From: WALLACE Andrew [Andrew.Wallace@ehp.qld.gov.au]
Sent: Monday, 31 October 2016 3:38 PM
To: WAKE Chris
CC: HENNEY Nina
Subject: RE: Ben Lomond radiation safety documents

Hi Chris,

In relation to livestock concerns at the Ben Lomond project the EPO draft response from UMVI states that since 2009, no surface water or groundwater sample taken by UMVI or its consultants from the project has exceeded the ANZECC guideline level for stock drinking water protection.
In general, the EA limits are set to protect public drinking water values which are more stringent than livestock protection levels.

The requirements of the EPO relate to the soil contaminant levels on and around the mine site infrastructure, both on the mountain side and on the valley floor. The concern is that the contaminants in soils in these areas may impact on grazing livestock, hence the requirements preventing livestock access until further testing proves the areas do not pose a risk.

Cheers, Andrew

From: WALLACE Andrew
Sent: Monday, 31 October 2016 9:40 AM
To: WAKE Chris <Chris.Wake@ehp.qld.gov.au>
Cc: HENNEY Nina <Nina.Henney@ehp.qld.gov.au>
Subject: FW: Ben Lomond radiation safety documents

Hi Chris,

See below my last email to Stephen Carter.
Find attached:

- KMZ of monitoring points
- Some maps of monitoring points
- The UMVI response to first EPO draft
- The Lottermoser review of that UMVI response
- The EPO
- The EA
- Monitoring data 2007 – 2012

Cheers, Andrew

From: WALLACE Andrew
Sent: Monday, 10 August 2015 2:55 PM
To: Stephen Carter <Stephen.Carter@health.qld.gov.au>
Subject: RE: Ben Lomond radiation safety documents

Hi Stephen,

I am kind of glad to hear that, as the inspection was cancelled late last week due to the illness of one my managers.

I will keep you posted on the re schedule dates, at this stage looking at 9-10 September.

Cheers, Andrew

Andrew Wallace
Senior Environmental Officer
North Queensland Compliance
Department of Environment and Heritage Protection

P 07 4722 5366
Level 10 Verde Tower, 445 Flinders Street, Townsville QLD 4810
PO Box 5391, Townsville QLD 4810

From: Stephen Carter [mailto:Stephen.Carter@health.qld.gov.au]
Sent: Monday, 10 August 2015 1:35 PM
To: WALLACE Andrew
Subject: RE: Ben Lomond radiation safety documents

Hello Andrew

Thanks for the invitation. I won't be able to make it this time though.

Regards

Stephen Carter | Consultant Health & Medical Physicist (Industrial & Environment)
Radiation Health Unit
Health Protection Branch | Prevention Division | Department of Health

Phone: (07) 3328 9202 | Email: stephen.carter@health.qld.gov.au
----
Office:
Level 3, 15 Butterfield Street | Herston Qld 4006
Phone : (07) 3328 9310 | Email: radiation_health@health.qld.gov.au | Web: www.health.qld.gov.au/radiationhealth

---

From: WALLACE Andrew [mailto:Andrew.Wallace@ehp.qld.gov.au]
Sent: Monday, 3 August 2015 10:07 AM
To: Stephen Carter
Cc: CONNOLLY Niall
Subject: RE: Ben Lomond radiation safety documents

Hi Stephen,

Thanks for providing this updated assessment. I will forward to my colleagues for information and consideration.
Again I would like to invite you to attend a site inspection next week on Wednesday 12th or Thursday 13th August.

Please consider and advise if you can attend.

Cheers, Andrew

Andrew Wallace
Senior Environmental Officer
North Queensland Compliance
Department of Environment and Heritage Protection

P 07 4722 5366
Level 10 Verde Tower, 445 Flinders Street, Townsville QLD 4810

PO Box 5391, Townsville QLD 4810

From: Stephen Carter [mailto:Stephen.Carter@health.qld.gov.au]
Sent: Friday, 31 July 2015 1:25 PM
To: WALLACE Andrew
Subject: RE: Ben Lomond radiation safety documents

Hi Andrew

Updated dose assessment is attached . I hope it makes sense.

The revised annual dose estimate, which I think represents a reasonably worst case estimate, is of 105µSv. This should be compared to the member of public limit of 1,000µSv.

Regards

Stephen Carter | Consultant Health & Medical Physicist (Industrial & Environment)
Radiation Health
Health Protection Unit | Department of Health

Phone: (07) 3328 9202 | Email: stephen.carter@health.qld.gov.au
----
Office:
Level 3, 15 Butterfield Street | Herston Qld 4006
Phone : (07) 3328 9310 | Email: radiation_health@health.qld.gov.au | Web: www.health.qld.gov.au/radiationhealth

From: WALLACE Andrew [mailto:Andrew.Wallace@ehp.qld.gov.au]
Sent: Wednesday, 17 June 2015 3:30 PM
To: Stephen Carter
Cc: CONNOLLY Niall
Subject: RE: Ben Lomond radiation safety documents

Hi Stephen,

As discussed, some new information has come to light since the previous radiation dose assessment for Ben Lomond was completed.

Can you please consider this new information (see XRF report attached) and provide advice of any changes to the radiation dose assessment required or if any further information is required?

Kind Regards, Andrew

Andrew Wallace
Senior Environmental Officer
North Queensland Compliance | Environmental Services and Regulation
Department of Environment and Heritage Protection

P 07 4722 5366 | **F** 07 4722 5351
Level 10 Verde Tower | 445 Flinders Street | Townsville, QLD 4810
PO Box 5391 Townsville QLD 4810

From: WALLACE Andrew
Sent: Thursday, 7 August 2014 11:20 AM
To: stephen.carter@health.qld.gov.au
Cc: BUTLER Hamish; RAINS John; ANSCOMB Matt; CONNOLLY Niall; SHARPE Dean
Subject: FW: Ben Lomond radiation safety documents

Hi Stephen,

Thanks for this. It's good to know what the recommended level is, and that officers are likely to be well below the recommended annual dose limit.
Interesting to see how presence at different areas of the site affects the dose.

Cheers, Andrew

Andrew Wallace
Senior Environmental Officer
Mining and Heavy Industry I Northern Region
Department of Environment and Heritage Protection
Level 10 Verde Tower, 445 Flinders Street, Townsville, QLD 4810
PO Box 5391 Townsville QLD 4810
Tel: (07) 4722 5366 **Fax:** (07) 4722 5351
andrew.wallace@ehp.qld.gov.au

From: Stephen Carter [mailto:Stephen.Carter@health.qld.gov.au]
Sent: Wednesday, 6 August 2014 3:35 PM
To: WALLACE Andrew
Subject: RE: Ben Lomond radiation safety documents

Hi Andrew

Sorry for the delayed reply – just a lot of urgent things to get out of the way.

I have made an assessment based on a radiation survey done in 2004. I have attached the results of the assessment which includes a few assumptions about where a DEHP officer may spend time on the site.

If an officer visits 5 times per year I estimate an annual effective dose of 30 µSv per year (compared to recommended member of public annual dose limit of 1,000µSv, and typical annual natural background of 2,000µSv)

Exposure to radon within the enclosure over the ore stockpile would add to the dose but it is difficult to estimate this. The highest measured concentration on top of the stockpile would lead to an estimated dose of 6 µSv/hr. Radon concentration can be reduced by good ventilation so the exposure could be reduced by delaying entry into the enclosure until some time after the door was opened. I think you may have said that part of the roof had fallen in? If so that would certainly be reducing the radon levels.

In summary, I think it is quite safe for DEHP officers to be visiting the site. However in the interests of minimising dose they should ventilate the ore stockpile enclosure before entry.

Regards

Stephen Carter | Consultant Health & Medical Physicist (Industrial & Environment)
Radiation Health
Health Protection Unit | Department of Health

Phone: (07) 3328 9202 | Email: stephen.carter@health.qld.gov.au
----
Office:
Level 3, 15 Butterfield Street | Herston Qld 4006
Phone : (07) 3328 9310 | Email: radiation_health@health.qld.gov.au | Web: www.health.qld.gov.au/radiationhealth

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From: WALLACE Andrew [mailto:Andrew.Wallace@ehp.qld.gov.au]
Sent: Tuesday, 5 August 2014 3:31 PM
To: Stephen Carter
Cc: ANSCOMB Matt; BUTLER Hamish
Subject: RE: Ben Lomond radiation safety documents

Hi Stephen,

Have you got anywhere with the radiation survey data from Ben Lomond to determine the member of the public annual limit?
It is intended that EHP will use this to determine the level of risk to EHP officers conducting X number of site visits per year.

Cheers, Andrew

Andrew Wallace
Senior Environmental Officer
Mining and Heavy Industry I Northern Region
Department of Environment and Heritage Protection
Level 10 Verde Tower, 445 Flinders Street, Townsville, QLD 4810
PO Box 5391 Townsville QLD 4810
Tel: (07) 4722 5366 **Fax:** (07) 4722 5351
andrew.wallace@ehp.qld.gov.au

From: ANSCOMB Matt
Sent: Wednesday, 30 July 2014 10:07 AM
To: stephen.carter@health.qld.gov.au
Cc: WALLACE Andrew
Subject: Ben Lomond radiation safety documents

FYI

Matt Anscomb
Senior Environmental Officer
Environmental Services and Regulation, Townsville
Department of Environment and Heritage Protection
(07) 4722 5370

Level 10, Flinders Tower
445 Flinders Street
Townsville Q 4810

If you have received this message in error, you are asked to inform the sender as quickly as possible and delete this message and any copies of this message from your computer and/or your computer system network.

DAUNT Bettina

From:	HANSON Anna
Sent:	Thursday, 27 October 2016 6:24 PM
To:	LAWRENCE Rob; WAKE Chris; SULLIVAN Scott
Cc:	Media NPSR/EHP; ELLWOOD Dean; STEELE Mary
Subject:	More changes to Ben Lomond release - for tomorrow morning
Attachments:	image002.png; ATT00001.htm; 271016 - MR - Ben Lomond Mine Environmental Protection Order PH edits.docx; ATT00002.htm

Hi, pls fact check this version.

Is it possible to receive this feedback by 930am?

I appreciate this is taking up considerable time to get this right. Thanks once again.

Begin forwarded message:

> **From:** Neil Doorley <Neil.Doorley@ministerial.qld.gov.au>
> **Date:** 27 October 2016 at 6:15:20 PM AEST
> **To:** HANSON Anna <Anna.Hanson@ehp.qld.gov.au>
> **Cc:** Media NPSR/EHP <Media@npsr.qld.gov.au>, Philip Halton <Philip.Halton@ministerial.qld.gov.au>, Katharine Wright <Katharine.Wright@ministerial.qld.gov.au>, Megan Surawski <Megan.Surawski@ministerial.qld.gov.au>
> **Subject: Revised revised release**
>
> Hello – with additional changes to be checked please,
>
> Regards,

Environmental Protection Order for Ben Lomond Mine

The state's environmental regulator has issued an Environmental Protection Order (EPO) to Uranium Mineral Ventures Incorporated (UMVI) in relation to the Ben Lomond Uranium Mine near Townsville.

Environment Minister Dr Steven Miles said the Department of Environment and Heritage Protection (EHP) issued the EPO on Friday (28 October) to further strengthen safeguards against any release of contaminants at the non-operational mine.

"Based on sampling and investigations undertaken by the company and EHP, we know the geology of the area naturally mineralises and releases contaminants due to natural weathering processes," Dr Miles said.

"However, it has also been identified that disturbed areas at the mine have the potential to release contaminants from the Ben Lomond site to the receiving environment.

"EHP has taken action to ensure that UMVI puts appropriate controls in place to prevent the release of contaminants from any of the mine disturbed areas.

"The company needs to develop and implement a scope of works to prevent contaminants being released from the historical mine disturbed areas.

"The EPO requires preventative measures to be taken over the next 12 months in the interest of the community and surrounding environment".

The Department's action follows elevated levels of contaminants – including arsenic, lead and uranium – being detected both on and off the mining lease.

"It's important to note that those elevated readings were measured against the very limits that are already in force for this site," Dr Miles said.

"At no point have there been readings at levels which raise any concerns for the public, but it's clearly appropriate for EHP to ensure that those tight limits are rigorously observed.

"The Ben Lomond mining project has never been a producing uranium mine, however between 1979 and 1981, an adit was driven into the ore body to obtain a bulk sample for metallurgical testing.

"Since 1984 the Ben Lomond site has been in care and maintenance and there are no operational activities on site.

"Under this government, we can assure Queenslanders uranium mining is banned in this state.

"The community has known about historically disturbed areas at the Ben Lomond site for many years, but we now have a better understanding of what we are dealing with, as a result of more comprehensive investigations and monitoring.

"In addition to the EPO, UMVI must continue to carry out all of the normal monitoring obligations that are required by the environmental authority," Dr Miles said.

ENDS
MEDIA

DAUNT Bettina

From: HANSON Anna
Sent: Thursday, 27 October 2016 4:36 PM
To: Neil.Doorley@ministerial.qld.gov.au; Katharine Wright
Cc: Media NPSR/EHP; REEVES Jim; ELLWOOD Dean; STEELE Mary
Subject: Neil/Kat - Ben Lomond EPO media release and QAs
Attachments: 271016 - QAs - Ben Lomond Mine Environmental Protection Order.docx; 271016 - MR - Ben Lomond Mine Environmental Protection Order.docx

Hello Neil and Kat

Please find attached:

1. Media Release
2. QAs

**PLEASE CHECK IN WITH US RE TIMING BEFORE THIS STATEMENT IS RELEASED.

Thank you, Anna.

Queensland Government

Anna Hanson
Media Director
Corporate Communications
Department of Environment and Heritage Protection
Department of National Parks, Sport and Racing

P 07 3339 5859   0423 020 746
Level 6, 400 George St, Brisbane Qld 4000
PO Box 2454, Brisbane Qld 4001

QAs – Ben Lomond Mine: Environmental Protection Order

When was the Environmental Protection Order (EPO) issued?

EHP issued an EPO to Uranium Mineral Ventures Incorporated (UMVI) on 28 October to address concerns regarding the mobilisation of contaminants at the non-operational mine.

What actions are required under the EPO?

The EPO is to ensure that UMVI puts appropriate controls in place to prevent the release of contaminants from any of the historical mine disturbed areas.

UMVI is required to develop and implement a scope of works to prevent contaminants being mobilised from the areas.

The EPO requires preventative measures to be taken over the next 12 months in the interest of the community and surrounding environment.

In addition to the EPO, UMVI must continue to carry out all of the normal monitoring obligations that are required by the environmental authority.

Given this is a historical issue, what prompted the EPO?

Based on sampling and investigations undertaken by the company and EHP, we know the geology of the area naturally mineralises and releases contaminants due to natural weathering processes.

It has also been identified that the historical mine disturbed areas have the potential to release contaminants from the Ben Lomond site to the receiving environment.

Based on the combination of information now available, EHP has taken action to ensure that UMVI puts appropriate controls in place to prevent the release of contaminants from any of the mine disturbed areas.

How high are contamination levels?

The historical monitoring results have indicated consistently elevated levels of contaminants and this in part is a result of mineralisation of the ore body that is occurring naturally in the local environment.

Some of these contaminants include Arsenic, Lead and Uranium.

Is contamination contained on site?

Elevated levels of contaminants have been detected both on and off the mining lease however the relative contributions of naturally occurring vs mine related is not well understood.

The EPO will serve to exclude any mine related impact and will assist in better understanding the naturally elevated levels of contaminants within the catchment.

Is the company doing enough to protect the community and environment?

EHP has previously required the company to investigate how the historical mine disturbed areas have been contributing to these elevated monitoring results.

The information provided by the company, in combination with EHP results, triggered the EPO which is a positive step to addressing concerns.

What is the status of the mine?

Ben Lomond has never been a "producing" uranium mine – only exploration and bulk sampling activities have ever been undertaken at the site.

The most significant activity that has occurred on site was the development of an adit between 1979 and 1981 to obtain a 3,500 tonne bulk sample of the ore for metallurgical testing.

The Commonwealth announced in 1984 its national policy to restrict uranium mining in Australia to just three mines.

Since that time, the Ben Lomond mine site has been in care and maintenance, and only care and maintenance and exploration activities are permitted on site.

The care and maintenance activities are strictly regulated through the conditions of the EA.

Is the mine is non-operational, what does the EA allow?

Under the existing EA, mining or processing of uranium, or any other material, is not permitted at the Ben Lomond mine site.

The EA does however allow UMVI to undertake care and maintenance activities and exploration activities.

As part of the care and maintenance activities undertaken by the company, UMVI is required to undertake regular sampling in the receiving environment to monitor contaminant levels which includes lead, arsenic and uranium.

What caused the mine discharge in 1981?

Reports indicate that in approximately 1981, during an extremely heavy rainfall event, material from the unprocessed bulk ore sample was released into nearby waterways.

This event is sometimes referred to as being a release from a tailings dam however there is no tailings dam onsite.

In 1984 the Ben Lomond Environmental Impact Statement was accepted by both Queensland and Commonwealth governments.

The reason Ben Lomond never became an operational mine is not because of the 1981 discharge or the mining warden report of that time, but because of the Commonwealth's three-mine policy introduced in 1984.

What is the government's position on uranium mining?

Under this government, we can assure Queenslanders uranium mining is banned in this state.

Department of **Environment and Heritage Protection (EHP)**

Draft media release

Deadline: 27 Oct 2016	**Briefing officer: Scott Sullivan**
Media Services contact: Anna Hanson	**Phone:** 4722 5200
Phone: 3339 5859	**DDG:** Dean Ellwood
Approved:	**Phone:** 3330 5628
Geographical area/s of interest: Townsville	

Environmental Protection Order for Ben Lomond Mine

The state's environmental regulator has issued an Environmental Protection Order (EPO) to Uranium Mineral Ventures Incorporated (UMVI) in relation to the Ben Lomond Uranium Mine near Townsville.

Environment Minister Dr Steven Miles said the Department of Environment and Heritage Protection (EHP) issued the EPO on 28 October to address concerns regarding the mobilisation of contaminants at the non-operational mine.

"Based on sampling and investigations undertaken by the company and EHP, we know the geology of the area naturally mineralises and releases contaminants due to natural weathering processes," Dr Miles said.

"However, it has also been identified that the historical mine disturbed areas have the potential to release contaminants from the Ben Lomond site to the receiving environment.

"EHP has taken action to ensure that UMVI puts appropriate controls in place to prevent the release of contaminants from any of the mine disturbed areas.

"The company needs to develop and implement a scope of works to prevent contaminants being mobilised from the historical mine disturbed areas.

"The EPO requires preventative measures to be taken over the next 12 months in the interest of the community and surrounding environment.

"The Ben Lomond mining project has never been a producing uranium mine, however between 1979 and 1981, an adit was driven into the ore body to obtain a bulk sample for metallurgical testing.

"Since 1984 the Ben Lomond site has been in care and maintenance and there are no operational activities on site.

"Under this government, we can assure Queenslanders uranium mining is banned in this state.

"The community has known about historically disturbed areas at the Ben Lomond site for many years, but we now have a better understanding of what we are dealing with as a result of a more comprehensive investigations and monitoring.

"In addition to the EPO, UMVI must continue to carry out all of the normal monitoring obligations that are required by the environmental authority."

ENDS

DAUNT Bettina

From: LAWRENCE Rob
Sent: Monday, 24 October 2016 2:04 PM
To: ELLWOOD Dean; ESR; LOWE Trinity; Corro EHP ESR MaNQC
Cc: SULLIVAN Scott; FOMIATTI MINNESMA Ingrid
Subject: ESR Alert - Ben Lomond Environmental Protection Order

Follow Up Flag: Follow up
Flag Status: Completed

Categories: Lisa / Trin / ED

ALERT CATEGORY:

- Enforcement activity

ALERT NAME:

- Ben Lomond Environmental protection Order

CUSTOMER DETAILS:

- Uranium Mineral Ventures Inc (UMVI) (Wholly owned subsidiary of Mega Uranium Ltd.)

SUMMARY OF ISSUE/S:

- UMVI hold a site specific Environmental Authority (EA) for the Ben Lomond Uranium Mine near Townsville.
- The EA authorises care and maintenance activities and exploration activities but **does not authorise** any mining, ore extraction or processing to take place.
- The company has not complied with the EA contaminant limits associated with monitoring downstream of the Ben Lomond mine.
- The company has always contended that the background mineralisation is high and the limits cannot be complied with.
- UMVI was required to conduct or commission an Environmental Evaluation (EE) to investigate these matters and an Environmental Report was submitted to EHP in 2014.
- EHP assessed and accepted the Environmental Report however UMVI were advised that EHP did not accept all the conclusions and recommendations particularly in relation to the source of contaminants.
- EHP accepts that natural mineralisation is contributing to the sampling results and long term negotiation has been occurring to amend the EA to address this issue.
- On site compliance inspections have continued as well as a review of historical sampling, a review of previous reports provided by the company and further samples were collected to undertake a leach test to better understand the potential for contaminants to be released from mine disturbed soils.
- As a result EHP has formed a view that contaminated sediments are being mobilised during rain events and this is contributing to elevated uranium levels in the adjacent waterway.
- In response EHP provided the company with a draft EPO in June 2016 and the company strongly objected to any assertion that it was contributing to elevated uranium levels and sought opportunity to present facts to dispute EHP's views.
- UMVI had considerable delays in providing this information to EHP but a meeting took place on Friday 21 October to hear representations and to resolve a path forward.
- Information presented by UMVI did not significantly alter EHP's view regarding the need to issue an EPO but feedback in relation to grounds and requirements of the EPO requires further consideration by EHP.
- While UMVI were advised that an EPO continues to be the preferred approach to resolve the matter, the company objected to the use of any enforcement tool and indicated it would appeal any notice.
- UMVI also indicated a pre-disposition to engaging with media in relation to the issue if an enforcement tool is issued.

- EHP advised UMVI that a revised draft of the notice would be prepared this week and they would be provided 48 hours to comment prior to the notice being issued.
- At the meeting UMVI indicated strong objection to the EPO and indicated that the company would vigorously oppose any enforcement action through review, stay of decision and legal appeal.
- It is currently expected that an EPO will be issued during the week commencing 24 October 2016.

POTENTIAL IMPACTS / RISKS:

- Areas of contamination and historical disturbance (potentially mobilising contaminants to surface waters, ground waters and sediments) remain present on the site and if not addressed may cause environmental harm and ongoing non-compliance with the EA.
- EHP has also received further advice from DSITI regarding the uranium levels in soil at the site which indicates that contaminants are at levels that may cause harm to livestock. These potential risks will be addressed through the EPO
- There is significant community interest in the Ben Lomond project and there is high potential for the matter to be escalated to media attention potential for interest to be heightened regarding contamination at the site.

CUSTOMER ACTIONS:

- UMVI continues to carry out water monitoring at the mine site as required by the EA.
- UMVI is waiting for a final draft EPO or any other compliance response to review from EHP.

DEPARTMENT ACTIONS:
[HISTORICAL ACTIONS]

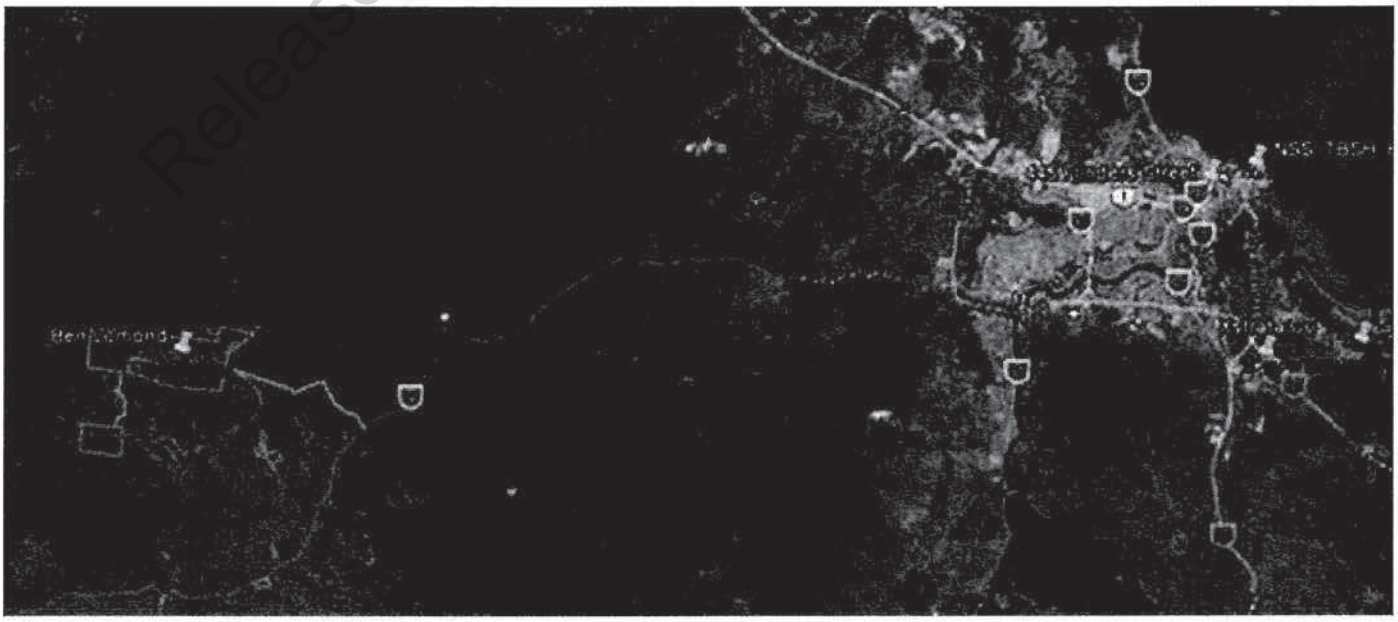
- EHP has to date conducted several compliance inspections at the Ben Lomond site.
- EHP has previously issued a notice to prepare an EE and has sent correspondence to UMVI and has met UMVI regarding the matters outlined in this alert.
- EHP provided UMVI with a draft copy of the proposed EPO on Thursday 9 June 2016 for consideration and feedback prior to issuing the notice.
- EHP met with UMVI on 21 October 2016.

PLANNED ACTIONS

- EHP intends to issue an EPO to UMVI requiring action to prevent the release of contaminants from the contaminant source areas on the mine site.
- EHP will provide UMVI with a final draft EPO 48 hours prior to issuing to provide opportunity for feedback.

LOCALITY DETAILS AND PHOTOGRAPHS:

- Ben Lomond uranium mine located approximately 50 km WSW of Townsville.



KEY COMMUNICATION MESSAGES:

- The Department of Environment and Heritage Protection (EHP) has issued Uranium Mineral Ventures Inc (UMVI) with an Environmental Protection Order to manage risks associated with contaminants being released from disturbed soils associated with historical mining activity.
- UMVI hold an Environmental Authority that authorises care and maintenance activities and exploration activities but **does not authorise** any mining, ore extraction or processing to take place.
- EHP takes the matter seriously and is requiring the company to take steps to ensure that previously disturbed areas are not contributing to contaminants in the receiving environment.

CONTACT DETAILS:

- Name: Rob Lawrence
- Phone number: (07) 4222 5338
- Division: ESR

This email is an initial alert in respect of this matter.
If further advice or action is required, it will be communicated via normal channels such as a briefing note.

END

Queensland Government

Rob Lawrence
Executive Director
Minerals & North Queensland Compliance
Department of Environment and Heritage Protection

P 07 42225338 **M** s.73
Level 3, 5b Sheridan Street, Cairns
PO Box 7230 Cairns, Q 4870

From: WALLACE Andrew [Andrew.Wallace@ehp.qld.gov.au]
Sent: Friday, 21 October 2016 1:52 PM
To: SULLIVAN Scott; FOMIATTI MINNESMA Ingrid (Ingrid.FomiattiMinnesma@ehp.qld.gov.au); BOOKER Rebecca; JOHNSTON Luke
Subject: FW: final uranium soil trigger report
Attachments: BenLomond risk assessment and soil trigger_revised_21-10-16_final.pdf

Hi , what timing, I Just received the final soil uranium review from DSITI
See attached

From: DUNLOP Jason
Sent: Friday, 21 October 2016 1:51 PM
To: WALLACE Andrew; CONNOLLY Niall (Niall.Connolly@ehp.qld.gov.au)
Cc: WITTE Christian; RAMSAY Ian; LOVEJOY Damian; MANN Reinier
Subject: final uranium soil trigger report

Hi Andrew and Niall,

Attached is the final version of the uranium soil trigger report for Ben Lomond. The report has been approved by DSITI for use by EHP. The final version has undergone internal and external reviews by Dr Susi Vardy, Principal Scientist DSITI and Dr Michael Warne, Senior Research Fellow, Coventry University and DSITI associate. The report has also benefited from input by Dick Watts, Principal Scientific Advisor and Qld AgVet Chemical Coordinator at Biosecurity Queensland, DAF.

Apologies this has taken some time to finalise. We have had a busy period so this one had to take a back seat for a while. Thanks for your patience.

Kind regards.

Jason

Dr Jason Dunlop
A/Senior Scientist
Water Assessment and Systems
Department of Science, Information Technology and Innovation

Adjunct Fellow
Centre for Water in the Minerals Industry
Sustainable Minerals Institute, University of Queensland

P 07 31705600
EcoSciences Precinct, Level 1 Block B, East Wing
41 Boggo Road, BRISBANE QLD 4102

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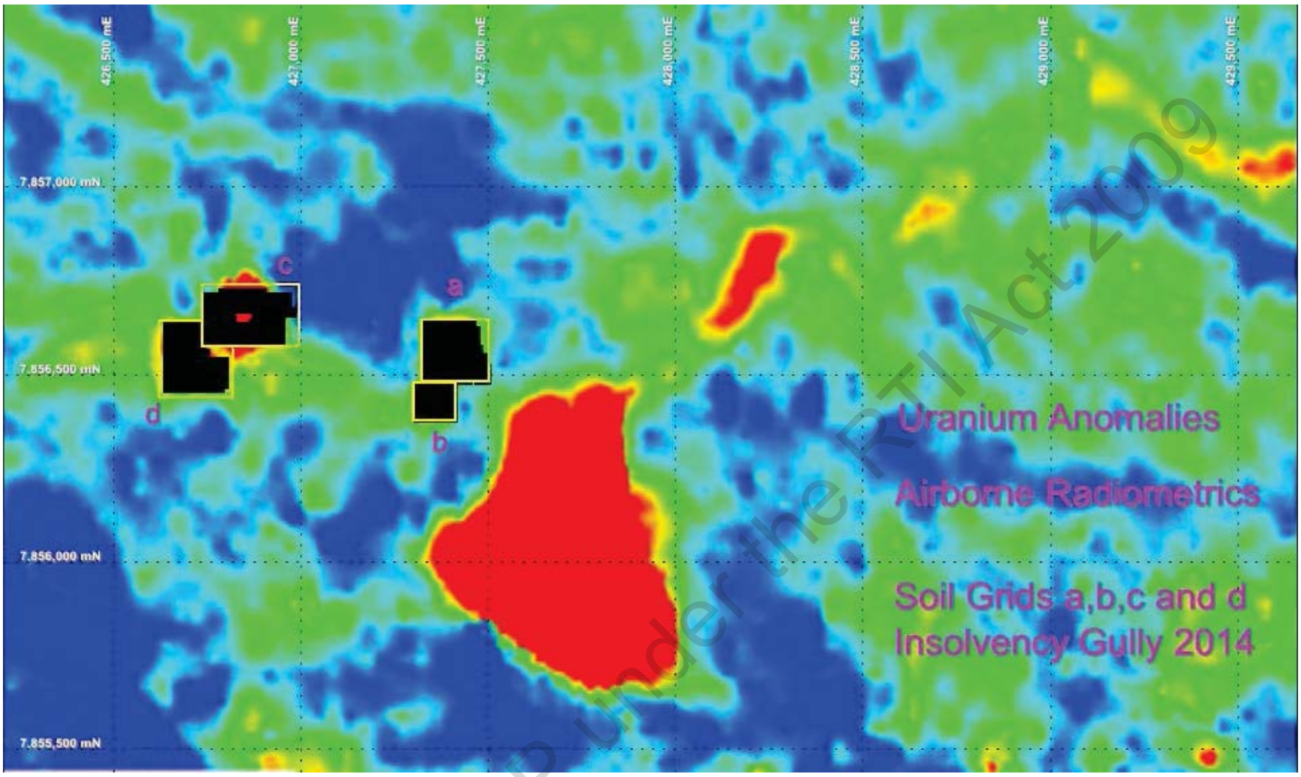
Department of Science, Information Technology and Innovation



Toxicity threshold value for uranium in soils for the protection of grazing cattle consequent to historical mining at Ben Lomond

Water Assessment and Systems, Science Division

August 2016

Queensland Government

Prepared by

Jason E. Dunlop and Reinier M. Mann
Water Assessment and Systems
Science Division
Department of Science, Information Technology and Innovation
PO Box 5078
Brisbane QLD 4001

This report that has been prepared specifically for use by the Department of Environment and Heritage Protection.

Disclaimer

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Citation

Dunlop, J.E., and Mann, R.M., 2016. Toxicity threshold value for uranium in soils for the protection of grazing cattle consequent to historical mining at Ben Lomond. Water Assessment and Systems, Queensland Department of Science, Information Technology and Innovation.

Acknowledgements

This report has been prepared by the Department of Science, Information Technology and Innovation. Acknowledgement is made of substantial input by Andrew Wallace and Niall Connelly from the Department of Environment and Heritage Protection. Input and oversight was provided Dr Ian Ramsay and reviews by Dr Michael Warne and Dr Suzanne Vardy are also appreciated.

Executive summary

The Ben Lomond Uranium-Molybdenum Project is situated approximately 50 kilometres south-west of the centre of Townsville on the western side of Hervey Range. Historical mining activities at Ben Lomond have potentially led to legacy contamination of soil, water and creek sediments. Uranium, as a marker of this contamination and a contaminant of concern has the potential to move within the soil and aquatic environment, and poses a potential risk to several environmental values as a consequence of soil and water contamination. The report focuses on the risks to the terrestrial environment in the immediate vicinity of areas potentially contaminated, where exposure to grazing cattle on site via ingestion or direct contact with soil and plants may occur. The report reviews the available soil quality criteria for uranium that may be used to evaluate the potential on-site impacts. As guidelines were not available for the protection of grazing cattle from uranium, and as there is no appropriate Australian method, a soil quality trigger was developed using approaches described in the Canadian guidelines (CCME, 2007). A toxicity threshold value for uranium in soils for the protection of grazing cattle was calculated as 239 mg/kg. Although this figure has some uncertainties associated with it, this trigger provides a basis for a preliminary assessment of risk based on current information. The merits of this and other soil quality guideline values are discussed. The report also discusses the chemical processes that are likely to influence the mobility of uranium in soil and water, and the pathways of exposure in the environment. Although not the focus of this report, future efforts may consider further evaluation of potential risk to groundwater and aquatic ecosystems including stream sediments. Options to further evaluate these risks, including site-specific evaluation of the risk to the environment are also considered.

Contents

List of tables

List of figures

Introduction

Ben Lomond is a uranium and molybdenum ore deposit owned by Uranium Mineral Ventures Incorporated (UMVI), a subsidiary of Mega Uranium LTD. It is an historical mine that is currently in care and maintenance (not operating). The Ben Lomond site is situated approximately 50 kilometres south-west of the centre of Townsville on the western side of Hervey Range. Ongoing surface and groundwater monitoring undertaken as part of the requirements of the existing Environmental Authority (EA) has identified a high proportion (20–90%) of samples collected at monitoring locations as having concentrations that exceed surface and groundwater limits for a range of water quality indicators.

The site is an area of natural mineralisation and has historically had mining and exploration activities undertaken on it. Although elevated contaminant concentrations may occur as a result of runoff from areas of natural mineralisation, the absence of pre-mining baseline data has hampered the efforts to quantify the contribution of contaminants from disturbed areas compared with natural areas. Due to ongoing non-compliance at EA monitoring sites, an Environmental Evaluation (EE) was issued under the Environmental Protection Act 1994 by the Department of Environment and Heritage Protection (EHP) on March 3, 2013. This EE required an investigation into the '*source, cause and extent of contamination on the site*'. The resultant EE report (AARC, 2013) suggested that the source of contaminants was largely natural. However, the EE report was found, by EHP, to not have satisfied this requirement. EHP requested an additional study be undertaken to evaluate temporal trends in water quality. That study (Golder Associates, draft 2014) found temporal trends in surface water quality were generally similar among sites.

Using the available historical monitoring data (provided by EHP on the 14/07/2014), draft local reference site-specific surface water quality trigger values were developed by the Water Assessment & Systems (WAS) group in the Science Division of the Department of Science, Information Technology and Innovation (DSITI). Review of the data against the newly developed draft trigger values indicated that most sites were compliant with the exception of sites SWM6 and SWM22 (see Figure 2).

Groundwater monitoring bores located in the vicinity of the covered ore stockpile had also recorded longstanding non-compliance with EA limits. At the request of EHP, a further study was undertaken by UMVI (UMVI, 2015) to evaluate the soils contaminant concentration in both unimpacted and disturbed areas of the site. That study identified several areas where material excavated from historical mining (waste rock) had been stockpiled in locations adjacent to the exploration adit (exploration occurred from 1976-1987). This material was used to construct haul roads, or stockpiled in areas of the valley floor before being stored in the covered ore shed or transported off site. This study also found that portal rock benches (areas where waste material was stockpiled) and haul roads that had been constructed of both mineralised rock from mining and local remnant soils, have since been eroded. Further studies, undertaken by UMVI, surveyed these features and estimated the volume of material exported as a result of erosional processes, and assessed the likelihood of further erosion occurring (Resource & Exploration Mapping Pty Ltd, 2014).

