LAND COURT OF QUEENSLAND

REGISTRY: Brisbane
NUMBER: EPA495-15
MRA496-15
MRA497-15

Applicant: **New Acland Coal Pty Ltd ACN 081 022 380**

AND

Respondents: **Frank Ashman & Ors**

AND

Statutory Party: **Chief Executive, Department of Environment and Heritage Protection**

STATEMENT OF EVIDENCE TO THE LAND COURT BY BRIAN GEORGE BARNETT

1. **Expert details and qualifications**

1.1 **Name**

My name is Brian George Barnett.

1.2 **Address**

My business address is Jacobs Group (Australia) Pty Ltd of Floor 11, 452 Flinders Street, Melbourne, in the State of Victoria.

1.3 **Qualifications**

(a) I hold a bachelor of Engineering (Civil) (Honours), University of Auckland, 1979.

(b) Annexure A to this statement is a copy of my curriculum vitae.

2. **Instructions**

2.1 I have been instructed by Clayton Utz on behalf of New Acland Coal Pty Ltd (**NAC**) to prepare a statement of evidence to the Land Court.

2.2 A copy of my letter of instructions from Clayton Utz dated 10 May 2016 is Annexure B to this statement.

3. **Facts and Assumptions**

3.1 In producing this statement, I did the following:

(a) I conducted a review of the transcripts of the evidence of Mr Duncan Irvine to the extent that evidence related to faulting issues.

(b) I undertook a brief review of archived files of Jacobs so as to refresh my memory in relation to the matters dealt with in my memorandum that is Annexure C to this statement.

4. **Structure of statement**

4.1 I prepared a memorandum on 20 April 2016.

4.2 Since completing my memorandum on 20 April 2016, I have made minor corrections to the memorandum, which are shown in tracked changes in the memorandum annexed as Annexure C.

5. **Summary of opinion and findings**

5.1 The following summarises my opinions and findings:

(a) The reference to "walls" and/or “barriers” in reports that describe the numerical groundwater model for the New Acland Coal Mine Stage 3 Expansion project should not be interpreted as impermeable faults.

(b) After trialling different modelling strategies it was decided to use the Horizontal Flow Barrier Package of Modflow to model the hydrogeological effect of faults. Faults were incorporated on the basis of mapped structures (data provided by New Hope), and additional faults were added to help achieve model calibration.

(c) The low permeability faults which create sharp discontinuities in the hydraulic conductivity distribution were found to be necessary to produce a groundwater model that achieves an appropriate level of calibration and is consistent with the conceptualisation.

(d) There was no intention to design a faulting pattern to restrict the predicted impacts of mining. To the contrary, some faults were intentionally modelled as being semi-permeable or leaky to avoid unwarranted restrictions on the predicted drawdown impacts of mining.

(e) Observed groundwater levels and other relevant data were used to initially calibrate the model in 2009 and again to re-calibrate it in 2013. The re-calibration of the model in 2013 used transient groundwater drawdown data obtained after mining had progressed to elevations below the water table. These data supported the modifications that were made to the faults in the 2013 modelling.

(f) The faulting pattern that was used in 2013 is relevant to the 2014 groundwater model referred to in the AEIS because, apart from the horizontal flow barrier conditions being removed from the Marburg Sandstone model layer, my understanding is that the hydrogeological characteristics of the fault in the 2014 AEIS model are the same as those included in the 2013 version of the model. This faulting pattern is illustrated in Figure 6 in the memorandum annexed as Annexure C to this statement.

6. **Expert's statement**

6.1 I confirm that:

(a) the factual matters included in this statement are, as far as I know, true;

(b) I have made all enquiries that I consider appropriate;

(c) the opinions stated in this statement are genuinely held by me;

(d) this statement contains reference to all matters I consider significant;

(e) I understand I have a duty to assist the court and that duty overrides any obligation I may have to any party to these proceedings or any person who is liable for my fees or expenses and I have complied with that duty;

(f) I have read and understand the rules contained in Part 5 of the Land Court Rules 2000, as far as they apply to me; and

(g) I have not received or accepted instructions to adopt or reject a particular opinion in relation to an issue in dispute in these proceedings.

B. S. Barnett
....
Brian Barnett

10 May 2016

Annexure A - Curriculum vitae

EDUCATION/QUALIFICATIONS

Bachelor of Engineering (Civil) Honours, University of Auckland, 1979

MEMBERSHIPS AND AFFILIATIONS

Member of the International Association of Hydrogeologists

Brian Barnett

SENIOR GROUNDWATER MODELLER

Brian Barnett has more than thirty five years' experience in groundwater resource assessment, groundwater modelling, hydrogeology and geothermal reservoir engineering. He has acquired a broad range of modelling experience through numerous technical investigations of groundwater resources, mine dewatering and water management, impacts of land use change and contaminant transport. Brian has been involved in more than one hundred groundwater modelling projects since joining the SKM groundwater group in Melbourne in May 2000. He is responsible for ensuring the highest technical standards in all aspects of numerical modelling of groundwater flow and solute transport throughout the company. Brian is a principal author and editor of the Australian Groundwater Modelling Guidelines. Published in 2012, the Guidelines have been accepted throughout Australia as a benchmark defining best industry practice.

Areas of Expertise

- Groundwater Modelling.
- Solute Transport Modelling
- Hydrogeology
- Geothermal Reservoir Engineering.

Relevant Project Experience

Australian Groundwater Modelling Guidelines

Client: National Water Commission

Title: Project Manager.

Start/End Dates: March 2011 to June 2012

Scope/Description: The Australian Groundwater Modelling Guidelines was produced by SKM and a team of leading groundwater modelling exponents drawn from the private and public sector including consultants, academics and regulators. Brian took a leading role in managing the project and the team and in editing and writing the document. It has been widely adopted throughout Australia as the benchmark for best industry practice for groundwater modelling in Australia. The Guidelines were published by the National Water Commission in June 2012.

Responsibilities: Project manager, co-editor and principal contributor author.

Murray Darling Basin Sustainable Yields Project

Client: CSIRO

Title: Groundwater Modeller

Start/End Dates: 2007 to 2008

Scope/Description: Brian was groundwater modelling team leader for a major project covering groundwater resources in Queensland, New South Wales, Victoria and South Australia. SKM was contracted by CSIRO in 2007 to undertake the groundwater resource assessment for

Brian Barnett

SENIOR GROUNDWATER MODELLER

the entire Murray Darling Basin. The project involved the numerical modelling of all major fresh water aquifers in the basin. Twelve finite difference numerical models were run for the study. Results were used to quantify the available groundwater resources of the basin and to assess the impacts of future climate change and impacts of groundwater development on river flows

Responsibilities: Leader of the groundwater modelling team that included eight modellers working in SKM's Melbourne, Adelaide and Sydney offices.

Tomago Sandbeds – Groundwater Modelling.

Client: Hunter Water Corporation.

Title: Groundwater Modeller.

Start/End Dates: October 2002 to December, 2010

Scope/Description: Groundwater modelling services were provided to Hunter Water Corporation over a period of eight years involving a number of significant modelling assignments. The work has included:

1. Development of a groundwater flow and solute transport model of the North Stockton Sandbeds (adjacent to the Tomago Sandbeds) in 2002 - 2003.

2. Development of a groundwater model of the Tomago Sandbeds to assist with assessment of impacts on GDE's in 2005.

3. Development of a local scale model of the Tanilba Bay WWTW on the Tomago Sandbeds in 2008.

4. Upgrading of the Tomago Sandbeds Gorundwater model in cooperation with Hunter Water staff in 2010 to assist with water resource planning.

Responsibilities: Project manager and lead modeller for all projects.

Cataby Mineral Sands Mine Feasibility Study – groundwater model, WA

Client: Iluka Resources Ltd.

Title: Groundwater Modeller.

Start/End Dates: November 2013 to December, 2014

Scope/Description: The Cataby Mineral Sands Deposit is located on the Swan Coastal Plain to the north of Perth, WA. The feasibility study for the mine included the development and calibration of a complex three dimensional groundwater flow model to assist with the design of mine dewatering and associated water disposal facilities.

Responsibilities: Project manager and lead modeller responsible for the design and construction of the model and the calibration and predictive analysis and uncertainty analysis.

Frieda River Mine Dewatering Investigations, Papua New Guinea.

Client: Xstrata Copper.

Title: Groundwater Modeller.

Start/End Dates: October 2012 to March, 2013

Brian Barnett

SENIOR GROUNDWATER MODELLER

Scope/Description: Groundwater modelling of a proposed copper mine in Papua New Guinea highlands. Groundwater models were used to estimate the dewatering pumping requirement for the mine and to provide an assessment of the environmental impacts that may accompany mine dewatering and operation of water storage and tailings storage facilities.

Responsibilities: Lead modeller responsible for the design and construction of the model and its use in predictive scenarios.

Millstream Aquifer Model, WA.

Client: Western Australia Department of Water.

Title: Groundwater Modeller.

Start/End Dates: October 2008 to February, 2010

Scope/Description: Groundwater modelling of an inland aquifer in the Pilbara area of Western Australia. The aquifer is used for municipal water supply purposes and the project was aimed at helping to determine sustainable extraction rates from the aquifer. A principal constraint on future development is the requirement to protect and maintain iconic groundwater dependent river pools and springs.

Responsibilities: Project Manager and lead modeller responsible for the design and construction of the model and its use in predictive scenarios.

Collie Coal Basin – Groundwater Model, WA

Client: Western Australia Department of Water.

Title: Groundwater Modeller.

Start/End Dates: June 2009 to February, 2010

Scope/Description: The groundwater resources of the Collie Basin are heavily impacted by many years of coal mining and power generation. A groundwater model of the basin was developed and calibrated and used to assess future impacts that may arise from expanded coal mining and increased water extraction for dewatering and power station cooling.

Responsibilities: Project Manager and supervising modeller.

Barwon Downs – Groundwater Model, Victoria

Client: Barwon Region Water Authority.

Title: Groundwater Modeller.

Start/End Dates: 2003 to 2010

Scope/Description: Brian has worked for a number of years with Barwon Water on the development and use of a complex groundwater flow model of the Barwon Downs Graben in Western Victoria. The Graben hosts deep confined aquifers that are used for water supply for the City of Geelong and surrounding urban centres. Work has continued for a number of years and has progressed from initial model design and development through various stages of upgrade and refinement. The work has been instrumental in allowing Barwon Water to secure ongoing groundwater extraction licenses for the borefield.

Responsibilities: Lead modeller.

Brian Barnett

SENIOR GROUNDWATER MODELLER

Lower De Grey and Lower Robe Groundwater Models, WA

Client: Western Australia Department of Water.

Title: Groundwater Modeller.

Start/End Dates: 2009 to 2010

Scope/Description: Groundwater models of two coastal alluvial aquifer systems in the Pilbara Region of Western Australia were develop and calibrated for the WA government. The work was aimed at defining the sustainable extraction limits for potential water supply borefields that may in future be used to supplement the Pilbara water supply.

Responsibilities: Project Manager and Supervising Modeller.

Kulwin and WRP mineral sand mine groundwater models, Victoria.

Client: Iluka Resources Ltd.

Title: Groundwater Modeller.

Start/End Dates: 2002 to 2009

Scope/Description: Groundwater models of two mineral sand mines in northern Victoria were developed and calibrated to assist in the design of mine dewatering and water disposal facilities required to support a dry mining operation. The modelling work was instrumental in establishing the feasibility of mining these deposits that are deep below the water table and in securing the required environmental approvals and water licenses for the project.

Responsibilities: Project Manager and Lead Modeller.

Lindsay River Groundwater Model

Client: Victoria Department of Natural Resources and Environment.

Title: Groundwater Modeller.

Start/End Dates: 2000 to 2002.

Scope/Description: Development of a three dimensional finite element groundwater model of the aquifers within the Lindsay River Anabranch of the Murray River. The model was developed in the FEFLOW modelling code and is being used to design a salt interception scheme. The model included density dependant solute transport so that salinity impacts associated with potential interception schemes could be assessed.

Responsibilities: Lead Modeller.

Employment History

1979 to 1981 Groundwater Engineer employed by the Hawkes Bay Regional Council, New Zealand. Responsible for field investigations and assessments required to support groundwater resource management responsibilities of the Council.

1981 to 1987 Geothermal Reservoir Engineer employed by Geothermal Energy New Zealand Ltd in Auckland, New Zealand. Responsible for reservoir engineering assessments including reservoir modelling investigations for large scale geothermal developments in Indonesia, Japan, Kenya and Greece.

Brian Barnett

SENIOR GROUNDWATER MODELLER

1987 to 1997 Geothermal Reservoir Engineer employed by Sumiko Consultants in Tokyo, Japan. Responsible for reservoir engineering investigations and geothermal reservoir modelling of various geothermal fields in Japan.

1997 to 2000 Geothermal Reservoir Engineer and Hydrogeologist employed by Kingston Morrison (merged with SKM in 1999) in Auckland New Zealand. Responsible for geothermal reservoir engineering and groundwater modelling assessments.

2000 to present Groundwater Modeller employed by SKM (acquired by Jacobs in 2013) in Melbourne, Australia. Responsible for groundwater modelling projects throughout Australia.

Annexure B - Letter of Instruction from Clayton Utz

CLAYTON UTZ

Confidential

Email 10 May 2016

Mr Brian Barnett
Jacobs
Floor 11, 452 Flinders Street
Melbourne VIC 3000

brian.barnett@jacobs.com

Dear Brian,

New Acland Coal Mine Stage 3 Project

1. **Instructions**

1.1 You are instructed to prepare a statement of evidence in relation to the abovementioned project in accordance with the Land Court Rules 2000 (Qld) (**Land Court Rules**) incorporating your memorandum of 20 April 2016.

1.2 You may also be required to appear in person as an expert witness in the Land Court proceedings.

1.3 Please see section 3 below regarding your duties as an expert witness.

2. **Format of report**

2.1 Any statement that you prepare should include the following:

(a) a copy of these instructions;

(b) details of your relevant qualifications, experience and expertise (preferably as an annexure to the report);

(c) all material facts, whether written or oral, on which the statement is based;

(d) references to any literature or other material on which you have relied to prepare the statement;

(e) details of any assumptions you have relied on for the purposes of the statement;

(f) details of any additional facts or documents which would assist you in reaching a more reliable conclusion on any aspect about which you have been instructed to prepare the statement;

(g) in respect of any inspection, examination or experiment conducted, initiated or relied on to prepare the statement:

(i) a description of what was done;

(ii) whether the inspection, examination or experiment was undertaken by you or under your supervision;

(iii) the names and qualifications of any other person involved; and

(iv) the result;

(h) if there is a range of opinions or values on matters dealt with in the statement, a summary of the range of opinions or values and the reasons why you have adopted a particular opinion or value in respect of that matter; and

(i) a summary of the conclusions that you have reached.

2.2 You should also confirm at the end of your report each of the following:

(a) the factual matters stated in the statement are, as far as you are aware, true;

(b) that you have made all enquiries that you consider are appropriate for the purpose of providing the opinions that you have expressed;

(c) the opinions stated in the report are genuinely held by you;

(d) the statement contains references to all matters you consider significant in reaching the conclusions that you have expressed;

(e) that you understand your duty to the court and have complied with that duty;

(f) that you have read and understand the rules contained in Part 5 of the Land Court Rules, a copy of which is **enclosed**, as far as they apply to you; and

(g) that you have not received or accepted instructions to adopt or reject a particular opinion in relation to an issue in dispute in the proceeding.

3. **Your responsibilities as an expert witness**

3.1 You are retained as an independent expert and may be required to assist the Land Court, to whom you have a duty.

3.2 Again, we draw your attention to Part 5 of the Land Court Rules, which set out the duties of expert witnesses. Specifically, under rule 24C of the Land Court Rules, you will be acting in these proceedings as an expert to assist the Land Court and this duty overrides any obligation you may have to New Acland Coal Pty Ltd.

3.3 The Land Court expects you to be objective, professional and to form an independent view as to the matters in respect of which your opinion is sought.

Please do not hesitate to contact us should you have any questions or require any further information.

CLAYTON UTZ

Yours sincerely

Mark Geritz, Partner
+61 7 3292 7221
mgeritz@claytonutz.com

Karen Trainor, Partner
+61 7 3292 7012
ktrainor@claytonutz.com

Our ref 12245/80145086

proceeding until the court is satisfied the parties have complied with the orders or directions.

(3) The parties must comply with the orders or directions before the proceeding is heard, unless the court considers it appropriate, because of the circumstances of the case, to hear the proceeding without the orders or directions being complied with.

21 Power to correct mistakes

(1) This rule applies if—

(a) there is a clerical mistake in an order or certificate of the court or in a record of an order or certificate of the court; and

(b) the mistake resulted from an accidental slip or omission.

(2) At any time, the court, on application by a party or on its own initiative, may correct the mistake.

Part 5 Evidence

Division 1 Preliminary

22 Definitions for pt 5

In this part—

expert means a person who would, if called as a witness in a proceeding, be qualified to give opinion evidence as an expert witness in relation to an issue in dispute in the proceeding.

joint report, for a proceeding, means a report—

(a) stating the joint opinion of experts in relation to an issue in dispute in the proceeding; and

(b) identifying the matters about which the experts agree or disagree and the reasons for any disagreement.

meeting of experts—

1 A *meeting of experts* is a meeting at which experts in each area of expertise relevant to a proceeding meet, in the absence of the parties—

(a) to discuss and attempt to reach agreement about the experts' evidence in relation to an issue in dispute in the proceeding as it relates to the experts' area of expertise; and

(b) to prepare a joint report.

