)	
Objective/s	• To put forward potential management options (if any) that would result in better outcomes for stock and domestic users downstream. • To identify potential remediation options for swamp and identify whether they would be beneficial
Task description	• Based on the conceptual site model completed in task 5a. Note, Jacobs should liaise with Prof John Webb to determine the best method to undertake tasks 5a and 5b and the preferred order. • Sub consultancy should consider: ○ Provide expert advice on the chemical and physical processes occurring in Yeodene swamp as it is today. *(This should provide additional expert advice, in addition to, or instead of Jacobs work in Task 5a)* ○ Explain the current condition of the swamp given previous environmental changes *(This should provide additional expert advice, in addition to, or instead of Jacobs work in Task 5a)* ○ Outline the options for remediation of the swamp to prevent future downstream acid flow events and improve the underlying ecological condition (including a do nothing option) ○ *Identify the advantages and disadvantages of each option and* potential risks ○ Identify a preferred option and future management regime ○ Provide estimates of remediation costs within a +/- 30% accuracy ○ Provide advice on whether a new supplementary release point downstream of Yeodene Swamp would provide a more consistent flow regime and water quality improvement for the lower reach of Boundary Creek or whether it would have a detrimental impact • Prepare a draft report noting that this will be a public document and as such, needs to be written in plain English • Prepare a final report based on feedback from Barwon Water
Inputs	• Task 2 • Task 5a • Jacobs (2016) Barwon Downs numerical model revision and recalibration report
Outputs	• Conceptual site model • Draft report • Final report

APPENDIX SEVEN *Charley Kohout's 22 August Submission*

Helpful Observations and Recommendations For Boundary Creek Rehabilitation

After Workshop Two in July 2018.

Project: **Remediation of Boundary Creek 2018 By Barwon Water**

Author: **Charley Kohout**

Prepared For:

LAWROC Inc. (Landcare Group)

& Barwon Water Workshop Three (22 Aug 2018)

(THE INTENTION of this report is to provide HELPFUL rather than judgemental OBSERVATIONS AND RECOMMENDATIONS)

At the conclusion of Barwon Water's Remediation of Boundary Creek Workshop 2, participants were invited by Barwon Water to prepare and submit their recommendations for discussion at Workshop Three on 22 August 2018. The following **9** recommendations are listed for discussion. Each recommendation is preceded by an Observation.

Observation That Leads to Helpful Recommendation 1.

There is scientific evidence that Unique Wetlands at Boundary Creek have been severly damaged for decades to come. This was explained in Workshop Two.

Helpful Recommendation 1.

Barwon Water Rehabilitate the Unique Wetlands at Boundary Creek. Remediation is no longer sufficient.

Observation That Leads to Helpful Recommendation 2.

There is scientific evidence that Groundwater Mining of the lower aquifers is the main cause of the growing number of identified impacts at Boundary Creek. Effective options for the rehabilitation of Unique Wetlands at Boundary Creek are dependent on the recovery of groundwater and aquifer systems. This was described by expert scientists at Workshop Two and it was confirmed that recovery of aquifers will take 25 years or 70 years or more.

Helpful Recommendation 2.

No groundwater harvesting is permitted until Unique Wetlands at Boundary Creek are rehabilitated and supported by aquifer and groundwater systems.

Observation That Leads to Helpful Recommendation 3

Earlier scientific evidence dating back to the 1980's produced recommendations on groundwater levels and vegetation studies that have not been acted on or included in this rehabilitation project.

Helpful Recommendation 3.

Barwon Water document all the scientific evidence in this rehabilitation project and use already stated recommendations to develop and document goals linked to the evidence and recommendations.

Observation That Leads to Helpful Recommendationzs 4 & 5.

Scientific evidence shows known serious impacts have occurred in soil, microbe, vegetation, surface water and aquifer systems outside the implied context supplied by Barwon Water.

Helpful Recommendation 4.

Barwon Water document impacts described at this stage.

Helpful Recommendation 5.

Barwon Water redefine context to include all known impacts.

Observation That Leads to Helpful Recommendation 6 & 7.

Scientific evidence shows clearly that there are many information gaps and missing data at this stage. 'Describe the current situation' is required under an adaptive management framework.

Helpful Recommendation 6.

Barwon Water list and define information gaps and missing data.

Helpful Recommendation7.

Barwon Water describe the current situation as required under an adaptive management framework. This will involve a broader desciption in a new context which includes known impacts, information gaps and missing data.

Observation That Leads to Helpful Recommendation 8.

Scientists consulted leading into workshop two have identified many problems which were not found or documented by Jacobs and Barwon Water.

Helpful Recommendation 8.

Barwon Water review the resources required for this rehabilitation of Unique Wetlands at Boundary Creek.

Attention needs to be given to people, knowledge, skills and money required for this project.

Observations That Leads to Helpful Recommendation 9.