Given that there are a number of sources of contaminant export on-site, there is a need to understand what hazard these represent to the environment. Although a number of metals are present at elevated concentrations, at the request of EHP, the focus of this report is on uranium as it is thought to be a good indicator of mine related impacts. The report considers the chemical processes that are likely to influence the mobility of uranium in soil and water and the pathways of exposure in the environment.

To provide a basis for the assessment of options for soil management, EHP requested the determination of action levels for uranium in soils at the Ben Lomond site for the protection of grazing cattle. Accordingly, available soil quality criteria for uranium are reviewed and the merits of applying available and derived soil quality triggers are discussed. Options for further site-specific evaluation of the risk to the environment are also considered.

Mobility and potential impacts of uranium

Source of contaminants

The sources of contaminants on-site include the outcropping of the natural ore body and areas disturbed as a result of historic mining and exploration. Areas of disturbance include the exploration adit apron, haul road and waste rock dump (referred to as benches 1, 2 and 3) that intersect the natural ore body. In addition, there are four areas previously used for mine activities where airborne radiometrics indicated elevated concentrations of uranium and other radionuclides (referred to as areas a – d in Figure 1). The XRF Characterisation Report (UMVI, 2015) showed that disturbed areas can have relatively high concentrations of a range of metals, dominated by uranium, lead and arsenic. Areas with an elevated uranium concentration are shown in Figure 2 below. This figure also shows the proximity of 1st and 2nd order streams and ground and surface water monitoring locations.

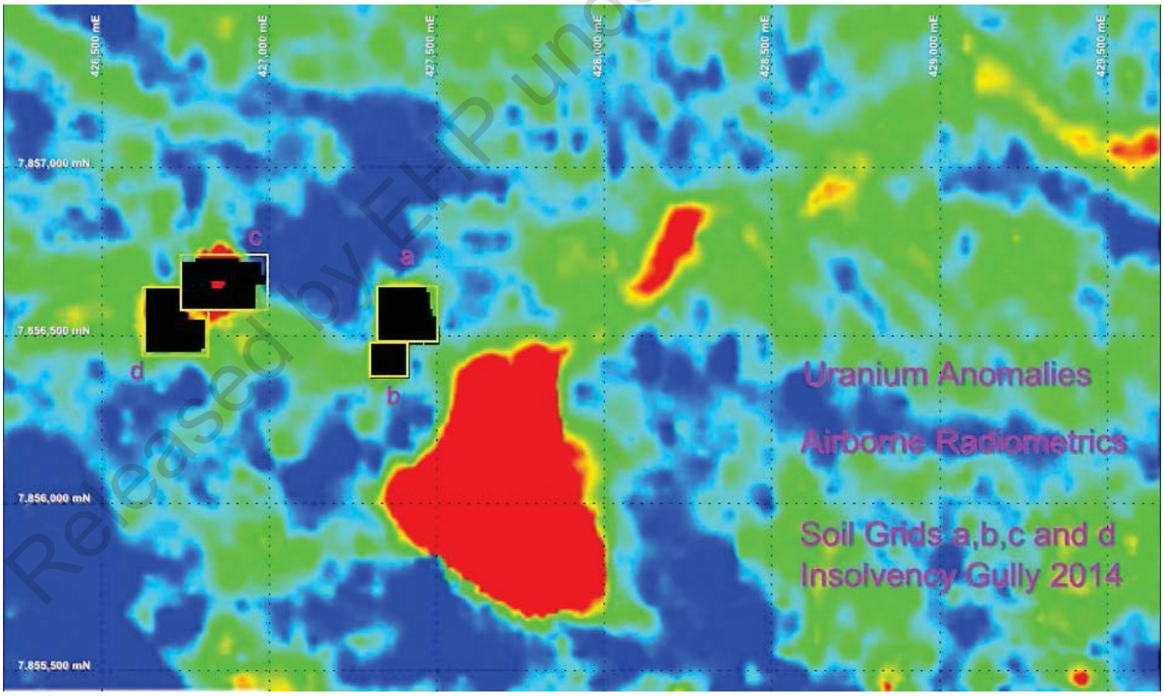

Figure 1. Location of areas a, b, c and d within Insolvency Gully, showing uranium gamma sources at the surface determined from airborne radiometry (source: UMVI, 2015). Concentration of uranium is greatest in red and least in blue.

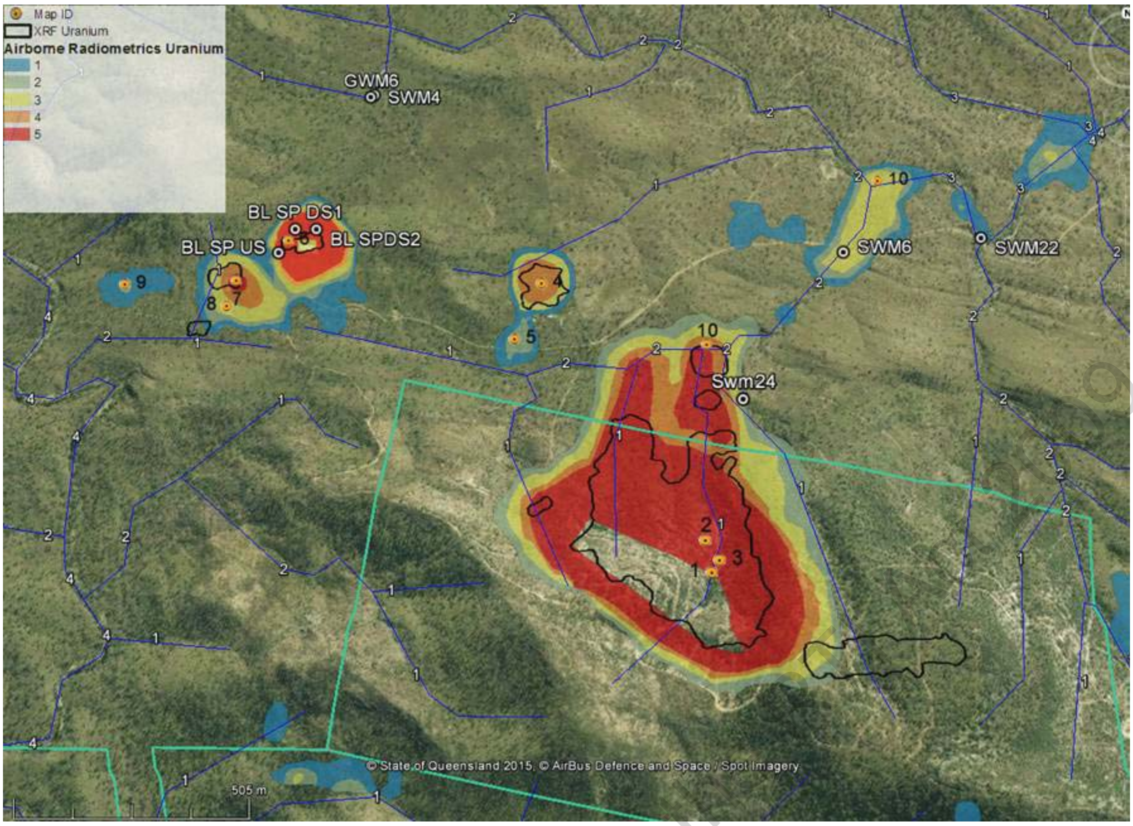

Figure 2. Airborne radiometrics survey showing uranium gamma sources in surface soils, the stream network and stream order (blue line), ground and surface water monitoring sites (map supplied by EHP). The lowest to highest concentration of uranium is soils is shown from 1 (blue) to 5 (red).

Conceptual model of contaminant transport and impacts

The conceptual model in Figure 3 is a simplified model that shows a range of processes likely to influence the mobility of contaminants from disturbed areas and potential environmental receptors. The figure shows the process of rainfall and erosion from disturbed areas, infiltration, seepage and runoff to surface waters. Although not depicted here, other exposure pathways can occur including cattle or wildlife drinking from surface waters and wind erosion and transport and deposition of uranium dust into waterways. Natural groundwater seeps are known to occur on site and may also be a source of uranium to surface waters.

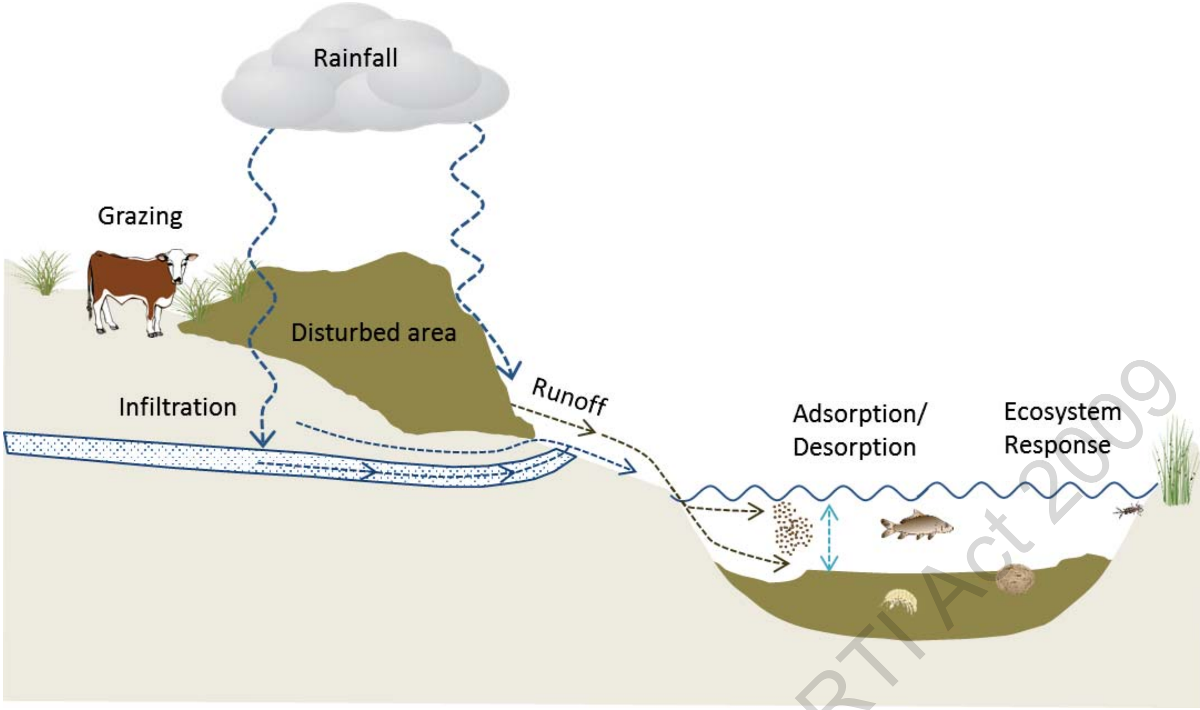

Figure 3. Simplified conceptual model of contaminant fate and effects in the environment at Ben Lomond. The blue hatched area represents a shallow aquifer and possible seepage.

Mobility of uranium in surface water run-off

Soluble forms of uranium can migrate with soil water, be taken up by plants or aquatic organisms or volatilise (Gavrilescu, et al., 2009). The oxidation state of uranium has a significant effect on its mobility, bioavailability and toxicity. Uranium can be present as U(IV), U(V), and U(VI) (Markich, 2002). Under anoxic conditions, uranium is in the tetravalent state (U(IV)) forming insoluble, immobile compounds. Under oxic conditions, uranium is in the hexavalent state (U(VI)) and is mobile, bioavailable, and tends to have higher toxicity (Bird, 2012). The dominant form of uranium in soils and oxidised waters is U(VI) that is present predominantly as the uranyl ion (UO_2^{2+}). Uranium (VI) is soluble and mobile but under oxidizing to mildly reducing conditions it forms soluble complexes with carbonate anions in natural waters (Gavrilescu, et al., 2009) and humic substances (e.g., uranyl fulvate) in dissolved, colloidal, and/or particulate forms (Markich, 2002). Sediments are a potential sink for contaminants and may have adverse effects on benthic macroinvertebrates and fish that feed on contaminated invertebrates (Bird, 2012).

Mobility of uranium within soils

Uranium mobility and partitioning in soil is dependent on the physical and chemical attributes of the soil such as soil composition (mineralogy and organic content), texture, pH and redox potential (E_h), temperature, soil texture, organic and inorganic compounds, moisture and microbial activity (Gavrilescu et al., 2009).

The key physicochemical property of inorganic contaminants that controls their potential movement to ground and/or surface waters is the soil−water partition coefficient (K_d) (NEPC, 2013a). This is the ratio of the concentration of a contaminant bound to the soil, to that dissolved in soil pore water at equilibrium. It is therefore related to the aqueous solubility of that contaminant (NEPC, 2013a). Increasing soil salinity has been found to mobilise U(VI) from soil exchange sites forcing it into solution (Rout et al., 2015) with the different ions known to have varying effects on mobility. The capacity of cations to provoke desorption is directly proportional to their ionic radius with large cations having a greater capacity than smaller cations (i.e. Ca^{2+} > Mg^{2+} > Na^{+}) (Rout et al., 2015). Many studies have shown that carbonate complexation reduces adsorption of uranium, thus leading to its release from soils (Gavrilescu et al., 2009). Uranium tends to occur in the solid phase at low redox potential (E_h) with the formation of dissolved uranium carbonate complexes at high E_h values (Gavrilescu et al., 2009). The presence of a high concentration of NO_3^- in ground water also has the potential to mobilise uranium by changing the redox potential of the environment (Rout et al., 2015).

Erosion, transport and deposition of uranium associated with particulates

Uranium associated with insoluble particulates may be transported via hydraulic and geomorphic processes. A study by ETS Geotechnical (2015) on behalf of UMVI indicated that fill batters and haul road have been eroding over the preceding 30 years and displayed signs of instability. In that study (ETS Geotechnical, 2015), batters were considered "*stable however, may be prone to instability during periods of intense rainfall*". Another report conducted on behalf of UMVI by Resource and Exploration Mapping (REM, 2014) provides estimates of the volume of material lost from drill pads and the haul road based on surveys of the estimated original and current landform. An estimated 298 m^3 of material has eroded from the three benches and haul road (REM, 2015).

It is likely that some of this material has been deposited in Bog Hole Creek, where it may pose a risk to sediment dwelling biota in the immediate vicinity of the site and further downstream. However, at this time there is limited information available describing the chemical composition of sediments in Bog Hole Creek.

Effect of uranium in the environment

Uranium can exhibit both radiological and chemical toxicity effects. A study by Mathews et al., (2009) showed that the risks to the environment as a consequence of uranium's chemical toxicity generally outweigh those of its radiological toxicity. Accordingly, direct chemical toxicity effects are the focus for ecological risk assessment. Uranium is comparatively less toxic than other metals (Goulet et al., 2011). However, Borgmann et al., (2005) found that uranium toxicity increases with decreasing water hardness. It does not biomagnify but is known to accumulate in bone, liver, and kidney tissue (Goulet et al., 2011).

Some uptake of uranium ions in vegetation is possible, although the degree to which this will occur is likely to be dictated by plant species (Bird, 2012). As the mining lease is subject to grazing, it is possible that metals present in soils and vegetation will pose a risk to beef cattle via consumption of plants and soil materials and ingestion of water from local water bodies. Most wild and domestic animals ingest some soil or sediment, and some species may routinely, or under special circumstances, ingest considerable amounts (Beyer & Fries, 2003). A study by Thornton and Abrahams (1983) found grazing cattle involuntarily ingest from 1% to nearly 18% of their dry matter intake as soil.

Although the intention of this report is to provide protection of grazing cattle, other species potentially at risk, include transitory wildlife, local plants, soil invertebrates and soil microbes that may also be exposed to soil and water on the site. Direct human contact with soils is not expected as access to the site is restricted.

Approach to assess and manage risk

Although the focus at this stage is on the effect of uranium in soils on grazing cattle, it is useful to consider how this aspect fits into a broader process of assessing the range of potential exposure pathways and receptors, as outlined in Figure 4. Depending on the outcome of risk assessment it may be necessary to implement strategies to contain contaminants and prevent potential impacts. Remediation strategies would require input from relevant experts but may include removing and covering material or implementing erosion and sediment control strategies to stabilise soils and capture those metals that might otherwise be mobilised in runoff and leachate. It may also be possible to limit or prevent stock and wildlife accessing contaminated areas.

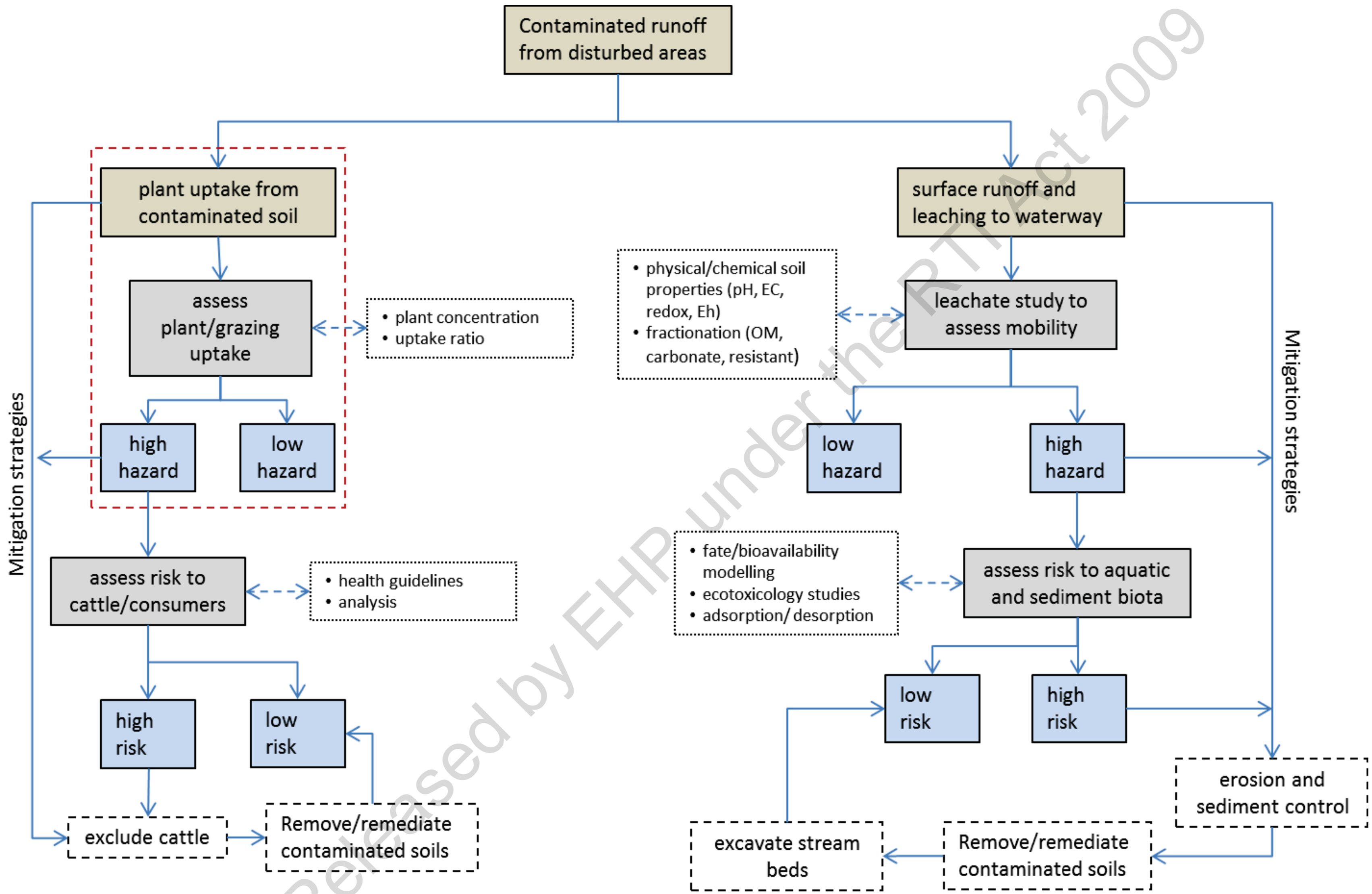

Figure 4. Assessment process for disturbed areas on the Ben Lomond lease area. Red dashed line shows the assessment being considered in this report.

Guidelines for uranium in soils

Ecological Investigation Levels (EILs) for contaminated soils are described in the National Environment Protection Measures (NEPMs) (NEPC, 2013a); however, these do not specify guidelines for uranium. In the absence of Australian ecological investigation levels for uranium, soil trigger values for uranium from other jurisdictions including those described in the Canadian soil quality guidelines (CCME, 2007) and those proposed by Sheppard et al., (2005) were considered. A summary of the available soil quality trigger values is provided in Table 1. The existing uranium trigger values had direct relevance to the protection of cattle as required for the Ben Lomond site.

Table 1. Summary of available uranium soil quality trigger values and a proposed trigger value to protect grazing animals.

Guideline category	Guideline value	Source
Protection for terrestrial plants	250 mg/kg	Sheppard et al., (2005)
Protection for soil biota including soil microbes and soil animals	100 mg/kg	Sheppard et al., (2005)
Protection for ‘agricultural land use’ (based on animal ingestion)	33 mg/kg	CCME (2007)
Protection of vascular plants and soil invertebrates (based on a species sensitivity distribution)	500 mg/kg	CCME (2007)
Protection for grazing animals (based on animal ingestion)	239 mg/kg	This report

Sheppard et al., (2005) recommended a Predicted No Observed Effect Concentration (PNEC) to be 250 mg/kg dry soil for the protection of plants, and 100 mg/kg dry soil for the protection of other soil biota including soil microbes and soil animals but did not consider higher vertebrates such as grazing cattle.

The Canadian guideline for exposure (SQG_E) relevant to ‘agricultural’ areas is 33 mg/kg (CCME, 2007). The ‘agricultural’ trigger value is considered the most relevant of the three land use categories in the CCME (2006) framework. This category refers to areas, “*where the primary land use is growing crops or tending livestock. This also includes agricultural lands that provide habitat for resident and transitory wildlife and native flora*” (CCME, 2006). With the exception of cropping, these exposure pathways are relevant to the Ben Lomond site. The (CCME 2007) trigger considers exposure via direct contact with soil, ingestion of soils as well as the ingestion of contaminated water by livestock at agricultural sites. The Canadian SQG_I (sediment quality for ingestion) was calculated using the Lowest Observed Adverse Effect Level (LOAEL) of 0.49 mg/kg bw/d for renal effects in New Zealand white rabbits. In that study, effect data for rabbits was used as it provided the most conservative assessment of effects for protection to biota relevant to ‘agricultural’ uses (CCME, 2007). The Canadian soil quality guideline for soil contact (SQG_{SC}) was derived using a species sensitivity distribution (SSD) approach that included 11 plant species and four invertebrate species from seven studies (CCME, 2007). The 25th percentile of the data distribution was 500 mg/kg (CCME, 2007).

This trigger is based on response data for vascular plants and soil invertebrates and did not include higher vertebrates such as grazing animals. The final Canadian soil quality guideline for uranium relevant to 'agricultural' land uses was adopted as the lower of the soil contact guideline (SQG_{SC}) and the soil and food ingestion guideline (SQG_I).

As none of the aforementioned triggers for soil were specific to cattle grazing, a trigger was developed by applying the approaches described in CCME (2006; 2007). This was achieved by substituting the food ingestion rate and effect data for rabbits with the Lowest Observed Adverse Effect Level (LOAEL) for observed effects in dairy cattle (Garner, 1963). Applying this approach, a Soil Quality Guideline for ingestion (SQG_I) was calculated as:

$$SQG_I = \frac{0.75 \times \mathrm{DTED} \times \mathrm{BW}}{(\mathrm{SIR} \times 1) + (\mathrm{FIR} \times \mathrm{BCF})}$$

where: SQG_I = Soil Quality Guideline – ingestion; 0.75 = a factor based on the assumption that water and dermal absorption/inhalation account for 25% of the total exposure and the remaining 75% of the total exposure is from food and soil ingestion (CCME 2006); DTED = daily threshold effects dose; BW = body weight; FIR = food ingestion rate; (calculated as dry matter ingestion rate (DMIR) – soil ingestion rate (SIR); BF = bioavailability factor; and BCF = soil to plant bio-concentration factor.

The study by Garner (1963) reported that a dose of 4 g uranium per day (as uranyl nitrate) over a period of 2 weeks resulted in deterioration in the general health of cattle and a decrease in milk yield, followed by a gradual return to an apparently normal state. The authors of that study assumed that a Lowest Observed Adverse Effect Level in cattle was likely to be represented by a 10 times lower dose (0.4 g/cow or 400 mg/cow). Garner (1963) suggested a slight depression in milk yield for one day only may occur at one tenth the dose which resulted in a deterioration in general health. The study refers to acute effects. Although no such data were available at the time of this study, the use of chronic effect data is expected to provide greater indication of long term animal health and may lead to more conservative estimates of toxicity.

In order to calculate a trigger specific for the protection of cattle we have assumed that a cow has a mass of 500 kg (Beyer & Fries, 2003). On this basis, a DTED for cattle is calculated as 400 ÷ 500 = 0.8 mg/kg bw/d. The response data are less than ideal as they are based only on the response of two individual cows to a single dosage rate and has a conservative assessment factor of 10 applied. Although based on a limited study, this represents the best available DTED and has been utilised in Canadian soil quality guideline (CCME 2007).

The CCME (2007) approach considers soil consumption to provide the primary route of exposure for grazing animals. Soil ingestion rate and percentage of soil in the diet of cattle was reported in Beyer & Fries (2003). In that study, the soil ingested by a 500 kg dairy cow (in a New Zealand study) was estimated to average 0.9 kg/day; it was assumed that dry matter intake was 15 kg/day and that cows grazed 365 days per year (i.e., SIR = 0.9 kg/day and FIR = 14.1 kg/day). Dry matter intake rate it is necessary to consider the conditions likely to affect pasture as soil intakes increases with aridness. The study referred to here was undertaken in New Zealand; however, it is recognised that in Queensland, conditions are likely drier and cattle may consume a greater volume of soil than reported in that study. Although estimates can vary, the dry matter intake rate used here is comparable with daily food intake estimates of 2.5% (as dry matter) of body weight applied by the American Petroleum Institute for risk-based screening levels for the protection of livestock (American Petroleum Institute, 2004).

The assumption regarding the average weight of a cow has implications for the magnitude of the DTED used in the equation, and flow-on effects on the magnitude of the SQG_I. The greater the assumed weight, the less conservative the soil trigger. We have assumed a weight of 500 kg as a conservative estimate rather than 650 kg as used in the Canadian guideline document. The bioavailability and uptake of uranium in animals is not well studied, so it was assumed that all uranium in ingested soil would be bioavailable (i.e., BF = 1). This was appropriate given the uranium administered the in the study by Garner (1963) was bioavailable. However, it is recognised that all uranium may not be bioavailable in the environment makes the estimate potentially conservative and increases uncertainty. The soil-to-plant bioconcentration factor (BCF) for uranium used for this calculation was that provided in CCME (2007), which was estimated by taking the geometric mean of all concentration ratios listed for plants, thereby resulting in a bioconcentration factor of 0.025.

By substituting the above values into the equation the following is obtained:

$$SQG_I = \frac{0.75 \times 0.8 \times 500}{(0.9 \times 1) + (14.1 \times 0.025)}$$

$$SQG_I = 239.5 \text{ mg/kg}$$

Discussion

This report addresses the need to derive a toxicity threshold value for uranium in soils for the protection of grazing cattle at the Ben Lomond project; however, a number of other possible routes of exposure and likely receptors were identified. These were runoff of contaminated soils into local waterways and the potential risk to aquatic and sediment biota. Although these receptors were not considered here, future evaluation should consider risks to those receptors.

The available trigger for the protection of ‘agricultural’ land use from the CCME (2007) of 33 mg/kg was considered overly conservative due to its use of a receptor (soil ingestion by rabbits) that was not considered relevant to the protection of grazing cattle. The Canadian soil quality guideline for soil contact (SQG_{SC}) of 500 mg/kg (CCME, 2007) did not consider potential response in vertebrate animals. A draft toxicity threshold value for uranium in soils was developed by substituting the available effect data for cattle using the Canadian approach (CCME, 2007). In lieu of established guidelines specifically designed to protect grazing cattle, the draft toxicity threshold value for uranium in soils calculated here of 239 mg/kg provides a basis for a preliminary assessment for protection of cattle, but would not necessarily provide a reliable basis for an assessment trigger or compliance limit that could provide protection to all environmentally relevant receptors. The Canadian approach to derive soil quality criteria shares similarities with the NEPC (2013a) but is not identical. Where there is a desire to further evaluate soil quality triggers, the approaches described in NEPC (2013a) should be applied.

Where specific action criteria are required (as requested in this case by EHP), a site-specific evaluation is recommended. More detailed site-specific investigations could consider aspects that are likely to influence risk, such as the physical and chemical characteristics of soils, leaching potential, and bioavailability of uranium in soil. An assumption made in the calculation of this toxicity threshold value for uranium in soils is the likely uptake of uranium in plants. As plant uptake will influence to the overall risk to grazing animals, there may be a need to assess the risk of uptake by plants found to occur locally. Schedule B2 of the National Environmental Protection Measures provides guidance on site characterisation (NEPC, 2013b). A further assumption is of constant exposure of cattle to contaminants. However, as cattle graze freely on the site, and as soil contaminant concentration varies spatially within the site, cattle will be exposed to varying contaminant concentrations. Because of these large uncertainties, the draft toxicity threshold value for uranium in soils derived through this process should be viewed as provisional.

Risk to cattle through drinking water may also be assessed against the ANZECC & ARMCANZ, (2000) guidelines for the protection of livestock water for uranium (0.2 mg U/L). Further considerations also include direct exposure to humans as a result of animal product consumption.

Additional considerations for environmental impacts include run-off from contaminated soil into local waterways and groundwaters. This exposure pathway has not been assessed at this time given the focus for assessment of soil contamination. Leachate studies are a useful way to determine the proportion of uranium and other metals likely to be soluble. Leachate studies could be undertaken by passing rainwater through a sample of soil collected from the site, and then analysing the concentrations of metals in the leachate. This would provide a direct measure of the likely solubility of metals taking into account the chemical and physical properties of the soils at the site. If leachate studies were to be conducted, then Australian Standard methods for soil or sediment sample collection techniques, study design and chemical analyses (AS4439.1, 1999; AS 4439.2, 1997 and AS 4439.3, 1997) or equivalent, should be used.

Assessment of potential impacts of uranium in aquatic ecosystems may be determined by comparing measured concentrations with the low reliability trigger value for uranium in freshwater ecosystems of 0.5 µg/L as derived using an assessment factor of 20 derived from limited chronic data (ANZECC & ARMCANZ, 2000). Since this trigger value was released, a site-specific chronic trigger value of 6 µg U/L was derived for 99% protection of species in Magela Creek downstream of the Ranger uranium mine in Kakadu National Park (Hogan et al., 2003). More recent studies have identified a national trigger value of 6.3 µg/L U would be protective of 95% of species (A Harford pers. comm. August 2016). A study by Sheppard et al., (2005) indicated a NOEC of 5 µg U/L was likely to be protective of most freshwater plants and invertebrates. The concentration of uranium in water at site SWM6 (located downstream of the ore body on Boghole Creek) has exceeded the licence limit of 20 µg/L on 67% of sampling occasions between 2007 and 2013 (Table 28, AARC, 2013). The maximum uranium concentration in that period was 570 µg/L. Elevated concentrations above established trigger values indicate toxicity is likely and that further evaluation is warranted.

There are currently no national uranium guidelines for sediment in Australia (Simpson et al., 2013). The study by Sheppard et al., (2005) proposed a Predicted No Effect Concentration (PNEC) for uranium of 100 mg/kg dry sediment as protective of freshwater benthos. In the absence of an Australian guideline for sediment, this value may be useful as a basis for initial assessment of risk. There are many factors that can influence the bioavailability and toxicity of uranium including the presence of calcium, magnesium, carbonates, phosphate, and dissolved organic matter (Goulet et al., 2011; 2015). Although it has not been possible to include information on the physical and chemical characteristics of soils at this time due to a lack of data, there is a need to consider such information in future assessments.

The soil quality trigger presented here provides a basis for an initial assessment of potential impacts to grazing cattle from ingestion of soil and plant matter only. Care must be taken in its application given the substantial uncertainty surrounding the toxicity estimates and exposure routes. Although ingestion of soil and plant matter to grazing cattle was evaluated here, as mentioned previously, it is important to note that there are a range of additional impacts that could be considered in a broader assessment of risk such as exposure of wildlife from soil ingestion, protection of soil biota, exposure of wildlife and cattle from drinking surface water, and aquatic ecosystem impacts.

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TROCCAZ Catherine

From: WALLACE Andrew
Sent: Friday, 21 October 2016 1:53 PM
To: SULLIVAN Scott; FOMIATTI MINNESMA Ingrid (Ingrid.FomiattiMinnesma@ehp.qld.gov.au); BOOKER Rebecca; JOHNSTON Luke
Subject: FW: final uranium soil trigger report
Attachments: BenLomond risk assessment and soil trigger_revised_21-10-16_final.pdf

Hi , what timing, I Just received the final soil uranium review from DSITI
See attached

From: DUNLOP Jason
Sent: Friday, 21 October 2016 1:51 PM
To: WALLACE Andrew; CONNOLLY Niall (Niall.Connolly@ehp.qld.gov.au)
Cc: WITTE Christian; RAMSAY Ian; LOVEJOY Damian; MANN Reinier
Subject: final uranium soil trigger report

Hi Andrew and Niall,

Attached is the final version of the uranium soil trigger report for Ben Lomond. The report has been approved by DSITI for use by EHP. The final version has undergone internal and external reviews by Dr Susi Vardy, Principal Scientist DSITI and Dr Michael Warne, Senior Research Fellow, Coventry University and DSITI associate. The report has also benefited from input by Dick Watts, Principal Scientific Advisor and Qld AgVet Chemical Coordinator at Biosecurity Queensland, DAF.

Apologies this has taken some time to finalise. We have had a busy period so this one had to take a back seat for a while. Thanks for your patience.

Kind regards.

Jason

Dr Jason Dunlop
A/Senior Scientist
Water Assessment and Systems
Department of Science, Information Technology and Innovation

Adjunct Fellow
Centre for Water in the Minerals Industry
Sustainable Minerals Institute, University of Queensland

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From: WALLACE Andrew [Andrew.Wallace@ehp.qld.gov.au]
Sent: Monday, 17 October 2016 11:05 AM
To: BROUGH Daniel
CC: HENNEY Nina
Subject: RE: Uranium in soils/sediment - natural v site disturbance

Thanks for that Dan,

I appreciate that some further contextual information would have helped with the review, though it looks clear that further monitoring is going to be needed.
We will keep working through the issues with the company, hopefully we have a resolution by this time next week.

If you have any further thoughts or queries please let me know.

Kind Regards, Andrew

From: BROUGH Daniel
Sent: Friday, 14 October 2016 4:21 PM
To: WALLACE Andrew <Andrew.Wallace@ehp.qld.gov.au>
Subject: RE: Uranium in soils/sediment - natural v site disturbance

Hi Andrew

I have had an initial look at the document.

The scenario does sound like it is likely to have the natural soil being elevated un uranium concentration if the ore body is close to the surface. To get an accurate comparison of the concentrations in the natural vs disturbed areas I would suggest some sampling from adjoining areas that are in the same landscapes. It appears the company has done some of this, but without knowing the location and layout of the site it was difficult to fully grasp.

Regards
Dan

Daniel Brough
Science Leader, Soil and Land Resources
Science Division
Department of Science, Information Technology and Innovation

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41 Boggo Road Dutton Park
GPO Box 5078 BRISBANE QLD 4001

From: WALLACE Andrew [mailto:Andrew.Wallace@ehp.qld.gov.au]
Sent: Wednesday, 12 October 2016 10:01 AM
To: Daniel Brough
Subject: Uranium in soils/sediment - natural v site disturbance

Hi Dan,

As discussed, could you please review this submission and provide any initial thoughts on the argument that uranium contaminants in soils/sediments are natural and not related to site disturbance?
We have a meeting with the company next Friday and would like to approach this meeting with a sound position on this matter.

I will also concurrently check geologic survey/services to attempt to gain a geology perspective.

Kind Regards, Andrew

Andrew Wallace
Senior Environmental Officer
North Queensland Compliance
Department of Environment and Heritage Protection

P 07 4722 5366 | **F** 07 4722 5351
Level 10 Verde Tower | 445 Flinders Street | Townsville Qld 4810
P.O. Box 5391 | Townsville Qld 4810

From: DUNLOP Jason [jason.dunlop@dsiti.qld.gov.au]
Sent: Tuesday, 11 October 2016 2:21 PM
To: WALLACE Andrew
Subject: FW: Garner paper and Canadian soil trigger for uranium

Hi Andrew,

As mentioned the soil trigger report has been approved for release to EHP. I have also received comments from Dick Watts in DAF. See comments below. I will need to go through these comments and revise the document but just need a half day. I will try to get a final version to you before next Friday.

Cheers,

Jason

Dr Jason Dunlop
A/Senior Scientist
Water Assessment and Systems
Department of Science, Information Technology and Innovation

Adjunct Fellow
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From: WATTS Richard J [mailto:Richard.Watts@daf.qld.gov.au]
Sent: Friday, 9 September 2016 1:33 PM
To: Jason Dunlop <jason.dunlop@dsiti.qld.gov.au>
Subject: RE: Garner paper and Canadian soil trigger for uranium

Jason

Thank you for the opportunity to comment on the paper, Toxicity threshold value for uranium soils for the protection of grazing cattle consequent to historical mining at Ben Lomond.

I think overall the approach is reasonably sound for animal health but there is fair amount of uncertainty in the value that perhaps could be further articulated for the purpose of guiding the understanding of any use of the value. The human health consideration really needs to move on from Garner 1963.