2 The term includes —

(a) a resumed meeting of experts or further meeting of experts; and

(b) a meeting attended by the experts in either, or a combination, of the following ways—

(i) personally;

(ii) a way that allows contemporaneous communication between the experts, including by telephone, video link or email.

party, for a proceeding, means a party to the proceeding or the party's lawyer or agent.

statement of evidence, of an expert, see rule 24E.

Division 2 Meetings of experts

23 Application of div 2

Unless the court otherwise orders, this division applies in relation to a meeting of experts ordered or directed by the court at any time in a proceeding.

24 Party must ensure expert ready to take part in meeting of experts

Before a meeting of experts, a party to a proceeding must do all things reasonably necessary or expedient to ensure an expert chosen by the party is ready to take part fully, properly and promptly in the meeting, including by giving the expert—

(a) reasonable prior notice that the court has ordered or directed a meeting of experts; and

(b) notice of the contents of any order or direction about the meeting, including the time by which the meeting must be held; and

(c) reasonable notice of the issue in dispute in the proceeding to the extent it is relevant to the expert's expertise; and

(d) enough information and opportunity for the expert to adequately investigate the facts in relation to the issue in dispute in the proceeding; and

(e) written notice that the expert has a duty to assist the court and the duty overrides any obligation the expert may have to the party or any person who is liable for the expert's fee or expenses.

24A Experts attending meeting must prepare joint report

(1) The experts attending a meeting of experts must, without further reference to or instruction from the parties, prepare a joint report in relation to the meeting.

(2) However, the experts attending the meeting may, at any time before the joint report is completed, ask all parties to respond to an inquiry the experts make jointly of all parties.

(3) Despite subrule (1), any of the experts may participate in a mediation involving the parties.

(4) The joint report must—

(a) confirm that each expert understands the expert's duty to the court and has complied with the duty; and

(b) be given to the parties.

(5) The applicant or appellant must deliver to the registry, personally or by facsimile or email, a copy of the joint report received under subrule (4) at least 21 days before the date set for the hearing.

24B Admissions made at meeting of experts

(1) Subrule (2) does not apply to a joint report prepared in relation to a meeting of experts.

(2) Evidence of anything done or said, or an admission made, at a meeting of experts is admissible at the hearing of the proceeding or at the hearing of another proceeding in the court or in another civil proceeding only if all parties to the proceeding agree.

(3) In this rule—

civil proceeding does not include a civil proceeding founded on fraud alleged to be connected with, or to have happened during, the meeting.

Division 3 Evidence given by experts

24C Duty of expert

(1) A witness giving evidence in a proceeding as an expert has a duty to assist the court.

(2) The duty overrides any obligation the witness may have to any party to the proceeding or to any person who is liable for the expert's fee or expenses.

24D Giving or accepting instructions to adopt or reject a particular opinion prohibited

A person must not give, and an expert must not accept, instructions to adopt or reject a particular opinion in relation to an issue in dispute in a proceeding.

24E Expert must prepare statement of evidence

(1) An expert must prepare a written statement of the expert's evidence (a ***statement of evidence***) for the hearing of a proceeding.

(2) If the expert has taken part in a meeting of experts—

(a) a joint report prepared in relation to the meeting is taken to be the expert's statement of evidence in the proceeding; and

(b) a further statement of evidence in relation to any issue of disagreement recorded in the joint report is to be prepared by the expert.

(3) However, the further statement of evidence must not, without the court's leave—

(a) contradict, depart from or qualify an opinion in relation to an issue the subject of agreement in the joint report; or

(b) raise a new matter not already mentioned in the joint report.

24F Requirements for statement of evidence other than joint report

(1) An expert's statement of evidence, other than a joint report, must be addressed to the court and signed by the expert.

(2) The statement of evidence must include the following information, to the extent the information is not already contained in a joint report prepared for the proceeding—

(a) the expert's qualifications;

(b) all material facts, whether written or oral, on which the statement is based;

(c) references to any literature or other material relied on by the expert to prepare the statement;

(d) for any inspection, examination or experiment conducted, initiated or relied on by the expert to prepare the statement—

(i) a description of what was done; and

(ii) whether the inspection, examination or experiment was done by the expert or under the expert's supervision; and

(iii) the name and qualifications of any other person involved; and

(iv) the result;

(e) if there is a range of opinion on matters dealt with in the statement, a summary of the range of opinion and the reasons why the expert adopted a particular opinion;

(f) a summary of the conclusions reached by the expert;

(g) a statement about whether access to any readily ascertainable additional facts would assist the expert in reaching a more reliable conclusion.

(3) The expert must confirm, at the end of the statement of evidence—

(a) the factual matters included in the statement are, as far as the expert knows, true; and

(b) the expert has made all enquiries considered appropriate; and

(c) the opinions included in the statement are genuinely held by the expert; and

(d) the statement contains reference to all matters the expert considers significant; and

(e) the expert understands the expert's duty to the court and has complied with the duty; and

(f) the expert has read and understood the rules contained in this part, as far as they apply to the expert; and

(g) the expert has not received or accepted instructions to adopt or reject a particular opinion in relation to an issue in dispute in the proceeding.

24G Serving statement of evidence other than joint report

(1) This rule applies to a statement of evidence other than a joint report.

(2) A party to a proceeding intending to call evidence by an expert in the proceeding must deliver to the registry, personally or by facsimile or email, and serve on each other party to the proceeding, a copy of the expert's statement of evidence.

(3) A party must comply with subrule (2) at least 21 days before the date set for the hearing or, if the court directs a different time, within the time directed by the court.

24H Matters contained in statement of evidence not to be repeated

During examination in chief, an expert must not, without the court's leave, repeat or expand on matters contained in the expert's statement of evidence or introduce new material.

24I Evidence from only 1 expert may be called

Other than with the court's leave, a party to a proceeding, at any hearing of the proceeding, may call evidence from only 1 expert for each area of expertise dealt with in the hearing.

Division 4 Non-expert statements of evidence

24J Statement of evidence of witness other than expert

(1) This rule applies to a party who intends to do either or both of the following—

(a) give evidence in a proceeding;

(b) call another person, other than an expert, to give evidence in a proceeding.

(2) Before giving the evidence or calling the other person, the party must deliver to the registry, personally or by facsimile or email, and serve on each other party, a written statement containing—

(a) the name, address and occupation of the party or other person; and

(b) the evidence of the party or other person for the hearing.

(3) The party must comply with subrule (2) at least 21 days before the date set for the hearing or, if the court directs a different time, within the time directed by the court.

(4) During examination in chief, the party or other person must not, without the court's leave, repeat or expand on matters contained in the party's or person's statement delivered under subrule (2) or introduce new material.

Division 5 General

24K Way evidence given

(1) Unless the court orders that a witness's evidence in a proceeding be given by affidavit or in another way, the evidence may only be given orally.

(2) Giving evidence orally may include merely swearing to the accuracy of a statement of evidence submitted to the court.

(3) If the court orders that evidence be given by affidavit, the court may impose conditions on the order.

24L Calling witnesses

A party to a proceeding must not, without the court's leave, call an expert or another person to give evidence in the proceeding unless the party has complied with the rules contained in this part.

Annexure C - Memorandum on the evolution of faults in groundwater models of the New Acland Coal Mine Stage 3

JACOBS

Memorandum

Floor 11, 452 Flinders Street
Melbourne VIC 3000
PO Box 312, Flinders Lane
Melbourne VIC 8009 Australia
T +61 3 8668 3000
F +61 3 8668 3001
www.jacobs.com

Date	20 April 2016
Attention	Mark Geritz
From	Brian Barnett
Subject	**Memorandum on the Evolution of Faults in Groundwater Models of the New Acland Coal Mine Stage 3**

Definitions and Terminology

Faults

Faults generally represent a discontinuity within a rock mass across which there has been some displacement as a result of geological stresses that build up as a result of local or regional tectonic activity. Faults, and the associated displacements, can occur at scales varying from a few centimetres to hundreds of kilometres.

Faulting is very common and in any rock mass the occurrence, scale and density of faults will depend upon the regional setting and tectonic history. The successful mapping of these faults will depend to a large extent on the scale and intensity of the geological investigations that are undertaken. A high density of faulting can often be discerned through excavation and intensive geological investigations that are commonly undertaken at mine sites. The fact that a particular area does not include mapped faults does not mean that faults are not present – they have just not been mapped. In the case of the New Acland Coal Mine Stage 3, it is entirely plausible that other faults exist that have not yet been detected.

The role that a particular fault will play in controlling or influencing groundwater behaviour depends on the character of the fault and this is usually unknown until the system is stressed by pumping or mine dewatering activities. Those faults that displace the aquifer in a manner that disrupts the horizontal continuity of the aquifer are likely to be almost completely impervious. Partial disruption of the aquifer continuity may result in a smaller reduction in permeability across the fault. Some faults have been shown to enhance the transmission of water, particularly along the fault plane.

Considering the nature of the Walloon Coal Measures, groundwater flow occurs predominantly through the more permeable coal seams which make up approximately 10% of the sequence as a whole. In this case relatively small fault displacements can lead to significant disruption in the flow of groundwater within the coal measures.

Barriers and Walls

I understand that there has been some confusion in the recent Court proceedings regarding the description of the faulting that has been included in the 2009 and subsequent groundwater models of the New Acland Coal Mine Stage 3. In particular, it has been suggested that all the faults were modelled as impermeable features. I believe that this misconception has arisen from the use of the terms *“barrier”* and *“wall”* in reports that describe the numerical model. The **Horizontal Flow Barrier** (HFB) package refers to a module in the MODFLOW[1] simulation code that was used to represent the

[1] MODFLOW is a computer modelling package that calculates groundwater behaviour.

faults. It allows the definition of faults as 2D planar subsurface features with a user defined permeability that may range between partially impermeable to almost completely impermeable. Where the term *barrier* is used in the reports that I have written, it refers to faults that are represented in the model by the HFB package. The term “wall” is the nomenclature adopted in the Visual Modflow[2] graphical user interface to describe this type of permeability condition (Visual Modflow was the software package used to formulate and run the model prior to 2013 at which point Groundwater Vistas[3] was used to develop the Stage 3 model). Again, use of the term “wall” in the modelling reports should not be interpreted as an impermeable fault.

Staged Reporting

I have become aware that during the recent court proceedings, the question of staged reporting has been raised with the inference that the reporting of the model development has not been undertaken in accordance with Guideline recommendations. I would like to provide some clarity on this issue.

Rather than selectively choosing sentences that are presented out of context I would like to present the entirety of Chapter 8.2 as follows:

8.2 Staged reporting

> ***Guiding Principle 8.1:*** *Reports should be prepared following the conceptualisation and design stage, after the calibration stage, and after predictive modelling and uncertainty analysis.*

Rather than producing a single model report at the end of the model project, it is recommended that a staged reporting approach is used. Staged reporting implies writing progress reports and organising meetings with clients and stakeholders after each major stage in the modelling project.

As a minimum, three such stages can be considered:

- *after conceptualisation and model design*
- *after calibration and sensitivity analysis*
- *after predictive modelling and uncertainty.*

Staged reporting of key model aspects not only makes it possible to change or remediate the direction of the project, it also allows the model team to align the expectations of the client and a stakeholder with what is achievable within the project. It also allows the overall report to be prepared progressively throughout the study, with opportunities for progressive reviews, which should benefit the quality of the final report.

All steps and assumptions should be clearly and thoroughly detailed in each report to render the information accessible to all stakeholders and any other interested parties.

As a principal author of the Guidelines, my understanding of the intention of this particular guidance recommendation is that reporting should start at an early stage of a modelling project and that

[2] Visual Modflow is a computer programme that helps modellers construct groundwater models, to run MODFLOW and to plot the results.
[3] Groundwater Vistas has the same function as Visual Modflow. It has additional functionality that make it particularly suitable for models of open pit and underground mining operations.

progress reports should be provided to the client and other key stakeholders at various milestones during the project. It is better to do this than to undertake all of the reporting at the end of the project. The benefit of a staged reporting approach is that a dialogue is encouraged between the modeller and key stakeholders throughout the project. In my experience, the content of the various staged reports is accumulated at the end of the project to produce a single document that describes all stages of model development. The Guidance does not make sense if it is interpreted that three or more reports are prepared and finalised and retained as standalone documents for the course of the project and beyond. Given that the modelling process is one of iteration as illustrated in Figure 1-2 of the Guidelines, it is highly likely that the individual stages such as the conceptualisation and calibration will change during the course of the project.

I can confirm that the staged reporting requirements of the Guidelines were met during the development of the groundwater models of the New Acland Coal Mine Stage 3. In one instance, a staged report was formalised and finalised as it represented the completion of a distinct package of work. This report is entitled "New Acland Coal Mine. Groundwater Modelling Report – Calibration to Observed Drawdown Responses, 8 August 2013" and it is included as **Attachment 1** to this Memorandum.

2009 Version of the Model

The model was first developed in 2009 before mining had progressed to elevations below the water table. Model calibration at this time was undertaken in "steady state" and included no groundwater extractive stresses (i.e., no groundwater extraction and no mining activities).

After trialling different modelling strategies, it was concluded that modelling the observed steep groundwater gradients in the vicinity of the mine in steady state conditions, as required during calibration, would be problematic. It was concluded at this stage that the best approach would be to include low permeability faults that create sharp discontinuities in the hydraulic conductivity distribution. This suggests a compartmental nature of the aquifers at the site such that might occur where faulting results in lateral discontinuity of permeable layers. In order to implement the necessary local scale heterogeneities required in the model to simulate the observed hydraulic gradients, the HFB (Horizontal Flow Barrier) Package was chosen to reproduce the hydrogeological effects of faulting.

At the time that the model was originally developed, SKM was in possession of two sets of mapped faults as electronic files in DXF format. To the best of my knowledge, these data sets were provided by New Hope. To help with viewing of this information, I have converted them to pdf format. They are included as **Attachments 2** and **3** and are called *"Acland_P10_Faults.pdf"* and *"Acland_Regional_Faults.pdf"*. The two sets of faults included in these files are shown in Figure 1. This figure also shows the locations of the faults included in the 2009 model.

Figure 2 shows the 2009 model faults and the observed groundwater levels that were used to define the pre-mining steady state condition that forms the model calibration target. The observed groundwater levels show that steady state heads are highly variable within the region of the mine and its surrounds.

Figure 1 : Fault maps and modelled faults at 2009.