Barwon Water *have failed to investigate numerous failures and issues leading up to the need to rehabilitate the Unique Wetlands at Boundary Creek.*

An inability to detect and review a success that has turned into a failure. One example is the scientific, political, and legal issues leading to the 2004 licence renewal process *failing to detect risk factors*.

As a consequence we have the 2019 licence renewal process *also failing to detect risk factors*.

An inability to identify problems has led to failures to:

. Heed warnings from earlier research results on Boundary Creek dating from the 1980's.

. Comply with Federal & State Guidelines & Policies.

. Identify and use Federal And State Guidelines designed for this type of project.

. Include known risks and dangers as required in guidelines.

. Predict or identify ASS in the Otways.

. Detect and document the extent of the major impacts of groundwater mining for 30 years. Groundwater pumping for 30 years has been described by expert scientists as the main cause of the problems in Boundary Creek Big Swamp.

. Notify the public of known risks of Groundwater Mining.

. Investigate the
2010 Victorian Auditor General Report
on Groundwater to find out how auditors could arrive at such a conclusion as
Victorian water authorities
do not know what they are doing.

. Identify the broad nature of impacts of Groundwater Mining.

. Use normal project procedures
designed for complex projects.

. Document and set priorities for
detailed problem identification.

. Use Australian Standards
definition of groundwater mining
by using the term groundwater pumping.

. Identify the level of complexity inherent in the project.

. Identify the resources needed for the project.

. Focus on 'the truth, the whole truth and nothing but the truth' as the main principle behind all project work.

. Focus on 'the intention to do no harm'
as a key intention behind remediation work.

. Develop the vision to see the consequences of actions taken.

. Understand the risks involved
when taking actions without appropriate assumptions, limitations, realistic contexts, problem identification, problem solving, planning, validation of data and processes ...

. Comply with state environment protection policies.

. Use the Jacobs model to predict impacts at Boundary Creek which have been evident to locals for 20 years and were formally communicated to Barwon Water and the board in 2008.

. State any assumptions or limitations of the Jacobs model or this remediation project.

. Heed scientific advice that goals are necessary to define the next steps in collecting additional data.

. Heed warnings and suggestions clearly stated in WWF reports of the consequences of current priorities and policies.

Helpful Recommendation 9.

Barwon Water review their priorities and culture to address these failures.

www. stopgroundwatermining .com.au

Following is a List of the 9 Recommendations.

Helpful Recommendation 1.

Barwon Water rehabilitate the Unique Wetlands at Boundary Creek. Remediation is no longer sufficient.

Helpful Recommendation 2.

No groundwater harvesting is permitted until Unique Wetlands at Boundary Creek are rehabilitated and supported by aquifer and groundwater systems.

Helpful Recommendation 3.

Barwon Water document all the scientific evidence in this rehabilitation project and use already stated recommendations to develop and document goals linked to the evidence and recommendations.

Helpful Recommendation 4.

Barwon Water document impacts described at this stage.

Helpful Recommendation 5.

Barwon Water redefine context to include all known impacts.

Helpful Recommendation 6.

Barwon Water list and define information gaps and missing data.

Helpful Recommendation 7.

Barwon Water describe the current situation as required under an adaptive management framework. This will involve a broader desciption in a new context which includes known impacts, information gaps and missing data.

Helpful Recommendation 8.

Barwon Water review the resources required for this rehabilitation of Unique Wetlands at Boundary Creek.

Attention needs to be given to people, knowledge, skills and money required for this project.

Helpful Recommendation 9.

Barwon Water review their priorities and culture as to address these failures.

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APPENDIX SEVEN *Water Minister's Directive.*

Media Release

The Hon Lisa Neville MP
Minister for Police
Minister for Water

Thursday, 9 August, 2018

REMEDIATION PLAN FOR OTWAY WATERWAYS

The Andrews Labor Government is protecting the health of Otway waterways by ensuring Barwon Water repair the environmental impacts of past groundwater extraction in the region.

Minister for Water Lisa Neville has intervened through Southern Rural Water (SRW) to request a legally enforceable remediation plan, under Section 78 of the Water Act, to improve and protect the health of key waterways in the Otways.

Ms Neville said she was also requesting extra work to determine whether any further extraction is sustainable. This is in addition to the normal assessment process.

The announcement – which affects waterways such as the Big Swamp, Boundary Creek and Barwon River (between Boundary Creek and Winchelsea) and important groundwater reserves – includes the following directions to SRW:

- That Barwon Water prepare a thorough remediation plan, given findings that past groundwater extraction have affected pH conditions in Boundary Creek
- That in addition to the normal assessment process, SRW establish an independent technical review panel to asses Barwon Water's groundwater extraction license renewal application
- That SRW work with DELWP to determine whether a change to the overall permissible consumptive volume for the Gerangamete Groundwater Management Area should be reduced
- That Barwon Water discontinue any extraction activities, other than for maintenance and emergency response purposes, while the assessment is being completed and until all remediation work dictated under the remediation plan has been completed.

While groundwater extraction to supplement supply hasn't been undertaken in the borefield in two years, the environmental impact from past extraction means there needs to be a change in approach.