With regard to the specific assumptions, generally

- chemical estimates for cattle assume they weight 500 kg and consume 20 kg dry matter per day (see Joint FAO and WHO Meeting on Pesticide Residues and APVMA guidance documents).

- The estimates for soil intake in animals are always very difficult and there is quite a difference in the range reported. Generally, you find that most reference estimate about 1-2% of DM per day. However, you may note the American Petroleum Institute and the HHRA for Oakey uses 2.5% of BW. API give a nice summary of the literature in footnote 3 of table1 http://www.api.org/environment-health-and-safety/environmental-performance/~/~/media/files/ehs/environmental_performance/final_as_published_4733.ashx The key to choosing a value is consideration of conditions as soil intakes increases with aridness. Therefore, it is questionable whether a new Zealand study is the best choice for Queensland conditions. Perhaps some of the studies from Arizona might be applicable.
- Bioavailability has been set at 1 because it is believed that uranyl nitrate is completely bioavailable. By contrast, EFSA report that uranium oral bioavailability is limited, and only up to 1-2 % of soluble uranium and 0.2 % of insoluble uranium is absorbed (EFSA human dietary risk assessment). https://www.efsa.europa.eu/en/efsajournal/pub/1018 Therefore, although uranyl nitrate may be bioavailable, it is plausible that uranium in soil has low bioavailability. In essence, plenty of uncertainty.

With regard to the cattle toxicity

- Garner 1963, as noted in the report, did a very limited study using 2 animals and 1 intake level. He then estimates a lower level that might produce an acute effect via reduction in milk production. I suggest that this estimate is probably an effect on commercial agriculture rather than on animal health per se. It is plausible that animal effects occur before milk production is affected given that in the critical toxicology study in rats from which the tolerable daily intake was estimates, the critical effect was degenerative kidney lesions. It should also be noted that the rat study was sub chronic (91 days) rather than acute as estimated by Garner. In essence, plenty of uncertainty.

With regard to whether values set for animal health would be protective of human health via consumption of animal tissues.

- Garner is obviously quite dated as reference for human health. His calculations about tissue concentrations were determined assuming even body distribution in an animal. This is obviously quite an unsophisticated approach but the only one possible in the absence of data. However it should also be noted that Garner did not apply the safety factors that occurs in human dietary risk assessment. The current human dietary risk assessment models weren't agreed internationally until well after 1963. It is margin of exposure calculation rather a margin of safety. Human dietary risk assessment is conducted at the individual level rather than a population level (as would be applicable to animals).
- Since then a tolerable daily intake (TDI) of 0.0006 mg per kg bodyweight per day has been derived by WHO (2004) for soluble uranium and adopted by Health Canada (2001), EFSA and Australia (NHMRC). This is based on a lowest-observed-adverse-effect level (LOAEL) of between 0.06 (males) and 0.09 (females) mg/kg bw/day in a 91-day rat drinking water study (Gilman et al. 1998) and application of an uncertainty factor of 100 (10 for interspecies extrapolation and 10 for intraspecies variation). If the TDI is 0.6 ug/bw/day then a 70 kg person can safely consume less than 0.042 mg/day.
- For the general population the 90th percentile consumption is 4.26 g/kg bw/day of meat mammalian. For a 70 kg person that is 298g meat mammalian.
- Therefore the acceptable concentration in the meat mammalian is 0.012 mg/kg.
- There is no transfer study for cattle. The best estimate comes from Thomas and Gates 1999 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1566655/pdf/envhper00512-0055.pdf for caribou feeding on Lichen. They estimate a dw transfer factor of 0.048 for feed intake to muscle.
- General literature suggest caribou eat ~5 to 6 kg per day. (assumed to be DM)
- This equates to 0.25 mg/kg in feed (dw) or a total exposure of 1.5 mg of soluble U/ day.
- Using this value one can estimate the maximum concentration in soil that would be acceptable for cattle used as human food. The key is knowing how much soluble U there is per Kg of soil.

regards

Dick Watts
Principal Scientific Advisor and Qld AgVet Chemical Coordinator
Biosecurity Queensland
Department of Agriculture and Fisheries

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From: DUNLOP Jason
Sent: Friday, 2 September 2016 9:46 AM
To: WATTS Richard J
Subject: Garner paper and Canadian soil trigger for uranium

Here are the two Garner papers. There was an update from the original 1963 paper in 1965. The Canadian soil trigger is also attached.

Cheers,

Jason

Dr Jason Dunlop
A/Senior Scientist
Water Assessment and Systems
Department of Science, Information Technology and Innovation

Adjunct Fellow
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DAUNT Bettina

From: SULLIVAN Scott
Sent: Monday, 26 September 2016 5:05 PM
To: ELLWOOD Dean
Subject: FW: For comment

Queensland Government

Dean

FYI

- Water quality limits in the Ben Lomond licence were largely set based on the 1996 drinking water quality guidelines
- The water quality limits are generally more stringent than stock values and aquatic ecosystem protection values
- Most EA's use a combination of drinking, stock and aquatic ecosystem protection values.
- The Ben Lomond EA considered the higher risk when setting more stringent values.
- The exceedances in a number of cases are below the stock and aquatic ecosystem protection values
- The parameters that are monitored include:
  - Total dissolved Solids (TDS)
  - Arsenic
  - Lead
  - Zinc
  - Molybdenum
  - Mercury
  - Copper
  - pH
  - Mobile Uranium (the metal)
  - Radium -226 (a radiation indicator)
  - Gross alpha and gross beta radiation (radiation indicators)
- Each of these parameters have previously been demonstrated to occur naturally through normal mineralisation as well as from historical mine disturbed areas.
- The health risk is not quantified and it is difficult to understand and distinguish the natural impact from mining activity sources.
- At Ben Lomond, the downstream limits have previously been exceeded particularly in relation to TDS, Arsenic, Gross Alpha and Beta Radiation, Lead, Mobile Uranium, Mercury and Radium-226
- Surface waters from the mine do not immediately report to drinking water sources and the mine is approximately 100km from the Charters Towers water supply, the Burdekin River.
- However the mine is located within the Burdekin River catchment so there is potential for the migration of contaminants.
- The Department of Environment and Heritage Protection is endeavouring to secure additional controls on site to minimise the risk of any mine related contamination from impacting water quality.

Scott Sullivan
A/Director Minerals
Minerals & North Queensland Compliance| Environmental Services & Regulation
Department of Environment and Heritage Protection

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5b Sheridan Street Cairns Q 4870 Postal address: PO Box 7230 Cairns Q 4870

From: MANN Reinier [reinier.mann@dsiti.qld.gov.au]
Sent: Tuesday, 23 August 2016 6:51 PM
To: DUNLOP Jason; CONNOLLY Niall; WALLACE Andrew
Subject: Re: U guidelines
Attachments: BenLomond risk assessment and soil trigger_revised_19-08-16_final.docx

Hi Jason

Edits and comments attached. We may need to discuss a few things

cheers

Reinier

From: Jason Dunlop
Sent: Tuesday, 23 August 2016 2:32:21 PM
To: CONNOLLY Niall; WALLACE Andrew
Cc: Reinier Mann
Subject: RE: U guidelines

Hi Niall and Andrew.

Here is the (near) final version after that incorporates comments from the reviewers. Given there were some changes I have sent this version to Reinier for a final read. If you could take a look also at the same time that would be great.

The toxicity trigger for cattle has not changed as a result of the review. I have added in greater explanation of the implications for assumptions made and added some additional references to qualify some of the statements made about the fate of uranium.

I decided not to put the additional information in the report on leachate concentrations at this stage given this would slow the release of the report.

The leachate data you collected was quite good though. It would be interesting to combine it with aquatic ecosystem and sediment data in an assessment but we can consider that in future if needed.

Jason

From: CONNOLLY Niall [mailto:Niall.Connolly@ehp.qld.gov.au]
Sent: Tuesday, 23 August 2016 1:33 PM
To: Jason Dunlop <jason.dunlop@dsiti.qld.gov.au>; WALLACE Andrew <Andrew.Wallace@ehp.qld.gov.au>
Cc: Reinier Mann <reinier.mann@dsiti.qld.gov.au>
Subject: RE: U guidelines

Thanks Jason,

I have just got back from s.73 [redacted] and Andrew is [redacted] This will be very timely information.

Cheers
Niall

From: DUNLOP Jason
Sent: Friday, 19 August 2016 9:29 AM
To: WALLACE Andrew; CONNOLLY Niall
Cc: MANN Reinier
Subject: U guidelines

Hi Andrew and Niall,

I have a review of the report on uranium triggers in soils back from Michael Warne and Susi Vardy. So far I have updated the report with Michael's comments and am going through Susi's at the moment.

Once complete I will submit the report for approvals to release. Hopefully final sign off shouldn't take too long.

I have also been in touch with Andrew Harford from Environmental Research Institute of the Supervising Scientist (ERISS) to make sure we were referencing the most current aquatic ecosystem protection trigger for Uranium in water. There will be a new national guideline coming out but this not published as yet. Interestingly it has been revised down substantially from previous numbers to 6.3 µg/L for 95% species protection (see toxicity report attached). We can reference this new number in the report using a pers comm. Also ERISS have released a radiological trigger for uranium mine rehabilitation of 1000 Bq/kg Ra based on goanna exposure.

Jason

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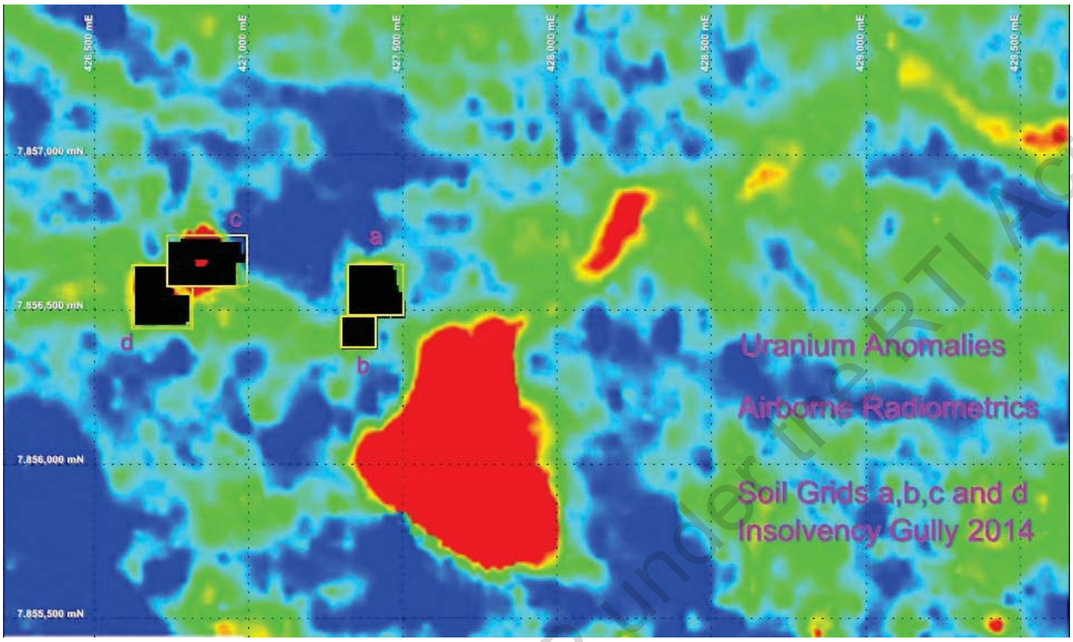

Toxicity threshold value for uranium in soils for the protection of grazing cattle consequent to historical mining at Ben Lomond

Water Assessment and Systems

August 2016

Queensland Government

Prepared by

Jason E. Dunlop and Reinier M. Mann
Water Assessment and Systems
Science Delivery Division
Department of Science, Information Technology and Innovation
PO Box 5078
Brisbane QLD 4001

This report that has been prepared specifically for use by the Department of Environment and Heritage Protection.

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Citation

Dunlop, J.E., and Mann, R.M., 2016. Toxicity threshold value for uranium in soils for the protection of grazing cattle consequent to historical mining at Ben Lomond. Water Assessment and Systems, Queensland Department of Science, Information Technology and Innovation.

Acknowledgements

This report has been prepared by the Department of Science, Information Technology and Innovation. Acknowledgement is made of contributions by Andrew Wallace and Niall Connelly from the Department of Environment and Heritage Protection. Input and oversight was provided Dr Ian Ramsay and reviews by Dr Michael Warne and Dr Suzanne Vardy are also appreciated.

Executive summary

The Ben Lomond Uranium-Molybdenum Project is situated approximately 50 kilometres south-west of the centre of Townsville on the western side of Hervey Range. Historical mining activities at Ben Lomond have potentially led to legacy contamination of soil, water and creek sediments. Uranium, as a marker of this contamination and a contaminant of concern has the potential to move within the soil and aquatic environment, and poses a potential risk to several environmental values as a consequence of soil and water contamination. The report ~~focusses~~focuses on the risks to the terrestrial environment in the immediate vicinity of areas potentially contaminated, where exposure to grazing cattle on site via ingestion or direct contact with soil and plants may occur. The report reviews the available soil quality criteria for uranium that may be used to evaluate the potential on-site impacts. As guidelines were not available for the protection of grazing cattle from uranium, and as there is no appropriate Australian method, a soil quality trigger was developed using approaches described in the Canadian guidelines (CCME, 2007). A toxicity threshold value for uranium in soils for the protection of grazing cattle was calculated as 239 mg/kg. Although this figure has some uncertainties associated with it, this trigger provides a basis for a preliminary assessment of risk based on current information. The merits of this and other soil quality guideline values are discussed. ~~It~~ The report also discusses the chemical processes that are likely to influence the mobility of uranium in soil and water, and the pathways of exposure in the environment. Although not the focus of this report, future efforts may consider further evaluation of potential risk to groundwater and aquatic ecosystems including stream sediments. Options to further evaluate these risks, including site-specific evaluation of the risk to the environment are also considered.

Contents

List of tables

List of figures

Introduction

Ben Lomond is a uranium and molybdenum ore deposit owned by Uranium Mineral Ventures Incorporated (UMVI), a subsidiary of Mega Uranium LTD. It is an historical mine that is currently in care and maintenance (not operating). The Ben Lomond site is situated approximately 50 kilometres south-west of the centre of Townsville on the western side of Hervey Range. Ongoing surface and groundwater monitoring undertaken as part of the requirements of the existing Environmental Authority (EA) has identified a high proportion (20–90%) of samples collected at monitoring locations ~~have~~ as having ~~values~~ concentrations that exceed surface and groundwater limits for a range of water quality indicators.

The site is an area of natural mineralisation and has historically had mining and exploration activities undertaken on it. Although elevated contaminant concentrations may occur as a result of runoff from areas of natural mineralisation, the absence of pre-mining baseline data has hampered the efforts to quantify the contribution of contaminants from disturbed areas compared with natural areas. Due to ongoing non-compliance at EA monitoring sites, an Environmental Evaluation (EE) was issued under the Environmental Protection Act 1994 by the Department of Environment and Heritage Protection (EHP) on March 3, 2013. This EE required an investigation into the '*source, cause and extent of contamination on the site*'. The resultant EE report (AARC, 2013) suggested that the source of contaminants was largely natural. However, the EE report was found, by EHP, to ~~not have satisfied~~ be unsatisfactory in this requirement. EHP requested an additional study be undertaken to evaluate temporal trends in water quality. That study (Golder Associates, draft 2014) found temporal trends in surface water quality were generally similar among sites.

Using the available historical monitoring data (provided by EHP on the 14/07/2014), draft local reference site-~~based~~ specific surface water quality trigger values were developed by the Water Assessment & Systems (WAS) group of the Department of Science, Information Technology and Innovation (DSITI). Review of the data against the newly developed draft trigger values indicated that most sites were compliant with the exception of sites SWM6 and SWM22 (see Figure 1).

Groundwater monitoring bores located in the vicinity of the covered ore stockpile had also recorded longstanding non-compliance with EA limits. At the request of EHP, a further study was undertaken by UMVI (UMVI, 2015) to evaluate the soils contaminant concentration in both unimpacted and disturbed areas of the site. That study identified several areas where material excavated from historical mining (waste rock) had been variously stockpiled adjacent to the exploration adit (used for exploration from 1976-1987), ~~and was~~ used to construct haul roads, or stockpiled in areas of the valley floor before being stored in the covered ore shed or transported off site. This study also found that portal rock benches (areas where waste material was stockpiled) and haul roads that had been constructed of both mineralised rock from mining and local remnant soils, have since been eroded. Further studies, undertaken by UMVI, surveyed these features and estimated the volume of material exported as a result of erosional processes, and assessed the likelihood of further erosion occurring (Resource & Exploration Mapping Pty Ltd, 2014).

Given that there are a number of sources of contaminant export on-site, there is a need to understand what hazard these represent to the environment. Although a number of metals are present at elevated concentrations, at the request of EHP, the focus of this report is on

Comment [RM1]: doesn't say draft in reference list

Comment [RM2]: is this a public document?

Comment [RM3]: Actually these sites are shown on Figure 2

Comment [RM4]: is this a public document?

Comment [RM5]: is this a public document?

uranium as it is thought to be a good indicator of mine related impacts. The report considers the chemical processes that are likely to influence the mobility of uranium in soil and water and the pathways of exposure in the environment.

To provide a basis for the assessment of options for soil management, EHP requested the determination of action levels for uranium in soils at the Ben Lomond site for the protection of grazing cattle. Accordingly, available soil quality criteria for uranium are reviewed and the merits of applying available and derived soil quality triggers are discussed. Options for further site-specific evaluation of the risk to the environment are also considered.

Mobility and potential impacts of uranium

Source of contaminants

The sources of contaminants on-site include the outcropping of the natural ore body and areas disturbed as a result of historic mining and exploration. Areas of disturbance include the exploration adit apron, haul road and waste rock dump (referred to as benches 1, 2 and 3) that intersect the natural ore body. In addition, there are four areas previously used for mine activities where airborne radiometrics indicated elevated concentrations of uranium and other radionuclides (referred to as areas a – d in Figure 1). The XRF Characterisation Report (UMVI, 2015) showed that disturbed areas can have relatively high concentrations of a range of metals, dominated by uranium, lead and arsenic. Areas with an elevated uranium concentration are shown in Figure 2 below. This figure also shows the proximity of 1st and 2nd order streams and ground and surface water monitoring locations.

Comment [RM6]: is this a public document?

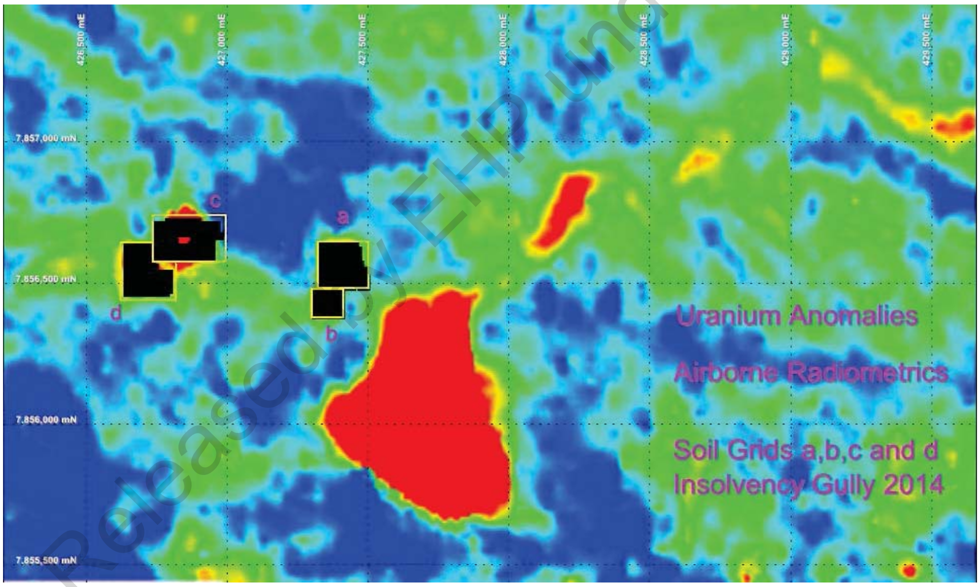

Figure 1. Location of areas a, b, c and d within Insolvency Gully, showing uranium gamma sources at the surface determined from airborne radiometry (source: UMVI, 2015). Concentration of uranium is greatest in red and least in blue.

Comment [RM7]: is this a public document?

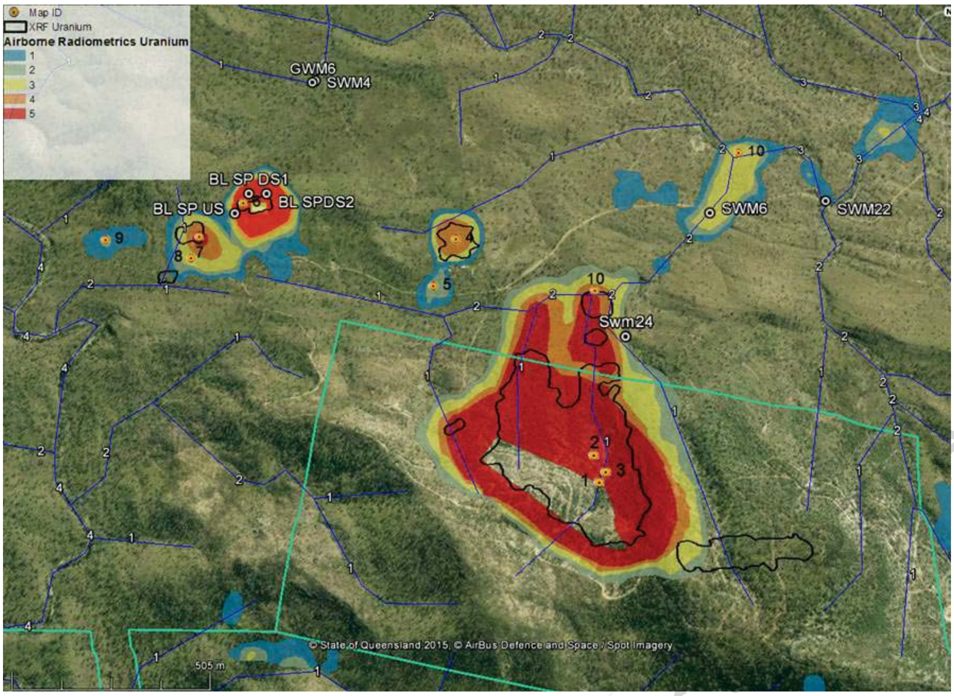

Figure 2. Airborne radiometrics survey showing uranium gamma sources in surface soils, the stream network and stream order (blue line), ground and surface water monitoring sites (map supplied by EHP). The lowest to highest concentration of uranium is soils is shown from 1 (blue) to 5 (red).

Conceptual model of contaminant transport and impacts

The conceptual model in Figure 3 is a simplified model that shows a range of processes likely to influence the mobility of contaminants from disturbed areas and potential environmental receptors. The figure shows the process of rainfall and erosion from disturbed areas, infiltration, seepage and runoff to surface waters. Although not depicted here, other exposure pathways can occur including cattle or wildlife drinking from surface waters and wind erosion and transport and deposition of uranium dust into waterways. Natural groundwater seeps are known to occur on site and may also be a source of uranium to surface waters.

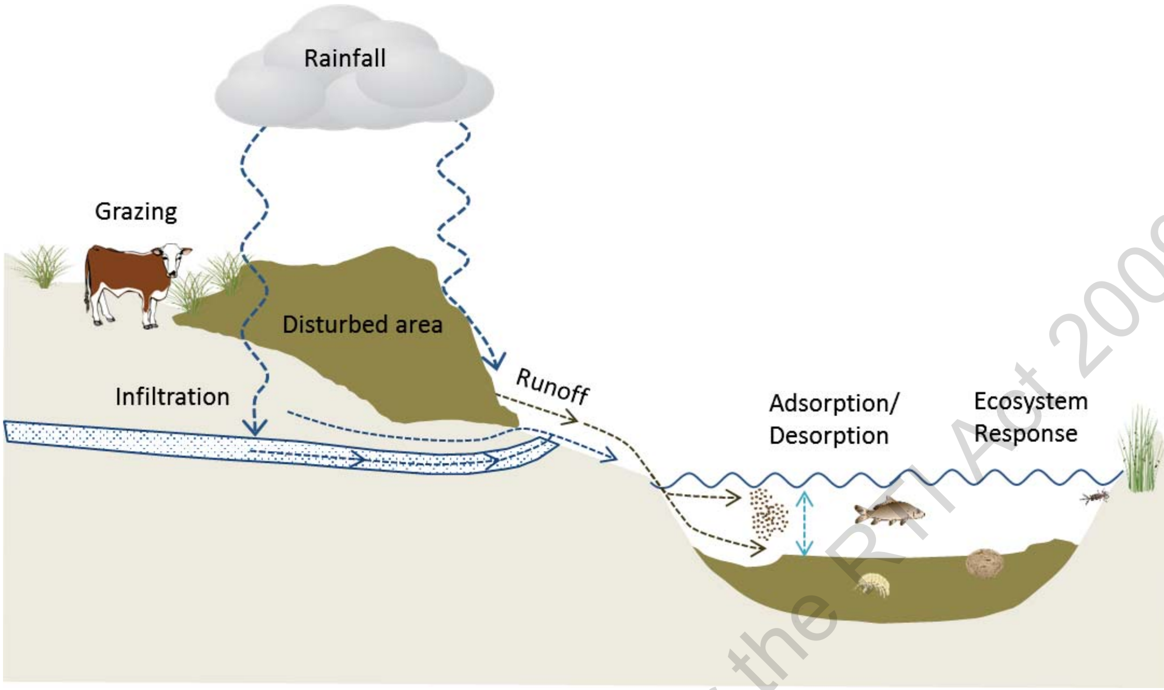

Figure 3. Simplified conceptual model of contaminant fate and effects in the environment at Ben Lomond. The blue hatched area represents a shallow aquifer and possible seepage.

Mobility of uranium in surface water run-off

Soluble forms of uranium can migrate with soil water, be taken up by plants or aquatic organisms or volatilise (Gavrilescu, et al., 2009). The oxidation state of uranium has a significant effect on its mobility, bioavailability and toxicity. Uranium can be present as U(IV), U(V), and U(VI) (Markich, 2002). Under anoxic conditions, uranium is in the tetravalent state (U(IV)) forming insoluble, immobile compounds. ~~and is immobile whereas u~~Under oxic conditions, uranium is in the hexavalent state (U(VI)) and is mobile, bioavailable, and tends to have higher toxicity (Bird, 2012). The dominant form of uranium in soils and oxidised waters is U(VI) that is present predominantly as the uranyl ion (UO_2^{2+}). Uranium (VI) is soluble and mobile but under oxidizing to mildly reducing conditions it forms soluble complexes with carbonate anions in natural waters (Gavrilescu, et al., 2009) and humic substances (e.g., uranyl fulvate) in dissolved, colloidal, and/or particulate forms (Markich, 2002). Sediments are a potential sink for contaminants and may have adverse effects on benthic macroinvertebrates and fish that feed on contaminated invertebrates (Bird, 2012).

Mobility of uranium within soils

Uranium mobility and partitioning in soil is dependent on the physical and chemical attributes of the soil such as soil composition (mineralogy and organic content), texture, pH and redox potential (E_h~~Eh~~), temperature, soil texture, organic and inorganic compounds, moisture and microbial activity (Gavrilescu et al., 2009).

The key physicochemical property of inorganic contaminants that controls their potential movement to ground and/or surface waters is the soil−water partition coefficient (K_d) (NEPC, 2013a). This is the ratio of the concentration of a contaminant bound to the soil, to that dissolved in soil pore water at equilibrium. It is therefore related to the aqueous solubility of that contaminant (NEPC, 2013a). Increasing soil salinity has been found to mobilise U(VI) from soil exchange sites forcing it into solution (Rout et al., 2015) with the different ions known to have varying effects on mobility. The capacity of cations to provoke desorption is directly proportional to their ionic radius with large cations having a greater capacity than smaller cations (i.e. Ca^{2+} > Mg^{2+} > Na^{+}) (Rout et al., 2015). Many studies have shown that carbonate complexation reduces adsorption of uranium, thus leading to its release from soils (Gavrilescu et al., 2009). Uranium tends to occur in the solid phase at low redox potential (E_h) with the formation of dissolved uranium carbonate complexes at high E_h values (Gavrilescu et al., 2009). The presence of a high concentration of NO_3^- in ground water also has the potential to mobilise uranium by changing the redox potential of the environment (Rout et al., 2015).

Erosion, transport and deposition of uranium associated with particulates

Uranium associated with insoluble particulates may be transported via hydraulic and geomorphic processes. A study by ETS Geotechnical (2015) on behalf of UMVI indicated that fill batters and haul road have been eroding over the preceding 30 years and displayed signs of instability. In that study (ETS Geotechnical, 2015), batters were considered "*stable however, may be prone to instability during periods of intense rainfall*". Another report conducted on behalf of UMVI by Resource and Exploration Mapping (REM, 2015) provides estimates of the volume of material lost from drill pads and the haul road based on surveys of the estimated original and current landform. An estimated 298 m^3 of material has eroded from the three benches and haul road (REM, 2015).

Comment [RM8]: Is this a public document?

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Comment [RM9]: Is this a public document? It's not in the bibliography!

It is likely that some of this material has been deposited in Bog Hole Creek, where it may pose a risk to sediment dwelling biota in the immediate vicinity of the site and further downstream. However, at this time there is limited information available describing the chemical composition of sediments in Bog Hole Creek.

Effect of uranium in the environment

Uranium can exhibit both radiological and chemical toxicity effects. A study by Mathews et al., (2009) showed that the risks to the environment as a consequence of uranium's chemical toxicity generally outweigh those of its radiological toxicity. Accordingly, direct chemical toxicity effects are the focus for ecological risk assessment. Uranium is comparatively less toxic than other metals (Goulet et al., 2011). However, Borgmann et al., (2005) found that uranium toxicity increases with decreasing water hardness. It does not biomagnify but is known to accumulate in bone, liver, and kidney tissue (Goulet et al., 2011).

Some uptake of uranium ions in vegetation is possible, although the degree to which this will occur is likely to be dictated by plant species (Bird, 2012). As the mining lease is subject to grazing, it is possible that metals present in soils and vegetation will pose a risk to beef cattle via consumption of plants and soil materials and ingestion of water from local water bodies. Most wild and domestic animals ingest some soil or sediment, and some species may routinely, or under special circumstances, ingest considerable amounts (Beyer & Fries, 2003). A study by Thornton and Abrahams (1983) found grazing cattle involuntarily ingest from 1% to nearly 18% of their dry matter intake as soil.

Although the intention of this report is to provide protection of grazing cattle, other species potentially at risk, include transitory wildlife, local plants, soil invertebrates and soil microbes that may also be exposed to soil and water on the site. Direct human contact with soils is not expected as access to the site is restricted.

Approach to assess and manage risk

Although the focus at this stage is on the effect of uranium in soils on grazing cattle, it is useful to consider how this aspect fits into a broader process of assessing the range of potential exposure pathways and receptors, as outlined in Figure 4. Depending on the outcome of risk assessment it may be necessary to implement strategies to contain contaminants and prevent potential impacts. ~~is outlined in Figure 4.~~ Remediation strategies would require input from relevant experts but may include removing and covering material or implementing erosion and sediment control ~~practices~~ strategies to stabilise soils and capture those metals that might otherwise be mobilised in runoff and leachate. It may also be possible to limit or prevent stock and wildlife accessing contaminated areas.

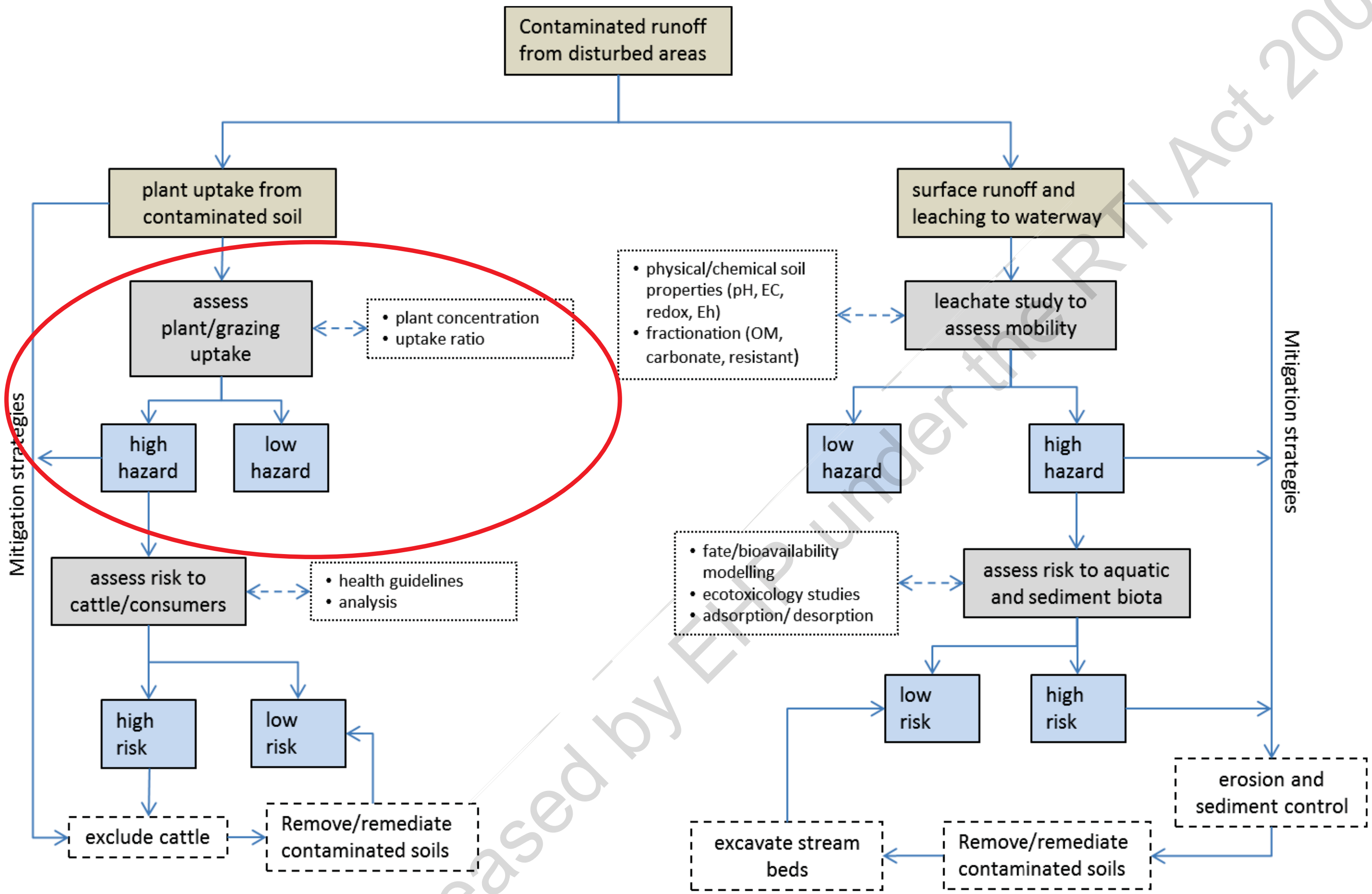

Figure 4. Assessment process for disturbed areas on the Ben Lomond lease area. Red circle shows the assessment being considered in this report.

Guidelines for uranium in soils

Ecological Investigation Levels (EILs) for contaminated soils are described in the National Environment Protection Measures (NEPMs) (NEPC, 2013a); however, these do not specify guidelines for uranium. In the absence of Australian ecological investigation levels for uranium, soil trigger values for uranium from other jurisdictions including those described in the Canadian soil quality guidelines (CCME, 2007) and those proposed by Sheppard et al., (2005) were considered. A summary of the available soil quality trigger values is provided in Table 1. Neither of the existing uranium trigger values had direct relevance to the protection of cattle as required for the Ben Lomond site.

Comment [RM10]: Neither suggests two – which one are they?

Table 1. Summary of available soil quality trigger values and a proposed trigger value to protect grazing animals

Guideline category	Guideline value	Source
Protection for terrestrial plants	250 mg/kg	Sheppard et al., (2005)
Protection for soil biota including soil microbes and soil animals	100 mg/kg	Sheppard et al., (2005)
Protection for 'agricultural land use' (based on animal ingestion)	33 mg/kg	CCME (2007)
Protection of vascular plants and soil invertebrates (based on a species sensitivity distribution)	500 mg/kg	CCME (2007)
Protection for grazing animals (based on animal ingestion)	239 mg/kg	This report

Sheppard et al., (2005) recommended a Predicted No Observed Effect Concentration (PNEC) to be 250 mg/kg dry soil for the protection of plants, and 100 mg/kg dry soil for the protection of other soil biota including soil microbes and soil animals but did not consider higher vertebrates such as grazing cattle.

The Canadian guideline for exposure (SQG_E) relevant to 'agricultural' areas is 33 mg/kg (CCME, 2007). The 'agricultural' trigger value is considered the most relevant of the three land use categories in the CCME (2006) framework. This category refers to areas, "*where the primary land use is growing crops or tending livestock. This also includes agricultural lands that provide habitat for resident and transitory wildlife and native flora*" (CCME, 2006). With the exception of cropping, these exposure pathways are relevant to the Ben Lomond site. The (CCME 2007) trigger considers exposure via direct contact with soil, ingestion of soils as well as the ingestion of contaminated water by livestock at agricultural sites. The Canadian SQG_I (sediment quality for ingestion) was calculated using the Lowest Observed Adverse Effect Level (LOAEL) of 0.49 mg/kg bw/d for renal effects in New Zealand white rabbits. In that study, effect data for rabbits was used as it provided the most conservative assessment of effects for protection to biota relevant to 'agricultural' uses (CCME, 2007). The Canadian soil quality guideline for soil contact (SQG_{SC}) was derived using a species sensitivity distribution (SSD) approach that included 11 plant species and ~~4~~ four invertebrate species from ~~7~~ seven studies (CCME, 2007). The 25th percentile of the data distribution was 500 mg/kg (CCME, 2007). This trigger is based on response data for vascular plants and soil invertebrates and did not include higher vertebrates such as grazing animals. The final Canadian soil quality guideline for uranium relevant to 'agricultural' land uses was adopted as the lower of the soil contact guideline (SQG_{SC}) and the soil and food ingestion guideline (SQG_I).