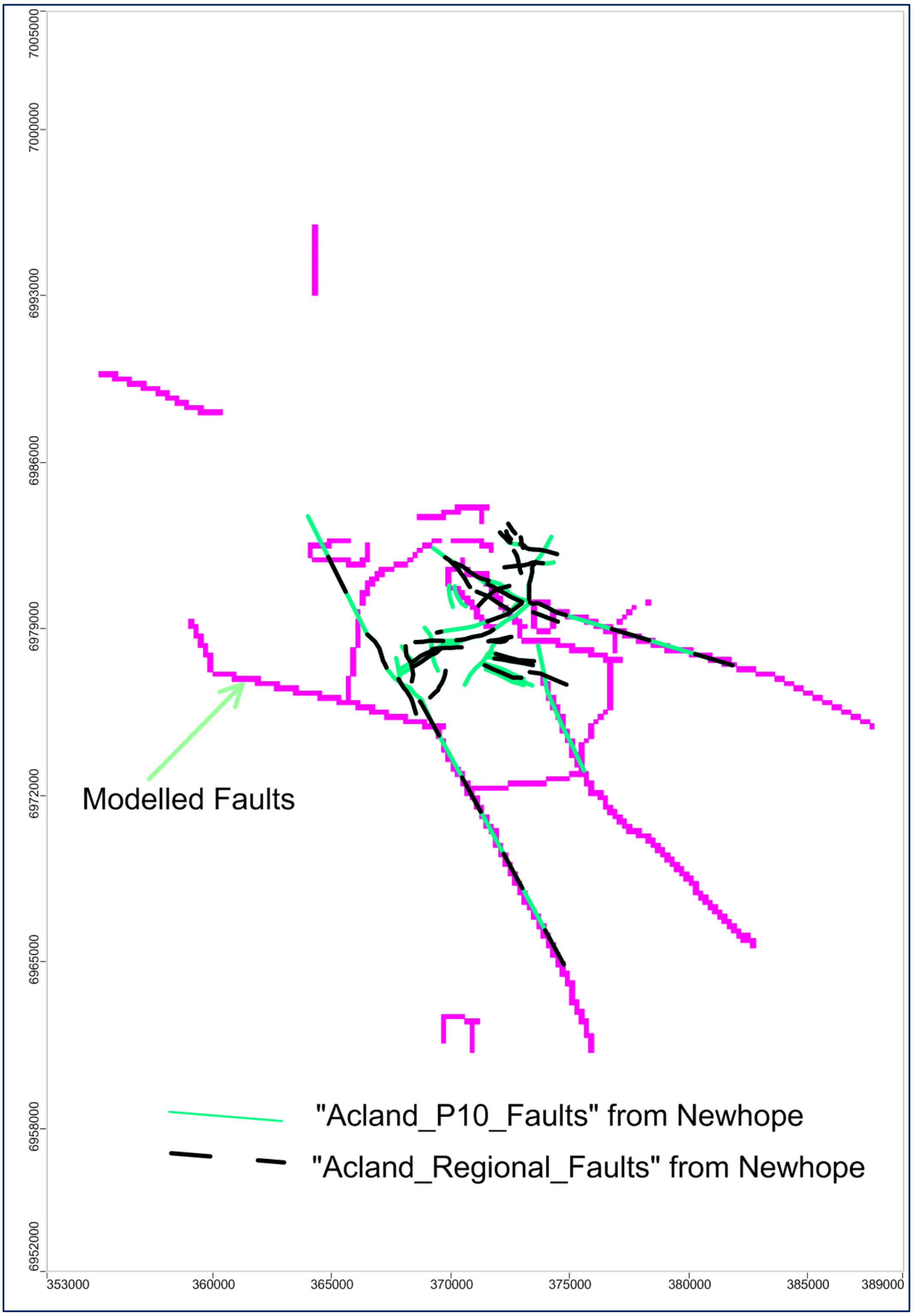
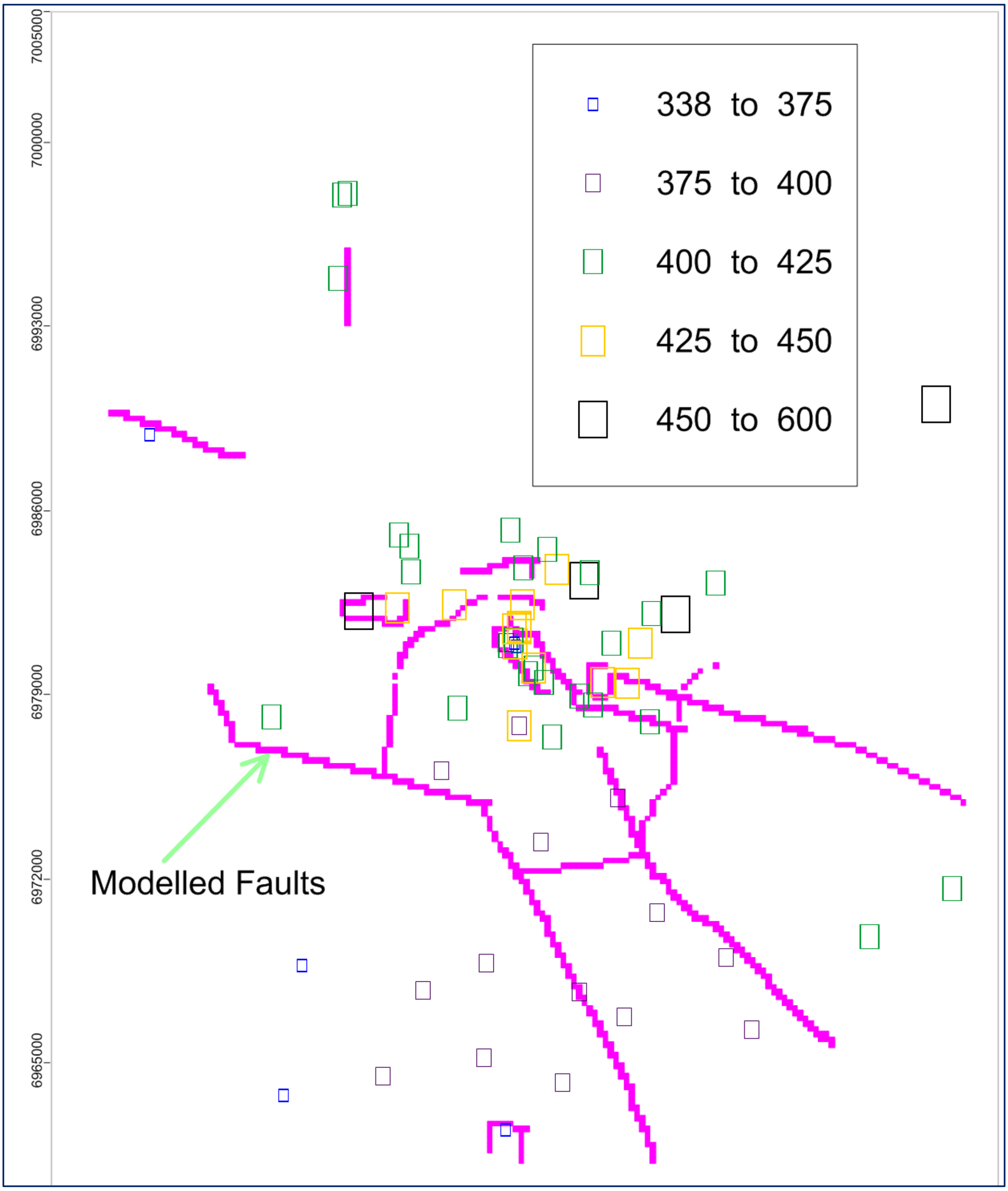


Figure 2 : Classification of groundwater levels (mAHD) in steady state and modelled faults (2009)



The reporting of the 2009 model does not include a detailed explanation of the assumptions and rationale behind the modelling of the faults. In the following paragraphs, I will try to address a number of questions that have arisen regarding this matter.

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How was the faulting layout chosen?

Faults were incorporated based on mapped structures (data provided by New Hope), and additional faults were added to help achieve model calibration where they were implied by significant changes in observed groundwater levels over short distances. The faults are generally located in between neighbouring groundwater head observations that are significantly different from each other.

How can the inclusion of unmapped faults be justified?

In order to understand the rationale behind the inclusion of faults and their locations and assumed properties, it is necessary to have an appreciation of how groundwater models are developed and the role that calibration plays in a modelling investigation.

The fundamental input data sets required to build a numerical groundwater model are always uncertain. In this regard, a groundwater flow model is quite different from most models used in engineering disciplines in which the main structural components of a model are well known. This is not the case for a groundwater model. Typically the available data for a groundwater model are restricted to inferred information obtained from surface observations and from sparsely distributed borehole data that help to define the geological conditions, water levels and pumping data at discrete points.

Groundwater level data is one dataset that can be measured with a greater degree of confidence and accuracy by direct observation in groundwater wells. Ironically, groundwater levels are not a key input dataset for a groundwater model (apart from initial groundwater levels); they are in fact a dataset that the model calculates and it forms one of the key outputs from a groundwater model. The only way that groundwater level measurements can be incorporated in a groundwater model (apart from defining initial model conditions) is to use them as target levels in model calibration. Faced with the dilemma of not being able to accurately characterise the hydrogeological conditions represented in a groundwater model, the modeller is forced to use the measured groundwater levels (data that can be measured with confidence) to help infer the hydrogeological parameters through a procedure known as calibration.

Calibration involves the process of running the groundwater model to estimate groundwater behaviour (for example groundwater levels) and comparing that behaviour with observations. Hydrogeological parameters such as hydraulic conductivity (a parameter defining the rate at which water may pass through a permeable medium), specific yield and specific storage (parameters defining the water storage capacity of the system) are iteratively refined until the best match can be obtained between the model-predicted and measured groundwater levels.

Typically, calibration will involve the modeller making various assumptions about the hydraulic conductivity distribution in the aquifer to achieve an acceptable calibration. Indeed this approach is adopted whenever automated parameter estimation software is used to assist with calibration (including the widely used PEST software package). This approach is deemed appropriate provided the resulting model hydraulic conductivities are reasonable (i.e., they are within a range of values that are physically plausible for the aquifer in question) and are consistent with the hydrogeological conceptualisation of the groundwater system. In the event that the calibration result is at odds with the conceptual model, then a decision is required as to whether the calibration based evidence is sufficiently compelling to invoke changes in the conceptualisation.

The faults included in the New Acland Mine Stage 3 model provide a means of adjusting the horizontal continuity between adjacent model cells to achieve the observed steep hydraulic gradients within the model. The addition of unmapped faults and exclusion of some mapped faults is justified in the same sense that defining hydraulic conductivity distributions is justified in any groundwater model. Trying to achieve the same hydrogeological effect simply by changing hydraulic conductivity within an aquifer is likely to result in unreasonable hydraulic conductivity values within an aquifer unit (i.e., values of hydraulic conductivity that are at odds with the hydrogeological conceptualisation). The justification for the adopted faults is simply that the model is able to explain observed groundwater behaviour as illustrated through calibration and it is consistent with the hydrogeological conceptualisation. In this regard, the New Acland Coal Mine Stage 3 model is no different from the vast majority of groundwater models where hydrogeological parameters are chosen with the only justification being that they produce a model that achieves an appropriate level of calibration and that they are consistent with the conceptualisation.

Why include some mapped faults and exclude others?

New Hope provided detailed fault mapping within the local area of the mine. Many of the mapped faults were identified as part of the detailed geological investigations undertaken as part of the exploration and subsequent mining of the coal. It is most likely that the fault data sets provided for the modelling investigation are incomplete in that additional faults are likely to exist in areas that have not been subject to intensive coal exploration.

While there is little doubt that the mapped faults are indeed faults, it is the hydrogeological significance of those faults that is not well known. The role that a particular fault will play in controlling or influencing groundwater behaviour depends on the character of the fault and this is usually unknown until the system is stressed by pumping or mine dewatering activities. Those faults that displace the aquifer in a manner that disrupts the horizontal continuity of the aquifer are likely to be almost completely impervious. Partial disruption of the aquifer continuity may result in a smaller reduction in permeability across the fault. Some faults have been shown to enhance the transmission of water particularly along the strike of the fault. Without further information on the hydrogeological significance of the faults, only those faults that appeared necessary to achieve calibration were included.

Were some of the faults intentionally modelled as being semi-permeable or leaky?

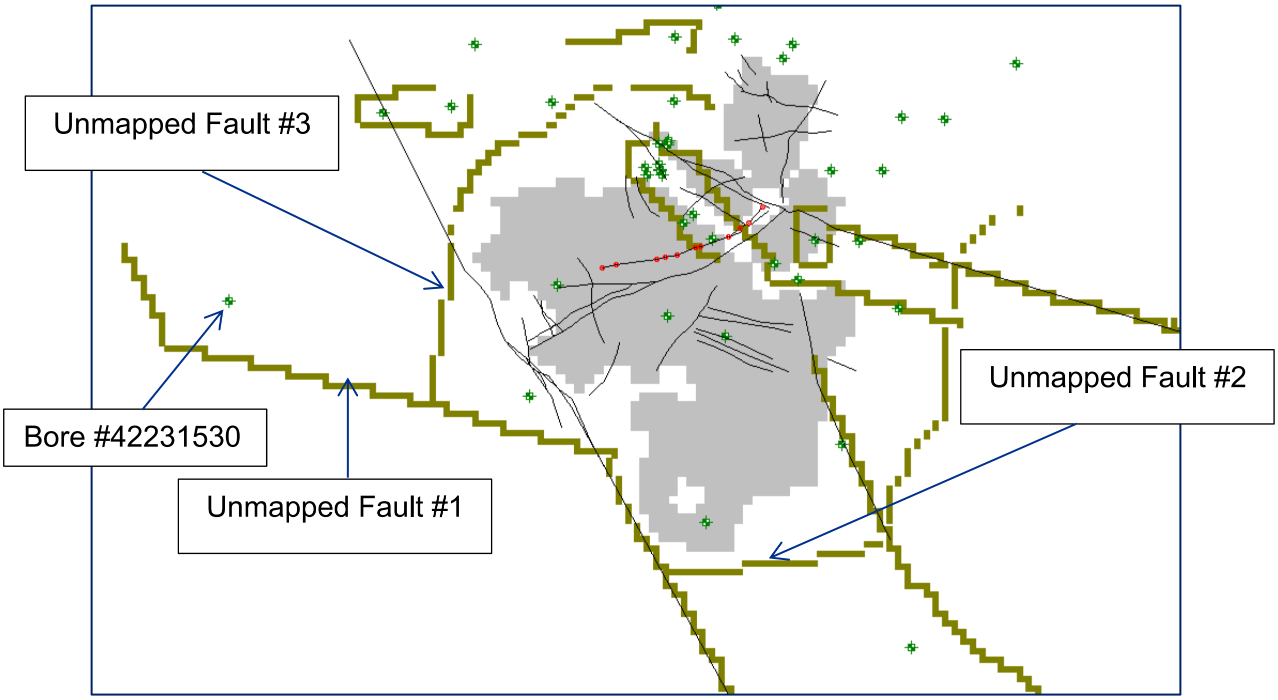
Yes. The HFB package requires the definition of a barrier of specified permeability and thickness on one of the four faces of the model grid cells on which the condition is applied. The HFB condition is able to define a restriction in hydraulic conductivity in the direction of one of the principal axes of the model domain. Where the HFB package is used to model a fault that cuts diagonally across the model grid, HFB conditions must be defined on orthogonal faces of adjacent cells if a completely impermeable barrier is to be modelled.

The HFB package does not necessarily define an impervious barrier through which water cannot flow. Indeed faults can be conceptualised as exerting a range of influences on groundwater movement depending on the displacement, localised fracturing and potential infilling of fault plane and fractures associated with the fault.

The HFB package allows some flexibility in how the fault permeability is represented. The most direct method is simply to adjust the specified hydraulic conductivity for the barrier that represents the fault. Where a fault is conceptualised as not being completely impervious an alternative approach is to allow increased fault permeability by allowing flow between adjacent HFB cells. This approach was implemented in the New Acland Coal Mine Stage 3 model as it has the advantage of providing a means of visually distinguishing between impermeable and semi-permeable faults.

The locations of those faults that were defined as semi-permeable features in the 2009 version of the model can be seen in Figure 3 as faults that are defined by HFB conditions on parallel model faces leaving gaps where the fault is aligned diagonally to the principal model axes. The figure also includes the two versions of the faulting maps that were available at the time (shown as thin black lines). It is of interest to note that ~~most~~ many of the unmapped faults (those that do not align with a mapped fault) have been modelled as being semi-impermeable and hence allow some water movement.

Figure 3 : Faulting included in the region of the mine in 2009 showing semi-permeable faults



Was the faulting pattern specifically designed to restrict the impacts that might arise from future mining?

It certainly was not my intention to create a faulting pattern that would unduly restrict the predicted impacts of mining. Indeed many of the faults were intentionally modelled as being semi-permeable to help reduce such influence. I am aware that three of the unmapped faults help to form a “curtain” that surrounds the mining lease and I would like to address each of these faults individually. The three faults in question are shown as Unmapped Fault #1, #2 and #3 respectively in Figure 3. Unmapped Fault #1 has been depicted as a fault that deviates away from a mapped fault. The mapped fault referred to here strikes southeast-northwest and continues well to the northwest of the point where the modelled fault is deviated. I do not have all iterations of the calibration model that were generated at the time. I expect that the model was run many tens or even hundreds of times during the calibration process. So I cannot reproduce the exact sequence of model runs and results that led to the choice of this fault alignment. Recently I have rerun the model with different fault assumptions and note that the Unmapped Fault #1 influences the steady state head modelled in the region of the observation bore #42231530 (refer to Figure 3 for the bore location). This bore has a measured head of about 408 mAHD and Figure 2 indicates that heads to the south of this bore are significantly lower (typically below 375 mAHD). From this I have inferred that Unmapped Fault #1 was included in the model to help calibration at the observation bore #42231530.

The Unmapped Fault #2 is aligned with the mining lease and it is difficult for me to recall why this fault would have been included at this location. Sensible explanations for the inclusion of this fault are that:

a) the modeller working under my supervision may have mistaken the line that defines the southern lease boundary as a mapped fault when constructing the model HFB conditions. This mistake was not picked up during my subsequent reviews.

b) the model was also being used at this time to help investigate the mine water balance and to help determine the need for the inclusion of an additional water supply for the mine. For this particular modelling objective, the inclusion of a restrictive faulting pattern is conservative in that the predicted mine inflows will be minimised and hence requirements for auxiliary water supply will be increased. If this is the case then the Unmapped Fault #2 should have been removed from the EIS version of the model.

c) I did not consider the mining lease area when undertaking my reviews.

In any event, the fact that the Unmapped Fault #2, and others, were removed from the model in 2013 suggests that the issue was identified and rectified at that time (refer to Figure 11, Page 15 of the Groundwater Numerical Modelling Report of August 2013 included in Appendix G.4.5 of the EIS Report[4]).

The Unmapped Fault #3 shown in Figure 3 (along with a number of other unmapped faults) was included as a leaky fault (determined to be leaky from the iterative modelling undertaken at calibration) and hence does not appear to unduly influence the drawdown predictions.