In addition, SRW will create a community reference group to provide input into the groundwater license renewal assessment process and a forum for issues to be raised in a formal manner.

People who wish to register interest to take part in the community reference group can contact Southern Rural Water on 1300 139 510.

The Labor Government has already invested in large-scale infrastructure projects such as the desalination plant, the Melbourne-Geelong pipeline and Anglesea borefield – which now means Geelong's water supply is future-proofed, more secure than ever before and less reliant on groundwater.

Quotes attributable to Minister for Water Lisa Neville

"Maintaining the health of these vital waterways is vital for both the Geelong community and local environment."

"I've placed strict requirements on Barwon Water's licence renewal process and I expect them to be complied with."

"I will ensure the health of our local waterways is prioritised, and that locals are kept well-informed on the development of the remediation plan."

Media contact: Elisa Fernandes 0438 021 203 | elisa.fernandes@minstaff.vic.gov.au

APPENDIX NINE *Barwon Water's Response to the Minister's Directive.*

Barwon Water

About us » Latest news blog » Remediation approach for Boundary Creek and Big Swamp environments

Remediation approach for Boundary Creek and Big Swamp environments

Thursday 9 August 2018

Barwon Water welcomes the direction from the Minister for Water in relation to a legally enforceable remediation plan for the Boundary Creek and Big Swamp environments impacted by past groundwater extraction at Barwon Downs, under Section 78 of the Water Act 1989.

Managing Director, Tracey Slatter said this not only provides added assurance to the community but legally enshrines Barwon Water's intention to remediate Boundary Creek and Big Swamp as part of its application to Southern Rural Water to renew the Barwon Downs borefield licence.

"Barwon Water is keen to cooperate with the Section 78 notice and the licence application process to get the right outcomes," Ms Slatter said.

"We are also committed to working closely with the local community, key agencies and technical experts in the years ahead as we work towards achieving this," Ms Slatter said.

"We have been consulting with the community and key stakeholders to help Barwon Water design the remediation plan including identifying what the success criteria might be."

At the request of community members, three independent technical experts were invited to contribute to the process. These experts will work with Barwon Water's existing technical consultant and the remediation working group to refine the remediation concept and address any important information gaps before finalising the plan.

For more information on the Big Swamp and Boundary Creek remediation project, please visit our dedicated microsite: Your Say - Boundary Creek and Big Swamp remediation.

Latest news blog

APPENDIX TEN *Some of the Known Impacts.*

- Creation of several Actual Acid Sulfate Soil sites
- Springs, soaks, creek and rivers with reduced baseflows
- The start of similar impacts in the Gellibrand Catchment
- The most likely cause of a cone of depression created at Kawarren
- Perennial creek and river flows reduced to ephemeral flows
- Platypus colonies decimated
- Fish kills a regular occurrence
- Groundwater dependent ecosystems ruined
- Peat wetlands destroyed
- Fire within the peat changing the whole regime of the wetlands
- Creation of toxic gases
- Threat from fire within the area increased
- Groundwater contamination
- Acid water and liberation of heavy metals and metaloids created
- A large area of groundwater drawdown influence created
- Beneficial uses disrupted including stock and domestic water supplies
- Artesian bores dropped below ground level
- Impost on water supply from the Otway/Colac system
- Corrosion of infrastructure, pipes, bridge pylons, pumps…

APPENDIX ELEVEN *Summary of Recommendations made to the Barwon Water Board from the Community Reference Group (CRG).*

Barwon Water Groundwater Community Reference Group (CRG)

Final Report to the Barwon Water Board.

Barwon Water has operated groundwater extraction licences since the drought of 1982-1983. These extractions taken from 400-600 metres below ground level have had an accumulative effect creating long term disastrous impacts. As part of the 2019 licence renewal application process, Barwon Water instigated an engagement program with local community stakeholders. This included the setting up of a Groundwater Community Reference Group in October 2013 and during the later stages of this Group's work several Community and Stakeholders public forums were conducted.

In October 2013 the Community Reference Group met for the first time. After 4 years of extensive and intensive community consultation the CRG, in April 2018, presented its recommendations to the Barwon Water Board.

Summary of Recommendations made to the Barwon Water Board.

1. Apply for a 15 year licence. (Groundwater extraction licences are usually for 15 years)
2. Reduce the yearly extraction limit down from 20,000 megalitres to 100 megalitres a year.
3. Use this 100 mega litres a year as part of infrastructure maintenance.
4. During this 15 year period remediate impacts caused from past extractions.
5. Monitor aquifer recovery.
6. Continue research and studies targeting gaps in the knowledge base.
7. Maintain the high level of community engagement.
8. Use the data and research findings compiled through the efforts of points 1-7 to determine how future extractions can be done in an environmentally sustainable way.

The full report of the Barwon Water Groundwater Community Reference Group can be found on www.otwaywater.com.au Book **46**, pages 3-12.

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3. Roger Blakes' (found on the Barwon Water web site….)
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