As none of the aforementioned triggers for soil were specific to cattle grazing, a trigger was developed by applying the approaches described in CCME (~~CCME~~ 2006; 2007). This was achieved by substituting the food ingestion rate and effect data for rabbits with the Lowest Observed Adverse Effect Level (LOAEL) for observed effects in dairy cattle (Garner, 1963). Applying this approach, a Soil Quality Guideline for ingestion (SQG_I) was calculated as:

$$SQG_I = \frac{0.75 \times \mathrm{DTED} \times \mathrm{BW}}{(\mathrm{SIR} \times 1) + (\mathrm{FIR} \times \mathrm{BCF})}$$

where: SQG_I = Soil Quality Guideline – ingestion; 0.75 = a factor based on the assumption that water and dermal absorption/inhalation account for 25% of the total exposure and the remaining 75% of the total exposure is from food and soil ingestion (CCME 2006); DTED = daily threshold effects dose; BW = body weight; FIR = food ingestion rate; (calculated as dry matter ingestion rate (DMIR) – soil ingestion rate (SIR); BF = bioavailability factor; and BCF = soil to plant bio-concentration factor.

The study by Garner (1963) reported that a dose of 4 g uranium per day (as uranyl nitrate) over a period of 2 weeks resulted in deterioration in the general health of cattle and a decrease in milk yield, followed by a gradual return to an apparently normal state. The authors of that study assumed that a Lowest Observed Adverse Effect Level in cattle was likely to be represented by a 10 times lower dose (0.4 g/cow or 400 mg/cow). Garner (1963) suggested a slight depression in milk yield for one day only may occur at one tenth the dose which resulted in a deterioration in general health. In order to calculate a trigger specific for the protection of cattle we have assumed that a cow has a mass of 500 kg (Beyer & Fries, 2003). On this basis, a DTED for cattle is calculated as 400 ÷ 500 = 0.8 mg/kg bw/d. The response data are less than ideal as they are based only on the response of two individual cows to a single dosage rate and has a conservative assessment factor of 10 applied. Although based on a limited study, this ~~it~~ represents the best available DTED and has been utilised in Canadian soil quality guideline (CCME 2007).

The CCME (2007) approach considers soil consumption to provide the primary route of exposure for grazing animals. Soil ingestion rate and percentage of soil in the diet of cattle was reported in Beyer & Fries (2003). In that study, the soil ingested by a 500 kg dairy cow (in a New Zealand study) was estimated to average 0.9 kg/day; ~~when~~ it was assumed that dry matter intake was 15 kg/day and that cows grazed 365 days per year (i.e., SIR = 0.9 kg/day and FIR = 14.1 kg/day). The assumption regarding the average weight of a cow has implications for the magnitude of the DTED used in the equation, and flow-on effects on the magnitude of the SQG_I. The greater the assumed weight, the less conservative the soil trigger. We have assumed a weight of 500 kg as a conservative estimate rather than 650 kg as used in the Canadian guideline document. The bioavailability and uptake of uranium in animals is not well studied, so it was assumed that all uranium in ingested soil would be bioavailable (i.e., BF = 1). This was appropriate given the ~~administration of uranium~~ in the study by Garner (1963) all the administered uranium was bioavailable. The soil-to-plant bioconcentration factor (BCF) for uranium used for this calculation was that provided in CCME (2007) ~~CCME, 2007)~~, ~~. This~~ which was estimated by taking the geometric mean of all concentration ratios listed for plants, thereby resulting in a bioconcentration factor of 0.025.

By substituting the above values into the equation the following is obtained:

$$SQG_I = \frac{0.75 \times 0.8 \times 500}{(0.9 \times 1) + (14.1 \times 0.025)}$$

$$SQG_I = 239.5 \text{ mg/kg}$$

Discussion

This report addresses the need to derive a toxicity threshold value for uranium in soils for the protection of grazing cattle at the Ben Lomond project; however, a number of other possible routes of exposure and likely receptors were identified. These were runoff of contaminated soils into local waterways and the potential risk to aquatic and sediment biota. Although these receptors were not considered here, future evaluation should consider risks to those receptors.

The available trigger for the protection of 'agricultural' land use from the CCME (2007) of 33 mg~~k~~/kg was considered overly conservative due to its use of a receptor (soil ingestion by rabbits) that was not considered relevant to the protection of grazing cattle. The Canadian soil quality guideline for soil contact (SQG_{SC}) of 500 mg/kg (CCME, 2007) did not consider potential response in vertebrate animals. A draft toxicity threshold value for uranium in soils was developed by substituting the available effect data for cattle using the Canadian approach (CCME, 2007). In lieu of established guidelines specifically designed to protect grazing cattle, the draft toxicity threshold value for uranium in soils calculated here of 239 mg/kg provides a basis for a preliminary assessment for protection of cattle, but would not necessarily provide a reliable basis for an assessment trigger or compliance limit that ~~should~~ could provide protection to all environmentally relevant receptors. The Canadian approach to derive soil quality criteria shares similarities with the NEPC (2013a) but is not identical. Where there is a desire to further evaluate soil quality triggers, the approaches described in NEPC (2013a) should be applied.

Where specific action criteria are required (as requested in this case by EHP), a site-specific evaluation is recommended. More detailed site~~-~~specific investigations could consider aspects that are likely to influence risk, such as the physical and chemical characteristics of soils, leaching potential, and bioavailability of uranium in soil. An assumption made in the calculation of this toxicity threshold value for uranium in soils is the likely uptake of uranium in plants. As plant uptake will influence to the overall risk to grazing animals, there may be a need to assess the risk of uptake by plants found to occur locally. Schedule B2 of the National Environmental Protection Measures provides guidance on site characterisation (NEPC, 2013). A further assumption is of constant exposure of cattle to contaminants. However, as cattle graze freely on the site, and as soil contaminant concentration varies spatially within the site, cattle will be exposed to varying contaminant concentrations. Because of these large uncertainties, the draft toxicity threshold value for uranium in soils derived through this process should be viewed as provisional.

Comment [RM11]: a or b

Risk to cattle through drinking water may also be assessed against the ANZECC & ARMCANZ, (2000) guidelines for the protection of livestock water for uranium (0.2 mg U/L). Further considerations also include direct exposure to humans as a result of animal product consumption. Garner (1965), proposed a revised threshold for the protection of human health that~~, which~~ equated to a permissible intake of uranium by cattle of 7 g/day based on a permissible concentration of natural uranium in meat of 2 x 10^{-5} g/g (assuming an adult human ~~to~~ eats 200 g meat daily), and in milk of 6 x 10^{-4} g/L (assuming a child to drink 0.7 L daily) (Garner, 1963;1965).

This is 17.5 times higher than the dose expected to result in an observable adverse effect in cattle (i.e. the concentration expected to reduce milk yield) (Garner, 1963). On this basis, the risk to human health as a consequence of transfer of uranium from animals through consumption of meat is expected to be of low risk and was not considered further. Although not expected to pose a risk based on current understanding, there is little information describing the potential risk to human health from the consumption of beef cattle.

Additional considerations for environmental impacts include run-off from contaminated soil into local waterways and groundwaters. This exposure pathway has not been assessed at this time given the focus for assessment of soil contamination. Leachate studies ~~is~~ are a useful way to determine the proportion of uranium and other metals likely to be soluble. Leachate studies could be undertaken by passing rainwater through a sample of soil collected from the site, and then analysing the ~~chemical composition~~concentrations of metals in the ~~resulting~~ leachate. This would provide a direct measure of the likely solubility of metals taking into account the chemical and physical properties of the soils at the site. If leachate studies were to be conducted, then Australian Standard methods for soil or sediment sample collection techniques, study design and chemical analyses (AS4439.1, 1999; AS 4439.2, 1997 and AS 4439.3, 1997) or equivalent, should be used.

Assessment of potential impacts of uranium in aquatic ecosystems may be determined by comparing measured concentrations with the low reliability trigger value for uranium in freshwater ecosystems of 0.5 µg/L as derived using an assessment factor of 20 derived from limited chronic data (ANZECC & ARMCANZ, 2000). Since this trigger value was released, a site-specific chronic trigger value of 6 µg U/L was derived for 99% protection of species in Magela Creek downstream of the Ranger uranium mine in Kakadu National Park (Hogan et al., 2003). More recent studies have identified a trigger value of 6.3 µg/L U would be protective of 95% of species (A Harford pers. comm. August 2016). A study by Sheppard et al., (2005) indicated a NOEC of 5 µg U/L ~~for uranium that is~~was likely to be protective of most freshwater plants and invertebrates ~~was 5 µg/L~~. The concentration of uranium in water at site SWM6 (located downstream of the ore body on Boghole Creek) has exceeded the licence limit of 20 µg/L on 67% of sampling occasions between 2007 and 2013 (Table 28, Ben Lomond Environmental Evaluation, 2013). The maximum uranium concentration in that period was 570 µg/L. Elevated concentrations above the established trigger value indicate toxicity is likely and that further evaluation is warranted.

There are currently no national uranium guidelines for sediment in Australia (Simpson et al., 2013). The study by Sheppard et al., (2005) proposed a Predicted No Effect Concentration (PNEC) for uranium of 100 mg/kg dry sediment ~~was~~ as protective of freshwater benthos. In the absence of an Australian guideline for sediment, this value may be useful as a basis for initial assessment of risk. There are many factors that can influence the bioavailability and toxicity of uranium including the presence of calcium, magnesium, carbonates, phosphate, and dissolved organic matter (Goulet et al., 2011; 2015). Although it has not been possible to include information on the physical and chemical characteristics of soils at this time due to a lack of data, there is a need to consider such information in future assessments.

The soil quality trigger presented here provides a basis for an initial ~~basis to~~ assessment of potential impacts to grazing cattle from ingestion of soil and plant matter only. Although this exposure route and receptor was evaluated here, as mentioned previously, it is important to note that there are a range of additional impacts that could be considered in a broader assessment of risk such as exposure of wildlife from soil ingestion, protection of soil biota, exposure of wildlife and cattle from drinking surface water, and aquatic ecosystem impacts.

Comment [RM12]: Need to be listed in reference section.

Comment [RM13]: for where – magela creek?

Comment [RM14]: NOEC or PNEC?

Comment [RM15]: Is tis a public document? Isn't this supposed to be cited as AARC 2013?

Comment [RM16]: which trigger?

Comment [RM17]: Not in reference list

Comment [RM18]: what's this?

Comment [RM19]: Needs review – forexample - The CCME, NEPC references and the various reports are incomplete
page numbers in Goulet et al

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From: WALLACE Andrew [Andrew.Wallace@ehp.qld.gov.au]
Sent: Friday, 26 June 2015 3:34 PM
To: MORRISON Anthony
CC: GONZO Gus; CONNOLLY Niall
Subject: Ben Lomond - plan of action

Follow Up Flag: Follow up
Flag Status: Flagged

Hi Tony,

As discussed at yesterday's meeting, find below a plan of action regarding Ben Lomond further information requirements.

1. Request Peter Gleeson assist to determine current rates of erosion, risk of mass failure and rates of input to the receiving environment from the waste rock dump and haul road. This may include: reviewing information collected by EHP officers, including photographs and video; reviewing information provided by UMVI; and a conducting a site inspection.
2. Include an assessment of the >100m of the haul road during next pre-wet inspection. Check for the presence of contaminants, stability and state of rehabilitation.
3. Based on the above information, request Peter Gleeson assist in identifying remediation options for the waste rock dump and haul road.
4. Respond to the UMVI Rehabilitation Plan submission, informing UMVI that "... EHP is considering the implications of the findings of the recently submitted geotechnical report and XRF report and cannot make a determination of the adequacy of the Rehabilitation Plan at this time."
5. Arrange a meeting with Reinier Mann and Jason Dunlop to discuss the availability of geochemistry skill sets and experience in DSITI to comment on the mobilisation processes and geochemical reactions and transformations for the potential contaminants and biophysical conditions at the Ben Lomond site.
6. Depending on the availability of the appropriate expertise identify the likely factors determining the mobility and bioavailability of contaminants being exported from the identified contaminated areas at the Ben Lomond site.
7. From the above information develop a program outlining the specific requirements to determine the level of contaminant export from these identified areas.
8. Discuss this program with Stephen Carter QH to gain any comments/input.
9. Arrange a meeting with UMVI to discuss the requirements to determine the level of contaminant export from the identified contaminated areas and identify the level of environmental risk associated with those requirements.
10. Develop a Plan of Action with UMVI to undertake necessary remedial actions to prevent or minimise contaminants from the identified areas to an acceptable level.

I will start progressing these actions next week. Happy to take any comments on board.
Cheers, Andrew

Andrew Wallace
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From: MORRISON Anthony [Anthony.Morrison@ehp.qld.gov.au]
Sent: Wednesday, 8 July 2015 6:02 PM
To: WALLACE Andrew
CC: CONNOLLY Niall
Subject: Ben Lomond

Andrew,

Some actions coming out from my discussion with Gus this afternoon.

1. Could you follow up with Peter, Reiner and Jason to see when we can expect their comments, and check they're aware there's time pressure to keep this one moving.

2. Draft the corro referenced in action item 4. In that also refer to the Cairns meeting and the info they provided afterwards, thanking them for it, and letting them know we're reviewing and considering, and will be in contact once the review's done to discuss the outcomes.

Also he flagged that we need to try and establish a framework for derriving an acceptable level for cleanup, and thought Reiner and Jason might be able to provide input. I'm aware you've done some work trying to identify a standard without much success so it'll remain to be seen what they can offer on this one.

Cheers,
Tony

Anthony Morrison
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Environmental Services and Regulation I North Queensland Compliance
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From: WALLACE Andrew [Andrew.Wallace@ehp.qld.gov.au]
Sent: Monday, 20 June 2016 2:54 PM
To: CONNOLLY Niall; DUNLOP Jason
CC: HENNEY Nina
Subject: RE: soil triggers for uranium
Attachments: BenLomond _requirements _vs2_comments from AW-NC.DOCX; EB1609059_1_COA.PDF; DRAFT - EPO 20160518 Notice STAT1024 EPML00418313 UMVI Ben Lomond.docx

Hi Jason,

As discussed, could you please update the draft advice with consideration of the contaminated areas as sources of groundwater non-compliance as suggested in the email below.
I have attached leach testing results and draft EPO. The sample IDs in the COA should match the locations mapped in the draft EPO.

When you have considered, we would be happy to discuss further.

Cheers, Andrew

From: CONNOLLY Niall
Sent: Tuesday, 1 March 2016 4:22 PM
To: DUNLOP Jason <jason.dunlop@dsiti.qld.gov.au>
Cc: WALLACE Andrew <Andrew.Wallace@ehp.qld.gov.au>
Subject: RE: soil triggers for uranium

Hi Jason,

See attached where I have added a few edits and comments to Andrew's suggestions.

The stock soil trigger value is going to be very useful to help us determine what actions might be necessary on the lay down areas in the valley.

I am not sure if it was included in our original request but we will also need to determine if these areas of contaminated soils could be a source of groundwater contamination and contributing to the non-compliance records in the groundwater bores near the covered or stockpile shed – areas c & d in the figs in the report. We will need to consider that at the proposed stock trigger level for these soils (or what levels) would these soils have the potential to contaminate ground waters. I suspect you can't comment on this without data from leach testing etc., but just a heads up.

Again thanks for all the effort.

Cheers
Niall

From: DUNLOP Jason
Sent: Tuesday, 1 March 2016 10:04 AM
To: CONNOLLY Niall
Subject: soil triggers for uranium

Hi Niall, I spoke to Andrew last week and he mentioned there was a need to finalise the report on soil triggers for uranium.

There are a couple of changes to incorporate form Andrew but just wanted to check if you had any comments to add before it is finalised. No worries if not. Reinier has reviewed at our end and I will ask Ian to take a look through also. The current version is attached.

Cheers,

Jason

Dr Jason Dunlop
A/Principal Scientist
Water Assessment and Systems
Department of Science, Information Technology and Innovation

Adjunct Fellow
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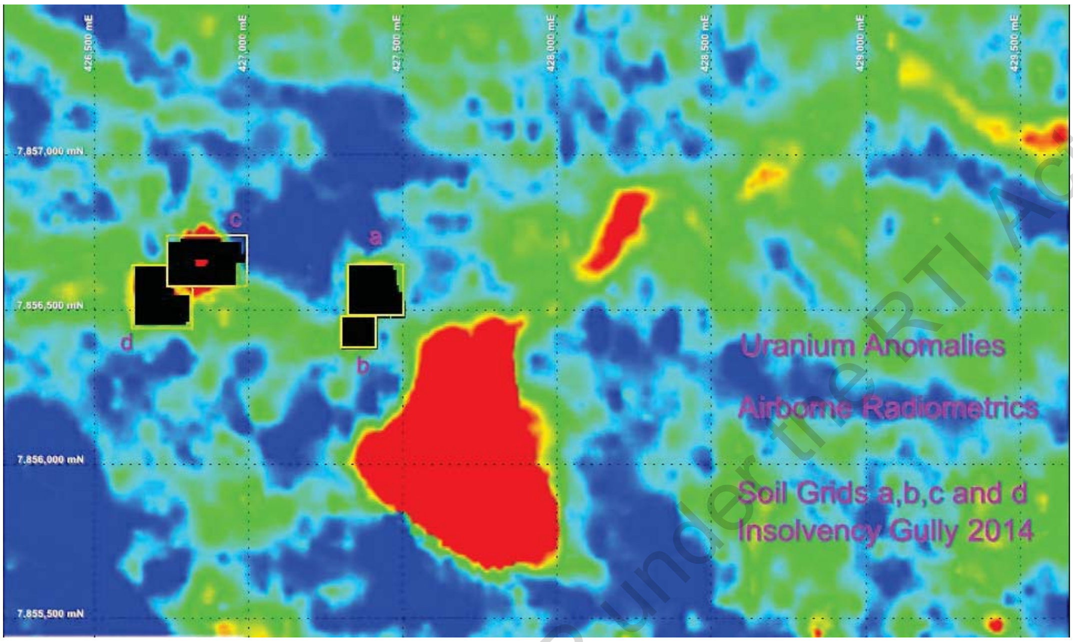
Department of Science, Information Technology and Innovation



Approaches to assess the mobility and potential impacts of uranium consequent to historic mining activities at Ben Lomond

Water Assessment and Systems

December 2015

Queensland Government

Prepared by

Jason E. Dunlop and Reinier M. Mann
Water Assessment and Systems
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Executive summary

Historic mining activities at Ben Lomond have potentially led to legacy contamination issues with the soil, water and creek sediments. Uranium, as a marker of this contamination and contaminant of concern has the potential to move within the soil and aquatic environment, and poses a potential risk to several environmental values as a consequence of soil and water contamination. This report discusses the chemical processes that are likely to influence the mobility of uranium in soil and water and the pathways of exposure in the environment. An overarching framework to assess and manage the potential risk of uranium is also presented. In the terrestrial compartment, cattle grazing could be viewed as the most relevant environmental value. Exposure to grazing cattle on site via ingestion or direct contact with soil and plants is considered to be the most likely exposure pathway. The report reviews the available soil quality criteria for uranium that may be used to evaluate the potential for impact on-site. As guidelines were not available for the protection of grazing cattle, a soil quality trigger was developed using approaches described in Canadian guidelines (CCME, 2007). A soil trigger for cattle that considers the potential for ingestion of uranium was calculated as 320 mg/kg. Although this figure has some uncertainties associated with it, this trigger provides a basis for a preliminary assessment of risk. The merits of this and other soil quality guideline values are discussed. Options for further site specific evaluation of the risk to the environment are also considered.

Contents

List of tables

List of figures

Introduction

Ben Lomond is a uranium and molybdenum ore deposit owned by Uranium Mineral Ventures Incorporated (UMVI), a subsidiary of Mega Uranium ~~(UMVI)~~ LTD, that is currently in care and maintenance (not operating). Ongoing surface and groundwater monitoring undertaken as part of the requirements of the existing Environmental Authority (EA) has identified a high proportion (between 20-90%) of samples at monitoring locations that are in exceedance of surface and groundwater limits for a range of water quality indicators.

The site is an area of natural mineralisation and has historically had mining and exploration activities undertaken on it. Although elevated contaminant concentrations may occur as a result of runoff from areas of natural mineralisation, the absence of pre-mining baseline data has ~~prevented an informed assessment of~~hampered the delineation of the potential contribution of contaminants from disturbed areas compared with natural areas. ~~As a result~~Due to ongoing non-compliance at monitoring sites, an Environmental Evaluation (EE) was issued to require an investigation of the '*source, cause and extent of contamination on the site*'. The resultant EE report suggested that the source of contaminants was largely natural. However, the EE report was found to have inadequately characterised the contribution from all potential sources. EHP requested an additional study be undertaken to evaluate longitudinal trends in water quality. That study was unable to identify the presence of either an increasing or decreasing trend in the concentrations of contaminants since the mid – 1980s when historic mining activities were active, but did identify consistent differences across sampling sites. For example, those sites that were reported as being in non-compliance with EA conditions, were consistently elevated compared to reference sites. Also, a subsequent field inspection of the site by EHP officers found ~~some~~ additional sources of contamination that had not previously been identified by UMVI. These additional ~~sites~~ sources were upstream of those sites that were in non-compliance.

Using the available historic monitoring data, local reference based surface water quality trigger values and limits were developed by the Water Assessment & Systems (WAS) group with the Department of Science, Information Technology and Innovation (DSITI). Review of the data against the newly developed draft triggers indicated compliance with triggers for most sites with the exception of sites SWM6 and SWM22. Groundwater monitoring sites ??, ?? and ?? had also recorded longstanding non-compliance with EA limits. ~~However, the source of elevated concentrations of metals (including uranium, lead and arsenic) at these sites could not be identified.~~ At the request of EHP, a further study ~~has since been~~was undertaken by UMVI to evaluate the concentration of contaminants in both the unimpacted and disturbed areas. That study identified several areas where material excavated from historic mining had been variously stockpiled adjacent to the adit portal apron, used to construct haul roads, or stockpiled in areas of the valley floor before being stored in the covered ore shed or transported offsite. This study also indicated that portal rock benches and haul roads, that had been constructed of both mineralised rock from mining and local remnant soils, have since undergone ~~some~~ erosion. ~~Following on from this, f~~Further studies, ~~have been~~ undertaken by UMVI, ~~to~~ surveyed these features ~~area~~ and estimated the volume of material exported as a result of erosional processes and ~~estimate~~ assessed the likelihood of further erosion occurring.

Given that there are a number of sources of contaminant exports on-site, there is ~~currently~~ a need to understand what hazard ~~this~~ these represent~~s~~ to the environment. ~~Where there is a genuine threat to the environment, UMVI have agreed to rehabilitate the site.~~

Comment [WA1]: Not sure of current UMVI position on this agreement.

Although a number of metals have been found to be present in elevated concentrations, at the request of EHP the focus of this report is on uranium as it is thought to ~~pose greatest risk to the environment~~be a good indicator of mine related impacts and does not have a guideline value for the protection of stock. The report considers the chemical processes that are likely to influence the mobility of uranium in soil and water and the pathways of exposure in the environment.

To provide a basis for ~~initial~~ the assessment ~~and consideration~~ of options for management, EHP has requested ~~consideration~~ the determination of action levels for uranium in soils at the Ben Lomond site. Accordingly, available soil quality criteria for uranium are reviewed and the merits of applying available and derived soil quality triggers are discussed. Options for further site specific evaluation of the risk to the environment are also considered.

Mobility and potential impacts of uranium

Source of contaminants

The sources of contaminants onsite include the outcropping of the natural ore body and areas disturbed as a result of historic mining and exploration. Areas of disturbance include the adit apron, haul road and waste rock dump (referred to as benches 1, 2 and 3) that intersect the natural ore body. In addition, there are four areas previously used for mine activities where airborne radiometrics indicated elevated concentrations of uranium and other radionuclides (referred to as areas a – d in Figure 1). The XRF Characterisation Report (UMVI, 2015) showed that disturbed areas can have relatively high concentrations of a range of metals dominated by U, Pb, and As. Areas with an elevated uranium concentration are shown in Figure 2 below. This figure also shows the proximity of 1st and 2nd order streams and ground and surface water monitoring locations.

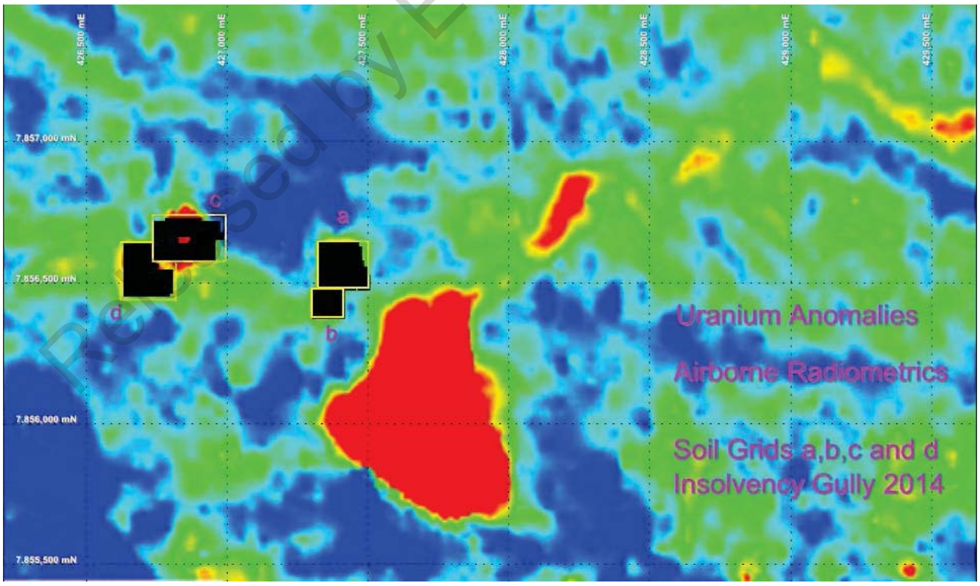

Figure 1. Location of areas a, b, c and d within Insolvency Gully, showing uranium gamma sources at the surface determined from airborne radiometry (source: UMVI, 2015). Concentration of uranium is greatest in red and least in blue.

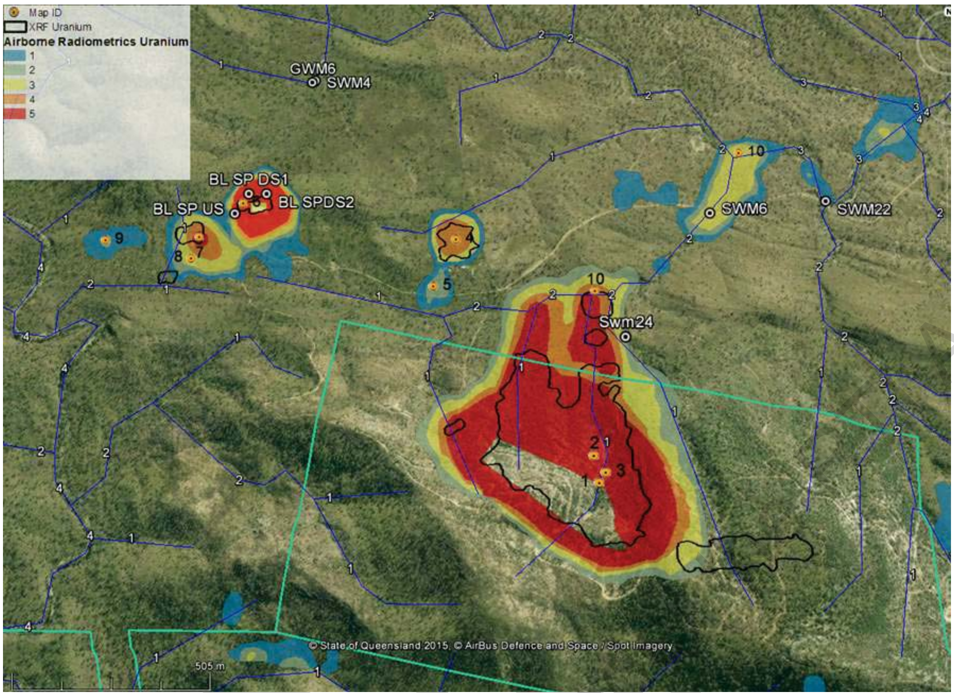

Figure 2. Airborne radiometrics survey for showing uranium gamma sources in surface soils, the stream network and stream order (blue line), ground and surface water monitoring sites (map supplied by EHP).

Conceptual model of contaminant transport and impacts

The conceptual model in Figure 3 shows a range processes that are likely to influence the mobility of contaminants from disturbed areas and indicates potential environmental receptors. Uranium is likely to bind with particulates and remain in soils. Some bioaccumulation of uranium ions in vegetation is also possible, although the degree to which this will occur is likely to be dictated by plant species. As the lease is subject to grazing, it is possible that metals present in soils and vegetation will pose a risk to beef cattle via consumption of plants and soil materials. Transitory wildlife, local plants, soil invertebrates and soil microbes may also be exposed to soil and water on the site. Direct human contact with soils is not expected as access to the site is restricted.

Under some circumstances uranium may be soluble in water and may enter surface waters as overland flow or alternatively may percolate into soils and enter groundwater posing a risk to aquatic ecosystems. Groundwater seeps are known to occur on site though it is not known whether they are present downslope from disturbed areas. Metals bound to particulates may also be transported from disturbed areas as a consequence of ~~natural~~ weathering and erosion processes. This material can enter streams where it may settle out and pose a risk to sediment biota. Under some conditions, contaminants may desorb from particulates making stream sediments a potential source of contaminants.

Comment [CN2]: SW24 is downstream from what appears to be a seep coming out of the hillslope that includes the main ore body – but on a different drainage to where the adit is located. Data from this site may indicate the quality of water seeping from this hillslope that is not influenced by the disturbance at the adit site.

Comment [CN3]: I have deleted "natural" to avoid referring to un-oxidised mine spoil being exposed at surface in an unconsolidated state as being considered as natural weathering and erosion equivalent to the already weathered and exposed surface outcropping.

In the terrestrial compartment, cattle grazing could be viewed as the most relevant environmental value and is considered here as an appropriate receptor for the purposes of this report evaluating the risk to terrestrial fauna. Ingestion of uranium by beef cattle is considered to be the most likely exposure pathway.

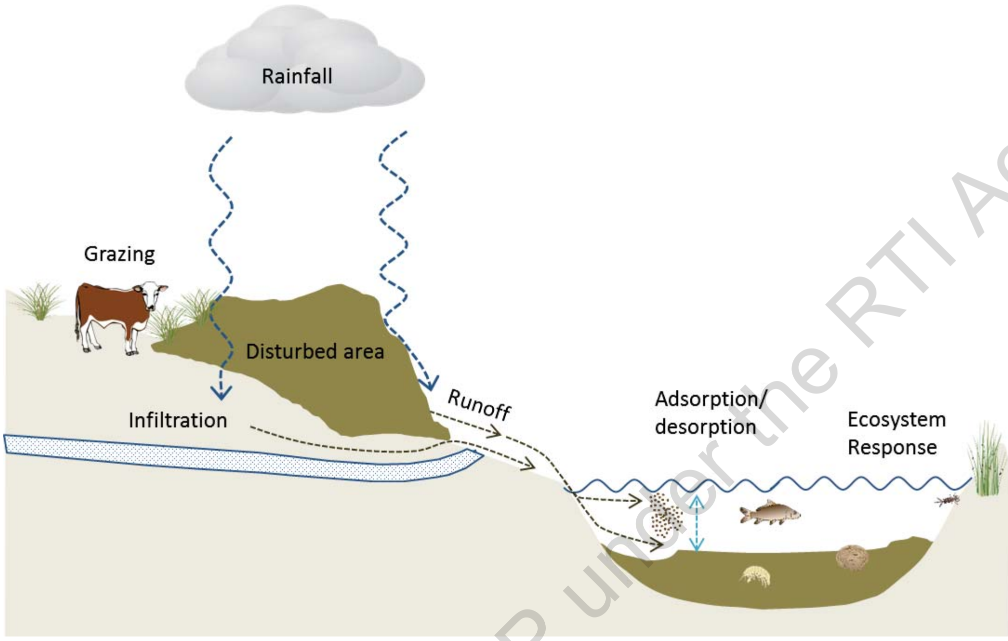

Figure 3. Conceptual model of contaminant fate and effects in the environment at Ben Lomond

Mobility of uranium in surface water run-off

The oxidation state of uranium has a significant effect on its mobility. Uranium can be present as U(IV), U(V), U(III) and U(VI). The dominant form of uranium in soils and oxidised waters is U(VI) present predominantly as the uranyl ion (UO_2^{2+}). Uranium (VI) is soluble and mobile under oxidizing to mildly reducing conditions forming soluble complexes with carbonate anions in natural waters (Gavrilescu, et al., 2009) and humic substances (e.g., uranyl fulvate) in dissolved, colloidal, and/or particulate forms (Markich, 2002).

Mobility of uranium within soils

Uranium has a strong tendency to bind with particulates and organic matter. Uranium mobility and partitioning in soil is dependent on the physical and chemical attributes of the soil. Physical attributes affecting the movement of metals in soils include grain size, porosity and hydraulic conductivity. Chemical attributes affecting the movement of metals in soils include the organic content, ionic strength (salinity), soil pH, redox potential (Eh) and presence of specific cations. A measure of cation exchange capacity (CEC) provides an indication of the ability of soils to retain exchangeable ions. The key physicochemical property of inorganic contaminants that controls their potential movement to ground and/or surface waters is the soil−water partition coefficient (K_d) (NEPC, 2013a). This is the ratio of the concentration of a contaminant bound to the soil to that dissolved in soil pore water at equilibrium, and therefore, is related to the aqueous solubility of that contaminant (NEPC, 2013a). Increasing soil salinity has been found to mobilise U(VI) from soil exchange sites forcing it into solution (Rout et al., 2015) with the different ions known to have varying effects on mobility. The capacity of cations to provoke desorption is directly proportional to ionic radius with large cations having a greater capacity than smaller cations (i.e. Ca^{2+} > Mg^{2+}> Na^{+}) (Rout et al., 2015). Many studies have shown that carbonate complexation reduces adsorption of uranium, thus leading to its release from soils (Gavrilescu et al., 2009). Uranium tends to occur in the solid phase at low redox potential (E_h) with the formation of dissolved uranium carbonate complexes at high E_h values (Gavrilescu et al., 2009). The presence of high concentration of NO_3^- in ground water also has the potential to mobilise uranium by changing the redox potential of the environment (Rout et al., 2015).

Erosion, transport and deposition of uranium associated with particulates

Uranium associated with insoluble particulates can be transported via hydraulic and geomorphic processes. A study by ETS Geotechnical (2015) on behalf of UMVI indicated that fill batters (referred to as benches 1, 2 and 3) and haul road ~~-~~have been eroding over the preceding 30 years and displayed signs of instability. In that study, batters were considered largely stable under normal conditions, although it was noted that they are prone to instability during periods of intense rainfall. The report by Resource and Exploration Mapping (REM, 2015) undertaken on behalf of UMVI provides estimates of the volume of material lost from drill pads and the haul road from surveys of the estimated original and current landform. An estimated 298 m^3 of material has eroded from the three benches and haul road.

Comment [CN4]: What are normal conditions? Intense rainfall is infrequent – but normal – and expected at this location.

If you are using ETS's words then maybe put in quotations – but we should be clear that intense rainfall is expected and therefore "normal".

It might also be worth clarifying what "instability" means – mass failure or more gradual erosion and slumping – which is what appears to be occurring.

It is likely that some of this material has been deposited in Bog Hole Creek, where it may pose a risk to sediment dwelling biota in the immediate vicinity of the site and further downstream. However, at this time there is limited information available describing the chemical composition of sediments in Bog Hole Creek. Although much of the uranium associated with particulates would remain adsorbed to particulates in the sediments, it is possible that under oxidising conditions U(VI) may desorb from sediments.

Effect of uranium in the environment

Uranium can exhibit both radiological and chemical toxicity effects. However, a study by Mathews et al. (2009) showed that the risks to the environment as a consequence of uranium's chemical toxicity generally outweigh those of its radiological toxicity. Accordingly, direct toxicity effects are likely to provide the focus for ecological risk assessment. Uranium can be toxic above certain thresholds, although it is comparatively less toxic than other metals (Goulet et al., 2011). However, Borgmann et al. (2005) found that uranium toxicity increases with decreasing water hardness. It does not biomagnify but is known to accumulate in bone, liver, and kidney tissue (Goulet et al., 2011).

As the lease is subject to grazing, one of the key pathways by which uranium may enter the terrestrial biota is expected to be grazing of beef cattle. As previously mentioned, stock may be exposed via consumption of soil, plants and ingestion of water from local waterbodies. Local and transitory wildlife may also be exposed to soils, plants and water from affected areas.

Approach to assess and manage risk

As uranium and other contaminants have been identified at receiving environment monitoring sites~~in elevated~~at concentrations above EA limits and the concentrations at these sites are also elevated compared to other monitoring sites~~background~~, the possibility of impacts to the environment cannot be excluded. In such a circumstance it may be worthwhile implementing strategies to contain contaminants and prevent potential impacts. Development of these strategies would require input from relevant experts but may include removing and covering material or implementing erosion and sediment control practices to stabilise soils and capture those metals that might otherwise be mobilised in runoff and leachate. It may also be possible to limit or prevent stock and wildlife accessing contaminated areas.