It appears to me that the intent was not to restrict or constrain the level of impact that would be predicted in future mining scenarios. Evidence for this can be seen in:

a) ~~Most~~ Many of the unmapped faults are modelled as being semi-permeable. If the intention was to restrict predicted impacts, the faults would have been characterised as impervious.

b) The Unmapped Fault #1 highlighted in Figure 3 that deviates from the mapped fault to the southwest of the mine has been deviated away from the mine and hence is less restrictive in terms of future impact predictions. If the fault had continued on the line of the mapped fault then a more restrictive spread of future impacts would be achieved.

c) A tighter restriction on the spread of future mining impacts would have been achieved if additional mapped faults were included in the model.

d) The faults have a minor impact on the predicted spread of drawdown in the Walloon Coal Measures, Basalts and alluvials. They do influence the drawdown predicted in the Marburg Sandstone model layer. Even so, it is noted that the model still predicts drawdown over a broad area in this aquifer due to the relatively high hydraulic conductivity that has been used (5 m/d).

How much confidence do we have in the faulting pattern included in the 2009 model?

The faults included in 2009 are one particular representation of faults that may explain the observed pre-mining groundwater levels at the site. I am sure that there are alternative representations of faults that could achieve a similar level of calibration. In this regard I can conclude that there was limited confidence in the faults included in the model in 2009. That is not to say that the modelling was inadequate or did not meet appropriate industry standards. It simply reflects the available data on which the model was conceptualised and calibrated.

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[4] Document ID: EHP.0056, p 19 (Exhibit 56).

A key aspect of many groundwater modelling studies, and one that is certainly important for the New Acland Coal Mine Stage 3 Groundwater Model, is the iterative improvement in the model through the repeated cycle of data collection and model update to take account of the new data. Increased confidence in the faults included in the model can be expected once the model is required to replicate the more extensive and greater drawdown that will occur once mining activities expand and deepen. The 2009 model should be considered as a starting point from which further modelling will help to constrain and improve the hydrogeological characterisation of the site.

2013 Version of the Model

In 2013, after the New Acland Coal Mine Stage 3 project was revised to reduce the mining lease area, the model was updated and recalibrated, this time in transient mode (i.e., calibration against a time series of observed groundwater level data). SKM was requested to consider observed drawdown in two particular observation wells located near the mining pits. Our brief was to determine whether the model was adequately predicting the measured drawdown and if not, recalibrate the model. We found that it was indeed necessary to recalibrate the model. The observed time series drawdown in a number of observation bores was used as a calibration target. Approximate estimates of the groundwater inflow rates to the mine workings were also available and were used as additional calibration targets.

The model was converted from Visual Modflow Graphical User Interface to Groundwater Vistas Version 6 Graphical User Interface at this time.

During the model upgrade, the model grid structure was rationalised in order to improve model run times. In areas that are relatively remote from the mine, the grid cells were coarsened to 400 m squares. As a result of grid coarsening, HFB cells located about 10 km to the northwest of the mine have become non-continuous as have some of the modelled faults some distance to the south of the mine.

Faulting was re-evaluated during model calibration undertaken in 2013. It was recognised that some modelled faults were more important than others to achieve an acceptable calibration in transient mode. It was also recognised that it would be beneficial to remove faults that had little or no useful contribution to calibration. As a result, some of the faults were modified and some were removed. Figure 4 shows the major faults that were removed at this time. Modifications involved reassigning the faces on which the HFB condition is defined generally leading to an increase in the effective permeability of the fault. The effective permeability of the Unmapped Fault #3 shown in Figure 3 was modified to reduce the faults effect on groundwater flow. This has been achieved through reassignment of the faces on which the HFB condition is defined. The intention was to increase the effective permeability of the fault. The change of the direction of groundwater flow across this fault was not an important consideration at this time. This can be seen in Figure 5 that shows an increase in the gaps between HFB cells in this version of the model.

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Figure 4 : Faults included in the 2009 version of the model that were removed in 2013.

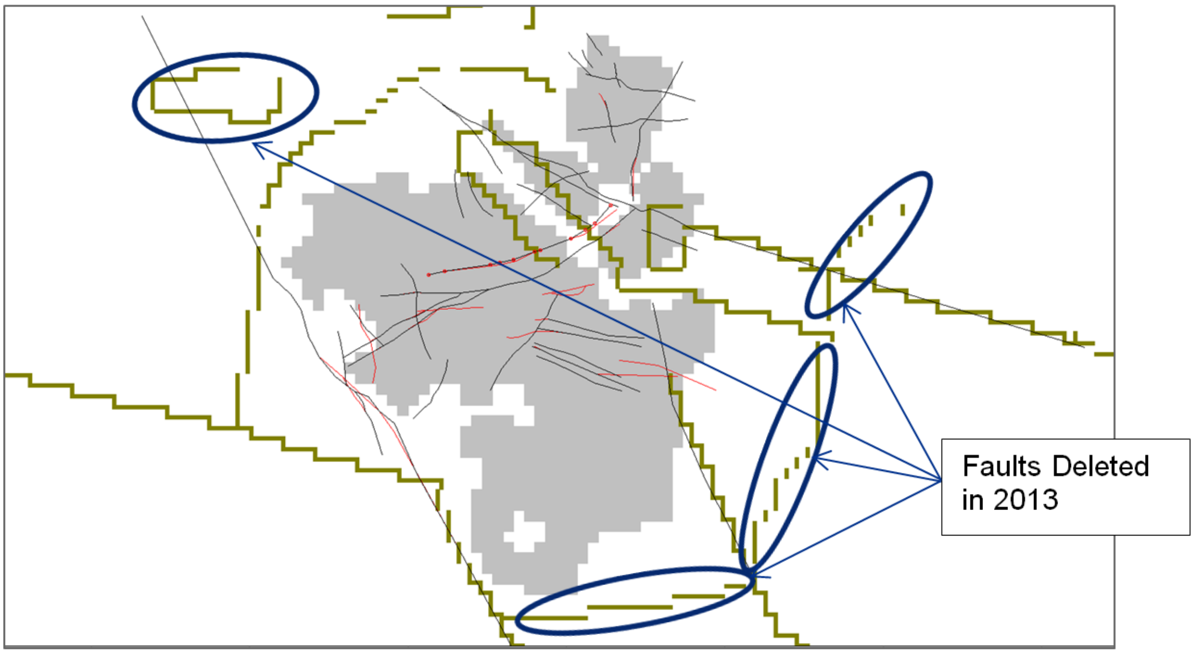
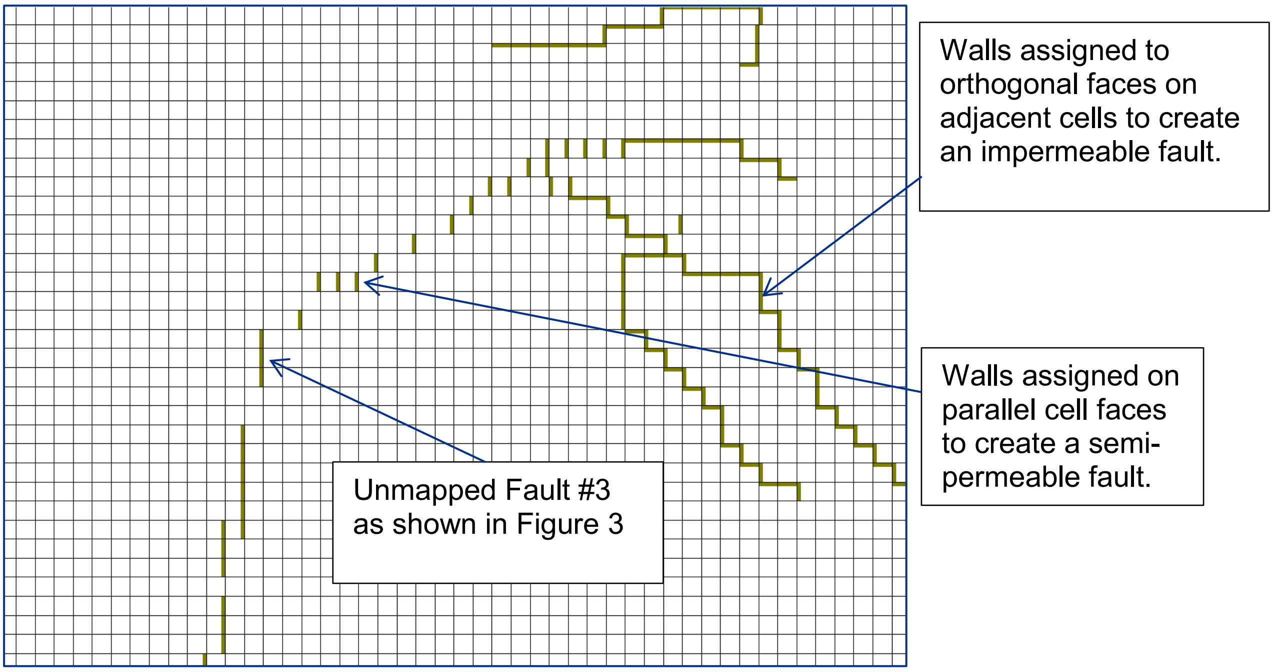


Figure 5 : Detail of the faults included in the 2013 and 2014 versions of the model



The network of faults included in the 2013 version of the model (as used in EIS modelling) is shown in Figure 6. Most of the modelled faults that are aligned with mapped faults are defined as highly impermeable features that severely constrain water movement. The faulting pattern included in the model at this stage provided little or no constraint on drawdown propagation in the Northwest - Southeast direction and a substantial restriction in drawdown in the Northeast – Southwest direction. I believe this to be entirely consistent with observations (referred to below) and with the hydrogeological conceptualisation of the groundwater system that is influenced by faulting leading to local scale heterogeneity and compartmentalisation.

My involvement with the modelling ceased in 2013. In 2014, the model was again revised as part of the work undertaken for the Additional Information to the EIS (AEIS) Report. I understand that at this time all HFB conditions were removed from the Marburg Sandstone model layer to better represent the hydrogeological conceptualisation of this aquifer. In all other respects the hydrogeological characteristics of the faults in this version of the model are the same as those included in the 2013 version of the model and as illustrated in Figure 6 below.

Was there any additional data used in 2013 that would support the fault pattern used in this version of the model?

The additional data provided for the 2013 modelling included:

a) Historic mine progressions including depths of mining and areas of mining,

b) Observed groundwater levels in a number of observation bores located near the mining areas (refer to Figure 6, Page 11 of the Groundwater Numerical Modelling Report of August 2013 included in Appendix G.4.5 of the EIS Report[5]). Particular attention was given to observation bores 848_B, 843_B, 81P_B, 82P_B and 83P_B. We were specifically requested by New Hope to consider the recent drawdown responses in 81P_B and 82P_B as these were believed to be illustrating a response to nearby mining activities.

c) Estimates of pit inflows during historic mining.

d) A faulting map that represented the current understanding in 2013. This document is included as **Attachment 4**.

e) Additional information on the future mining plan was provided to help guide the development of appropriate predictive modelling scenarios.

The first three data sets were used to calibrate the model and in this sense provided evidence that supported the modifications that were made to the faults included in the model.

Did Calibration in 2013 require a reconceptualisation of the hydrogeological effects of the faults?

No. Apart from those changes to the faults described above, the principal modification to the model arising from recalibration was a reduction in the ~~specific~~ storage ~~parameter~~ parameters that ~~was~~ were previously used for the predictive scenarios. ~~Specific storage~~Storage parameters cannot be calibrated within a steady state calibration and there is little surprise that ~~this~~ these ~~parameter~~ parameters needed to be revised during the transient recalibration. It suggests that the faulting pattern included in the model at this time was consistent with the observed drawdown and mine inflows that were used in the calibration exercise.

How much confidence do we have in the faulting pattern included in the 2013 model?

As a result of ongoing calibration, the 2013 model represents an improvement over the 2009 model. Although the 2013 version of the model is constrained by a transient calibration that requires the model to replicate drawdown behaviour, there is still non-uniqueness associated with the model and with the faults in particular. I am sure that there are different faulting patterns that could have been

[5] Document ID: EHP.0056, p 15 (Exhibit 56).

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invoked to provide equally good calibration to the historic groundwater behaviour. I can reiterate that the modelling at that stage met industry standard for that stage of the project.

Given the continuing levels of uncertainty around the faults, a calibration controlled uncertainty analysis that considers the predictive uncertainty associated with HFB cell hydraulic conductivities should be conducted during future model reviews. Further monitoring and calibration, undertaken whilst actual mining operations for New Acland Mine Stage 3 are underway, are anticipated to further improve confidence in the faults and in the model in general.

Can the confidence in the faulting pattern be increased?

Continued monitoring of groundwater responses during mining and future calibration of the model supported by additional uncertainty analysis will improve our understanding of the hydrogeological effect of the faults and will improve the model's ability to replicate actual groundwater behaviour. As stated earlier, the groundwater model should be progressively improved as more information on groundwater responses to mine dewatering are gathered and used to further constrain model parameters (including faulting) through calibration.

Does the faulting pattern have a significant influence on the predictions of drawdown that might arise from future mining?

No. The revised faulting pattern is less restrictive than that included in the 2009 model and impacts are predicted to spread widely. The extent of the predicted drawdown for a relatively shallow mine, is contrary to any suggestion that the model is overly constrained by faulting. This broad drawdown extent is evidenced in Figures 6-26 to 6-30 of Chapter 6 of the EIS[6], as updated by Figures 6-20 to 6-31 of the Groundwater Modelling Technical Addendum included in Appendix F of the AEIS[7] and Figures 2-1 to 2-3 of the Updated Groundwater Monitoring and Impact Management Plan included in Appendix C of the Response to Information Request[8].

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[6] Document ID: EHP.0024 pp 65-69 (Exhibit 24).
[7] Document ID: EHP.0103 pp 77-88 (Exhibit 103).
[8] Document ID: EHP.0005 pp 288-290 (Exhibit 5).

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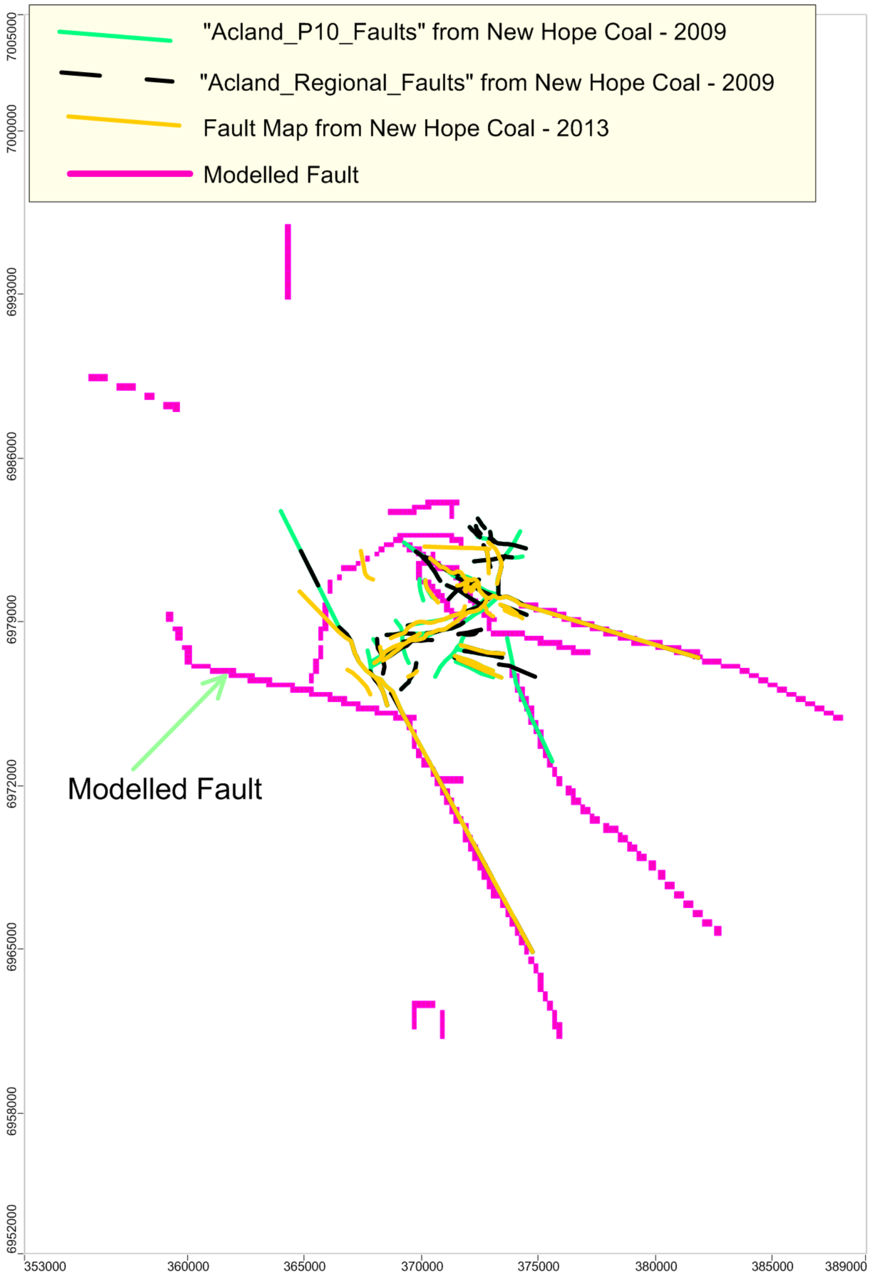
Figure 6 : Faults included in the 2013 and 2014 versions of the model used for EIS and AEIS reporting.