The diagram in Figure 4 provides an indication of a process that may be followed to assess the risks and determine the need for remedial actions. The key focus at this stage is on the effect of uranium in soils on grazing cattle; however, this process may be followed to expand the assessment of risk to a broader range of exposure pathways and receptors. Subsequent sections provide information to assess risk in accordance with this assessment process.

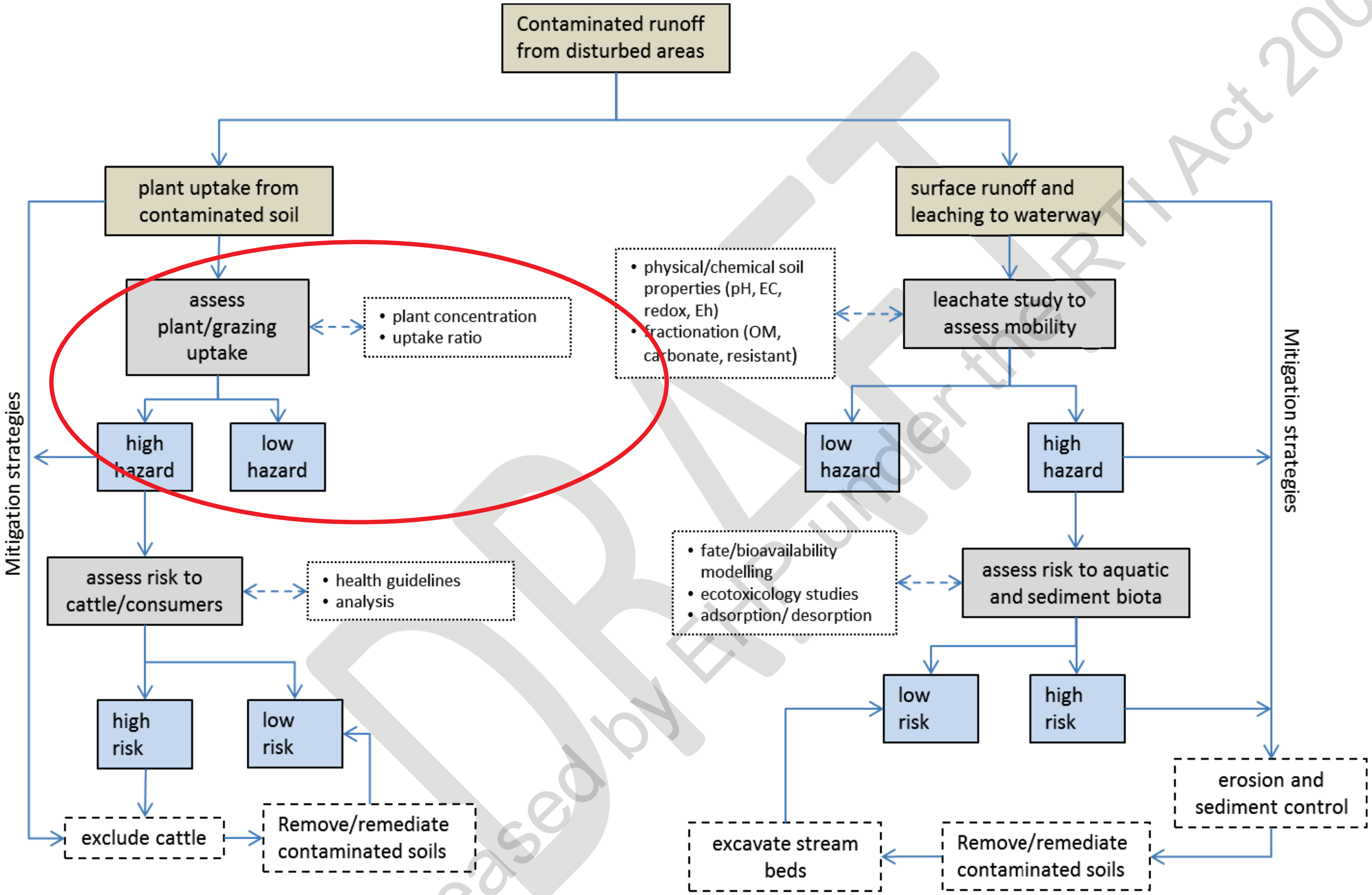

Figure 4. Assessment process for disturbed areas on the Ben Lomond lease area. Red circle shows the current stage of assessment considered here.

Guidelines for uranium in soils

Investigation levels for contaminated soils are described in the National Environment Protection Measures (NEPMs); however, these do not specify guidelines for uranium. In the absence of Australian soil quality guidelines for uranium, available soil triggers for uranium including those described in the Canadian soil quality guidelines (CCME, 2007) and those proposed by Sheppard et al. (2005) were considered. A summary of the available soil quality triggers is provided in Table 1. Neither of the existing triggers had direct relevance to the protection of cattle as required for the Ben Lomond site.

Table 1. Summary of available soil quality trigger values

Guideline category	Guideline value	Source
Protection for terrestrial plants	250 mg/kg	Sheppard et al. (2005)
Protection for soil biota including soil microbes and soil animals	100 mg/kg	Sheppard et al. (2005)
Protection for 'agricultural land use' (based on animal ingestion)	33 mg/kg	CCME (2007)
Protection of vascular plants and soil invertebrates (based on a species sensitivity distribution)	500 mg/kg	CCME (2007)
Protection for grazing animals (based on animal ingestion)	320 mg/kg	Derived below

Sheppard et al. (2005) recommended a Predicted No Observed Effect Concentration (PNEC) to be 250 mg/kg dry soil for the protection of plants, and 100 mg/kg dry soil for the protection of other soil biota including soil microbes and soil animals but did not consider higher vertebrates such as grazing cattle.

The Canadian guideline for exposure (SQG_E) relevant to 'agricultural' areas is 33 mg/kg (CCME, 2007). The 'agricultural' trigger is considered the most relevant of the three land use categories for which triggers are derived under the CCME (2006) framework. This category refers to areas, "*where the primary land use is growing crops or tending livestock. This also includes agricultural lands that provide habitat for resident and transitory wildlife and native flora*" (CCME, 2006). With the exception of cropping, these exposure pathways are relevant to the Ben Lomond site. The (CCME 2007) trigger considers exposure via direct contact with soil, ingestion of soils as well as the ingestion of contaminated water by livestock at agricultural sites. The Canadian SQG_I (sediment quality for ingestion) trigger was calculated using the LOAEL of 0.49 mg/kg bw/d for renal effects in New Zealand white rabbits. Effect data for rabbits was used as it provided the most conservative assessment of effects for protection to biota relevant to 'agricultural' uses (CCME, 2007). As rabbits are not a relevant value requiring protection at the Ben Lomond site, the relevance of the resultant trigger was questioned. The Canadian soil quality guideline for soil contact (SQG_{SC}) was derived using an species sensitivity distribution (SSD) approach that included 11 plant species and 4 invertebrate species from 7 studies (CCME, 2007). The 25th

percentile of the data distribution was 500 mg/kg (CCME, 2007). This trigger is based on response data for vascular plants and soil invertebrates and did not include higher vertebrates such as grazing animals. The final Canadian soil quality guideline for uranium relevant to 'agricultural' land uses was adopted as the lower of the soil contact guideline (SQG_{SC}) and the soil and food ingestion guideline (SQG_I).

As none of the aforementioned triggers for soil were specific to cattle grazing, a trigger was developed by applying the approaches described in (CCME 2006; 2007). This was achieved by substituting the food ingestion rate and effect data for rabbits with the Lowest Observed Adverse Effect Level (LOAEL) for observed effects in dairy cattle (Garner, 1963). Applying this approach, a Soil Quality Guideline for ingestion (SQG_I) was calculated as:

SQG_I= (0.75 x DTED x BW) / [(SIR x BF) + (FIR x BCF)]

$$SQG_I = \frac{0.75 \times \mathrm{DTED} \times \mathrm{BW}}{(\mathrm{SIR} \times 1) + (\mathrm{FIR} \times \mathrm{BCF})}$$

Where:

SQG_I = Soil Quality Guideline - ingestion

0.75 = A factor based on the assumption that water and dermal absorption/inhalation account for 25% of the total exposure and the remaining 75% of the total exposure is from food and soil ingestion (CCME 2006).

DTED = Daily Threshold Effects Dose

BW = Body Weight

FIR = Food Ingestion Rate, calculated as Dry Matter Ingestion Rate (DMIR) – Soil Ingestion Rate (SIR)

BF = Bioavailability Factor

BCF = soil to plant Bio-concentration Factor

The study by Garner (1963) reported that a dose of 4 g uranium per day (as uranyl nitrate) over a period of 2 weeks resulted in deterioration in the general health of cattle and a decrease in milk yield, followed by a gradual return to an apparently normal state. The authors assumed that a Lowest Observed Adverse Effect Level (LOAEL) in cattle was likely to be represented by a 10 times lower dose (0.4 g/cow). In order to calculate a trigger specific for the protection of cattle, a ~~Lowest Observed Adverse Effect Level (~~LOAEL~~)~~, we have assumed that a cow has a weight of 500 kg (Beyer & Fries, 2003). On this basis, a LOAEL for cattle is calculated as 400 ÷ 500 = 0.8 mg/kg bw/d. Although this represents the best available LOAEL, the data are based on the response of two individual cows to a single dosage rate. In using this data, we have also made assumptions about the weight of the dosed animals (not stated in the original study). In considering this same study, the Canadian guideline document assumed the weight of the animals to be 640 kg, which has implications for the magnitude of the LOAEL index used in the equation, and flow on effects on the magnitude of the SQG_I. Because of these large uncertainties, the number derived through this process should be viewed as provisional.

The CCME (2007) approach considers soil consumption to provide the primary route of exposure for grazing animals. The CCME (2007) approach to calculate a SQG_I uses a food ingestion rate (FIR) calculated as a dry matter ingestion rate (DMIR) minus the soil ingestion rate (SIR). Soil ingestion rate and percentage of soil in the diet of cattle was reported in Beyer & Fries (2003). In that study, the soil ingested by a 500 kg dairy cow (in a New Zealand study) was estimated to average 900 g/day when it was assumed that dry matter intake was 15 kg/day and that cows grazed 365 days per year. The bioavailability and uptake of uranium in animals is not well studied. It was assumed that all uranium in ingested soil would be bioavailable. This was appropriate given the administration of uranium in the study by Garner (1963) was bioavailable. Soil-to-plant bioconcentration of uranium was that used in (CCME, 2007) which was estimated by taking the geometric mean of all concentration ratios listed for plants resulting in a bioconcentration factor of 0.025. A SQG_I for cattle was calculated as 320 mg/kg.

The calculation of a trigger for cattle using the CCME techniques is as follows:

$$SQG_I = \frac{0.75 \times 0.8 \times 500}{(0.9 \times 1) + (14.1 \times 0.025)}$$

$$SQG_I = 320.8 \text{ mg/kg}$$

Where:

DTED = LOAEL of 0.8 mg/kg body mass/d[1] (Garner, 1963).

BW = 500 kg (Beyer & Fries, 2003)

FIR = 14.1 kg/d dw, calculated as DMIR – SIR (where DMIR = 0.9 kg/day for soil ingestion divided by 15 kg/day DMI = 6%).

15 kg/day dw - 0.9 kg/day) (Beyer & Fries 2003)

BF = information not available, therefore a bioavailability factor of one (unitless) is assumed (CCME, 2005).

BCF = 0.025 (unitless) the soil to plant bioconcentration factor that was derived in CCME (2005).

Discussion

This report addresses the requirement to derive a soil quality trigger for uranium given grazing was considered the key route of exposure to contaminated soils; however, a number of other possible routes of exposure and likely receptors were identified, such as runoff of contaminated soils into local waterways and the potential risk to aquatic and sediment biota. Although these were not considered here, future evaluation should consider risks to those receptors.

The available trigger for the protection of ‘agricultural’ land use from CCME (2007) of 33 mk/kg was considered overly conservative due to its use of a receptor that was not relevant to the site. The Canadian soil quality guideline for soil contact (SQG_{SC}) of 500 mg/kg (CCME, 2007) did not consider potential response in vertebrate animals. A soil quality guideline of uranium in soils was developed by substituting the available effect data for cattle using the Canadian approach (CCME, 2007). The resultant trigger of 320 mg/kg is expected to provide a reasonable trigger value for soils in an area subject to grazing. In lieu of established guidelines specifically designed to protect

[1] The Lowest Observed Adverse Effect Level (LOAEL) from Garner 1963 was based on a limited study of two individuals to provide an estimate of depression in milk yield. The original Garner (1963) paper cites data from a pers. comm.

grazing cattle, the soil quality guideline calculated here may provide a basis for a preliminary assessment and allow comparison with similar triggers but would not necessarily provide a reliable basis for an assessment trigger or compliance limit. The Canadian approach to derive soil quality criteria shares similarities with the NEPC (2013a) but is not identical. Where there is a desire to further evaluate soil quality triggers, the approaches described in NEPC (2013a) may be applied. Where specific action criteria are required (as requested by EHP), a site-specific evaluation is recommended. Site specific investigations could consider those aspects that are likely to influence risk, such as the physical and chemical characteristics of soils, leaching potential, and bioavailability of uranium in soil. An assumption made in the calculation of this trigger is the likely uptake of uranium in plants. As plant uptake will influence to the overall risk to grazing animals, there may be a need to assess the risk of uptake by plants found to occur locally. Schedule B2 of the National Environmental Protection Measures provides guidance on site characterisation (NEPC, 2013). A further assumption is of constant exposure of cattle to contaminants. However, as cattle graze unconstrained at this location and as soil contaminant concentration varies spatially, cattle will be exposed to varying contaminant concentration.

Risk to cattle through drinking water may also be assessed against the ANZECC & ARMCANZ, (2000a) guidelines for the protection of livestock (cattle) water for uranium (0.2 mg U/L). Further considerations also include direct exposure to humans as a result of animal product consumption. Garner (1965), proposed a revised threshold for the protection of human health, which equated to a permissible intake of uranium by cattle of 7 g/day. This is 17.5 times higher than the dose expected to result in an observable adverse effect in cattle (Garner, 1963;1965). On this basis the risk to human health as a consequence of transfer of uranium from animals through consumption of meat is expected to be of low risk and was not considered further. Although not expected to pose a risk based on current understanding, there is little information describing the potential risk to human health from the consumption of beef cattle.

Additional considerations include run-off of contaminated sediments into local waterways and groundwaters. This exposure pathway has not been assessed at this time given the focus for assessment of soil contamination. A useful approach to determine the proportion of uranium and other metals that are likely to be soluble is to undertake leachate studies. Leachate studies are undertaken by passing a solute through a sample of soil collected from the site and analysing the chemical composition of the leachate. This approach provides a direct measure of the likely solubility of metals taking into account the chemical and physical properties of the soils at the site. Appropriate soil or sediment sample collection techniques, study design and chemical analyses should be used that comply with the relevant standards including AS4439.1 (1999), AS 4439.2 (1997) and AS 4439.3 (1997) for the preparation of leachates.

Assessment of potential impacts in aquatic ecosystems may be determined considering the low reliability trigger value for uranium in freshwater ecosystems of 0.5 (µg U/L) as derived using an assessment factor of 20 derived from limited chronic data (ANZECC & ARMCANZ 2000). Since this earlier figure was released, a site-specific chronic trigger value of 6 (µg U/L) was derived for 99% protection of Magela Creek in Alligator Rivers by (Hogan~~, R.A.,~~ et al., 2003). A trigger of 7.8 µg/L (1.8 – 15 µg/L) for the protection of 95% of species was presented by Rick van Dam, Andrew Harford and Alicia Hogan at the Society for Environmental Toxicology and Chemistry – Australasian chapter annual conference in Melbourne in 2013. There are also Canadian Guidelines for uranium in waters (CCME, 2011) that may be considered. Those guidelines are 15 µg/L uranium (total recoverable) long term exposure, and 33 µg/L uranium (total recoverable) short term exposure. A study by Sheppard et al.~~,~~ (2005) indicated a NOEC for uranium that is likely to be protective of most freshwater plants and invertebrates was 5 µg/L. There are currently no national uranium guidelines for sediment in Australia (Simpson et al., 2013). The study by Sheppard et al.

(2005) proposed a Predicted No Effect Concentration (PNEC) of 100 mg/kg dry sediment for uranium was protective of freshwater benthos. In the absence of an Australian guideline for sediment, this value may be useful as a basis for initial assessment of risk. There are many factors that can influence the bioavailability and toxicity of uranium including the presence of calcium, magnesium, carbonates, phosphate, and dissolved organic matter (Goulet et al., 2011; 2015).

Comment [CN5]: To provide some indication of risk (or potential impacts – as per the report title) it would be useful here to make some comparison to the current EA limit and concentrations that have been recorded in Boghole Creek and Keelbottom Creek.

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ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1609059**	Page	: 1 of 7
Amendment	: **1**		
Client	: **QLD DEPT OF ENVIRONMENT & HERITAGE PROTECTION**	Laboratory	: Environmental Division Brisbane
Contact	: MR ANDREW WALLACE	Contact	: Customer Services EB
Address	: GPO BOX 5391 TOWNSVILLE MC QLD, AUSTRALIA 4810	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 47225353	Telephone	: +61-7-3243 7222
Project	: Ben Lomond	Date Samples Received	: 07-Apr-2016 09:45
Order number	: ----	Date Analysis Commenced	: 11-Apr-2016
C-O-C number	: 133174 - 133175	Issue Date	: 19-Apr-2016 18:08
Sampler	: ANDREW WALLACE		
Site	: ----		
Quote number	: ----		
No. of samples received	: 12		
No. of samples analysed	: 12		

NATA Accredited Laboratory 825
Accredited for compliance with
ISO/IEC 17025.

NATA
WORLD RECOGNISED ACCREDITATION

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.

- It is recognised that EG020-T (Total Metals by ICP-MS) is less than EG020-F (Dissolved Metals by ICP-MS). However, the difference is within experimental variation of the methods.
- Amendment (18/4/16): This report has been amended and re-released to allow the reporting of additional analytical data. The results for samples "SWM6" and "SWM22" have now been included.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	BLTA1	BL TA US	BL TA 2	BL TA 3	BL TA 4
			Client sampling date / time	30-Mar-2016 11:10	30-Mar-2016 11:20	30-Mar-2016 11:30	30-Mar-2016 11:40	30-Mar-2016 12:10
Compound	*CAS Number*	*LOR*	*Unit*	**EB1609059-001**	**EB1609059-002**	**EB1609059-003**	**EB1609059-004**	**EB1609059-005**
				Result	Result	Result	Result	Result
EN59: SPLP Leach								
Extraction Fluid Number	----	1	-	**2**	**2**	**2**	**2**	**2**
Final pH	----	0.1	pH Unit	**4.7**	**6.2**	**5.6**	**4.9**	**6.3**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	BL TA 5	BL TA 6	BL TA 8	BL TA 7	BL TA 9
			Client sampling date / time	30-Mar-2016 12:25	30-Mar-2016 12:40	30-Mar-2016 12:55	30-Mar-2016 13:05	30-Mar-2016 14:05
Compound	CAS Number	LOR	Unit	EB1609059-006	EB1609059-007	EB1609059-008	EB1609059-009	EB1609059-010
				Result	Result	Result	Result	Result
EN59: SPLP Leach								
Extraction Fluid Number	----	1	-	**2**	**2**	**2**	**2**	**2**
Final pH	----	0.1	pH Unit	**7.0**	**6.6**	**6.7**	**6.4**	**6.7**

Analytical Results

Sub-Matrix: **SPLP LEACHATE** (Matrix: **WATER**)			Client sample ID	**BLTA1**	**BL TA US**	**BL TA 2**	**BL TA 3**	**BL TA 4**
			Client sampling date / time	30-Mar-2016 11:10	30-Mar-2016 11:20	30-Mar-2016 11:30	30-Mar-2016 11:40	30-Mar-2016 12:10
Compound	CAS Number	LOR	Unit	**EB1609059-001**	**EB1609059-002**	**EB1609059-003**	**EB1609059-004**	**EB1609059-005**
				Result	Result	Result	Result	Result
EG005C: Leachable Metals by ICPAES								
Arsenic	7440-38-2	0.1	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Lead	7439-92-1	0.1	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG020C: Leachable Metals by ICPMS								
Arsenic	7440-38-2	0.005	mg/L	<0.005	**0.016**	<0.005	<0.005	**0.008**
Lead	7439-92-1	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	**0.02**
Uranium	7440-61-1	0.001	mg/L	**0.381**	**0.036**	**0.345**	**0.010**	**0.049**

Analytical Results

Sub-Matrix: **SPLP LEACHATE** (Matrix: **WATER**)			Client sample ID	**BL TA 5**	**BL TA 6**	**BL TA 8**	**BL TA 7**	**BL TA 9**
			Client sampling date / time	30-Mar-2016 12:25	30-Mar-2016 12:40	30-Mar-2016 12:55	30-Mar-2016 13:05	30-Mar-2016 14:05
Compound	CAS Number	LOR	Unit	**EB1609059-006**	**EB1609059-007**	**EB1609059-008**	**EB1609059-009**	**EB1609059-010**
				Result	Result	Result	Result	Result
EG005C: Leachable Metals by ICPAES								
Arsenic	7440-38-2	0.1	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Lead	7439-92-1	0.1	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG020C: Leachable Metals by ICPMS								
Arsenic	7440-38-2	0.005	mg/L	**0.037**	<0.005	<0.005	<0.005	**0.007**
Lead	7439-92-1	0.01	mg/L	**0.01**	<0.01	<0.01	<0.01	<0.01
Uranium	7440-61-1	0.001	mg/L	**0.023**	<0.001	**0.026**	**0.006**	**0.001**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SWM 6	SWM 22	----	----	----
			Client sampling date / time	30-Mar-2016 14:05	30-Mar-2016 14:30	----	----	----
Compound	CAS Number	LOR	Unit	EB1609059-011	EB1609059-012	--------	--------	--------
				Result	Result	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.75**	**7.74**	----	----	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**216**	**119**	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.005**	**0.004**	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.002**	**0.002**	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.006**	**0.038**	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.008**	**0.003**	----	----	----
Uranium	7440-61-1	0.001	mg/L	**0.002**	<0.001	----	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.006**	**0.004**	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.001**	**0.002**	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.008**	**0.003**	----	----	----
Uranium	7440-61-1	0.001	mg/L	**0.002**	<0.001	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----

TROCCAZ Catherine

From: WALLACE Andrew
Sent: Monday, 20 June 2016 1:34 PM
To: CONNOLLY Niall
Subject: FW: Ben Lomond
Attachments: Ben_Lomond_U_mobility_and_impacts_23-12-2015_Draft.docx

Hi Niall,

Just for your update, I have spoken with Jason since this version was provided.
Jason identified that review is ongoing and the intention was to publish the ingestion recommendations into a journal at some point.
Also, there was a calculation error in the soil trigger level in this draft version, so it should be 220 odd mg/kg, not 320 mg/kg.

Calc from page 10 corrected:

$$SQG_I = \frac{0.75 \times 0.8 \times 500}{(0.9 \times 1) + (14.1 \times 0.025)}$$

$$SQG_I = \mathbf{221.8\ mg/kg}$$

Cheers, Andrew

From: CONNOLLY Niall
Sent: Friday, 17 June 2016 2:31 PM
To: WALLACE Andrew <Andrew.Wallace@ehp.qld.gov.au>
Subject: FW: Ben Lomond

FYI

From: CONNOLLY Niall
Sent: Friday, 17 June 2016 2:23 PM
To: SULLIVAN Scott
Cc: HENNEY Nina; LAWRENCE Rob
Subject: RE: Ben Lomond

Scott,

See attached BN with some edits to consider.

Re leaching tests:

- Indicator that U and other elements will dissolve and therefore potentially migrate from contaminate soils/waste
- The test does indicate mobilisation is likely but the precise solubility and toxicity (i.e. species of U ions) *in situ* will vary with environmental factors such as EC, Redox potential etc.
- The concentrations of leachate in the test are specific to that analysis and were high relative to EA limits, but don't account for dilution and transformations that may occur *in situ* and are the result of the sample volume and concentration
- The exact load that may leach from a contaminated area will be complex to predict and depend on the above and concentrations in the receiving environment will depend on available dilution etc.
- The groundwater bores in areas of contaminated soils have frequent (or almost continuous) exceedances.

The above were determined in collaboration with Jason Douglas and Mann Reinier at DSITI. They also derived an interim soil concentration that was likely to cause harm – see attached report. The Executive summary below describes their findings.

Niall

Executive summary

Historic mining activities at Ben Lomond have potentially led to legacy contamination issues with the soil, water and creek sediments. Uranium, as a marker of this contamination and contaminant of concern has the potential to move within the soil and aquatic environment, and poses a potential risk to several environmental values as a consequence of soil and water contamination. This report discusses the chemical processes that are likely to influence the mobility of uranium in soil and water and the pathways of exposure in the environment. An overarching framework to assess and manage the potential risk of uranium is also presented. In the terrestrial compartment, cattle grazing could be viewed as the most relevant environmental value. Exposure to grazing cattle on site via ingestion or direct contact with soil and plants is considered to be the most likely exposure pathway. The report reviews the available soil quality criteria for uranium that may be used to evaluate the potential for impact on-site. As guidelines were not available for the protection of grazing cattle, a soil quality trigger was developed using approaches described in Canadian guidelines (CCME, 2007). A soil trigger for cattle that considers the potential for ingestion of uranium was calculated as 320 mg/kg. Although this figure has some uncertainties associated with it, this trigger provides a basis for a preliminary assessment of risk. The merits of this and other soil quality guideline values are discussed. Options for further site specific evaluation of the risk to the environment are also considered.

From: SULLIVAN Scott
Sent: Friday, 17 June 2016 1:28 PM
To: CONNOLLY Niall
Cc: HENNEY Nina; LAWRENCE Rob
Subject: Ben Lomond

Niall

Can you asap review the attached BN for content and accuracy please.

Can you also provide in reply all email some 'macro' background re the importance of the leach testing to understanding potential for migration of contaminants as well as some explanation regarding the 'may cause harm to livestock' statement.

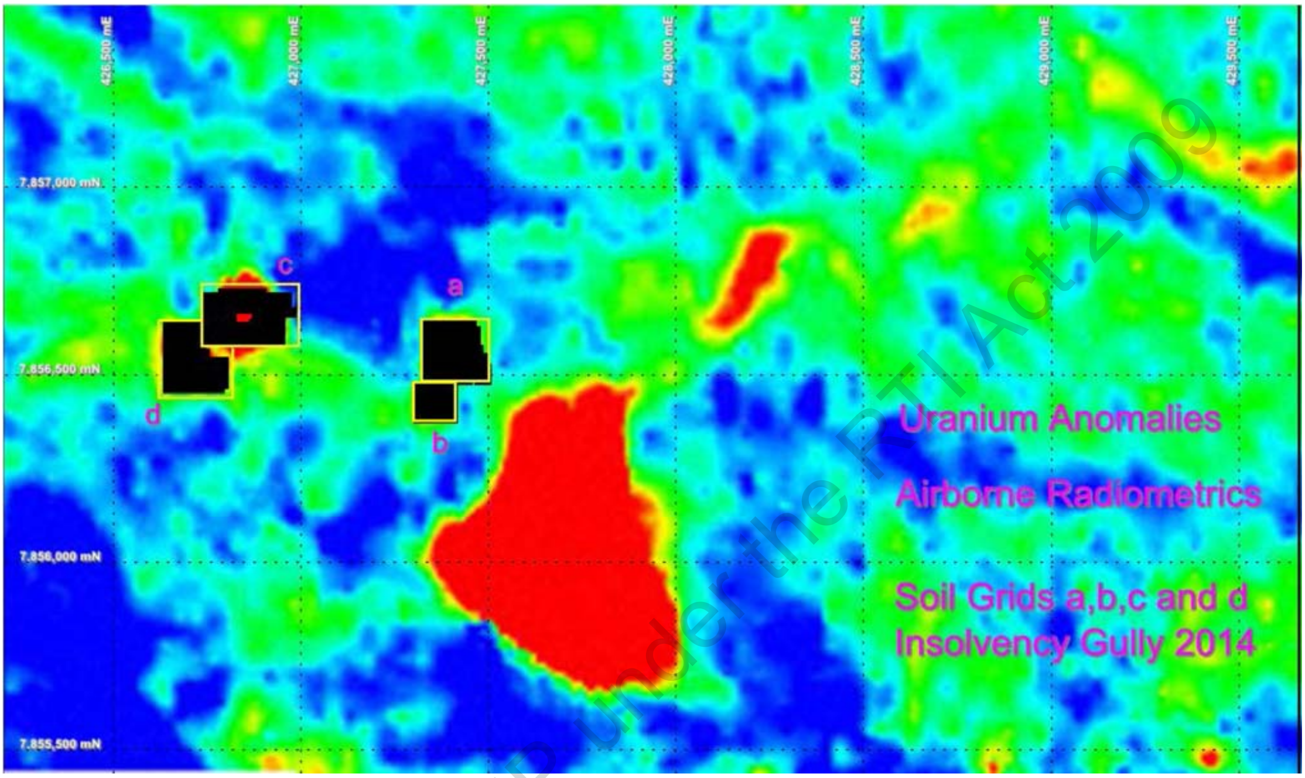
Many thanks

Queensland Government

Scott Sullivan
Program Manager Compliance
Minerals and North Queensland Compliance I Environmental Services and Regulation
Department of Environment and Heritage Protection

P 07 4722 5200
Level 10, Verde Tower, 445 Flinders Street, Townsville QLD 4810
PO Box 5391, Townsville QLD 4810

Department of Science, Information Technology and Innovation



Approaches to assess the mobility and potential impacts of uranium consequent to historic mining activities at Ben Lomond

Water Assessment and Systems

December 2015

Queensland Government

Prepared by

Jason E. Dunlop and Reinier M. Mann
Water Assessment and Systems
Science Delivery Division
Department of Science, Information Technology and Innovation
PO Box 5078
Brisbane QLD 4001

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Executive summary

Historic mining activities at Ben Lomond have potentially led to legacy contamination issues with the soil, water and creek sediments. Uranium, as a marker of this contamination and contaminant of concern has the potential to move within the soil and aquatic environment, and poses a potential risk to several environmental values as a consequence of soil and water contamination. This report discusses the chemical processes that are likely to influence the mobility of uranium in soil and water and the pathways of exposure in the environment. An overarching framework to assess and manage the potential risk of uranium is also presented. In the terrestrial compartment, cattle grazing could be viewed as the most relevant environmental value. Exposure to grazing cattle on site via ingestion or direct contact with soil and plants is considered to be the most likely exposure pathway. The report reviews the available soil quality criteria for uranium that may be used to evaluate the potential for impact on-site. As guidelines were not available for the protection of grazing cattle, a soil quality trigger was developed using approaches described in Canadian guidelines (CCME, 2007). A soil trigger for cattle that considers the potential for ingestion of uranium was calculated as 320 mg/kg. Although this figure has some uncertainties associated with it, this trigger provides a basis for a preliminary assessment of risk. The merits of this and other soil quality guideline values are discussed. Options for further site specific evaluation of the risk to the environment are also considered.

Contents

List of tables

List of figures

Introduction

Ben Lomond is a uranium and molybdenum ore deposit owned by Mega Uranium (UMVI) that is currently in care and maintenance (not operating). Ongoing surface and groundwater monitoring undertaken as part of the requirements of the existing Environmental Authority (EA) has identified a high proportion (between 20-90%) of samples at monitoring locations that are in exceedance of surface and groundwater limits for a range of water quality indicators.

The site is an area of natural mineralisation and has historically had mining and exploration activities undertaken on it. Although elevated contaminant concentrations may occur as a result of runoff from areas of natural mineralisation, the absence of pre-mining baseline data has prevented an informed assessment of the potential contribution of contaminants from disturbed areas compared with natural areas. As a result, an Environmental Evaluation (EE) was issued to require an investigation of the '*source, cause and extent of contamination on the site*'. The resultant EE report suggested that the source of contaminants was largely natural. However, the EE report was found to have inadequately characterised the contribution from all potential sources. EHP requested an additional study be undertaken to evaluate longitudinal trends in water quality. That study was unable to identify the presence of either an increasing or decreasing trend in the concentrations of contaminants since the mid – 1980s when historic mining activities were active, but did identify consistent differences across sampling sites. For example, those sites that were reported as being in non-compliance with EA conditions, were consistently elevated compared to reference sites. Also, a subsequent field inspection of the site by EHP officers found some additional sources of contamination that had not previously been identified by UMVI. These additional sites were upstream of those sites that were in non-compliance.

Using the available historic monitoring data, local reference based water quality trigger values and limits were developed by the Water Assessment & Systems (WAS) group with the Department of Science, Information Technology and Innovation (DSITI). Review of the data against the newly developed draft triggers indicated compliance with triggers for most sites with the exception of sites SWM6 and SWM22. However, the source of elevated concentrations of metals (including uranium, lead and arsenic) at these sites could not be identified. At the request of EHP, a further study has since been undertaken by UMVI to evaluate the concentration of contaminants in both the unimpacted and disturbed areas. That study identified several areas where material excavated from historic mining had been variously stockpiled adjacent to the adit portal apron, used to construct haul roads, or stockpiled in areas of the valley floor before being stored in the covered ore shed. This study also indicated that portal rock benches and haul roads, that had been constructed of both mineralised rock from mining and local remnant soils, have since undergone some erosion. Following on from this, further studies have been undertaken by UMVI to survey the area and estimate the volume of material exported as a result of erosional processes and estimate the likelihood of further erosion occurring.

Given that there are a number of sources of contaminants on-site, there is currently a need to understand what hazard this represents to the environment. Where there is a genuine threat to the environment, UMVI have agreed to rehabilitate the site.

Although a number of metals have been found to be present in elevated concentrations, at the request of EHP the focus of this report is on uranium as it is thought to pose greatest risk to the environment. The report considers the chemical processes that are likely to influence the mobility of uranium in soil and water and the pathways of exposure in the environment.

To provide a basis for initial assessment and consideration of options for management, EHP has requested consideration of action levels for uranium in soils at the Ben Lomond site. Accordingly, available soil quality criteria for uranium are reviewed and the merits of applying available and derived soil quality triggers are discussed. Options for further site specific evaluation of the risk to the environment are also considered.

Mobility and potential impacts of uranium

Source of contaminants

The sources of contaminants onsite include the outcropping of the natural ore body and areas disturbed as a result of historic mining and exploration. Areas of disturbance include the adit apron, haul road and waste rock dump (referred to as benches 1, 2 and 3) that intersect the natural ore body. In addition, there are four areas previously used for mine activities where airborne radiometrics indicated elevated concentrations of uranium and other radionuclides (referred to as areas a – d in Figure 1). The XRF Characterisation Report (UMVI, 2015) showed that disturbed areas can have relatively high concentrations of a range of metals dominated by U, Pb, and As. Areas with an elevated uranium concentration are shown in Figure 2 below. This figure also shows the proximity of 1st and 2nd order streams and ground and surface water monitoring locations.

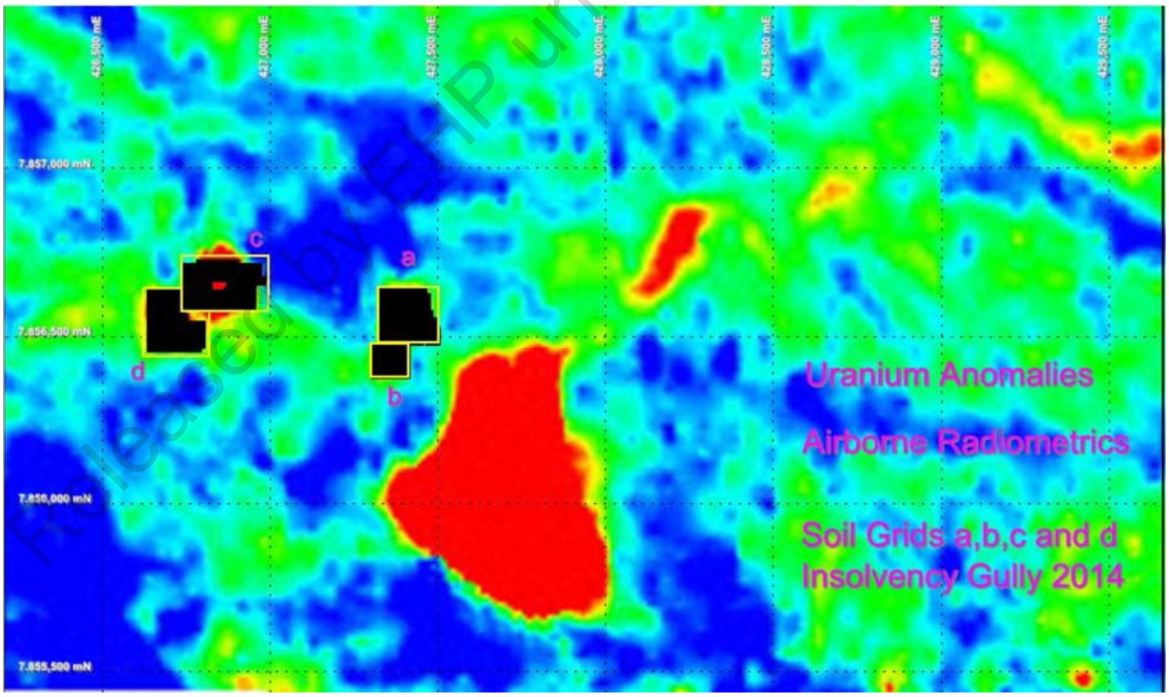

Figure 1. Location of areas a, b, c and d within Insolvency Gully, showing uranium gamma sources at the surface determined from airborne radiometry (source: UMVI, 2015). Concentration of uranium is greatest in red and least in blue.