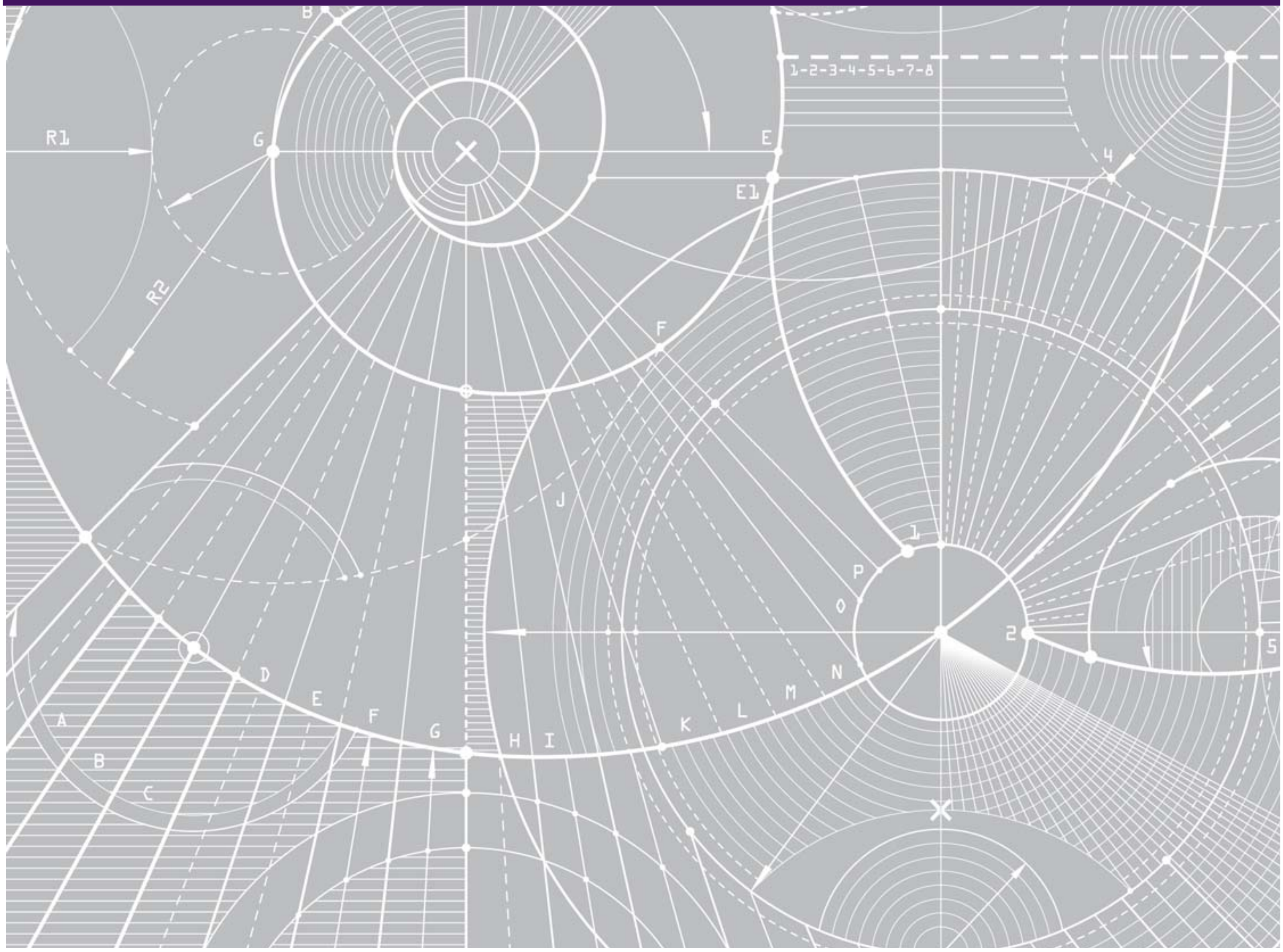


Attachment 1: Groundwater Modelling Report – Calibration to Observed Drawdown Responses (8 August 2013)

New Acland Coal Mine

GROUNDWATER MODELLING REPORT – CALIBRATION TO OBSERVED DRAWDOWN RESPONSES

8 August 2013



SINCLAIR KNIGHT MERZ

SKM

New Acland Coal Mine

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Sinclair Knight Merz
ABN 37 001 024 095
Floor 11, 452 Flinders Street
Melbourne VIC 3000
PO Box 312, Flinders Lane
Melbourne VIC 8009 Australia

Tel: +61 3 8668 3000
Fax: +61 3 8668 3001
Web: www.globalskm.com

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1. Background

This report details the refinement of SKMs numerical groundwater flow model for the New Acland mine to achieve greater accuracy in replicating currently observed effects on groundwater levels.

Recent groundwater monitoring reports (WSA, 2013) prepared by Waste Solutions Australia (WSA) have indicated that a discrepancy has arisen in recent months between observed groundwater levels in observation bores 81P and 82P to the east of the current Stage 2 New Acland mine workings and the groundwater modelling predictions prepared by WSA. The currently observed groundwater level reductions at these monitoring locations were not predicted by the WSA model. New Hope are concerned that this discrepancy may indicate that the WSA Stage 2 model impact predictions are unreliable and may undermine the integrity of the Stage 3 mine expansion impact predictions.

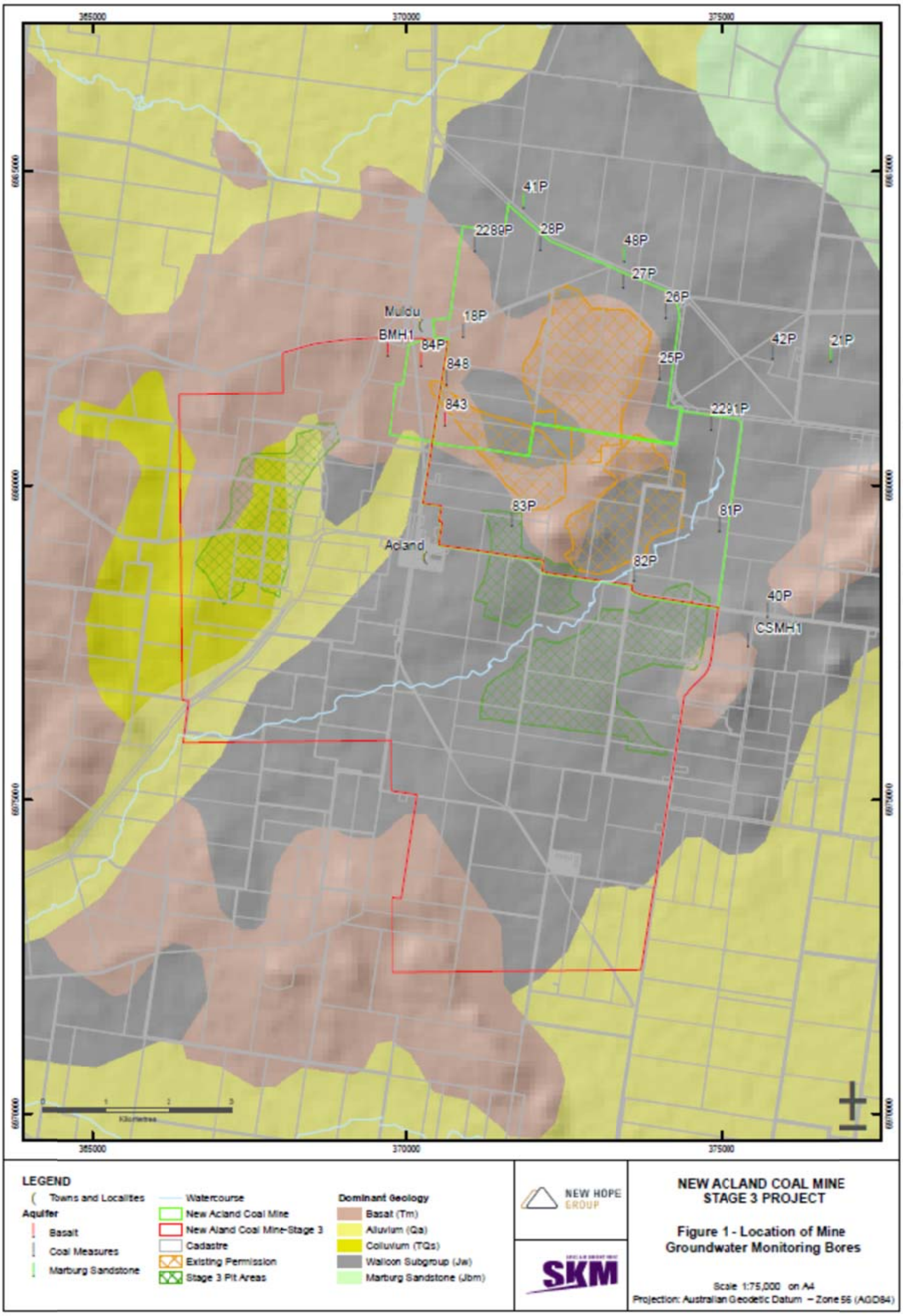
SKM are currently in the process of updating the original Stage 3 groundwater model to assist with groundwater impact assessments in support of the revised Stage 3 mine expansion plan. Clearly, it is important that this model is capable of replicating the key historic groundwater observations at the site, particularly the recently observed drawdown in 81P and 82P.

The location of observation bores and the mining pit are shown in **Figure 1.1**. Observation bores 81P and 82P are located immediately to the south and east of the mining pit.

The work described in this report is aimed at ensuring that the model currently being refined for the revised Stage 3 mine expansion impact assessment can demonstrate a faithful reproduction of recent drawdown and pit inflow measurements and provide confidence in the groundwater impact predictions for future phases of mining.

The existing SKM groundwater model was calibrated in steady state mode using information obtained prior to 2009. At this time mining had largely occurred at elevations above the water table. Therefore, no groundwater responses to mine dewatering (i.e. drawdown observed in nearby observation bore and measured inflows to the pit) were available for model calibration. Recent observations of groundwater responses to mining provide an opportunity to upgrade calibration to a transient calibration which will in turn improve the confidence with which predictions can be made.

Figure 1.1 Location of Mining Pit and Nearby Observation Bores



2. Objectives

The key objectives of the work undertaken and described in this report are:

- To upgrade the current Stage 3 numerical groundwater model so that it is able to replicate recently observed groundwater level responses (both observed drawdown and estimated pit inflows) in and around the New Acland Coal Mine,
- To allow New Hope to better understand the impact on groundwater levels around the current Stage 2 mining operation using the Stage 3 model.
- To help address comments from DEHP in relation to investigating observed groundwater level reductions at 81P and 82P.

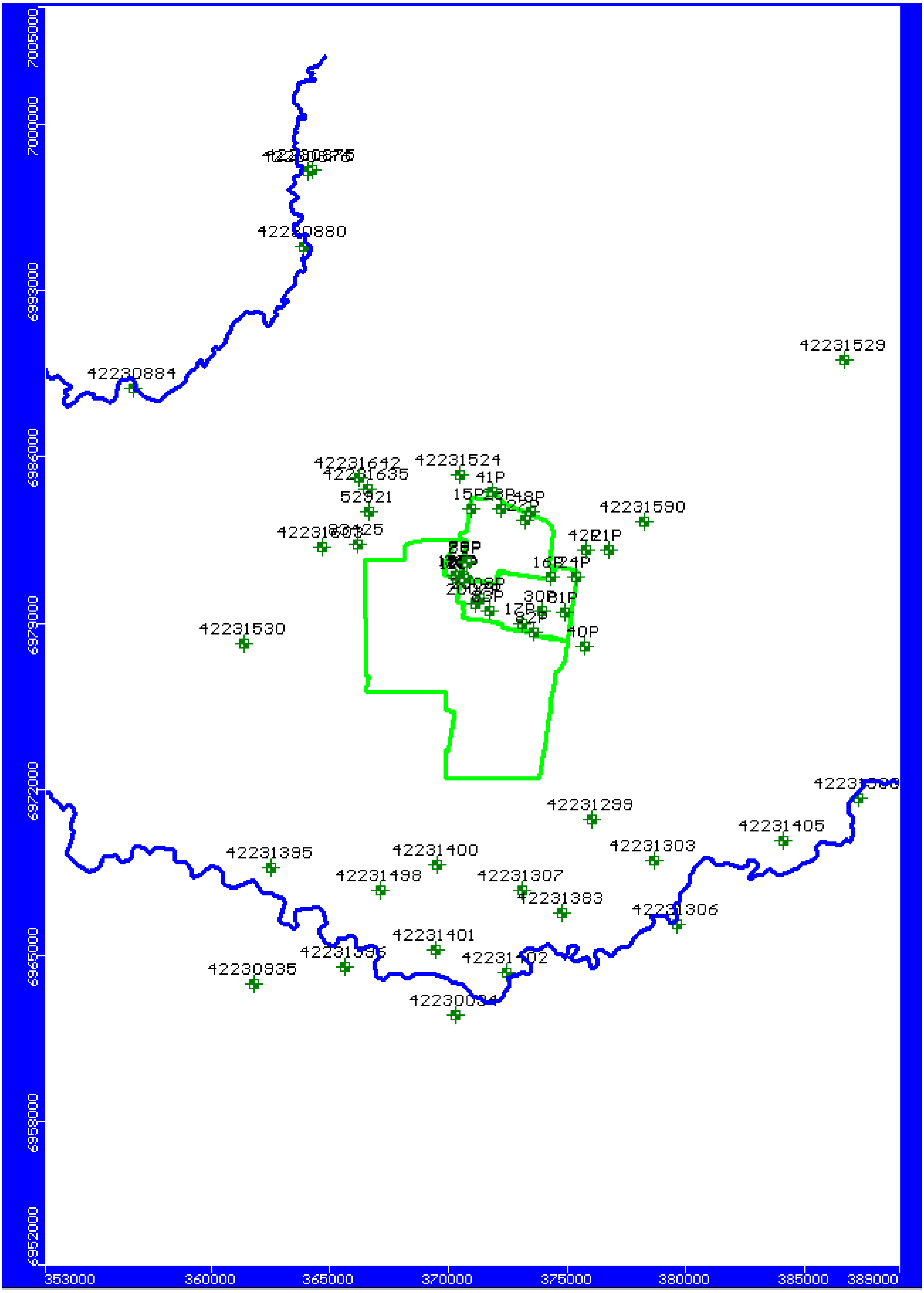
3. Procedure

In order to address NAC and potential community concerns it was necessary to carry out a transient model calibration exercise on the New Acland groundwater model aimed at demonstrating that the model is able to replicate the observed drawdown in observation bores and to replicate the inferred inflows to the pit (as detailed in the WSA report).

The following specific tasks undertaken were:

- Data collection. New Hope provided SKM with updated mining data including:
    a) Pit floor elevation data for the current mine location and for the period 1 January 2011 to present,
    b) Estimated inflows to the pit.
    c) Pit outlines for the period since 1 Jan 2011 to present,
    d) Pit floor elevations for the region of future mine expansion.
- A transient calibration model was formulated with the updated model configuration and data. The model covers the entire history of mining operations and continues through to the end of 2012. The model has a one month stress period and includes time varying drain boundary conditions to simulate historic mining operations. The model structure is described in detail in SKM, 2013. The calibration process is aimed at obtaining a set of model input parameters that, when run with the historic disturbances caused by mining operations, will produce estimates of groundwater behaviour that are comparable to the observed groundwater behaviour.
- Model input parameters (those describing the aquifer characteristics, recharge and connection to creeks) were initially manually revised to try to obtain an acceptable match between the model predictions and the pit inflows and the drawdowns measured in observation bores, the locations of which are shown in **Figure 3.1**.
- The PEST software package was used to optimise the calibration.

Figure 3.1 : Locations of observation bores.



4. Results

Updated data collected for this investigation includes recent observations of groundwater levels in observation bores located near the mining pit and estimated constraints on pit inflows. Both data sets are included in WSA, 2013. Examples of the latest bore hydrographs measured in observation wells near the pit are illustrated in **Figure 4.1** and measured rates of water extracted from the mine supplied by New Acland Coal are shown in **Figure 4.2** (WSA, 2013). Note that the estimates include groundwater inflows as well as rainfall on the pit and runoff from surrounding areas that accumulates in the pit. Groundwater inflows are therefore expected to be lower than the fluxes shown in **Figure 4.2**.

Figure 4.1 Groundwater head observations near the mining pit

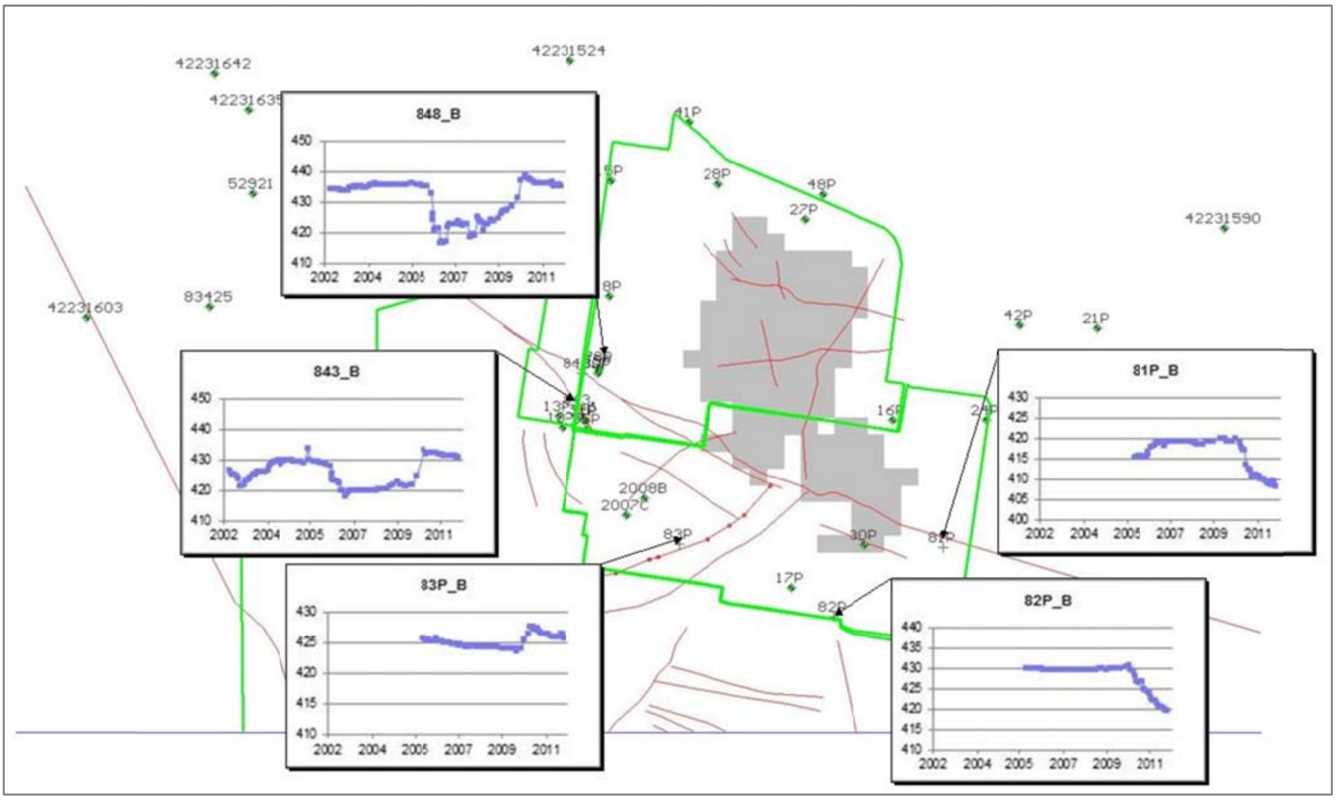
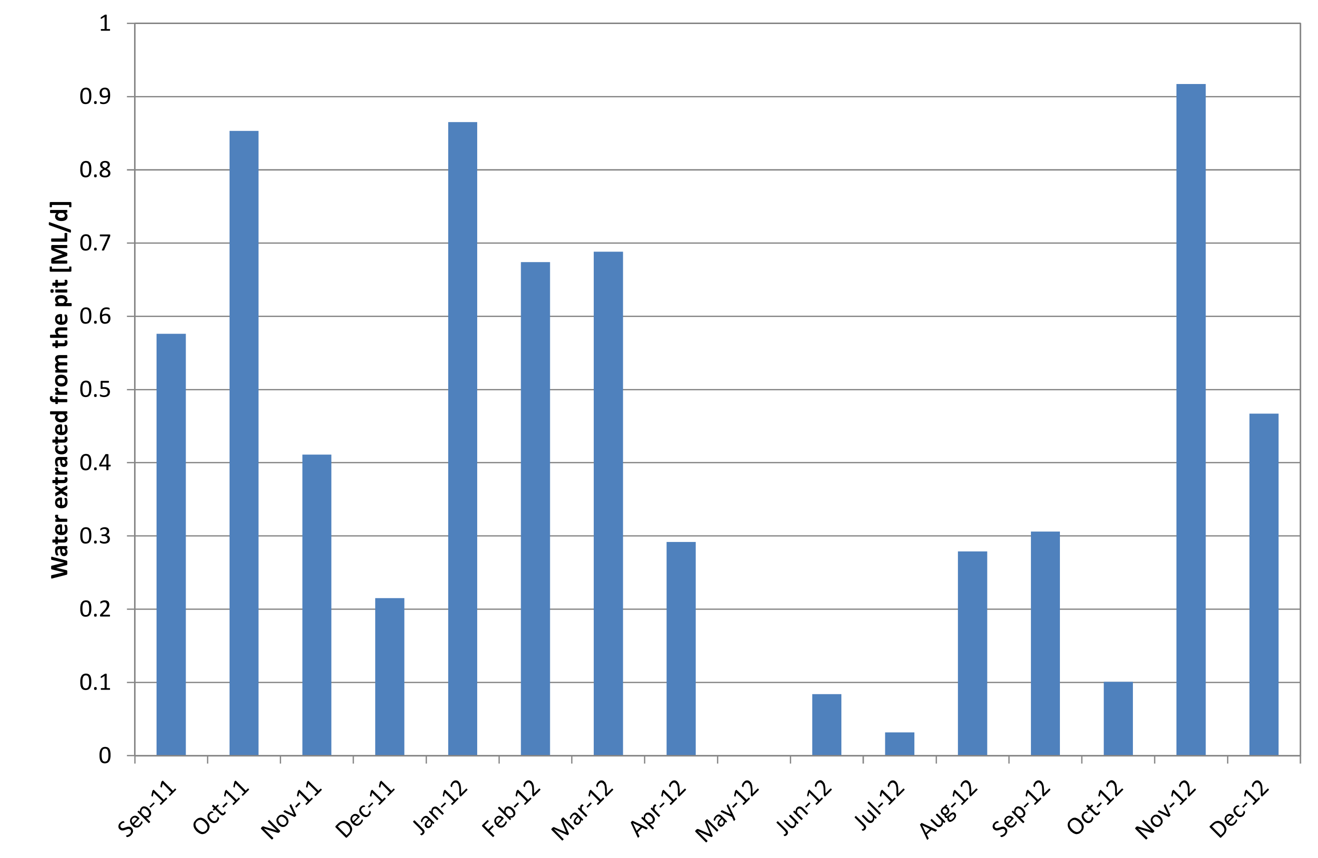


Figure 4.2 Measured rates of water extracted from the mining pit.

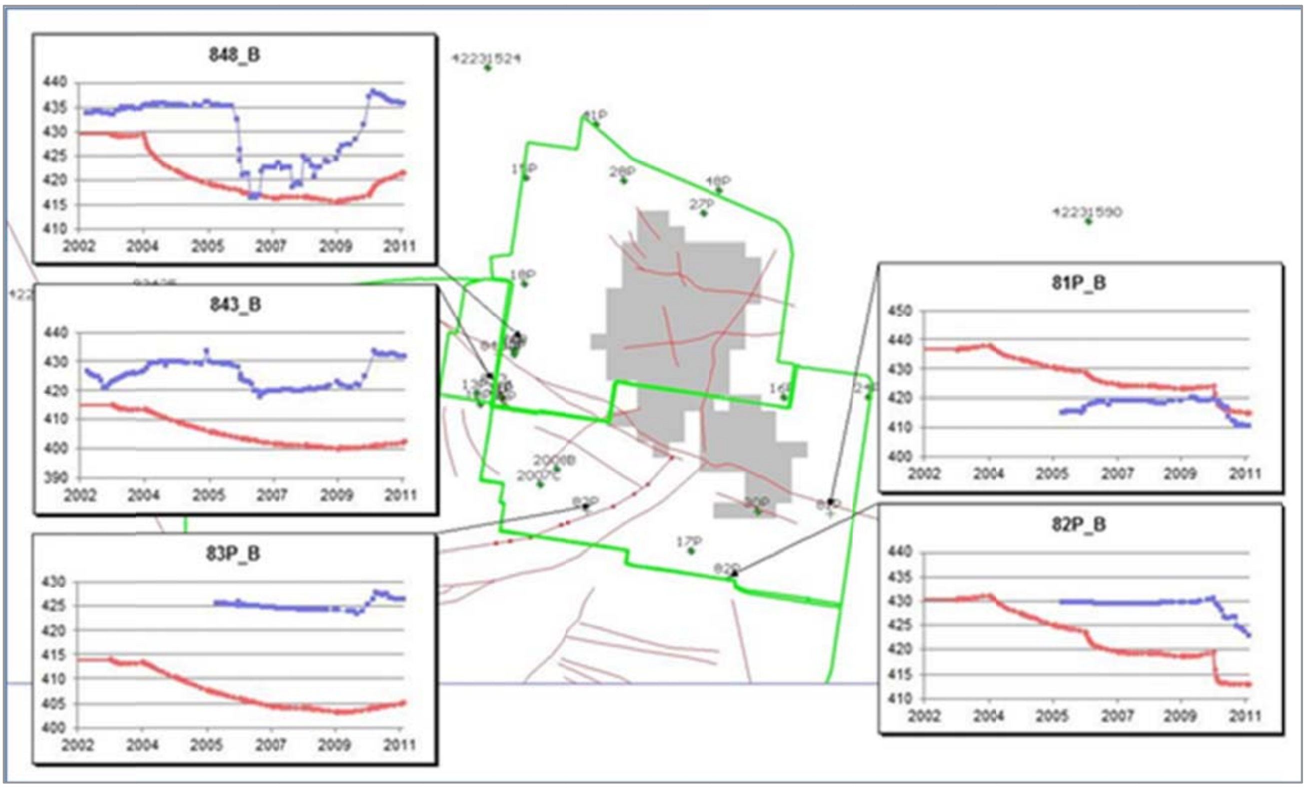


Initial runs of the revised model indicated that a minor response to the current mining operation was predicted and it was found that it was not necessary to implement additional explicit representation of local faulting. Instead, modifications to the regional hydrogeological model parameters controlling the formations' ability to transmit and store water were made in an effort to improve the model's ability to calculate groundwater heads and fluxes that match the observed groundwater responses. Manual trial and error calibration runs were followed by PEST automated calibration. The following constraints were placed on the calibration procedure:

1) Calibration was attempted without changing the hydrogeological zonation as defined by the interpreted distribution of the principal hydrogeological units present at the site,
2) Calibration was attained through refinement of the following model parameters and features:
   a) Hydraulic conductivity in the horizontal (kx, ky) and vertical (Kz) dimensions,
   b) Anisotropy between the principal components of horizontal hydraulic conductivity (i.e. the kx/ky ratio),
   c) Specific yield,
   d) Recharge,
   e) Hydraulic conductivity assigned to the Modflow Walls already present within the model to replicate the influence of faults,
   f) Conductance assigned to the Drain cells that define the flux of water into the mining pit.

The results of the re-calibration are illustrated by the hydrographs showing the model match to observed groundwater responses in the region of the pit presented in **Figure 4.3**. It should be noted that the focus of the calibration effort was to try to replicate temporal trends in the measured data after 2010. Decline in heads measured in bores P81 and P82 are clearly illustrated in the modelled result. Some of the other trends observed in the monitoring wells, particularly those measured prior to 2010, are more difficult to reproduce and more detailed descriptions of historic mining activities would be required to improve the calibration.

Figure 4.3 Calibration hydrographs



The calibration to observed heads can be quantified through estimation of the scaled RMS error for the goodness of fit (in this case 8%). The scatter plot and estimates of goodness of fit are shown in **Figure 4.4**. The model predicted inflows to the pit are presented in **Figure 4.5** and are consistent with the recorded rates at which water has been removed from the pit (by tanker) in recent months as shown in **Figure 4.2**. Note that the observed rate of water removal from the pit shown in **Figure 4.2** is not necessarily equal to the groundwater inflow to the pit. The figure includes rainfall and runoff accumulation in the pit as well as evaporation and leakage processes. The "measured" pit inflows therefore include significant uncertainty and its use in calibration should be viewed as an approximate target (i.e. a sanity check) only.

Figure 4.4 Calibration scatter plot showing a comparison in all observation bores

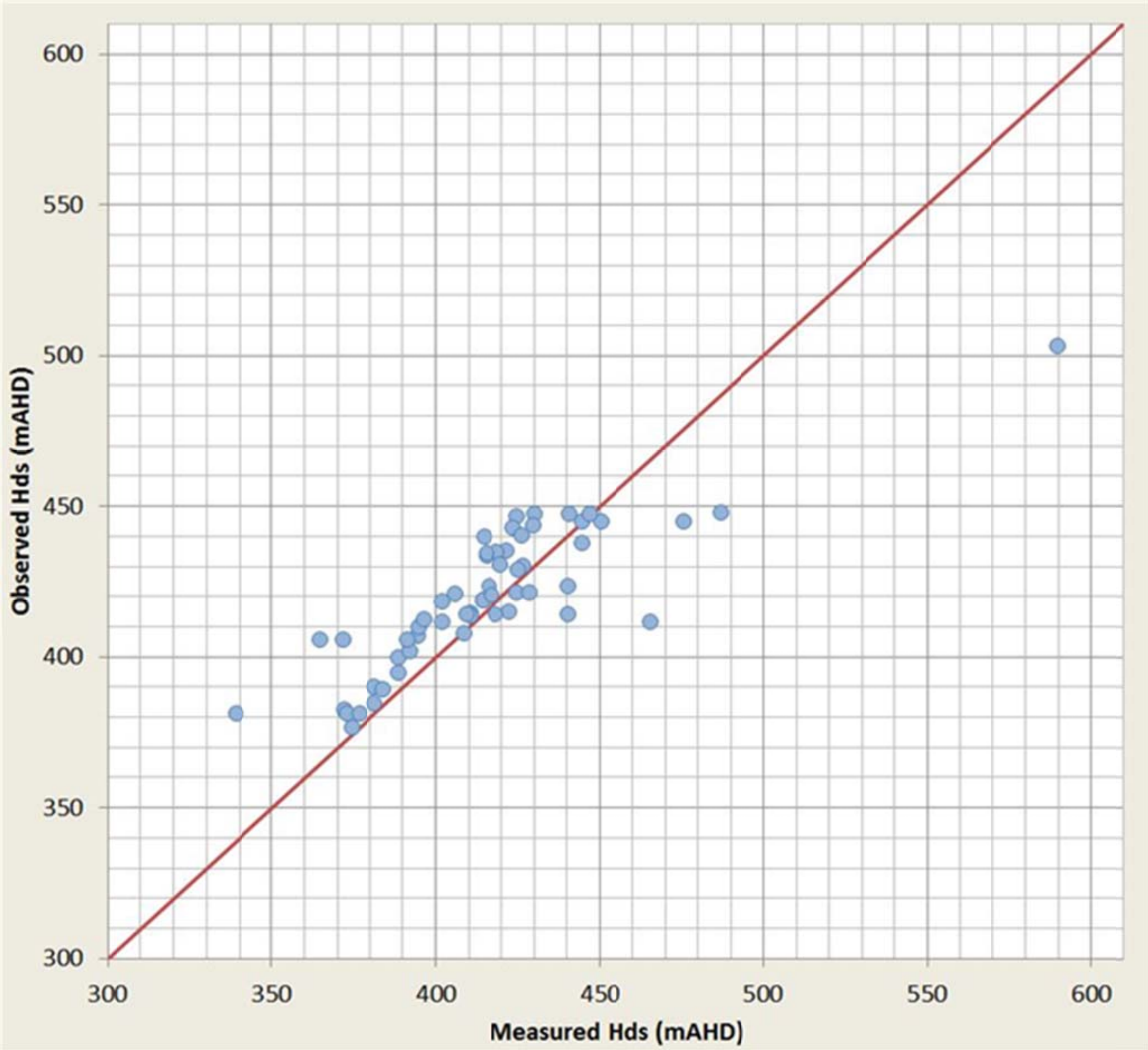
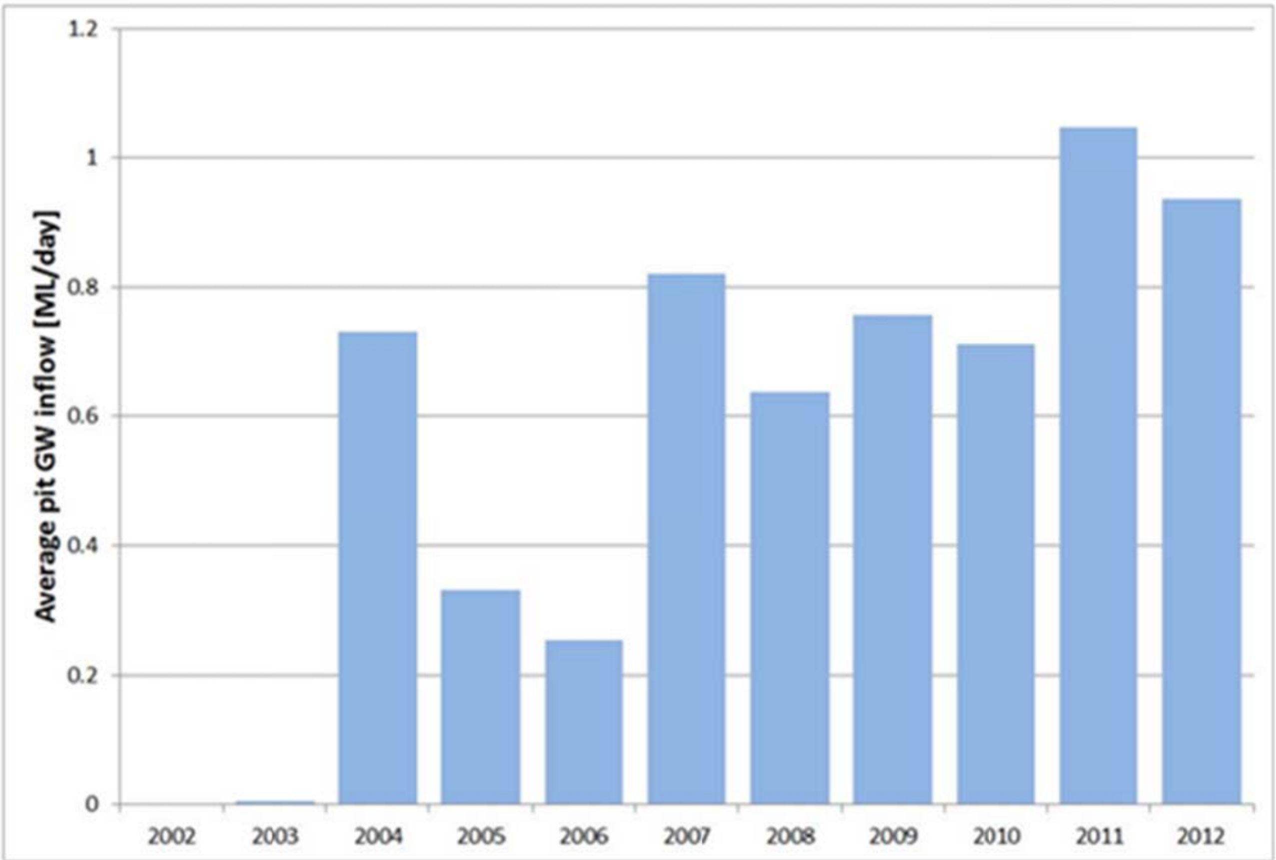


Figure 4.5 Model predicted groundwater inflow to the pit



5. Description of the calibrated model

5.1 Model Grid

The model covers an area of 1908 km^2 extending 36 km from east to west and 53 km from north to south. It is centred on the mine and has grid cells of 200 m by 200 m near the mine and 400 m by 400 m in outer areas.