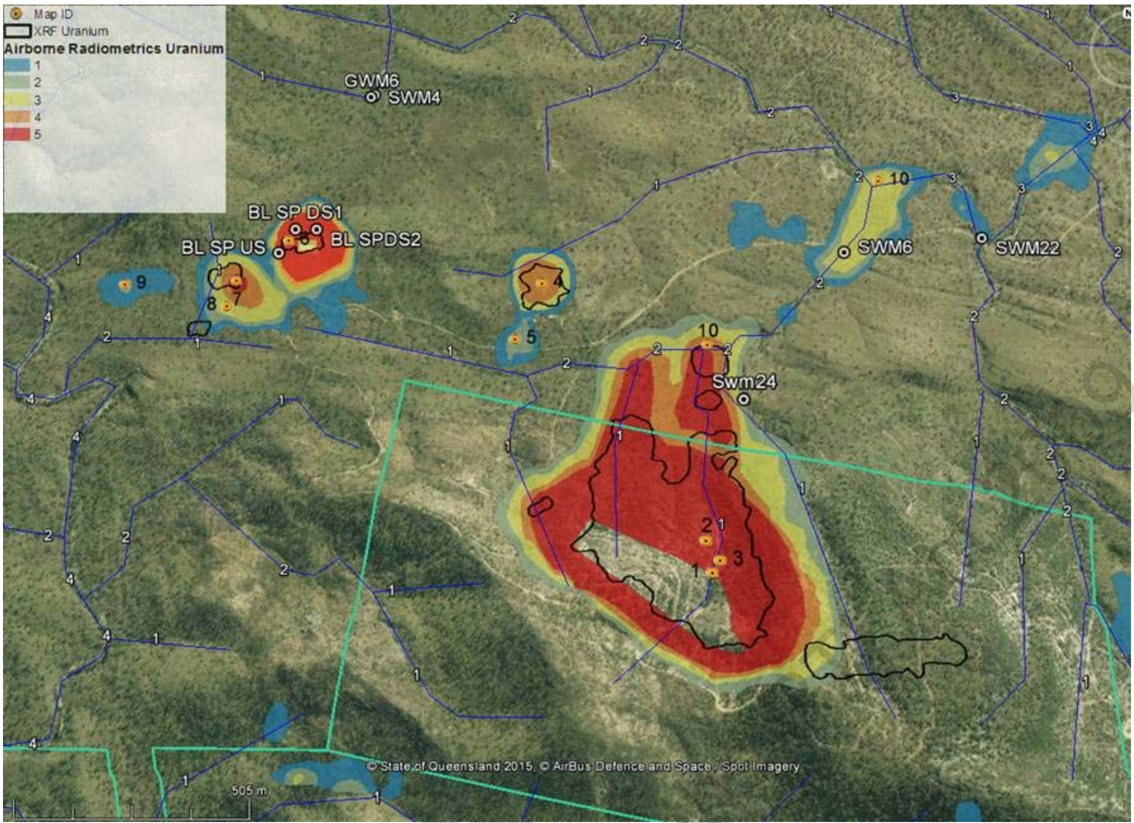

Figure 2. Airborne radiometrics survey for showing uranium gamma sources in surface soils, the stream network and stream order (blue line), ground and surface water monitoring sites (map supplied by EHP).

Conceptual model of contaminant transport and impacts

The conceptual model in Figure 3 shows a range processes that are likely to influence the mobility of contaminants from disturbed areas and indicates potential environmental receptors. Uranium is likely to bind with particulates and remain in soils. Some bioaccumulation of uranium ions in vegetation is also possible, although the degree to which this will occur is likely to be dictated by plant species. As the lease is subject to grazing, it is possible that metals present in soils and vegetation will pose a risk to beef cattle via consumption of plants and soil materials. Transitory wildlife, local plants, soil invertebrates and soil microbes may also be exposed to soil and water on the site. Direct human contact with soils is not expected as access to the site is restricted.

Under some circumstances uranium may be soluble in water and may enter surface waters as overland flow or alternatively may percolate into soils and enter groundwater posing a risk to aquatic ecosystems. Groundwater seeps are known to occur on site though it is not known whether they are present downslope from disturbed areas. Metals bound to particulates may also be transported from disturbed areas as a consequence of natural weathering and erosion processes. This material can enter streams where it may settle out and pose a risk to sediment biota. Under some conditions, contaminants may desorb from particulates making stream sediments a potential source of contaminants.

In the terrestrial compartment, cattle grazing could be viewed as the most relevant environmental value and is considered here as an appropriate receptor for the purposes of this report evaluating the risk to terrestrial fauna. Ingestion of uranium by beef cattle is considered to be the most likely exposure pathway.

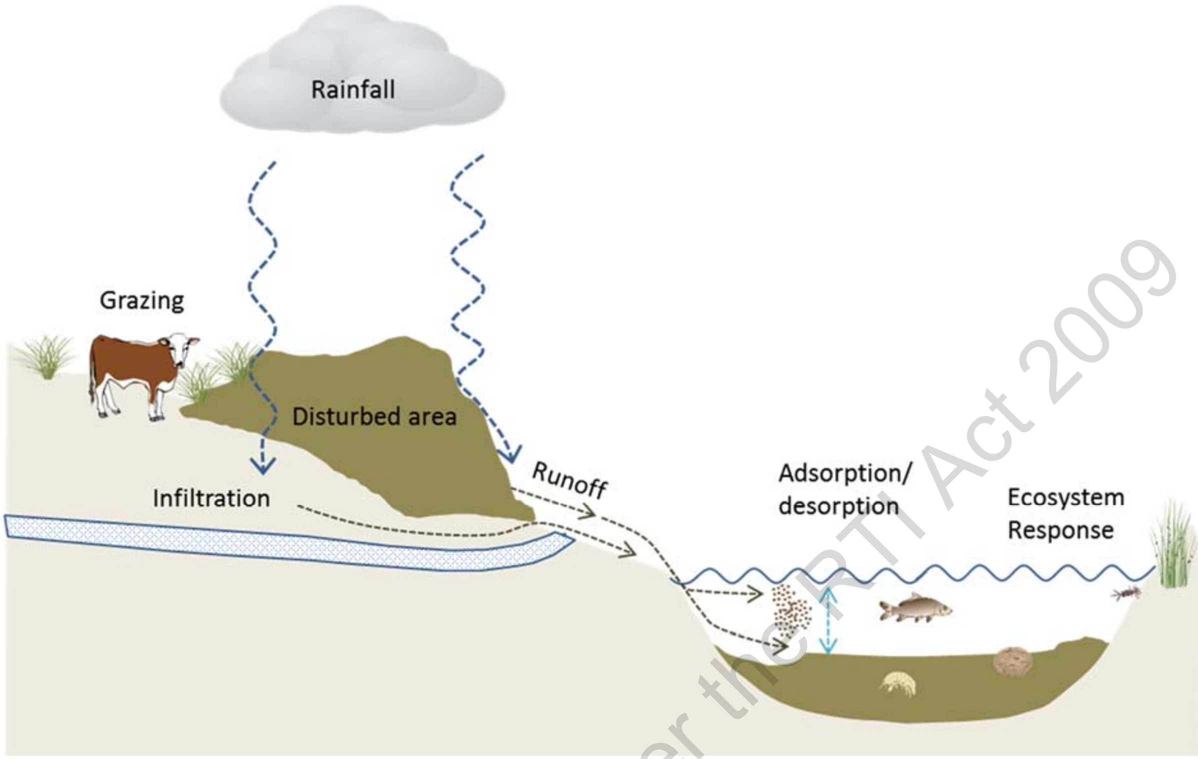

Figure 3. Conceptual model of contaminant fate and effects in the environment at Ben Lomond

Mobility of uranium in surface water run-off

The oxidation state of uranium has a significant effect on its mobility. Uranium can be present as U(IV), U(V), U(III) and U(VI). The dominant form of uranium in soils and oxidised waters is U(VI) present predominantly as the uranyl ion (UO_2^{2+}). Uranium (VI) is soluble and mobile under oxidizing to mildly reducing conditions forming soluble complexes with carbonate anions in natural waters (Gavrilescu, et al., 2009) and humic substances (e.g., uranyl fulvate) in dissolved, colloidal, and/or particulate forms (Markich, 2002).

Mobility of uranium within soils

Uranium has a strong tendency to bind with particulates and organic matter. Uranium mobility and partitioning in soil is dependent on the physical and chemical attributes of the soil. Physical attributes affecting the movement of metals in soils include grain size, porosity and hydraulic conductivity. Chemical attributes affecting the movement of metals in soils include the organic content, ionic strength (salinity), soil pH, redox potential (Eh) and presence of specific cations. A measure of cation exchange capacity (CEC) provides an indication of the ability of soils to retain exchangeable ions. The key physicochemical property of inorganic contaminants that controls their potential movement to ground and/or surface waters is the soil−water partition coefficient (K_d) (NEPC, 2013a). This is the ratio of the concentration of a contaminant bound to the soil to that dissolved in soil pore water at equilibrium, and therefore, is related to the aqueous solubility of that contaminant (NEPC, 2013a). Increasing soil salinity has been found to mobilise U(VI) from soil exchange sites forcing it into solution (Rout et al., 2015) with the different ions known to have varying effects on mobility. The capacity of cations to provoke desorption is directly proportional to ionic radius with large cations having a greater capacity than smaller cations (i.e. Ca^{2+} > Mg^{2+}> Na^{+}) (Rout et al., 2015). Many studies have shown that carbonate complexation reduces adsorption of uranium, thus leading to its release from soils (Gavrilescu et al., 2009). Uranium tends to occur in the solid phase at low redox potential (E_h) with the formation of dissolved uranium carbonate complexes at high E_h values (Gavrilescu et al., 2009). The presence of high concentration of NO_3^- in ground water also has the potential to mobilise uranium by changing the redox potential of the environment (Rout et al., 2015).

Erosion, transport and deposition of uranium associated with particulates

Uranium associated with insoluble particulates can be transported via hydraulic and geomorphic processes. A study by ETS Geotechnical (2015) on behalf of UMVI indicated that fill batters have been eroding over the preceding 30 years and displayed signs of instability. In that study, batters were considered largely stable under normal conditions, although it was noted that they are prone to instability during periods of intense rainfall. The report by Resource and Exploration Mapping (REM, 2015) undertaken on behalf of UMVI provides estimates of the volume of material lost from drill pads and the haul road from surveys of the estimated original and current landform. An estimated 298 m^3 of material has eroded from the three benches and haul road.

It is likely that some of this material has been deposited in Bog Hole Creek, where it may pose a risk to sediment dwelling biota in the immediate vicinity of the site and further downstream. However, at this time there is limited information available describing the chemical composition of sediments in Bog Hole Creek. Although much of the uranium associated with particulates would remain adsorbed to particulates in the sediments, it is possible that under oxidising conditions U(VI) may desorb from sediments.

Effect of uranium in the environment

Uranium can exhibit both radiological and chemical toxicity effects. However, a study by Mathews et al. (2009) showed that the risks to the environment as a consequence of uranium's chemical toxicity generally outweigh those of its radiological toxicity. Accordingly, direct toxicity effects are likely to provide the focus for ecological risk assessment. Uranium can be toxic above certain thresholds, although it is comparatively less toxic than other metals (Goulet et al., 2011). However, Borgmann et al. (2005) found that uranium toxicity increases with decreasing water hardness. It does not biomagnify but is known to accumulate in bone, liver, and kidney tissue (Goulet et al., 2011).

As the lease is subject to grazing, one of the key pathways by which uranium may enter the terrestrial biota is expected to be grazing of beef cattle. As previously mentioned, stock may be exposed via consumption of soil, plants and ingestion of water from local waterbodies. Local and transitory wildlife may also be exposed to soils, plants and water from affected areas.

Approach to assess and manage risk

As uranium and other contaminants have been identified in elevated concentrations above background, the possibility of impacts to the environment cannot be excluded. In such a circumstance it may be worthwhile implementing strategies to contain contaminants and prevent potential impacts. Development of these strategies would require input from relevant experts but may include removing and covering material or implementing erosion and sediment control practices to stabilise soils and capture those metals that might otherwise be mobilised in runoff and leachate. It may also be possible to limit or prevent stock and wildlife accessing contaminated areas.

The diagram in Figure 4 provides an indication of a process that may be followed to assess the risks and determine the need for remedial actions. The key focus at this stage is on the effect of uranium in soils on grazing cattle; however, this process may be followed to expand the assessment of risk to a broader range of exposure pathways and receptors. Subsequent sections provide information to assess risk in accordance with this assessment process.

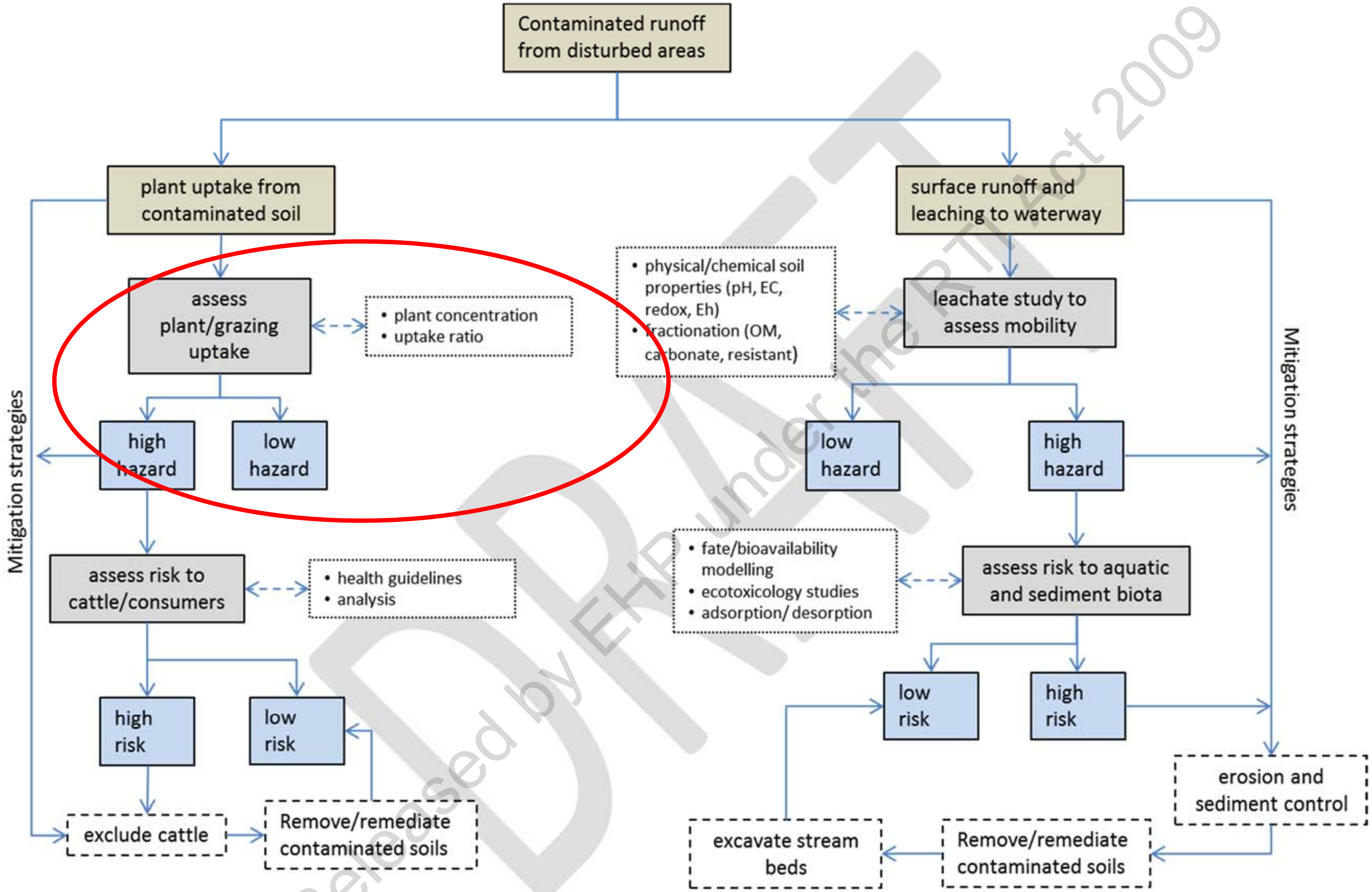

Figure 4. Assessment process for disturbed areas on the Ben Lomond lease area. Red circle shows the current stage of assessment considered here.

Guidelines for uranium in soils

Investigation levels for contaminated soils are described in the National Environment Protection Measures (NEPMs); however, these do not specify guidelines for uranium. In the absence of Australian soil quality guidelines for uranium, available soil triggers for uranium including those described in the Canadian soil quality guidelines (CCME, 2007) and those proposed by Sheppard et al. (2005) were considered. A summary of the available soil quality triggers is provided in Table 1. Neither of the existing triggers had direct relevance to the protection of cattle as required for the Ben Lomond site.

Table 1. Summary of available soil quality trigger values

Guideline category	Guideline value	Source
Protection for terrestrial plants	250 mg/kg	Sheppard et al. (2005)
Protection for soil biota including soil microbes and soil animals	100 mg/kg	Sheppard et al. (2005)
Protection for 'agricultural land use' (based on animal ingestion)	33 mg/kg	CCME (2007)
Protection of vascular plants and soil invertebrates (based on a species sensitivity distribution)	500 mg/kg	CCME (2007)
Protection for grazing animals (based on animal ingestion)	320 mg/kg	Derived below

Sheppard et al. (2005) recommended a Predicted No Observed Effect Concentration (PNEC) to be 250 mg/kg dry soil for the protection of plants, and 100 mg/kg dry soil for the protection of other soil biota including soil microbes and soil animals but did not consider higher vertebrates such as grazing cattle.

The Canadian guideline for exposure (SQG_E) relevant to 'agricultural' areas is 33 mg/kg (CCME, 2007). The 'agricultural' trigger is considered the most relevant of the three land use categories for which triggers are derived under the CCME (2006) framework. This category refers to areas, "*where the primary land use is growing crops or tending livestock. This also includes agricultural lands that provide habitat for resident and transitory wildlife and native flora*" (CCME, 2006). With the exception of cropping, these exposure pathways are relevant to the Ben Lomond site. The (CCME 2007) trigger considers exposure via direct contact with soil, ingestion of soils as well as the ingestion of contaminated water by livestock at agricultural sites. The Canadian SQG_I (sediment quality for ingestion) trigger was calculated using the LOAEL of 0.49 mg/kg bw/d for renal effects in New Zealand white rabbits. Effect data for rabbits was used as it provided the most conservative assessment of effects for protection to biota relevant to 'agricultural' uses (CCME, 2007). As rabbits are not a relevant value requiring protection at the Ben Lomond site, the relevance of the resultant trigger was questioned. The Canadian soil quality guideline for soil contact (SQG_{SC}) was derived using an species sensitivity distribution (SSD) approach that included 11 plant species and 4 invertebrate species from 7 studies (CCME, 2007). The 25th percentile of the data distribution was 500 mg/kg (CCME, 2007). This trigger is based on response data for vascular plants and soil invertebrates and did not include higher vertebrates such as grazing animals. The final Canadian soil quality guideline for uranium relevant to 'agricultural' land uses was adopted as the lower of the soil contact guideline (SQG_{SC}) and the soil and food ingestion guideline (SQG_I).

As none of the aforementioned triggers for soil were specific to cattle grazing, a trigger was developed by applying the approaches described in (CCME 2006; 2007). This was achieved by substituting the food ingestion rate and effect data for rabbits with the Lowest Observed Adverse Effect Level (LOAEL) for observed effects in dairy cattle (Garner, 1963). Applying this approach, a Soil Quality Guideline for ingestion (SQG_I) was calculated as:

SQG_I= (0.75 x DTED x BW) / [(SIR x BF) + (FIR x BCF)]

$$SQG_I = \frac{0.75 \times \mathrm{DTED} \times \mathrm{BW}}{(\mathrm{SIR} \times 1) + (\mathrm{FIR} \times \mathrm{BCF})}$$

Where:

SQG_I = Soil Quality Guideline - ingestion

0.75 = A factor based on the assumption that water and dermal absorption/inhalation account for 25% of the total exposure and the remaining 75% of the total exposure is from food and soil ingestion (CCME 2006).

DTED = Daily Threshold Effects Dose

BW = Body Weight

FIR = Food Ingestion Rate, calculated as Dry Matter Ingestion Rate (DMIR) – Soil Ingestion Rate (SIR)

BF = Bioavailability Factor

BCF = soil to plant Bio-concentration Factor

The study by Garner (1963) reported that a dose of 4 g uranium per day (as uranyl nitrate) over a period of 2 weeks resulted in deterioration in the general health of cattle and a decrease in milk yield, followed by a gradual return to an apparently normal state. The authors assumed that a LOAEL in cattle was likely to be represented by a 10 times lower dose (0.4 g/cow). In order to calculate a trigger specific for the protection of cattle, a Lowest Observed Adverse Effect Level (LOAEL), we have assumed that a cow has a weight of 500 kg (Beyer & Fries, 2003). On this basis, a LOAEL for cattle is calculated as 400 ÷ 500 = 0.8 mg/kg bw/d. Although this represents the best available LOAEL, the data are based on the response of two individual cows to a single dosage rate. In using this data, we have also made assumptions about the weight of the dosed animals (not stated in the original study). In considering this same study, the Canadian guideline document assumed the weight of the animals to be 640 kg, which has implications for the magnitude of the LOAEL index used in the equation, and flow on effects on the magnitude of the SQG_I. Because of these large uncertainties, the number derived through this process should be viewed as provisional.

The CCME (2007) approach considers soil consumption to provide the primary route of exposure for grazing animals. The CCME (2007) approach to calculate a SQG_I uses a food ingestion rate (FIR) calculated as a dry matter ingestion rate (DMIR) minus the soil ingestion rate (SIR). Soil ingestion rate and percentage of soil in the diet of cattle was reported in Beyer & Fries (2003). In that study, the soil ingested by a 500 kg dairy cow (in a New Zealand study) was estimated to average 900 g/day when it was assumed that dry matter intake was 15 kg/day and that cows grazed 365 days per year. The bioavailability and uptake of uranium in animals is not well studied. It was assumed that all uranium in ingested soil would be bioavailable. This was appropriate given the administration of uranium in the study by Garner (1963) was bioavailable. Soil-to-plant bioconcentration of uranium was that used in (CCME, 2007) which was estimated by taking the geometric mean of all concentration ratios listed for plants resulting in a bioconcentration factor of 0.025. A SQG_I for cattle was calculated as 320 mg/kg.

The calculation of a trigger for cattle using the CCME techniques is as follows:

$$SQG_I = \frac{0.75 \times 0.8 \times 500}{(0.9 \times 1) + (14.1 \times 0.025)}$$

$$SQG_I = 320.8 \text{ mg/kg}$$

Where:

DTED = LOAEL of 0.8 mg/kg body mass/d[1] (Garner, 1963).

BW = 500 kg (Beyer & Fries, 2003)

FIR = 14.1 kg/d dw, calculated as DMIR – SIR (where DMIR = 0.9 kg/day for soil ingestion divided by 15 kg/day DMI = 6%).

15 kg/day dw - 0.9 kg/day) (Beyer & Fries 2003)

BF = information not available, therefore a bioavailability factor of one (unitless) is assumed (CCME, 2005).

BCF = 0.025 (unitless) the soil to plant bioconcentration factor that was derived in CCME (2005).

Discussion

This report addresses the requirement to derive a soil quality trigger for uranium given grazing was considered the key route of exposure to contaminated soils; however, a number of other possible routes of exposure and likely receptors were identified, such as runoff of contaminated soils into local waterways and the potential risk to aquatic and sediment biota. Although these were not considered here, future evaluation should consider risks to those receptors.

The available trigger for the protection of 'agricultural' land use from CCME (2007) of 33 mk/kg was considered overly conservative due to its use of a receptor that was not relevant to the site. The Canadian soil quality guideline for soil contact (SQG_{SC}) of 500 mg/kg (CCME, 2007) did not consider potential response in vertebrate animals. A soil quality guideline of uranium in soils was developed by substituting the available effect data for cattle using the Canadian approach (CCME, 2007). The resultant trigger of 320 mg/kg is expected to provide a reasonable trigger value for soils in an area subject to grazing. In lieu of established guidelines specifically designed to protect

[1] The Lowest Observed Adverse Effect Level (LOAEL) from Garner 1963 was based on a limited study of two individuals to provide an estimate of depression in milk yield. The original Garner (1963) paper cites data from a pers. comm.

grazing cattle, the soil quality guideline calculated here may provide a basis for a preliminary assessment and allow comparison with similar triggers but would not necessarily provide a reliable basis for an assessment trigger or compliance limit. The Canadian approach to derive soil quality criteria shares similarities with the NEPC (2013a) but is not identical. Where there is a desire to further evaluate soil quality triggers, the approaches described in NEPC (2013a) may be applied. Where specific action criteria are required (as requested by EHP), a site-specific evaluation is recommended. Site specific investigations could consider those aspects that are likely to influence risk, such as the physical and chemical characteristics of soils, leaching potential, and bioavailability of uranium in soil. An assumption made in the calculation of this trigger is the likely uptake of uranium in plants. As plant uptake will influence to the overall risk to grazing animals, there may be a need to assess the risk of uptake by plants found to occur locally. Schedule B2 of the National Environmental Protection Measures provides guidance on site characterisation (NEPC, 2013). A further assumption is of constant exposure of cattle to contaminants. However, as cattle graze unconstrained at this location and as soil contaminant concentration varies spatially, cattle will be exposed to varying contaminant concentration.

Risk to cattle through drinking water may also be assessed against the ANZECC & ARMCANZ, (2000a) guidelines for the protection of livestock (cattle) water for uranium (0.2 mg U/L). Further considerations also include direct exposure to humans as a result of animal product consumption. Garner (1965), proposed a revised threshold for the protection of human health, which equated to a permissible intake of uranium by cattle of 7 g/day. This is 17.5 times higher than the dose expected to result in an observable adverse effect in cattle (Garner, 1963;1965). On this basis the risk to human health as a consequence of transfer of uranium from animals through consumption of meat is expected to be of low risk and was not considered further. Although not expected to pose a risk based on current understanding, there is little information describing the potential risk to human health from the consumption of beef cattle.

Additional considerations include run-off of contaminated sediments into local waterways. This exposure pathway has not been assessed at this time given the focus for assessment of soil contamination. A useful approach to determine the proportion of uranium and other metals that are likely to be soluble is to undertake leachate studies. Leachate studies are undertaken by passing a solute through a sample of soil collected from the site and analysing the chemical composition of the leachate. This approach provides a direct measure of the likely solubility of metals taking into account the chemical and physical properties of the soils at the site. Appropriate soil or sediment sample collection techniques, study design and chemical analyses should be used that comply with the relevant standards including AS4439.1 (1999), AS 4439.2 (1997) and AS 4439.3 (1997) for the preparation of leachates.

Assessment of potential impacts in aquatic ecosystems may be determined considering the low reliability trigger value for uranium in freshwater ecosystems of 0.5 (µg U/L) as derived using an assessment factor of 20 derived from limited chronic data (ANZECC & ARMCANZ 2000). Since this earlier figure was released, a site-specific chronic trigger value of 6 (µg U/L) was derived for 99% protection of Magela Creek in Alligator Rivers by (Hogan, R.A., et al, 2003). A trigger of 7.8 µg/L (1.8 – 15 µg/L) for the protection of 95% of species was presented by Rick van Dam, Andrew Harford and Alicia Hogan at the Society for Environmental Toxicology and Chemistry – Australasian chapter annual conference in Melbourne in 2013. There are also Canadian Guidelines for uranium in waters (CCME, 2011) that may be considered. Those guidelines are 15 µg/L uranium (total recoverable) long term exposure, and 33 µg/L uranium (total recoverable) short term exposure. A study by Sheppard et al., (2005) indicated a NOEC for uranium that is likely to be protective of most freshwater plants and invertebrates was 5 µg/L. There are currently no national uranium guidelines for sediment in Australia (Simpson et al., 2013). The study by Sheppard et al.

(2005) proposed a Predicted No Effect Concentration (PNEC) of 100 mg/kg dry sediment for uranium was protective of freshwater benthos. In the absence of an Australian guideline for sediment, this value may be useful as a basis for initial assessment of risk. There are many factors that can influence the bioavailability and toxicity of uranium including the presence of calcium, magnesium, carbonates, phosphate, and dissolved organic matter (Goulet et al. 2011; 2015).

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From: WALLACE Andrew [Andrew.Wallace@ehp.qld.gov.au]
Sent: Wednesday, 4 November 2015 8:43 AM
To: DUNLOP Jason; CONNOLLY Niall
CC: MANN Reinier; RAMSAY Ian; MORRISON Anthony
Subject: RE: draft: options to assess risks of contaminant migration from disturned areas
Attachments: Draft_Assessment of contaminants at Ben Lomond_29-07-2015.docx; Ben Lomond - contaminated leachate ; RE: Ben Lomond - contaminated leachate

Follow Up Flag: Follow up
Flag Status: Flagged

Hi Jason,

As discussed, further to this request can you give some further thought to the section on the 'Effect of uranium and other metals on grazing cattle' in the attached draft assessment.
EHP is seeking to establish an action level for soil uranium contaminant levels.
The intent is that the detection of uranium contaminant levels in soil above the action level would establish the need for rehabilitation/control actions to commence.

It is understood that an action level (or levels) may be able to set from other studies and current site data.
If not, then the steps required to establish an action level are sought. Costings could then be estimated for these steps and a project to establish the level can proposed.

Hope this request is clear enough to commence, please feel free to contact me for further information or if you would like to meet to discuss.

Kind Regards, Andrew

Andrew Wallace
Senior Environmental Officer
North Queensland Compliance
Department of Environment and Heritage Protection

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From: DUNLOP Jason
Sent: Wednesday, 29 July 2015 7:20 PM
To: WALLACE Andrew; CONNOLLY Niall
Cc: MANN Reinier; RAMSAY Ian
Subject: draft: options to assess risks of contaminant migration from disturned areas

Hi Andrew and Niall,

Attached for your input is a very draft document prepared in follow up to our discussion last Friday. This considers possible approaches/options to assess the mobility and environmental risks of uranium and other metals present at Ben Lomond. This document is marked 'draft for comment' as it has not been reviewed as yet. Please forgive any editorial errors ☺, the timeline has been very tight. It would be great to get your input on areas requiring further information, whether the process diagram needs to be changes and any broad comments you may have. The info in the background section may need checking to ensure it is an accurate reflection of the history and it may not be all that necessary anyway.

Hopefully this should give you some information to support your internal discussions regarding the options for management.

Note that our expertise is primarily aquatic ecosystem impacts and ecotoxicology and not soils or cattle health. I have collated some information regarding the assessment of mobility of uranium is soils and the assessment of risk to grazing animals but I suggest that relevant experts in those areas be consulted. Also, I have looked at but not fully reviewed the NEPM measures for site contamination, likewise I have also only done a first pass of the available guidelines so conclusions for those need to be revisited.

Cheers,

Jason

Dr Jason Dunlop
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Evaluation of the potential for contaminant export and potential impacts at Ben Lomond

Background

Ben Lomond is a uranium and molybdenum ore deposit owned by Mega Uranium (UMVI) that is in care and maintenance and not operating. Ongoing surface and groundwater monitoring undertaken as part of the requirements of the existing environmental authority has identified a high proportion (between 20-90%) of samples at monitoring locations are in exceedance of surface and groundwater triggers for a range of water quality indicators. The site is an area of natural mineralisation and has had historic mining and exploration activities undertaken on it. The potential contribution of contaminants from disturbed areas compared with natural areas was not known. As a result an Environmental Evaluation was issued to require an investigation of the source, cause and extent of contamination on the site. This study undertaken in behalf of UMVI found that the source of contaminants was largely natural. However, the report was not found to have adequately characterised the contribution from all potential sources. A field evaluation of the site found some additional sources not previously identified by UMVI. EHP requested an additional study be undertaken to evaluate longitudinal trends in water quality. That study was unable to identify the presence of either an increasing or decreasing trend in the concentrations of contaminants had occurred since the mid 1980s when historic mining activities were active. Local reference based water quality trigger values developed using the available historic monitoring data. These triggers showed that greater compliance with triggers for most sites with the exception of sites GWM6 and SWM22; however, the source of elevated concentrations at these sites was not able to be defined. A further study has since been undertaken by UMVI to evaluate the concentration of contaminants in both the unimpacted and disturbed areas. That study identified material excavated from historic mining was stockpiled and used to construct haul roads. In some instances this material had high concentrations of metals. This study indicated portal rock benches and haul roads were constructed of both mineralised rock from mining and local remnant soils with some material having eroded soon after construction. Following on from this, further studies have been undertaken by UMVI to survey the area and estimate the volume of material exported as a result of erosional processes and estimate the likelihood of further erosion occurring.

Given that there are a number of sources of contaminants on-site, there is currently a need to understand what hazard this represents to the environment. Where there is a genuine threat to the environment, UMVI have agreed to rehabilitate the site. The information presented here seeks to define the requirements to assess the risk associated with elevated concentrations of contaminants in soils. The receptors considered here are a) risk to aquatic ecosystems in surface water, b) risk to sediment biota in stream channels, c) losses to groundwater, and d) uptake by cattle as a result of grazing on contaminated land.

Mobility and potential impacts of uranium

Areas disturbed as a result of historic mining and exploration activities include the adit apron, haul road, and waste rock dump (referred to as benches 1, 2 and 3). In addition, there are five areas of where elevated concentrations of uranium and other metals have been found (referred to as areas A – D). The XRF Characterisation Report (UMVI, 2015) shows the concentration of metals present in the surface layer of soils at each of those locations. The XRF survey has shown that disturbed areas can have relatively high concentrations of a range of metals. Dominant metals include U, Pb, and As. The potential mobility and environmental effects of contaminants from disturbed areas have not been characterised.

The conceptual model in Figure 1 shows a range processes that are likely to influence the mobility of contaminants and indicates the likely environmental receptors. Most metals (including uranium) have a strong affinity to bind with particulates and organic matter. Although metals are likely to bind with particulates, under some circumstances they may be soluble in water and can enter surface waters as overland flow or alternatively may percolate into soils and enter groundwater. It is thought that most water that percolates through the soil at this site and may return to the surface at seepage points downslope from disturbed areas. Where the landform is stable and not eroding, metals bound to particulates may remain on-site. As the lease is subject to grazing, it is possible that metals present in soils may accumulate in grasses and pose a risk to cattle and human consumers. Metals bound to particulates may be transported from disturbed areas due to natural weathering and erosion processes. This material can enter streams where it may settle out and pose a risk to sediment biota. Under some conditions, contaminants may desorb from particulates making stream sediments a potential source of contaminants also.

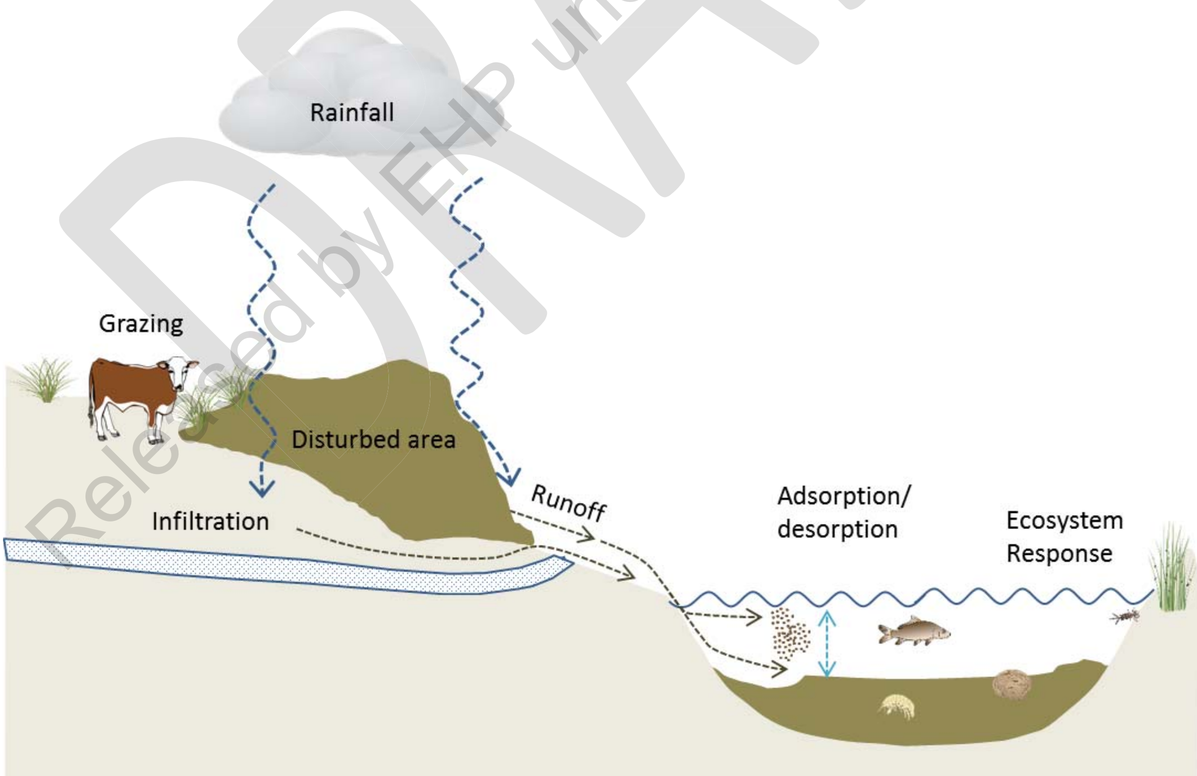

Figure 1. Conceptual model of contaminant fate and effects in the environment at Ben Lomond.