The model consists of four layers with depth intervals that correspond to features of the geology in and around the mine such that the model layer structure does not always match the interpreted contacts between geological units. Rather the geological units are distinguished by the assignment of variable parameter values in both the vertical and horizontal planes. The model layers are described in **Table 1**. Note that the method of model construction results in individual layers that include a number of different hydrogeological units. The distribution of hydrogeological units in each model layer is shown in **Figure 5.1**. It can be seen that the distribution of hydrogeological units in Layer 1 and 2 are identical. The reason for including two layers here is that the base of layer 1 has been set as the base of the mining pit thus assisting with the implementation of mining operations in the past and future.

Table 1 Definition of model layers

Model Layer	Elevation range	Hydrogeological Units Present
1	Ground surface to base of pit	Walloon Coal Measures, Tertiary Basalts
2	Base of pit to base of the Basalts	Walloon Coal Measures, Tertiary Basalts, alluvium, Marburg Sandstone
3	45 m thickness	Lower part of the Walloon Coal Measures, alluvium, Marburg Sandstone
4	250 m thickness	Marburg Sandstone

5.2 Boundary Conditions

The model provides for exchange of water with surrounding aquifers through the inclusion of Constant Head Boundary Conditions assigned to its external boundaries. All the other lateral model boundaries are defined as no-flow boundaries through which water cannot enter or leave the groundwater model domain.

Faulting is known to have occurred from mapping of underground mines in the Acland area and has also been interpreted from bore data. Faulting is developed along two main trends, northeast-southwest and northwest-southeast. Folding has been interpreted from photogeological mapping, regional drilling and geological interpretation of the drilling results elsewhere in the Clarence-Moreton Basin. Model calibration highlighted the fact that there are significant head differences measured in neighbouring groundwater wells suggesting localised areas of low permeability and associated compartmental nature of the aquifers in the region of the mine.

In the model the MODFLOW HORIZONTAL FLOW BARRIER PACKAGE was implemented in order to represent the compartmental nature of the groundwater system. This package simulates thin, vertical low-permeability geologic features that impede the horizontal flow of groundwater. Faults are approximated as a series of horizontal-flow barriers (or “walls”) conceptually situated on the boundaries between pairs of adjacent cells in the finite-difference grid. Wall settings were adopted to represent the faulting present at the mine. The locations, alignment and permeability of the flow walls were derived from faults mapped by New Hope Mining at the site and during model calibration process. The walls were defined through Layer 1 to Layer 4. Figure 5.2 shows the location of the faulting (represented as green lines) assumed in the model.

Myall Creek is included as a Modflow Drain Boundary Condition which is a head dependent boundary condition that allows water to exit the model only. In other words it is modelled as a gaining creek and groundwater recharge resulting from the loss of water through the creek bed is not allowed for in the model. This representation is consistent with the fact that it is an ephemeral watercourse that is not a consistent source of groundwater recharge throughout the year. Oakey Creek has been represented in the model as a Modflow

River Boundary Condition that allows groundwater to enter or exit the model depending on the predicted groundwater levels and those specified as the river stage. In this case the river stage is assumed to be 5 m below the ground surface and the river bottom 6 m below ground surface (i.e. the water in the creek is 1 m deep).

Lagoon Creek is not included in the model as a boundary condition because this feature is conceptualised as being dis-connected from the local groundwater systems. Groundwater elevations in all aquifers lie significantly below stream bed elevations in the revised Project Area. Studies undertaken as part of Stage 2 EIS compared groundwater levels to stream bed levels in Lagoon Creek under average conditions and found that groundwater does not contribute to surface water flows.

Inflows to the mining pit are modelled as time varying Drain Boundary Conditions that drain the pit to the elevation of the pit floor. The locations of Drain Boundary Conditions in the calibration model are shown in **Figure 5.2**.

Figure 5.1 Hydrogeological units in model layers

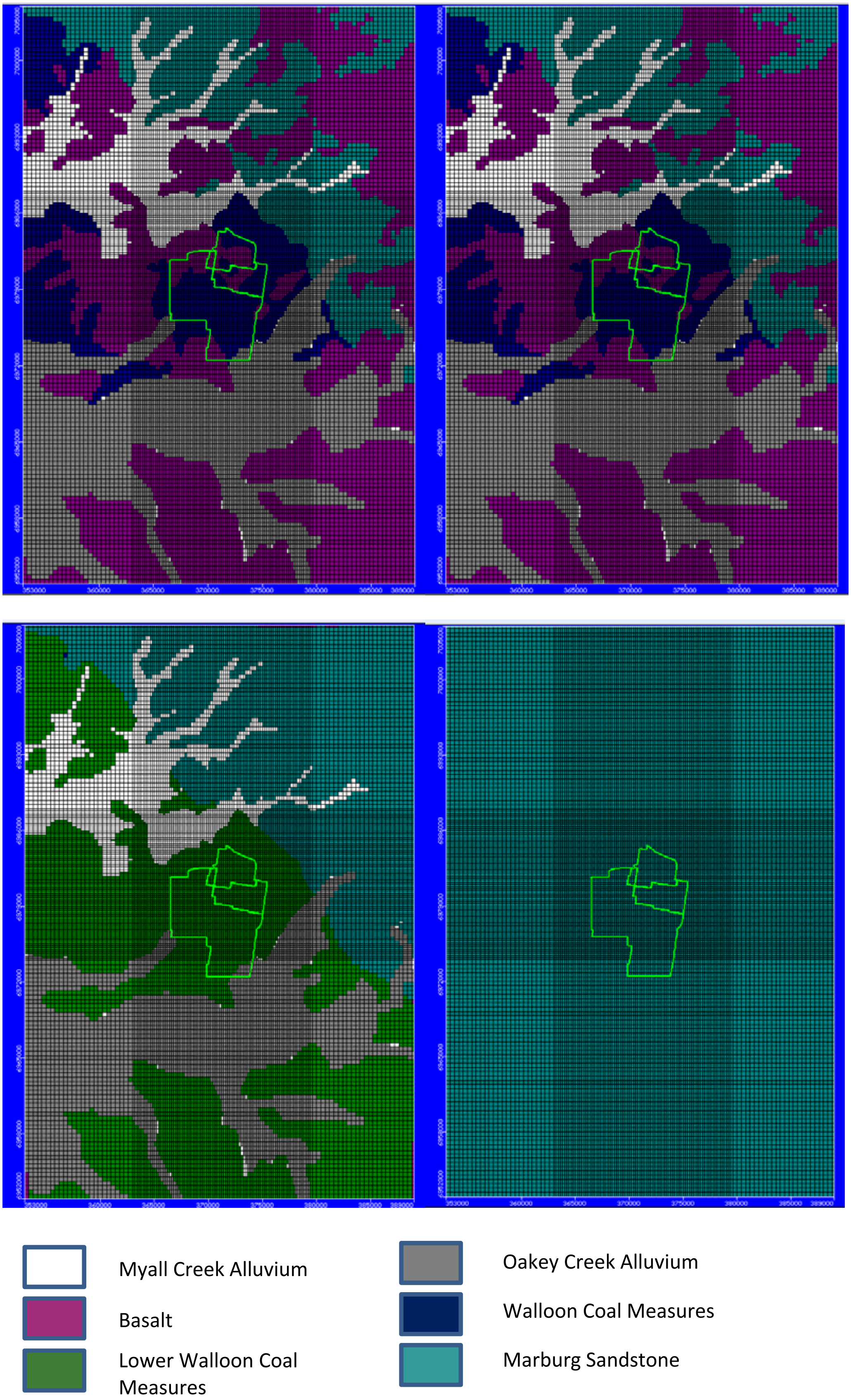
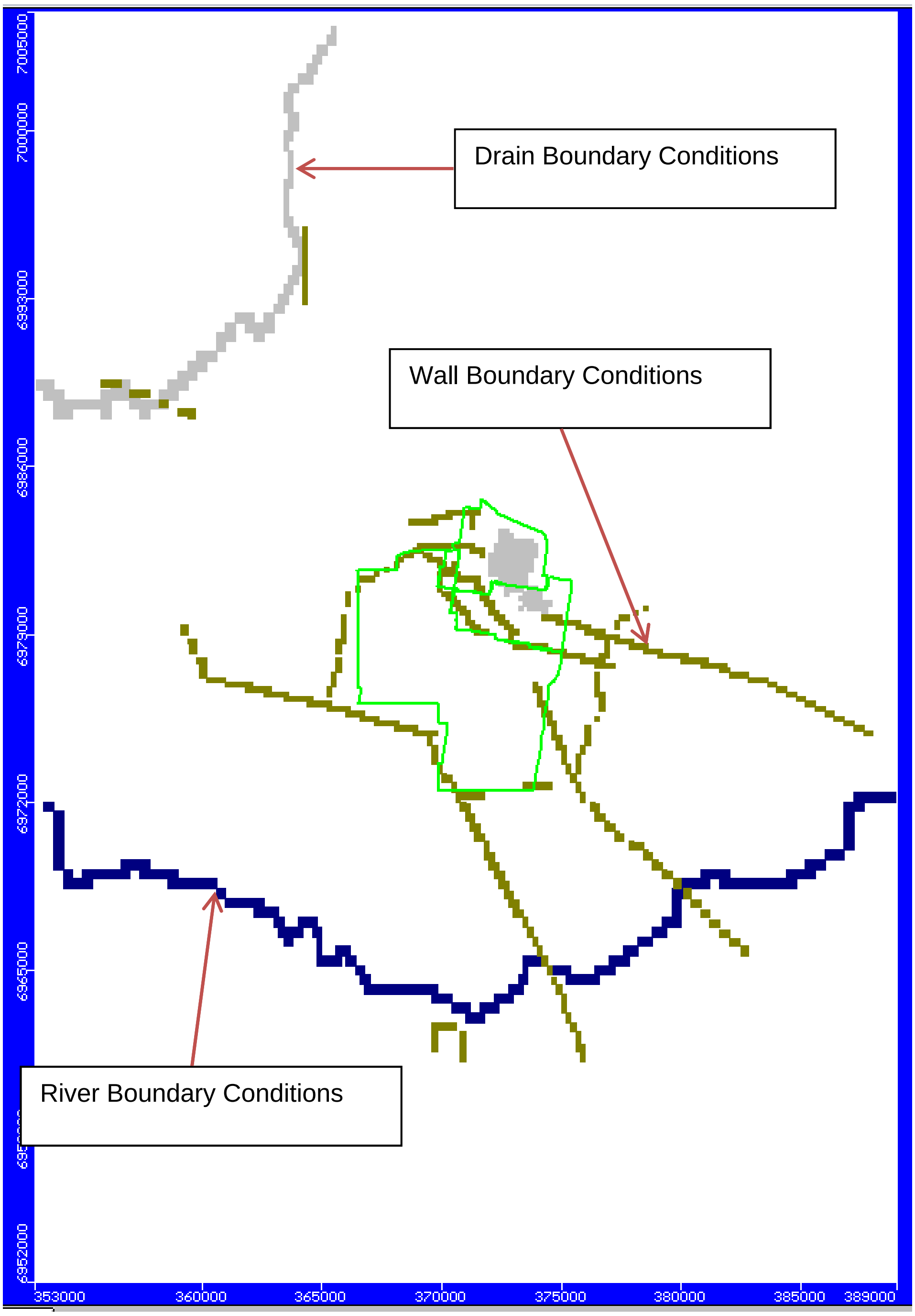


Figure 5.2 Model boundary conditions

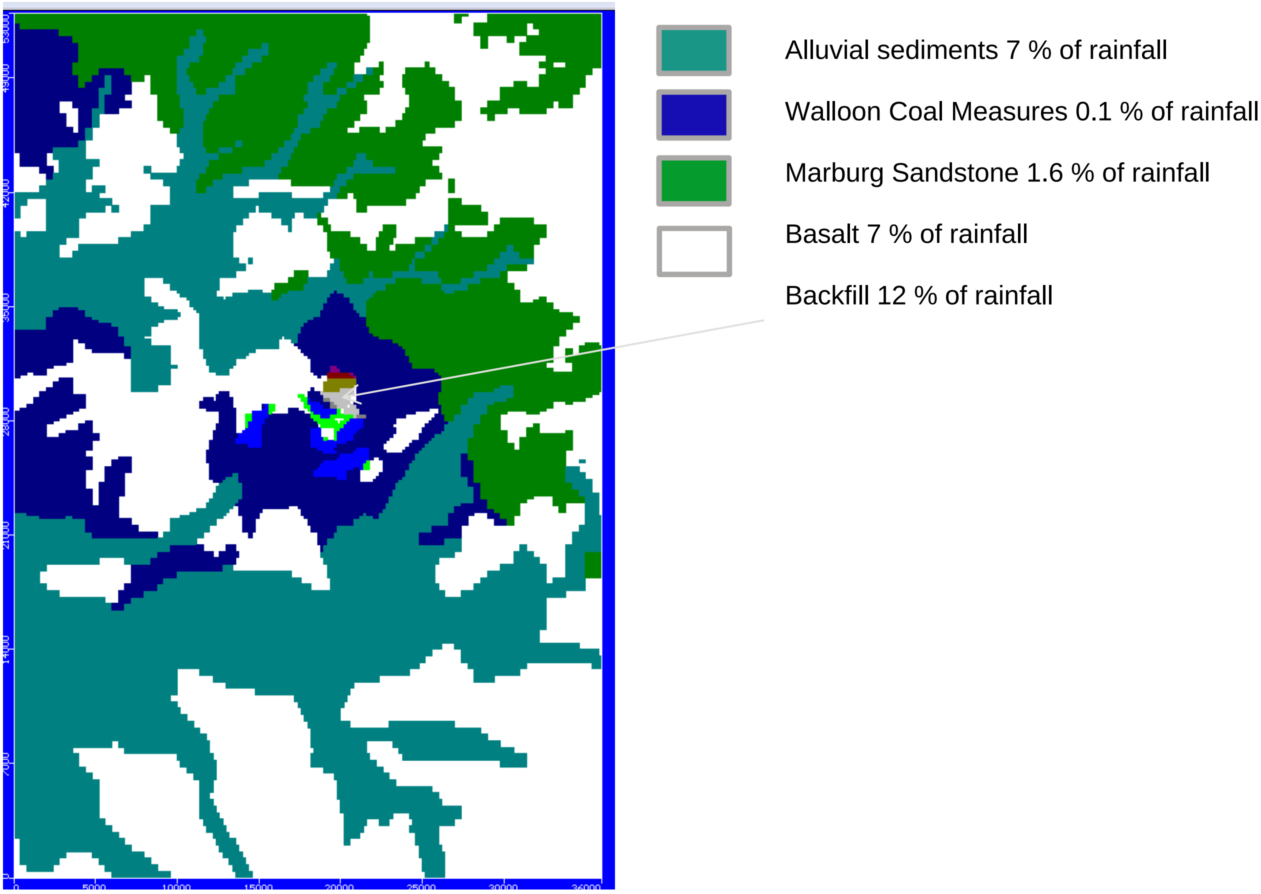


5.3 Recharge

A nominal level of rainfall recharge has been applied across the top surface of the model. Initial estimates of recharge were set at a fixed percentage of rainfall measured in gauges located within and near the model domain. The assumed distribution of recharge is shown in **Figure 5.3**. The figure shows that the model is subdivided into a number of recharge zones according to the permeability of the outcropping hydrogeological units. Zone 1 (coded as areas of white in **Figure 5.3**) represents the Tertiary Basalts. Zone 2 (shown in dark blue) represents the Walloon Coal Measures outcrop, Zone 3 is the Marburg Sandstone (shown in green in

Figure 5.3) and zone 4 (with various colours) is the pit backfill region. Each backfill colour represents five years of backfilling.