Assessment of contaminant mobility

The mobility of uranium and other metals present in disturbed areas at Ben Lomond has not been described. In order to characterise the hazard, there is a need to identify the factors influencing uranium mobility and to describe approaches that may be used to assess the risk.

Leaching potential

Uranium mobility is dependent on the physical and chemical attributes of the soil. Physical attributes affecting the movement of metals in soils include grain size, porosity and hydraulic conductivity. Chemical attributes affecting the movement of metals in soils include soil organic content, ionic strength (salinity) and cations present, soil pH and redox potential (Eh). The cation exchange capacity (CEC) provides an indication of the ability of soils to retain exchangeable ions. The soil water distribution coefficient (Kd) also provides an indication of the sorption capacity of soils. Increasing soil salinity has been found to mobilise U(VI) from soil exchange sites forcing it into solution (Rout et al. 2015) with the different ions known to have varying effects on mobility. The desorption capacity of cations is directly proportional to ionic radius (Ca^{2+} > Mg^{2+}> Na^{+}) (Rout et al. 2015).

The oxidation state of uranium has a significant effect on its mobility. Uranium can be present as U(IV), U(V), U(III), and U(VI). The dominant form of uranium in soils is the uranyl ion (UO_2^{2+}) Uranium(VI). Uranium(VI) is soluble and mobile under oxidizing to mildly reducing environments forming soluble complexes with carbonate anions in natural waters (Gavrilescu et al. 2009). Many studies have shown that carbonate complexing reduces adsorption of uranium leading to its release from soils (Gavrilescu et al. 2009). Uranium (IV) is comparatively very insoluble forming uraninite (UO_2) under reducing conditions (Gavrilescu et al. 2009). Uranium tends to occur in the solid phase at low Eh and predominance of dissolved uranium carbonate complexes at high Eh values (Gavrilescu et al. 2009). The presence of high concentration of NO_3^- in ground water also has the potential to mobilize the soil U(VI) by changing the redox potential of environment (Rout et al. 2015).

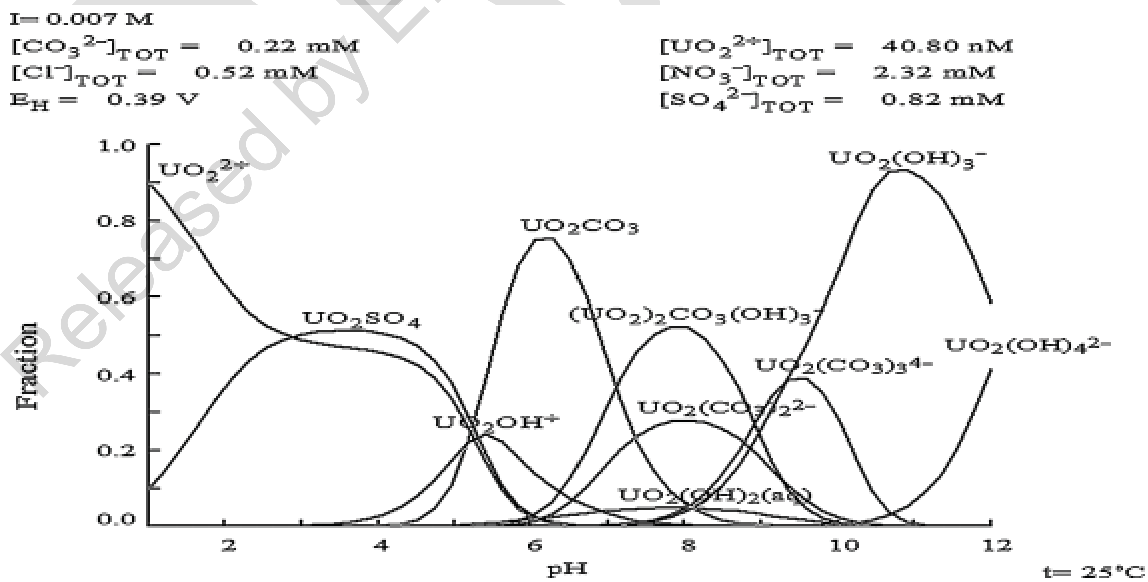

Figure 2. Speciation of U(VI) in soil solution

Leachate studies

A useful approach to determine the proportion of uranium and other metals that are likely to be soluble is to undertake leachate studies. Leachate studies are undertaken by passing a solute through a sample of soil collected from the site and analysing the chemical composition of the leachate. This approach provides a direct measure of the likely solubility of metals taking into account the soils chemical and physical properties that occur on site. An appropriate sample collection techniques, study design and chemical analysis should be used that comply with the relevant standards including AS4439.1 (1999), AS 4439.2 (1997) and AS 4439.3 (1997) for the preparation of leachates including.

To gain a full understanding of how mobility is affected by soil chemistry, it would be worthwhile describing the proportion of uranium present in each oxidation state. This would show for example the % present as U(VI) that is mobile as compared with the immobile fraction of U (IV). In addition, it would be worthwhile identifying what fraction of uranium (as % of total) is associated with organic matter, clay minerals, and carbonates compared with the proportion exchangeable.

It is also possible to model the proportion of metals likely to be soluble. A model can provide an indication of the likely mobility of contaminants under relevant chemical and physical conditions. Examples of models include PHREEQC. Programs such as Geochemist workbench can also be used to provide an indication of the likely speciation of compounds under varying conditions.

Erosion, transport and deposition of metals associated with particulates

Metals including uranium that are associated with particulates can be transported via hydraulic and geomorphic processes. A study by ETS Geotechnical (2015) on behalf of UMVI indicated that fill batters have been eroding during the 30 year life and display signs of instability. In that study, batters were considered largely stable under normal conditions though it was noted that they are prone to instability during periods of intense rainfall. The report by Resource and Exploration Mapping (REM 2015) undertaken on behalf of UMVI provides estimates of the volume of material lost from drill pads and the haul road from surveys of the estimated original and current landform. An estimated 298 m^3 of material has eroded from the three benches and haul road.

It is likely that some of this material has been deposited in Bog Hole Creek and is being transported within the stream. However, at this time there is no information available describing the chemical composition of sediments in Bog Hole Creek. Although much of the uranium associated with particulates would remain adsorbed to particulates in the sediments, it is possible that under some conditions it may desorb from sediments, though there is not much information available describing the release of uranium from contaminated sediments. Uranium present in stream sediments may pose a risk to sediment dwelling biota though at this stage the concentration of metals in Bog Hole Creek have not been determined.

Assessing the effect of uranium and other metals in water and stream sediments

Uranium can exhibit impacts in both the aqueous and solid phases hence it is important to understand the potential risk to both aquatic and benthic fauna. Isotopic ratios can be used to determine the faction of uranium likely to be present in each phase with the proportion present in the aqueous phase posing greater risk to aquatic biota. A study by Siddeeg et al. (2015) found that ^{234}U is expected to be more abundant in water relative to ^{238}U, and ^{238}U is expected to be more abundant in sediment.

Uranium can exhibit both radiological and toxicity effects. However, a study by Mathews et al. (2009) showed that the risks to the environment from uranium's chemical toxicity generally outweigh those of its radiological toxicity. Accordingly, the direct toxicity effects are likely to provide the focus for ecological risk assessment. Uranium can be toxic above certain thresholds, though it is comparatively less toxic than other metals (Goulet et al. 2011). It does not biomagnify but is known to accumulate in bone, liver, and kidney tissue (Goulet et al. 2011). There is potential for uptake of uranium via the gill, though diet and/or sediment may be the major route of uptake, and may vary with feeding strategy (Goulet et al. 2011).

A range of toxicity assessment studies may be undertaken using aquatic or sediment biota. There are many factors that can influence the toxicity of uranium including the presence of calcium, magnesium, carbonates, phosphate, and dissolved organic matter (Goulet et al. 2011; and Goulet et al. 2015). It is also possible to monitor the concentration of metals present in resident biota. A study by (Bollhöfer 2011) provides an example where lead isotopes present in freshwater mussels were used to estimate the contribution of uranogenic lead associated with mining.

There are currently no national uranium guidelines for aquatic ecosystems in ANZECC/ARMCANZ (2000) or for sediments Simpson et al. (2005) that are applicable at the national level in Australia. There are Canadian Guidelines for uranium in waters (Canadian Council of Ministers of the Environment 2011). Those guidelines are 15 µg/L uranium (total recoverable) long term exposure, and 33 µg/L uranium (total recoverable) short term exposure. A study by (Sheppard et al. 2005) indicated a NOEC for uranium that is protective of freshwater plants was 0.005 mg/L and 0.005 mg/L for freshwater invertebrates. Sheppard et al. (2005) also proposed Predicted No Effect Concentrations (PNECs) of 100 mg/kg dry sediment for uranium was protective of freshwater benthos. Such values may be used as a basis for initial assessment of risk, though consideration of local species and water quality conditions would provide the most accurate results.

Effect of uranium and other metals on grazing cattle

It is difficult to assess to the risk associated with beef cattle grazing. A study by (Lottermoser 2011) evaluated plant uptake of metals on pots mined land at the Mary Kathleen mine in Queensland. That study showed *Calotropis procera* accumulated sufficient concentrations of Ca, K, Mg and S in its tissue to potentially cause harmful effects on stock and wildlife feeding on it. However, the species studied, *C. procera* is a non-native perennial shrub and may not be representative of potential uptake in native grasses found on site. This study did not assess uranium risks as there is no known maximum acceptable threshold concentration that are protective of beef cattle (Nrc 2005).

Accordingly, there may be a need to assess the risk of update by cattle that may occur as a result of grazing as part of a localised study that analyses the concentrations present in local grasses and considers the potential uptake in cattle. Such a study would provide useful information to describe this risk. Alternatively it may be possible to adopt a value for a surrogate species or to adopt soil guidelines though such an approach may not be protective.

In lieu of such information it may be possible to utilise the information from Sheppard et al. (2005) that suggested terrestrial plants (250 mg/kg dry soil, and other soil biota 100 mg/kg dry soil. In addition there are soil guidelines by the (Canadian Council of Ministers of the Environment Canadian Guidelines (CCME, 2007) for uranium. Those guidelines state a PSQGHH of 23 mg/kg uranium for Agricultural areas, 33 mg/kg uranium for commercial and 330 mg/kg uranium for Industrial land. As there are large differences between these values there is a need to further evaluate their source and relevance. A study by (Sheppard et al. 2005) suggested maximum thresholds for uranium to be protective of terrestrial plans and soil biota. The Predicted No Effect Concentrations (PNECs) protective of terrestrial plants was 250 mg U/kg dry soil and 100 mg/kg dry soil for other soil biota.

Approach to assess and manage risk

As uranium and other contaminants have been identified in elevated concentrations above background, the possibility of impacts to the environmental cannot be excluded. In such a circumstance it may be worthwhile implementing strategies to contain contaminants and prevent potential impacts. Strategies would require input from relevant experts but may include removing and covering material or implementing erosion and sediment control practices to stabilise soils material and capture material in runoff and leachate. It may also be possible to limit or prevent stock and wildlife accessing contaminated areas. Where there is a desire to evaluate the risk and determine the need for remediation, there is likely to assess the risks to the environment. The diagram in Figure 3 provides an indication of a process that may be followed to assess the risks and determine the need for remedial actions.

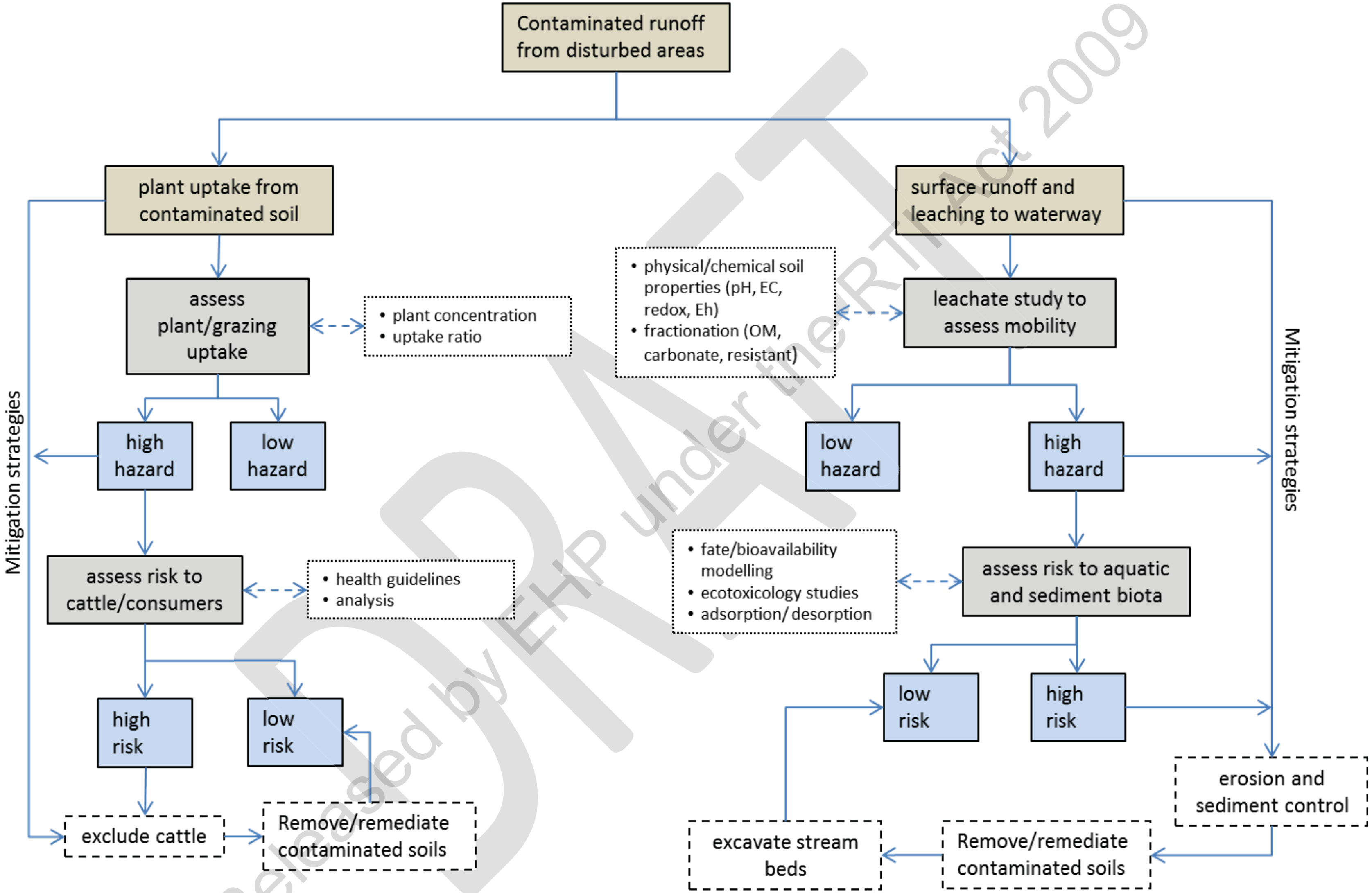

Figure 3. Assessment process for disturbed areas on the Ben Lomond lease area.

References

[note: the following references will be placed in alphabetic order in final draft]

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TROCCAZ Catherine

From: WALLACE Andrew
Sent: Tuesday, 30 June 2015 1:05 PM
To: DUNLOP Jason
Cc: CONNOLLY Niall
Subject: Ben Lomond - contaminated leachate
Attachments: UMVI XRF Characterisation Report May 2015.pdf; ES1418038_0_COA.PDF

Hi Jason,

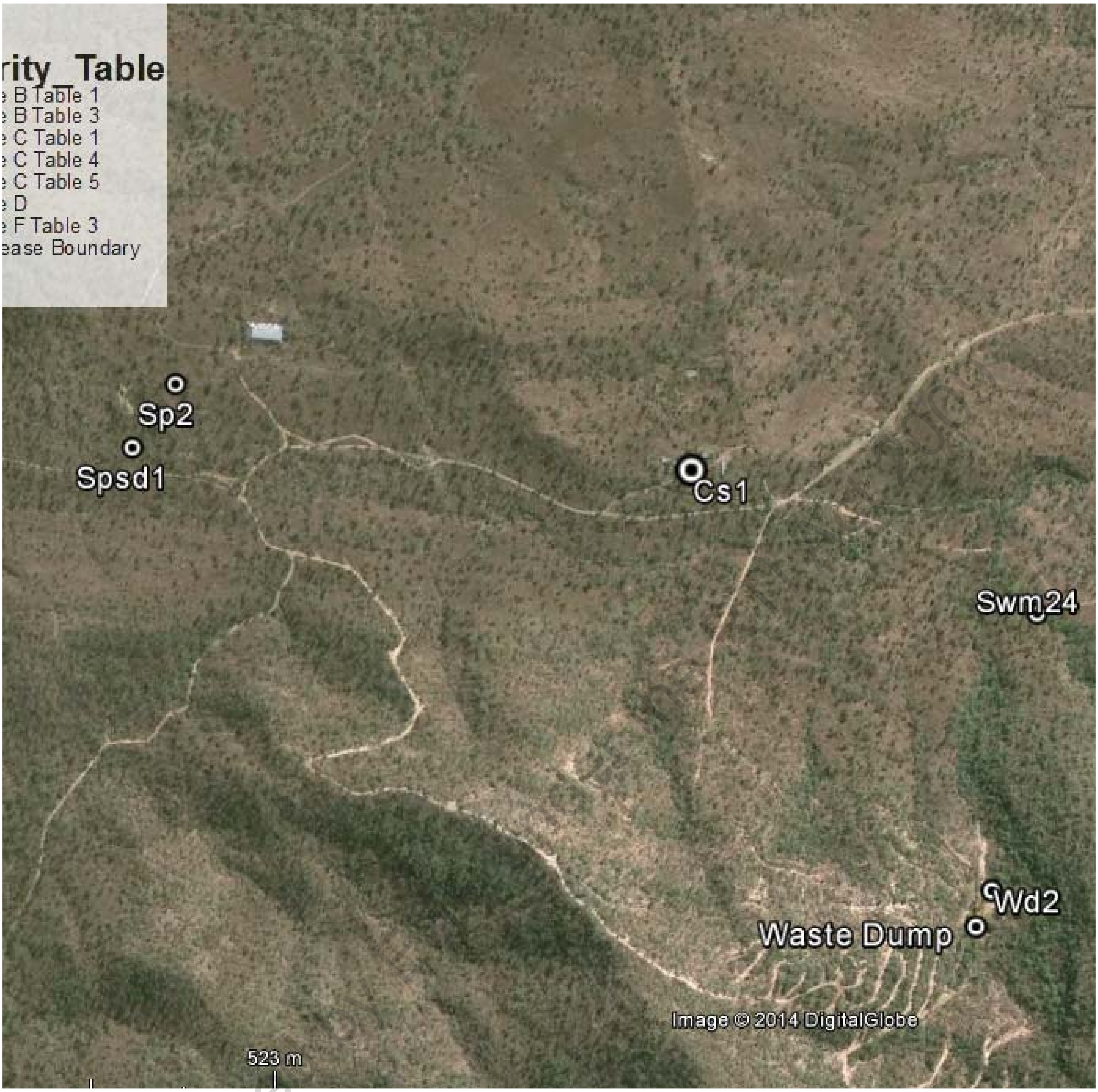
As discussed, EHP has received new information on the location and level of contaminated areas at the Ben Lomond site.
There has been a concern raised that the contaminant areas may be a source of contaminants to surface and groundwater.

EHP is seeking to identify the specific requirements needed to determine the level of contaminant export from the identified areas. These may form part of formal request for action in the future.
Specifically, EHP is seeking to understand:

- geochemical reactions, mobilisation processes and transformations for the potential contaminants;
- the likely factors affecting bioavailability of contaminants; and
- testing requirements

I have attached a pXRF report which identifies contaminant levels present, and maps of the areas (see below) and corresponding EHP sampling results.
We are happy to meet to discuss further as required. Note that Niall is on leave until the 13th of July.

Kind Regards, Andrew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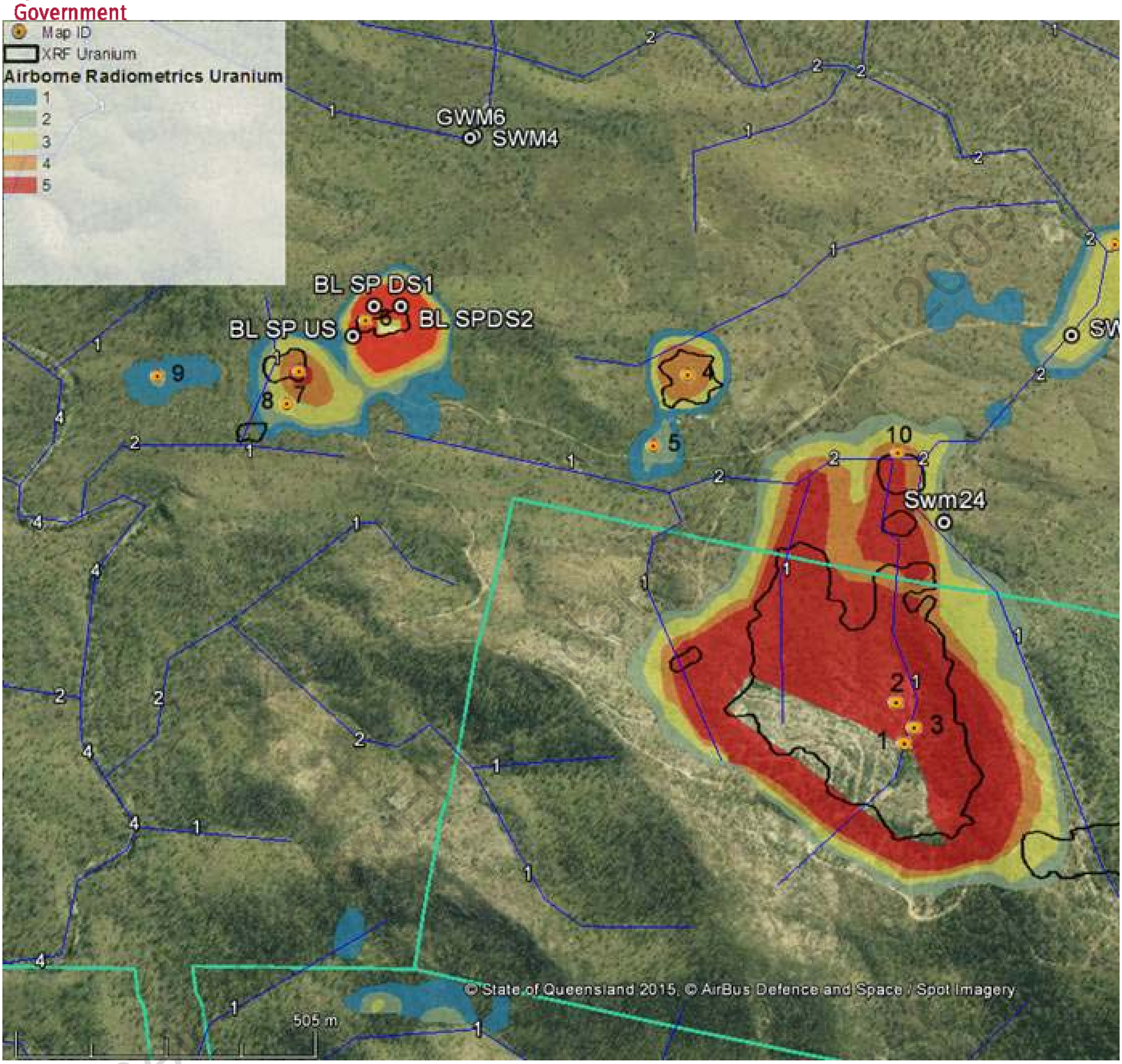

Andrew Wallace
Senior Environmental Officer
North Queensland Compliance | Environmental Services and Regulation
Department of Environment and Heritage Protection

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From: WALLACE Andrew
Sent: Friday, 17 July 2015 10:34 AM
To: DUNLOP Jason
Cc: CONNOLLY Niall; MANN Reinier; MORRISON Anthony
Subject: RE: Ben Lomond - contaminated leachate
Attachments: BL survey report November 2014.pdf; GT14-266-001R REV 1.pdf; Ben Lomond options analysis(GG1NC3AW7).docx

Hi Jason,

Thanks for the catch up today. Find attached the survey and geotech reports.
Note that Peter Gleeson, EHP geotechnical engineer is reviewing.

I have also included below the UMVI commitment to conduct analysis which EHP are yet to receive.

As per the discussion, could you also give some thought to both an action level and final rehabilitation level for uranium in soil?
A brief review of other approaches is included in Page 17 of the options analysis.
A site inspection is currently planned for 17th September 2015.

Aim to reconvene at end of next week to discuss the proposed specific requirements for the request for action, as per Table 6 and the examples below in the options analysis. Keeping to this framework will help to manage the project forward with the delegate.

Feel free to call to discuss any further information requirements.
Cheers, Andrew

Environmental Protection Act 1994

Ben Lomond compliance response options

This analysis details the key issues at the Ben Lomond uranium/molybdenum project and recommends a compliance response.

Identifying details	
Compliance activity number	CA32391
EcoTrack number	173012, Ben Lomond mine
Permit number	EPML00418313
File number	101/0008126
Applicant number	Uranium Mineral Ventures Inc
Trading as	N/A
Registered business address	Level 1, 57 Havelock Street, West Perth WA 6005

1. Non-compliances and regulatory compliance

The following non-compliances and areas of concern have been identified with the current EA.

Table 1: non-compliances with the current EA

Condition	Evidence
C1-1 Surface water	The EE report submitted by UMVI dated September 2013 details the non-compliances of surface water quality sample results with limits in the EA. For the period 2007-2013:

Monitoring point	Number of analyses	Total number of non-compliances
SWM4	415	53
SWM24	692	81
SWM22	431	90
SWM6	439	48
SWM23	447	23
KB2	787	34
SWM11	821	35
KB13	752	35
KB3	729	34

Recent notifications of non-compliance from UMVI received on 26 September 2014, 9 February 2015 and 7 May 2015 have showed ongoing non-compliance with the limits of the EA.

These compliance monitoring points are downstream of the potential contaminant sources identified in Table 5 below.

ABN 46 640 294 485

Condition	Evidence
C2-1 Groundwater	The EE report submitted by UMVI dated September 2013 details the non-compliances of Groundwater quality sample results with limits in the EA. For the period 2007-2013:

Monitoring point	Number of analyses	Total number of non-compliances
GWM6	716	164
BL SP US	478	154
BL SP DS1	98	42
BL SP DS2	179	33
GWM16	484	132

Condition	Evidence
C2-1 Groundwater (continued)	Recent notifications of non-compliance from UMVI received on 26 September 2014, 9 February 2015, 7 May 2015 and 5 June 2015 have showed ongoing non-compliance with the limits of the EA. These compliance monitoring points are downstream of the potential contaminant sources identified in Table 5 below.

Table 2: areas of concern with the current EA

Condition	Evidence
F1-1	Condition: All areas significantly disturbed by mining activities must be rehabilitated to a geotechnical and geochemical stable landform with a self-sustaining vegetation cover in accordance with Schedule F – Table 1. Schedule F – Table 1, Column 'Rehabilitation Success Criteria' = 'To be detailed in report required under Condition (F1-3) of this Environmental Authority.' The Rehabilitation Plan dated July 2014 page 5-6: "Mega does not consider that rehabilitation of the Site in the short term should be undertaken unless there is clear evidence that disturbance from previous exploration activities conducted by the previous owners of the Project poses a genuine threat to the environment. Where there is a genuine threat to the environment Mega and UMVI acknowledge and agree that rehabilitation should be completed promptly, but without inhibiting the option to further evaluate the resources within the project." The rehabilitation plan sets out the intention to rehabilitate the site, however as there is no set completion date for the rehabilitation to occur, UMVI cannot be considered non-compliant. This condition would have to be complied with prior to the surrender of the EA. UMVI do acknowledge that rehabilitation should be brought forward to deal with any 'genuine threats to the environment'.
F1-2	Condition: Progressive rehabilitation must commence when areas become available within the operational land. The Rehabilitation Plan dated July 2014 page 7 identifies that rehabilitation commenced in 1988 when the site was placed into care and maintenance. Therefore UMVI cannot be considered non-compliant with this condition.
F1-3	Condition: Complete an investigation into rehabilitation of disturbed areas and submit a report to the administering authority detailing rehabilitation objectives and rehabilitation success criteria to measure the performance of the rehabilitation. This report must be submitted by 1 December 2008. Following a compliance inspection on 26 March 2013 EHP requested a copy of the report. The report was submitted in July 2014. The Rehabilitation Plan dated July 2014 page 8-9 sets out the objectives for disturbed areas and Appendix B 2004 EMOS sets out rehabilitation success criteria.

Table 3: Other offences*

Condition	Evidence
Section 440ZG of the Act	• The rehabilitation report dated July 2014 identifies a number of possible source areas of contaminants, for example, page 6 states: "A low level airborne radiometric survey completed by UMVI in 2007 confirmed the areas of anomalous surface uranium occurrence due to previous exploration and mining activity were restricted to the portal, covered ore stockpile, core sheds and original ore dump site a previously identified by Kleinschmidt." • The EE Report submitted to EHP identified a number of possible source areas of contaminants, for example, Figure 21 on page 26 identifies elevated soil uranium levels. Most of these areas can be matched to current and previous disturbance areas on the site. • The XRF Characterisation report identified areas on site where uranium (and other contaminants) occur at elevated concentrations in areas affected by mining disturbance. Areas of naturally occurring surface uranium mineralisation were also described (p 3 and throughout report). • The mine site continues to report non-compliances with EA limits downstream of areas affected by mining disturbance that have reported to have elevated contaminants (see Table 1 above).

*Other offences do not include s319 GED, though not an offence is a trigger for further enforcement action if required.

EHP worked with DSITIA to develop contemporised, site-specific surface water quality objectives (WQOs) for the site using all the available surface water monitoring data supplied by UMVI. This included stratifying data to derive separate WQOs for Keelbottom Creek and Bog Hole Creek. The newly derived WQOs were then tested against the historical data set. The frequency of non-compliance and breach of new trigger values was significantly reduced at several sites. However, sites SWM6 and SWM22 remained frequently non-compliant with the new WQOs. This result was consistent with the analysis of time series and trends that identified that these sites were elevated for several contaminant parameters.

Similar analysis of groundwater monitoring data indicated that variation between current reference bore data and compliance bore data could not be partitioned between background variation, impacts or sampling errors. The results concluded that the groundwater monitoring framework required detail review.

The evidence summarised in Table 4 below assumes that the following will not be submitted to EHP:

1. Commencement of confirmatory sediment sampling – May 2015 following the completion XRF reporting.

Table 4: Summary of evidence

Evidence	Description
The EE Report 'Environmental Evaluation'; dated September 2013	Includes detailed and summarised surface water, groundwater and sediment/soil monitoring data results and analysis for the project site. Also includes mapping and tabulated data. This includes details of non-compliances with EA limits and potential source areas of contamination.

Evidence	Description
Additional Information for the Ben Lomond Uranium Molybdenum Project Environmental Evaluation Report; dated 31 March 2014	Includes additional detailed and summarised surface water, groundwater and sediment/soil monitoring data results and analysis for the project site. Also includes mapping and tabulated data. This includes details of non-compliances with EA limits and potential source areas of contamination.
Groundwater and Surface Water Trend Analysis; dated June 2014	Includes detailed and summarised surface water, groundwater and sediment/soil monitoring data results and analysis for the project site. Also includes mapping and tabulated data.
The Rehabilitation Plan dated July 2014	Submitted in compliance with Condition F1-3 of the EA, includes areas of contamination and proposes rehabilitation strategies. The actions of the plan are not intended to be implemented until a final decision on the feasibility of the project is made or disturbance from previous activities poses a genuine threat to the environment.
EHP field observations; 30 July 2014	EHP officer observations during site inspection on 30 July 2014.
EHP sample analysis; 30 July 2014 **(FIND ATTACHED)**	Water and sediment quality results from samples taken during site inspection on 30 July 2014. Also, Department of Health interpretation of radiometric levels and uranium progeny.
Survey of Areas and Volumes Ben Lomond Deposit November 2014	Submitted by UMVI in December 2014 in response to EHP letter dated 19 August 2014. Prepared by REM, provides quantitative areas and volumes of: 1. Moved rock used by Minatome to construct 3 drill pads and fill for the access haul road. 2. Estimate of how much of this fill material has been washed away since construction.
Radiological Characterisation Report 22 June 2014	Appendix A of the rehabilitation plan, prepared by Ross Kleinschmidt. Includes a review of the radiological status of the Ben Lomond project and makes recommendations on dose limits, structural design criteria and radiological health and environmental impacts.
Review of draft groundwater limits for Ben Lomond March 2015	DSITI review of groundwater data long term averages against proposed triggers and limits in the draft EA.
ETS Geotechnical – Adit Apron Assessment – Ben Lomond Mine, Dotswood April 2015 – Revision 1	Submitted by UMVI in May 2015 in response to EHP letter dated 19 August 2014. Prepared by ETS Geotechnical, reports on the assessment of the risk of further discharge of material from the waste rock dump to the watercourse. Recommends measures to prevent further discharge.
XRF Characterisation Report – Ben Lomond Uranium/Molybdenum Project – May 2015	Submitted by UMVI in June 2015 in response to EHP letter dated 19 August 2014. Prepared by UMVI, reports on portable X-Ray Fluorescence analyser (pXRF) assessment results of the adit apron, haul road and other radiometric anomaly areas identified in the EHP letter dated 19 August 2014.

UMVI maintain that natural mineralisation is the main contributor to elevated levels of contaminants and that the levels of contaminant elevation are not of serious concern. However, the analysis by EHP suggests that **the potential contaminant sources associated with mining activities on site identified in Table 5 (and Figure 1 & 2) below are contributors to the non-compliances in Table 1 above**. Sources 1-10 may also be in breach of s440ZG and s319 of the Act, evident through the risk summary described in Table 5 below.

The risk level attributed to each area represents the probability of non-compliances being attributable to this area/issue based on the understanding of the evidence currently available.

Table 5: Areas of concern / Sources

Map ID	Potential contaminant Source	Evidence source (See Table 2 above)	Supporting evidence of compliance issue	Risk Summary
1	The adit apron Risk level: Low	Inspection observations and photographs Rehabilitation plan EE report mapping Additional Information for EE Report mapping	During the inspection it was observed that: • The apron is covered with woody vegetation and appears more stable than the adjacent waste rock dump and haul road. The rehabilitation plan states that: • Ore and waste rock from the exploration adit was assessed using a radiometric discriminator, the waste rock (less than 200 parts per million (ppm) uranium) being dumped at the entrance of the adit, where it remains today. (s2.5.2 p12) • The apron to the adit has low grade mineralised material in its fill and should be covered by at least a meter of unmineralised crushed rock . .. (s3.4 p15) The EE report mapping indicates that: • There is an area of contamination detected by XRF uranium soil mapping in the area of the adit apron. (Fig 21 p 42) Additional Information for EE Report mapping indicates that: • There is an area of contamination detected by airborne radiometrics in the area of the adit apron. (Fig 43 p 52) The XRF Characterisation Report indicates that: • Small amounts of mineralised materials are present on the uppermost	The adit apron is located adjacent to the portal and provides a level surface to locate machinery and materials moving into or out of the adit. There is also a mineralised outcrop immediately adjacent to the adit portal. The key risks for the adit apron are minor surface erosion and subsurface flow-through if water percolates through the apron material and collects contaminates prior to discharging from the structure into the downstream gully which flows to Boghole Creek. There is currently no specific measure of the adit discharging contaminated leachate into the gully, however downstream monitoring data indicates the presence of contaminants.