Figure 5.3 Recharge zonation



5.4 Aquifer Properties

Hydraulic conductivity and storage parameters included in the model as refined during the calibration procedure are presented in **Table 2**. Values of hydraulic conductivity are at the higher end of the range indicated by pumping tests (transmissivity between 7 and 40 m^2/d) carried out in the Walloon Coal Measures. Similarly the Marburg Sandstone hydraulic conductivity included in the model is higher than indicated by pumping tests. Parameter values included in the model provide a reasonable level of calibration and are consistent with observations from the mine and from the general recognition that the Marburg Sandstone is an important regional aquifer while the Walloon Coal Measures do not yield substantial quantities of water.

Calibration has resulted in extremely low values of vertical hydraulic conductivity in most hydrogeological units. This has been necessary to maintain strong vertical gradients and to maintain heads in that shallow model layers at levels close to those observed. When this parameter is increased the heads in the shallow model layers decline to level that are well below those observed in monitoring bores.

The hydrogeological parameters and recharge assigned to each layer are also listed in **Table 2**.

Table 2 Calibrated model parameters

Unit	Kx (m/d)	Kz (m/d)	Sy	Recharge (% of rainfall)
Marburg Formation	1	0.0003	0.0004	1.6
Basalt	3	0.004	0.007	7.0
Coal Measures	0.5	0.0003	0.002	0.1
Myall Creek Alluvium	10	0.1	0.01	7.0
Oakey Creek Alluvium	10	0.1	0.01	7.0
Lower Walloon Coal Measures	0.2	0.0001	0.0004	NA

6. Confidence Level Classification

The Australian Groundwater Modelling Guidelines (Barnett et al., 2012) define the Confidence Level Classification for groundwater models. The classification provides an indication as to the relative confidence with which a particular groundwater model can be used in predictive analyses. The classification relies on assessment against a number of criteria related to the available data from which the model has been conceptualised and calibrated, the method of calibration and calibration outcomes and the manner in which the predictive scenarios are formulated. The model described in this report has the characteristics that are typical of a Class 2 model which means that it is suitable for assessing mine dewatering problems and for estimating impacts in medium value aquifers and to medium value environmental assets. It is considered suitable for the on-going modelling objectives required for the Stage 3 EIS.

It was agreed with DNRM in February 2013 that a Class 2 Model would be acceptable to assess the impacts from Stage 3 operations.

The calibration work described in this report has been instrumental in upgrading the model Confidence Level Classification by incorporating a transient calibration in the model development and by calibrating to fluxes as well as heads measured in and around the mine.

7. Concluding Remarks

This investigation has resulted in a transient calibration to observed groundwater heads and fluxes in and around the mine pit. Calibration has been hampered by the non-homogeneous nature of the fractured rock aquifers present at the site. In particular calibration has been difficult because of the low vertical hydraulic conductivity present at the site causes apparent discontinuities and anomalies in the measured groundwater heads in the vicinity of the mining pit. These anomalies can be seen where there are clusters of bores at particular locations with substantially different behaviour observed in bores that are in close proximity to each other. These observations help to reinforce the general conclusion that the shallow aquifers present at the mine site (in particular the Walloon Coal Measures) are relatively impermeable and low yielding.

In the recalibration process the most important change required to trigger groundwater head responses at 81P and 82P was a substantial reduction in the specific yield (the capacity of the aquifer to store water) of all hydrogeological units represented within the groundwater model. The final specific yields for the units included in the model are extremely low and suggest that unconfined groundwater conditions are limited in their capacity to store water in the filling and draining of connected pore space.

The re-calibration of the model has been successfully completed without the need to implement preferential flow along discrete fractures or faults intersected by the mine. The calibration was attained by global changes in hydraulic conductivity and specific yield without the need to implement local scale anomalies. While faults and fractures in the rocks around the mine may be of hydrogeological importance, the fact that the model has been calibrated without explicit fracture representation and without including patches of anomalous conductivity or storage suggests that preferential flow along such structures is not necessary to explain observed groundwater behaviour. Experience to date suggests that most of the mapped faults do not necessarily represent preferred flow channels. The exclusion of these features in the model at this stage eliminates the need to decide where additional anomalies and faults may need to be activated in the model in the future as the pit migrates to the south.

We would recommend regular comparison of observed mine impacts with model predictions as the mine workings progress to demonstrate that the observed impacts are in line with predictions. Where observations deviate from predicted impacts model revision may be required and predictions of future impacts revised.

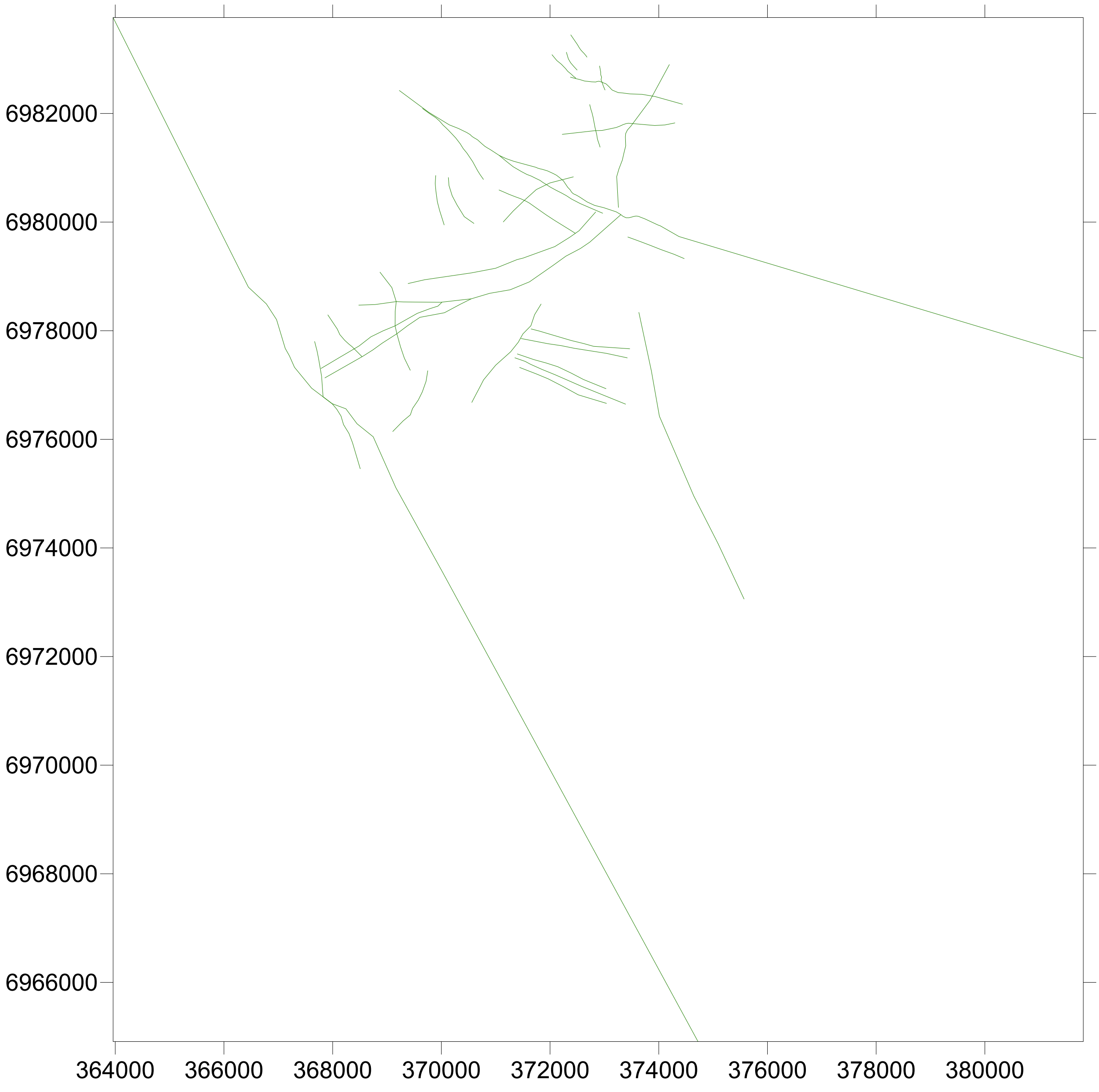
8. References

Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A. *Australian Groundwater Modelling Guidelines*. Waterlines report #82, National Water Commission, Canberra

WSA, 2013. Stage 1 *Groundwater Investigation at 81P and 82P.* Consultancy report prepared by Waste Solutions Australia for New Acland Coal PTY Ltd. Draft C, 15 May, 2013.

SKM, 2013. New Acland Coal Mine - Stage 3 Environmental Impact Statement – Water Report. In preparation.

Attachment 2: Acland_P10_Faults.pdf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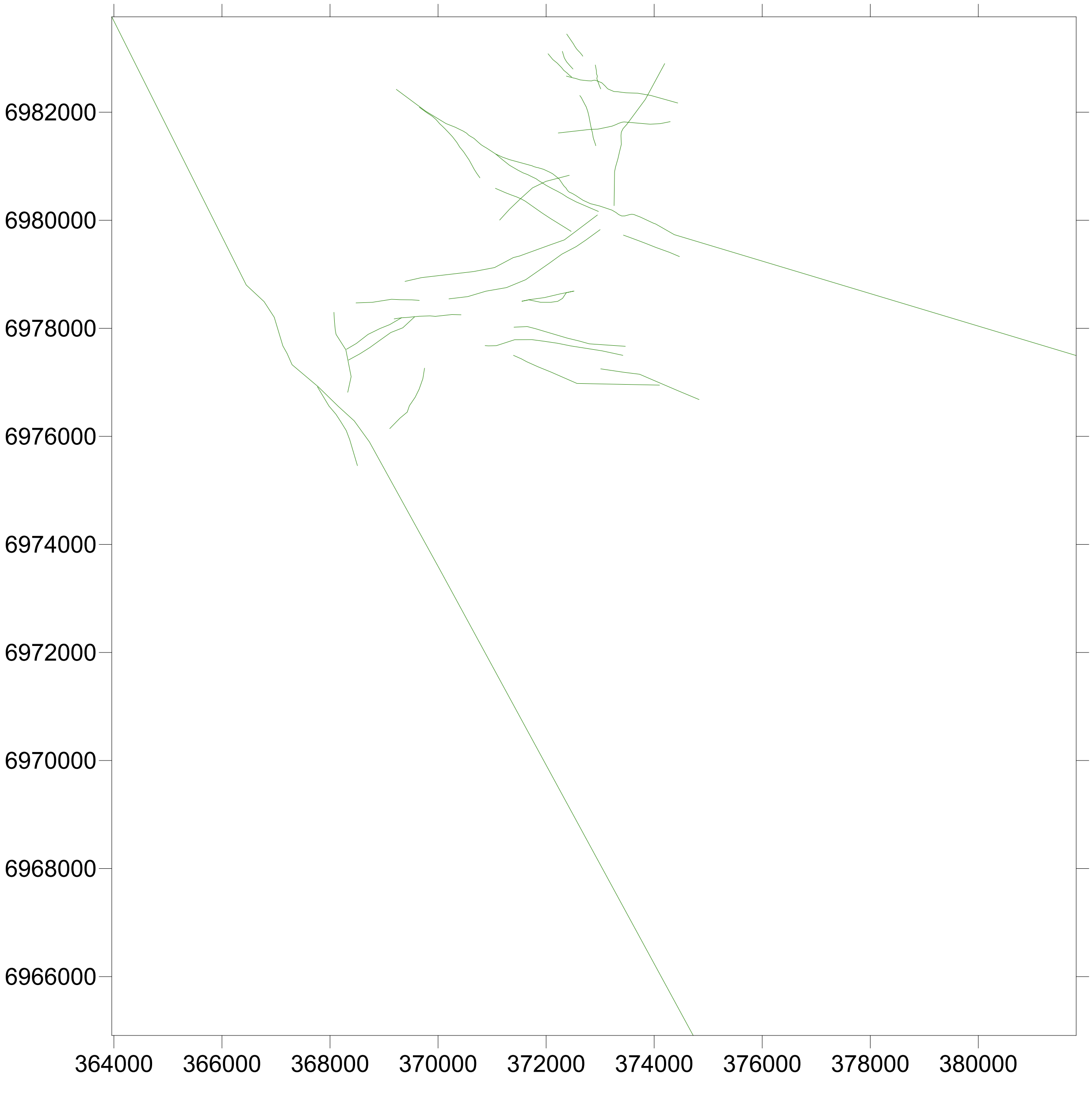
Attachment 3: Acland_Regional_Faults.pdf



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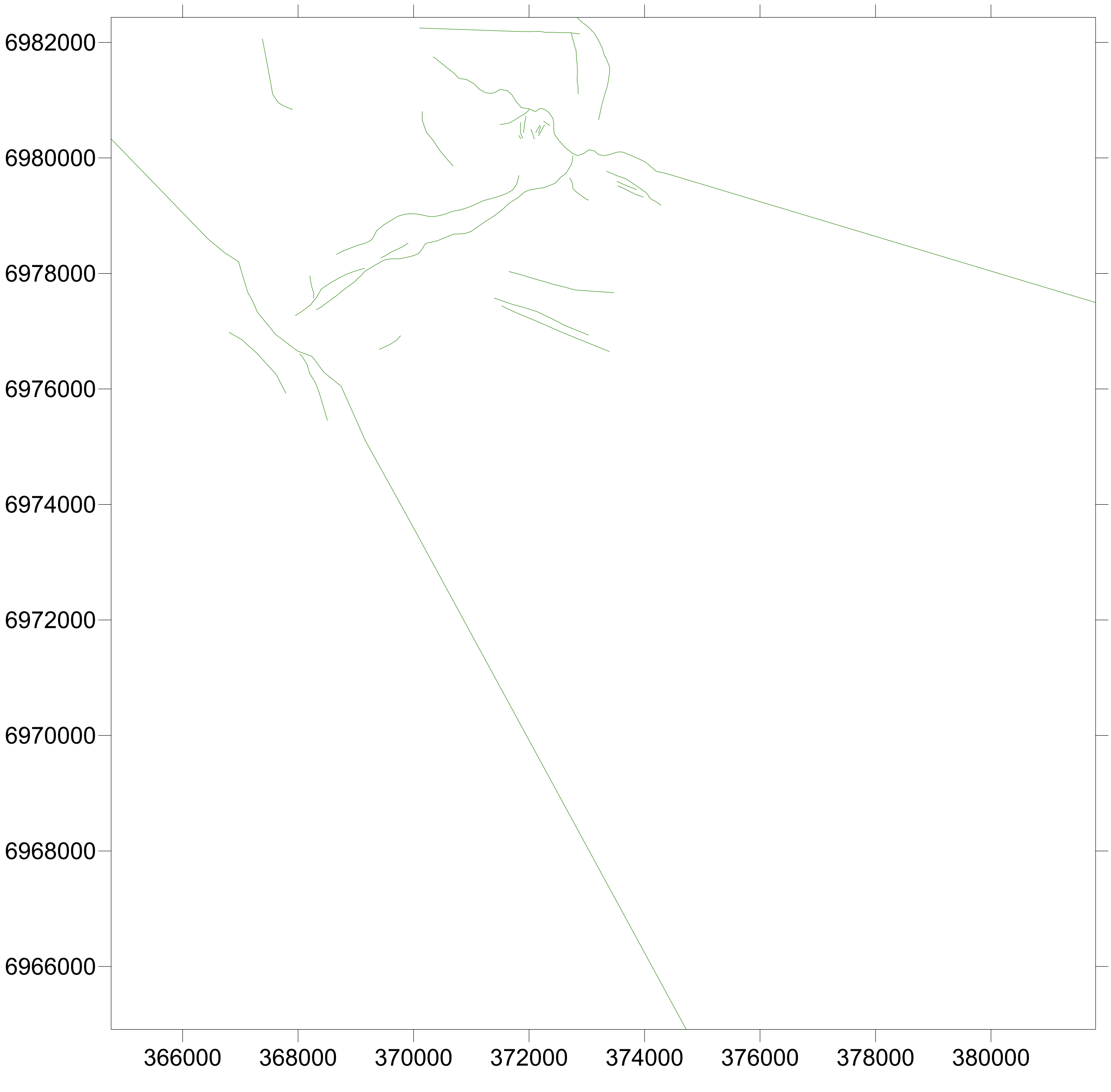
Attachment 4: 2013 NAC Faults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