Map ID	Potential contaminant Source	Evidence source (See Table 2 above)	Supporting evidence of compliance issue	Risk Summary
		XRF Characterisation Report	bench (bench 3), where rail trucks were unloaded into surface vehicles as part of the operations of the previous Project owner. (p3) • Mineralised outcrop immediately upstream of bench 3 (adit site): the max and mean uranium levels at surface where 6,168 ppm and 755.9 ppm respectively. (p9)	
2	Haul road Risk Level: Medium	Inspection observations and photographs Survey of Areas and Volumes Ben Lomond Deposit EE report Additional Information for EE Report mapping XRF Characterisation Report	During the inspection it was observed that: • The haul road connects the adit apron and portal to the valley floor. The haul road traverses the Ben Lomond mountain with a cut and fill design to maintain a safe gradient. It was observed that at the connecting causeway between the haul road and the adit apron sections of the road had been washed away by the creek. Survey of Areas and Volumes Ben Lomond Deposit states that: • Estimated volume of current haul road spoil * : 112 m3 Estimated volume of original haul road spoil * : 243 m3 Estimated volume of eroded haul road fill * : 131 m3 Estimated planimetric area: 0.02451 ha * Note: the original haul road spoil is likely to have been 50% yellow mines and 50% surface scree material. (s6.1 p9) The EE report mapping indicates that: • There is an area of contamination picked up by XRF uranium soil mapping in part of the area of the haul road closest to the adit apron. (Fig 21 p 42) Additional Information for EE Report mapping indicates that: • There is an area of contamination picked up by airborne radiometrics in part of the area of the haul road closest to the adit apron. (Fig 43 p 52) The XRF Characterisation Report indicates that: • Some small zones of naturally present mineralisation occur along the hillside traversed by the haul road and some infill used weakly mineralised materials. (p3) • pXRF analysis results demonstrated that outcropping mineralisation approximately 2m west of the haul road contained uranium grades of between 2,100 and 8,700 ppm and mean and max arsenic 252 ppm and 2,047 ppm. This surface mineralisation has an east to west trend and has been covered by the much lower grade haul road fill as it trends under the haul road and Bench 3 before re-emerging in mineralised outcrops on either side of the portal. (p14) • The first 100 meters of the haul road had a mean and max uranium of 65.3	The former haul road connects the adit apron to the former processing site on the valley floor. The EE report indicates that the portion of the haul road nearest to the adit may be contaminated. The survey indicates that approximately 50% of the haul road may be contaminated and that a significant quantity (approx. 54%) of the haul road has been eroded down the Ben Lomond mountain slope. The first section of the haul road starting from the adit is most of concern due the presence of imported fill material. The other sections have no imported fill material present and have largely naturally rehabilitated to a stable state. Therefore the key risk for the haul road is that further material is eroded down the mountain side or that rainfall or overland flow passes through the haul road material and collects contaminants prior to transporting suspended sediments and leachate downslope. Action is required to prevent contaminant loss by erosion or

Map ID	Potential contaminant Source	Evidence source (See Table 2 above)	Supporting evidence of compliance issue	Risk Summary
			ppm and 126 ppm, and a mean and max arsenic of 169 ppm and 2,564 ppm, and a mean and max lead of 106 ppm and 1,875 ppm. (p15)	leaching in the first 100 meters of the haul road.
3	Waste rock dump Risk Level: High	Inspection observations and photographs Rehabilitation plan EHP sample analysis results, Survey of Areas and Volumes Ben Lomond Deposit EE report Additional	During the inspections it was observed that: • The waste rock dump is composed of several benches that step down the Ben Lomond mountain from the adit apron to the top of a waterfall. The waste dump slopes do not support vegetation growth, were composed of coarse soil material, with numerous erosion rills and slumps. The waste material was not vegetated and had the appearance of being freshly deposited. The rehabilitation plan states that: • Ore and waste rock from the exploration adit was assessed using a radiometric discriminator, the waste rock (less than 200 parts per million (ppm) uranium) being dumped at the entrance of the adit, where it remains today. (s2.5.2 p12) EHP sample results indicate that: • The arsenic level of the waste rock dump soil is > 100 mg/kg. This is above the ISQG high level. Survey of Areas and Volumes Ben Lomond Deposit states that: Bench 1: Estimated volume of current bench: 65 m3 Estimated volume of original bench: 78 m3 Estimated volume of eroded bench: 13 m3 Estimated planimetric area: 0.017026 ha Bench 2: Estimated volume of current bench: 2083 m3 Estimated volume of original bench: 2292 m3 Estimated volume of eroded bench: 209 m3 Estimated planimetric area: 0.12105 ha Bench 3: Estimated volume of current bench: 787 m3 Estimated volume of original bench: 787 m3 (no obvious erosion of bench 3 was observed) Estimated planimetric area: 0.09181 ha The EE report mapping indicates that: • There is an area of contamination picked up by XRF uranium soil mapping in part of the area of the waste rock dump. (Fig 21 p 42) Additional Information for EE Report mapping indicates that:	The waste rock dump is located immediately downslope of the adit apron and is composed of three (3) benches of material that step down the slope. The EE report and XRF report indicates that the waste rock material is contaminated. The survey indicates that a quantity (approx. 7% volume) of the haul road has been eroded down the Ben Lomond mountain slope. EHP sampling indicates that the sediment contaminant levels are above the ISQG high levels. The geotechnical report identifies that erosion from the waste rock dump has occurred and it is likely that material from the waste rock dump is eroded and transported downstream during periods of intense rainfall. Therefore the key risk for the waste rock dump is that further material is eroded down the mountain side or that rainfall or overland flow passes through the waste rock material and collects contaminants prior to leaching downslope. Action is required to prevent contaminant loss by erosion or leaching.

Map ID	Potential contaminant Source	Evidence source (See Table 2 above)	Supporting evidence of compliance issue	Risk Summary
		Information for EE Report mapping ETS Geotechnical – Adit Apron Assessment XRF Characterisation Report	• There is an area of contamination picked up by airborne radiometrics in part of the area of the waste rock dump. (Fig 43 p 52) The ETS Geotechnical – Adit Apron Assessment identifies that: • It is considered likely that progressive erosion of the batters has occurred during the 30 year life of the fill slopes. The rate in which the erosion and subsequent deterioration of the batters has taken place is unknown based on the information available. From our visual assessment and experience with similar slopes elsewhere, the batters are considered to be stable however may be prone to instability during periods of intense rainfall. As a result, it is likely that transportation of the fill material into the downstream watercourse will occur during these periods of intense rainfall. The XRF Characterisation Report indicates that: • Small amounts of mineralised materials are present on the uppermost bench (bench 3), where rail trucks were unloaded into surface vehicles as part of the operations of the previous Project owner. (p3) • Bench 3: the major portion of the material is crushed granite rock. This crushed rock contains iron sulphides with lesser amounts of arsenic and lead sulphides. (p5) • … arsenic and lead mineralisation has formed in several rock types in the greater area and is not restricted to within the granite. (p6) • Both flat tops (of benches 1 and 2) have areas of higher uranium soil levels than the sloping banks and their lower perimeters. (p5) • Bench 1: Almost all analyses over the batters recorded grades less than 60 ppm uranium, while three of the twelve samples on the bench top exceed 100 ppm with a maximum of 951 ppm uranium. (p7) • Bench 2: More than 50% of all analyses over the batters had grades lower than 100 ppm uranium while 42 of the 44 samples on the bench top exceeded 100 ppm uranium with a further ten exceeding 1,000 ppm uranium. (p8) • Bench 3: The max and mean uranium level on the top of the bench were 109 ppm and 570 pm. (p9) • Mineralised outcrop immediately upstream of bench 3 (adit site): the mean and max uranium levels at surface where 755.9 ppm and 6,168 ppm respectively. (p9)	

Map ID	Potential contaminant Source	Evidence source (See Table 2 above)	Supporting evidence of compliance issue	Risk Summary
			• Watercourse downstream of benches: the mean and max uranium levels were 62 ppm and 937 ppm and the mean and max arsenic levels were 71 ppm and 2,542 ppm. • Watercourse gully upstream of benches: the mean uranium level 5,530 ppm, Mo 1,800 ppm, Pb 380 ppm, Sb 75 ppm, As 985 ppm.	
4	Area approx. 100m north of core sheds (Area A) Risk Level: High	EE report mapping Additional Information for EE Report mapping Groundwater and Surface Water Trend Analysis XRF Characterisation Report	The EE report mapping indicates that: • There is an area of contamination picked up XRF uranium soil mapping in the area approx. 100m north and downslope of the core shed complex. (Fig 21 p 42) The Additional Information for EE Report mapping indicates that: • There is an area of contamination picked up by airborne radiometrics in the area approx. 100m north and downslope of the core shed complex. (Fig 43 p 52) The Groundwater and Surface Water Trend Analysis indicates that: • … it is evident that U is occurring at surface in an area surrounding the covered ore stockpile and north of the core sheds. It is assumed that the core shed occurrence at least and possible both there occurrences are related ore processing and storage activities that occurred between 1976 and 1984. Both these sites are on a plateau above the headwaters of Boghole creek so during heavy wet season rainfall that they may contribute to elevated U concentrations in Boghole Creek. (s4.2.2.6 p43) The XRF Characterisation Report indicates that: • The anomaly identified in Area A is situated in an area historically used to store and sort exploration and mining samples from Ben Lomond (refer to Figure 8). The internal operations reports of the previous Project owner suggest these samples were relocated to the covered ore stockpile area in 1982-83. Radiometrics and pXRF soil sampling indicates a thin veneer of mineralised material now remains in this area. (p20) • Of the 241 pXRF uranium analysis samples, 210 soils assayed recorded between 0 and 50 ppm uranium, 14 recorded between 50 and 190 ppm uranium, six recorded between 190 and 330 ppm uranium and 11 recorded greater than 330 ppm uranium to a maximum of 1084 ppm uranium on the small ridge north of the core sheds. (p22) • … residual ore material is still at surface or less than 0.3 m from surface. (23)	The former use of this area is unclear however observations of ground disturbance indicate that it was linked to previous mine activities. The EE report indicates that contaminants are present in soils in an area approx. 100m north of the core sheds. The XRF report confirms the presence of contaminants. The trend analysis indicates that this area may be the result of previous ore processing and storage activities and may be releasing contaminants to Boghole creek and groundwater during heavy wet season rainfall. Action is required to prevent contaminant loss by erosion or leaching.

Map ID	Potential contaminant Source	Evidence source (See Table 2 above)	Supporting evidence of compliance issue	Risk Summary
			• As a general guide to the likely occurrence and potential location of the uranium - molybdenum mineralised material in Areas A, B, C and D, ground disturbance is a key factor. All four areas contain evidence of previous ground disturbance from mining and exploration activities. This is visible both on the ground and in aerial photography. In most cases the uranium - molybdenum in soil anomalies are closely linked to dozed ground. In Area A (Figure 21) flat dozed pads were used to store ore samples prior to their relocation to Area C and then ultimately into the covered ore stockpile. (p32-33)	
5	Area around the crushing pad or loading ramp (Area B) Risk Level: Medium	Rehabilitation plan, EE report mapping Radiological Characterisation Report XRF Characterisation Report	The rehabilitation plan states that: • The results of the gamma radiation surveys which have identified residual contamination (i.e. crushed ore) surrounding the remaining foundations of the crusher should be used to identify the areas of remnant surface material. This contaminated material should also be recovered and incorporated into the covered ore stockpile facility. (s3.3 p15) The Radiological Characterisation Report states that: • It is recommended that topsoil in the vicinity of the crusher pads be scraped from the surface and placed in the containment system (useful in filling voids around drums and irregular waste). (s5.1 p19) The XRF Characterisation Report indicates that: • Anomalous uranium in soils occurs approximately 50m south of the field office, near a small concrete loading area just below the access road to the office and core sheds. Maximum values in soils were up to 202 ppm uranium with seven of the 109 surface samples having values above 40 ppm uranium. The anomaly covers an area of approximately 1,313m2 as shown in Figure 14. (p26) • In Area B (Figure 22) the uranium - molybdenum is spatially linked to a concrete loading area. (p32-33)	This small area is immediately south of the core shed area adjacent to the site access road. The rehabilitation plan identifies contaminants in the surface soils around the former crusher pads. The XRF report confirms the presence of contaminants. The key risk is that the areas around the former crusher pad may be contributing contaminants to Boghole creek and groundwater. Action is required to prevent contaminant loss by erosion or leaching.

Map ID	Potential contaminant Source	Evidence source (See Table 2 above)	Supporting evidence of compliance issue	Risk Summary
6	Area surrounding covered ore stockpile (Area C) Risk Level: High	EE report mapping Additional Information for EE Report mapping Groundwater and Surface Water Trend Analysis Radiological Characterisation Report XRF Characterisation Report	The EE report mapping indicates that: • There is an area of contamination picked up by XRF uranium soil mapping in the areas immediately adjacent to and surrounding the covered ore stockpile. (Fig 21 p 42) Additional Information for EE Report mapping • There is an area of contamination picked up by airborne radiometrics in the areas immediately adjacent to and surrounding the covered ore stockpile. (Fig 43 p 52) The Groundwater and Surface Water Trend Analysis indicates that: • … it is evident that U is occurring at surface in an area surrounding the covered ore stockpile and north of the core sheds. It is assumed that the core shed occurrence at least and possib[ly] both there occurrences are related ore processing and storage activities that occurred between 1976 and 1984. Both these sites are on a plateau above the headwaters of Boghole creek so during heavy wet season rainfall that they may contribute to elevated U concentrations in Boghole Creek. (s4.2.2.6 p43) The Radiological Characterisation Report states that: • p14 indicates that in the area of covered ore stockpile natural uranium bearing outcrops are responsible for the elevated background levels in isolated areas. The XRF Characterisation Report indicates that: • Eleven of the 286 surface analyses gave uranium levels greater than 100 ppm with two samples close to the perimeter of the covered ore stockpile exceeding 1000 ppm uranium. The maximum value (1466 ppm uranium) sample was located near the north east corner of the covered ore stockpile. It is likely these elevated results are due to material left outside the covered ore stockpile after it was constructed. (p28) • In Area C the soil has been built up around the northern perimeter of the covered ore stockpile (Figure 23) and prior to the covered ore stockpile construction this site was used to store ore samples from the underground workings. (p32-33)	The areas immediately adjacent to the covered ore stockpile may have previously stored uranium ore prior to the development of the covered ore stockpile. The EE report indicates that contaminants are present in soils in an area surrounding the covered ore stockpile. The XRF report confirms the presence of contaminants. The XRF report also identifies that the areas was previously used to store underground ore samples. The Radiological Characterisation report indicates that contaminants may be due to natural uranium bearing outcrops. Action is required to prevent contaminant loss by erosion or leaching and contributing contaminants to surface drainages and groundwater.
7	Area approx.	EE report mapping	The EE report mapping indicates that: • There is an area of contamination picked up by XRF uranium soil mapping	The former use of this area is unclear

Map ID	Potential contaminant Source	Evidence source (See Table 2 above)	Supporting evidence of compliance issue	Risk Summary
	150m SW of covered ore stockpile. (Area D) Risk Level: Medium	Additional Information for EE Report mapping EHP inspection observations Radiological Characterisation Report XRF Characterisation Report	in an area approx. 150m SW of the covered ore stockpile. (Fig 21 p 42) Additional Information for EE Report mapping • There is an area of contamination picked up by airborne radiometrics in an area approx. 150m SW of the covered ore stockpile. (Fig 43 p 52) During the inspection it was observed that: • Areas of historic ground disturbance, including cut-and-fill type works were observed within area identified by airborne radiometrics and XRF uranium soil mapping. The Radiological Characterisation Report states that: • p14 indicates that in the area of covered ore stockpile natural uranium bearing outcrops are responsible for the elevated background levels in isolated areas. The XRF Characterisation Report indicates that: • The area of higher surface radiometrics appears to be over areas that show remnants of ground disturbance. (p32) • The difference between the two peak locations may be explained by the volumes and grades of waste material remaining at the two locations, with less material but a higher ore grade at the 647 ppm location and greater volumes of lower grade material at the 1,800 cps site 20m away.(p32) • In Area D (Figure 22) remnants of dozed earth works are linked to the current peak anomalies. (p32-33)	however observations of ground disturbance indicate that it was linked to previous site activities. The EE report indicates that contaminants are present in soils in an area approx. 150m SW of the covered ore stockpile. The XRF report confirms the presence of contaminants. EHP officers observed evidence of prior ground disturbing activities in this area. The XRF report confirms the presence of disturbance areas. The Radiological Characterisation report indicates that contaminants may be due to natural uranium bearing outcrops. Further monitoring data is required to identify areas approx. 150m SW of the covered ore stockpile which contain contaminants at levels of concern. Further information is required to determine if natural uranium bearing outcrops are responsible for elevated levels of contaminants. Then action may be required to prevent contaminant loss by erosion or leaching and contributing contaminants to surface drainages and groundwater.

Map ID	Potential contaminant Source	Evidence source (See Table 2 above)	Supporting evidence of compliance issue	Risk Summary
8	Small dam approximately 150 m SW of covered ore stockpile (Area D) Risk Level: High	EE report mapping Additional Information for EE Report mapping EHP inspection observations EHP sample analysis results Radiological Characterisation Report XRF Characterisation Report	The EE report mapping indicates that: • There is an area of contamination picked up by XRF uranium soil mapping in the area of the small sediment dam. (Fig 21 p 42) Additional Information for EE Report mapping indicates that: • There is an area of contamination picked up by XRF uranium soil mapping in the area of the small sediment dam. (Fig 43 p 52) During the inspection it was observed that: • A small sediment dam is located downslope of the covered ore stockpile and possible location of former stockpile area. Constructed drainage features were evident directing surface flow to the dam from upslope area. The dam was dry at the time of the inspection but had a base of deposited cracking clay. A sediment sample was taken from the approximate centre of the dam. EHP sample results indicate that: • The level of uranium in the dam sediment sample was 125 mg/kg. • This was the highest level of uranium detected by EHP during the inspection and was elevated in comparison to other test sites where the levels did not exceed 16 ppm. The Radiological Characterisation Report states that: • p14 indicates that in the area of covered ore stockpile natural uranium bearing outcrops are responsible for the elevated background levels in isolated areas. The XRF Characterisation Report indicates that: • The report is missing monitoring data for the small dam. This may be due to wet soil conditions which prevented pXRF use thought this was not identified in the report.	The former use of this area is unclear however observations of ground disturbance upstream of the dam indicate that it may contain contaminated fine sediments from areas linked to previous site activities. The EE report indicates that contaminants are present in soils in the small dam approx. 150m SW of the covered ore stockpile. EHP officers sampled elevated uranium levels in the dam sediments. The Radiological Characterisation report indicates that contaminants may be due to natural uranium bearing outcrops. The dam appears to be a remnant sediment retention or catch-dam, capturing runoff from area 7. It therefore may be beneficial to retain this function. There was evidence (hoof prints) that stock have accessed this dam. Stock and animal access should be restricted. Action is required to prevent access and contaminant loss by erosion or leaching.

Map ID	Potential contaminant Source	Evidence source (See Table 2 above)	Supporting evidence of compliance issue	Risk Summary
9	Area approximately 250 m W of the small dam Risk Level: Low	EE report mapping Additional Information for EE Report mapping XRF Characterisation Report	The EE report mapping indicates that: • There is an area of contamination picked up by XRF uranium soil mapping in the area approximately 250 m W of the small dam. (Fig 21 p 42) Additional Information for EE Report mapping • There is an area of contamination picked up by airborne radiometrics in the area approximately 250 m W of the small dam. (Fig 43 p 52) The XRF Characterisation Report indicates that: • The report is missing monitoring data for this area.	This area is separate to known or observed areas of disturbance on site. The EE report indicates that contaminants are present in soils in the area approx. 250m W of the small dam. There is no indication of previous ground disturbance in this area. Further monitoring data is required to identify area approx. 250m W of the small dam which contain contaminants at levels of concern. Further information is required to determine if natural uranium bearing outcrops are responsible for elevated levels of contaminants. Then action may be required to prevent contaminant loss by erosion or leaching.
10	Areas of Bog Hole Creek Risk Level: Medium	EE report mapping Additional Information for EE Report mapping Groundwater and Surface Water Trend Analysis	The EE report mapping indicates that: • There are areas of contamination picked up by XRF uranium soil mapping in areas of the bed and banks of Bog Hole Creek leading from other source areas. (Fig 21 p 42) Additional Information for EE Report mapping • There are areas of contamination picked up by airborne radiometrics in areas of the bed and banks of Bog Hole Creek leading from other source areas. (Fig 43 p 52) The Groundwater and Surface Water Trend Analysis indicates that: • … it is evident that U is occurring at surface in an area surrounding the covered ore stockpile and north of the core sheds. It is assumed that the core shed occurrence at least and possible both there occurrences are related ore processing and storage activities that occurred between 1976	The EE report indicates that contaminants are present in sediments or beds of Boghole creek upstream of EA monitoring points SWM6 and SWM22. The trend analysis indicates that these areas of contaminants may be the result of previous ore processing and storage activities and may be releasing contaminants to Boghole creek during heavy wet season rainfall. The key risk is that contaminated sediments are having a direct impact on the receiving environment and

Map ID	Potential contaminant Source	Evidence source (See Table 2 above)	Supporting evidence of compliance issue	Risk Summary
		XRF Characterisation Report	and 1984. Both these sites are on a plateau above the headwaters of Boghole creek so during heavy wet season rainfall that they may contribute to elevated U concentrations in Boghole Creek. (s4.2.2.6 p43) The XRF Characterisation Report indicates that: • The report is missing monitoring data for this area.	may be a source for further impacts downstream. Further monitoring data is required to identify areas of the bed and banks of Boghole creek which contain contaminants at levels of concern. Then action is required to prevent contaminant loss by erosion or leaching.
	Sampling error Risk Level: High	Review of draft groundwater limits for Ben Lomond	The DSITI review indicates that: • There is an upswing in data in recent data that cannot be explained with available information. This may be associated with poor sampling technique and sampling error e.g. bores not purged and sampling disturbing bore sediments. It is recommended that proper methodology and QA procedures for sampling groundwater bores are followed and that total and dissolved concentrations are measured.	The key risk is that all or part of the recent (2012-present) upswing in non-compliances in the monitoring data is the result of sampling error. Therefore sampling must follow the Queensland Sampling Manual 2009 to minimise sampling error.
	Natural catchment characteristics Risk Level: High	The EE report Review of draft groundwater limits for Ben Lomond	The EE report indicates that: • The current EA does not account for natural variation in contaminant levels between the Bog Hole and Keelbottom creek catchments. The DSITI review indicates that: • The elevated contaminant levels in groundwater may be due to natural catchment characteristics.	The key risk is that natural catchment characteristics are all or part of the source of non-compliances in the monitoring data. Therefore the EA must recognise the differing catchment characteristics by separating the compliance objectives for the catchments.

Table 6: Response requirements

Map Id	Source/area	Required outcomes	Compliance tools
1	The adit apron	a) Confirm and quantify the potential for contaminants present to generate contaminated leachate b) Take action to prevent release of contaminants through leaching processes	EE, then EPO
2	Haul road	a) Confirm and quantify the potential for contaminants present to generate contaminated leachate b) Take action to prevent release of contaminants through leaching and erosive processes	EE, then EPO
3	Waste rock dump	a) Confirm and quantify the potential for contaminants present to generate contaminated leachate b) Take action to prevent release of contaminants through leaching and erosive processes	EE, then EPO
4	Area approx. 100m north of core sheds	a) Confirm and quantify the potential for contaminants present to generate contaminated leachate b) Take action to prevent release of contaminants through leaching and erosive processes	EE, then EPO
5	Area around the crushing pad or loading ramp	a) Confirm and quantify the potential for contaminants present to generate contaminated leachate b) Take action to prevent release of contaminants through leaching and erosive processes	EE, then EPO
6	Area surrounding the covered ore stockpile	a) Confirm and quantify the potential for contaminants present to generate contaminated leachate b) Take action to prevent release of contaminants through leaching and erosive processes	EE, then EPO
7	Area approx. 150m SW of covered ore stockpile.	a) Confirm and quantify the potential for contaminants present to generate contaminated leachate b) Take action to prevent release of contaminants through leaching and erosive processes	EE, then EPO
8	Small dam approximately 150m SW of covered ore stockpile	a) Confirm areas with contaminants of concern, and then b) Take action to limit stock and wildlife access to the dam, and then c) Confirm and quantify the potential for contaminants present to generate contaminated leachate, and then d) Take **maintenance** action to prevent release of contaminants through leaching and erosive processes	EE, then EPO
9	Area approximately 250m W of the small dam	a) Confirm areas with contaminants of concern, and then b) Confirm if naturally generated, and then c) Confirm and quantify the potential for contaminants present to generate contaminated leachate, and then d) Take action to prevent release of contaminants through leaching and erosive processes	EE, then EPO
10	Areas of Boghole Creek	a) Confirm areas with contaminants of concern, and then b) Confirm if naturally generated, and then c) Confirm and quantify the potential for contaminants present to generate contaminated leachate, and then d) Take action to prevent release of contaminants through leaching and erosive processes	EE, then EPO
	Sampling error	a) Confirm that surface water and groundwater monitoring processes conform to the Monitoring and Sampling Manual 2009	EA amendment
	Natural catchment	a) Separate surface water, groundwater and sediment compliance monitoring sites into separate catchments	EA

Map Id	Source/area	Required outcomes	Compliance tools
	characteristics	b) Create catchment specific surface water, groundwater and sediment limits in the EA	amendment

Example EPO Action: Area Map ID 4 – 100m north of core shed

Summary

Map ID	Area description	Risk description	Offences
4	Approximately 100 m north and downstream of the current core shed area. The anomaly .. is situated in an area historically used to store and sort exploration and mining samples from Ben Lomond.	Residual ore from the stockpiling activity remains at the site. 210 soils assayed recorded between 0 and 50 ppm uranium, 14 recorded between 50 and 190 ppm uranium, six recorded between 190 and 330 ppm uranium and 11 recorded greater than 330 ppm uranium to a maximum of 1084 ppm uranium on the small ridge north of the core sheds. The area affected above 50 ppm uranium is 2,923 m^2 to 0.3 m depth. The mapped area of contamination appears to continue downstream and is upslope and upstream of potential contaminated areas in Boghole Creek and surface water and groundwater sites with records of EA limit non-compliances.	s 440ZG (a) (iii) (unlawful) s 430 (3) Condition C1-1 (potential) s 430 (3) Condition C2-1) (potential) s 319 GED (likely to cause, reasonable and practicable)

Objective: Take action to prevent release of contaminants from area 4 (or areas X – Y) through leaching and erosive processes

Action 1: confirm depth and extent of contaminants to specified contaminant level[1]

Action 2: remove soils with contaminant to specified contaminant level[1] and relocate to a specified location[2]

Action 3: take measures to prevent erosion and sediment export from the area

Action 4: restore area to stable landform condition

[1] specified contaminant level: TBD for the site under a separate (possible EE) action.

There are no sediment quality guideline values used by Australian Governments for uranium.
Of the projects reviewed in detail both Mary Kathleen (global average 7.4 ppm, sub minor 100-1000 ppm, minor 1000-10000 ppm, major >10000 ppm) and Rum Jungle (100 ppm) used locally derived values for elevated uranium levels based on variance for a mean background or locally prevalent level.

In relation to other jurisdictions, Canada has established a set of recommended uranium guideline values of soils as described below:

Canadian Council of Ministers of the Environment (CCME) - Canadian Environmental Quality Guidelines (CEQGs)
According to the CCME the recommended soil quality guideline for uranium for the protection of both human and environmental health – Agricultural and Residential/parkland is 23 mg/kg (equivalent to ppm) based on a formulaic food and soil ingestion scenario for rabbits. Other levels include 33 mg/kg for Commercial and 300 mg/kg for Industrial land uses. These levels are non-binding guideline value which can be used by member government jurisdictions for the assessment and remediation of contaminated sites in Canada.
It is used for example by the State Governments of Ontario, Alberta and Nova Scotia for their soil remediation guidelines.

[2] specified location: TBD under a separate EPO action of any compliance tool. Likely to be within the current covered stockpile (p15, rehab plan) or in the adit

Example EE requirements in summary

Action	Areas	Timeframes	Offences
Confirm remaining areas with contaminants of concern. The pXRF analysis did not include the following areas: • Small dam approximately 150m SW of covered ore stockpile • Area approximately 250m W of the small dam • Areas of Boghole Creek • Areas extending east of the area approximately 100m north of the core sheds pXRF analysis should be carried out on these areas for completeness.	Map ID 4, 8, 9, 10	2 months from day 1	s 440ZG (a) (iii) (unlawful) s 430 (3) Condition C1-1 (potential) s 430 (3) Condition C2-1) (potential) s 319 GED (likely to cause, reasonable and practicable)
Confirm if contaminants from the areas of Boghole Creek and the area approximately 250m W of the small dam are naturally generated. Note: there is aerial imagery which suggests natural mineralised rock may be present at these sites, and EHP field observations have confirmed the presence of outcropping rock in one of the areas of Boghole Creek.	Map ID 9 and 10	3 months from day 1	s 440ZG (a) (iii) (unlawful) s 430 (3) Condition C1-1 (potential) s 430 (3) Condition C2-1) (potential) s 319 GED (likely to cause, reasonable and practicable)
Confirm and quantify the potential for contaminants present to generate contaminated leachate. These areas are located upslope and upstream of EA surface water and groundwater monitoring sites with reported non compliances. Their potential to generate contaminated leachate is required determine if the areas are a direct source of contaminants to surface water and groundwater.	Map ID 1-10	5 months from day 1	s 440ZG (a) (iii) (unlawful) s 430 (3) Condition C1-1 (potential) s 430 (3) Condition C2-1) (potential) s 319 GED (likely to cause, reasonable and practicable)
Determine a trigger level for uranium soil levels at the site. There is no available sediment or soil guideline for uranium. A sediment and soil guideline value is required to determine a significance level for uranium contamination at affected areas. See for example section 3.5.4.3 page 3.5-5 of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality Vol 1.	Map ID 1-10	2 months from day 1	s 319 GED (likely to cause, reasonable and practicable)

Figure 1: Source areas

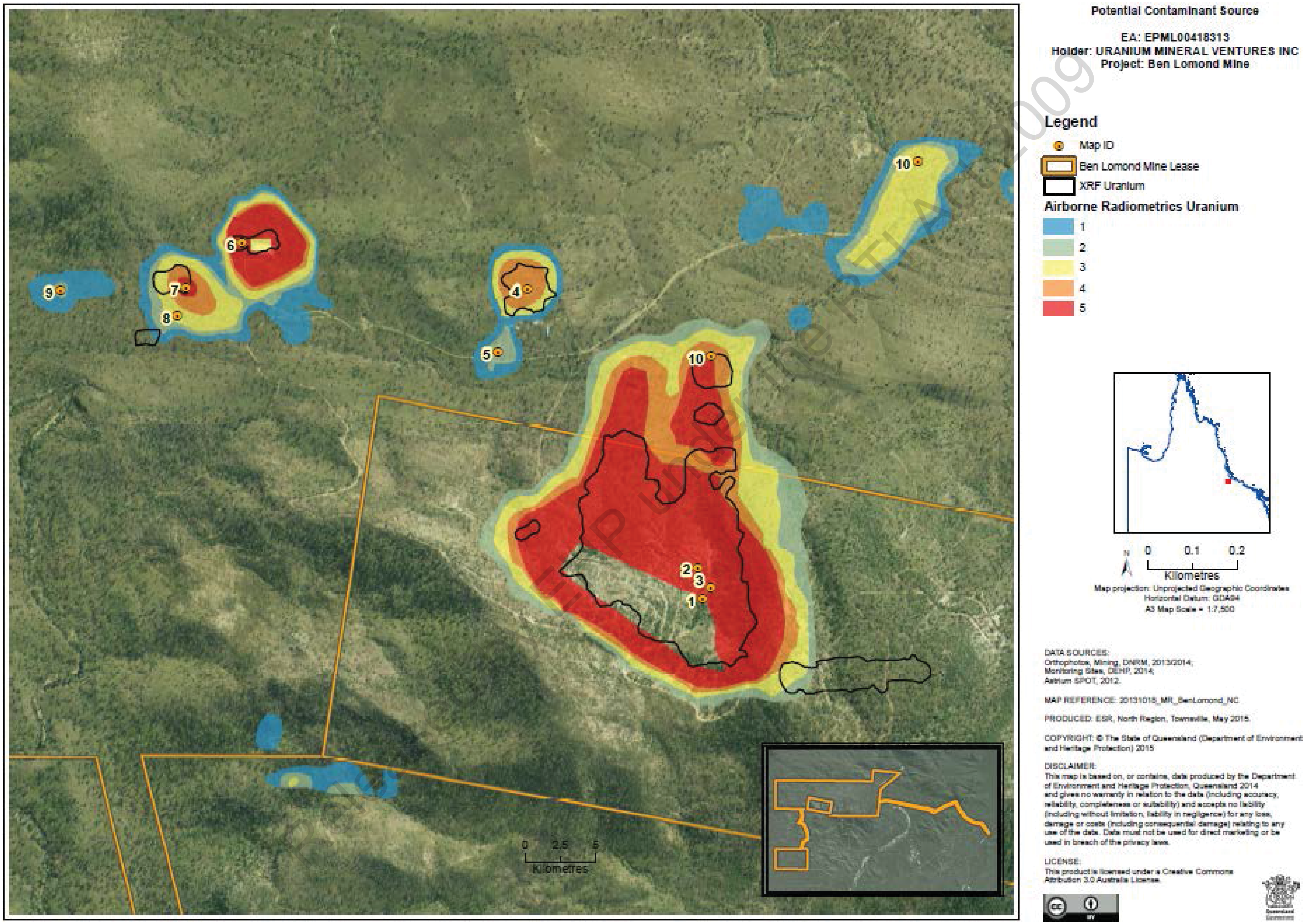
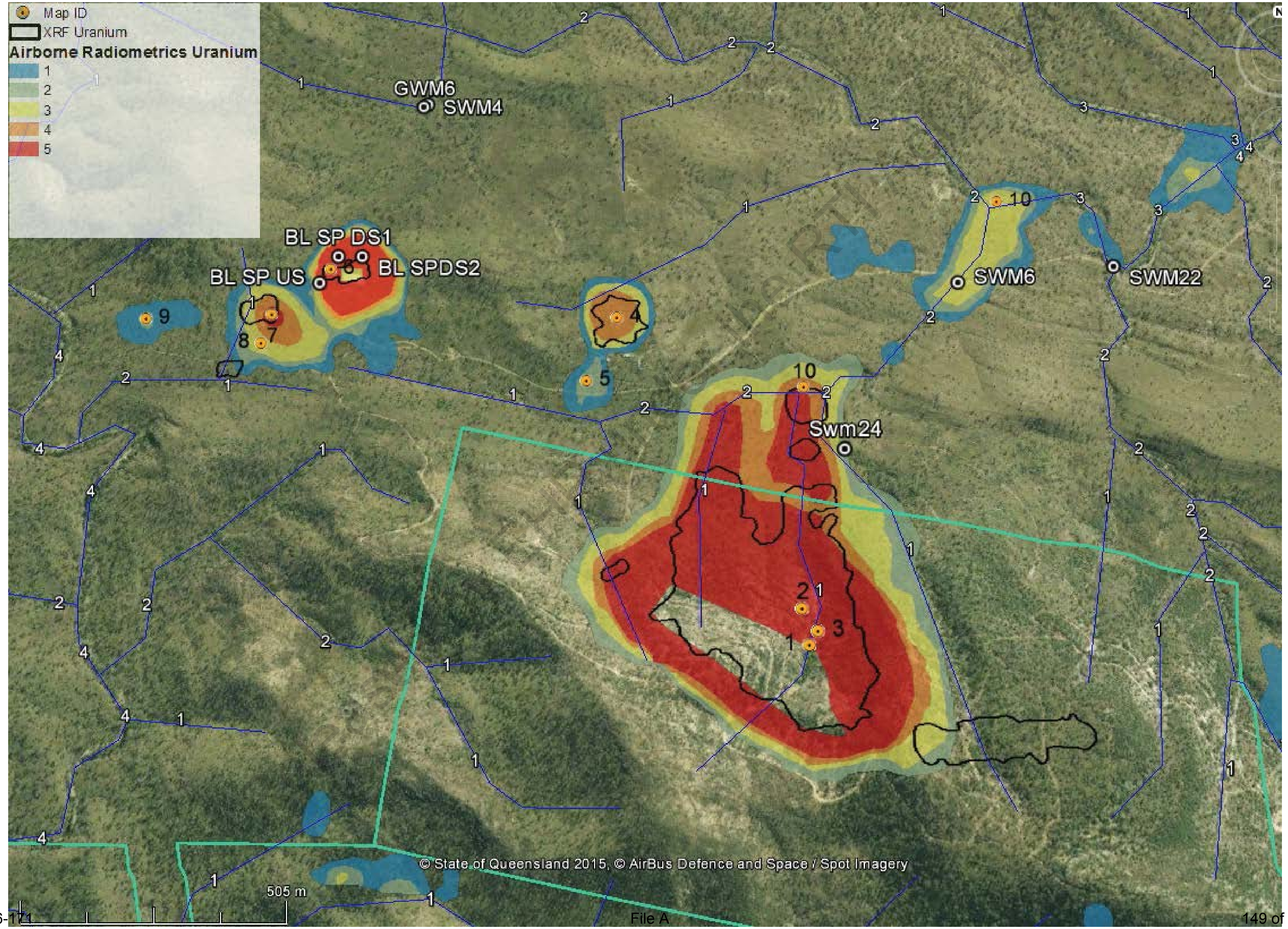


Figure 2- groundwater and surface water monitoring point, and waterway overlay



Release

TROCCAZ Catherine

From: WALLACE Andrew
Sent: Wednesday, 4 November 2015 8:45 AM
To: DUNLOP Jason; CONNOLLY Niall
Cc: MANN Reinier; RAMSAY Ian; MORRISON Anthony
Subject: draft: options to assess risks of contaminant migration from disturned areas
Attachments: Draft_Assessment of contaminants at Ben Lomond_29-07-2015.docx; Ben Lomond - contaminated leachate

Queensland Government

Hi Jason,

As discussed, further to this request can you give some further thought to the section on the 'Effect of uranium and other metals on grazing cattle' in the attached draft assessment.
EHP is seeking to establish an action level for soil uranium contaminant levels.
The intent is that the detection of uranium contaminant levels in soil above the action level would establish the need for rehabilitation/control actions to commence.

It is understood that an action level (or levels) may be able to set from other studies and current site data.
If not, then the steps required to establish an action level are sought. Costings could then be estimated for these steps and a project to establish the level can proposed.

Hope this request is clear enough to commence, please feel free to contact me for further information or if you would like to meet to discuss.

Kind Regards, Andrew

Andrew Wallace
Senior Environmental Officer
North Queensland Compliance
Department of Environment and Heritage Protection

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From: DUNLOP Jason
Sent: Wednesday, 29 July 2015 7:20 PM
To: WALLACE Andrew; CONNOLLY Niall
Cc: MANN Reinier; RAMSAY Ian
Subject: draft: options to assess risks of contaminant migration from disturned areas

Hi Andrew and Niall,

Attached for your input is a very draft document prepared in follow up to our discussion last Friday. This considers possible approaches/options to assess the mobility and environmental risks of uranium and other metals present at Ben Lomond. This document is marked 'draft for comment' as it has not been reviewed as yet. Please forgive any editorial errors ☺, the timeline has been very tight. It would be great to get your input on areas requiring further information, whether the process diagram needs to be changes and any broad comments you may have. The info in the background section may need checking to ensure it is an accurate reflection of the history and it may not be all that necessary anyway.

Hopefully this should give you some information to support your internal discussions regarding the options for management.

Note that our expertise is primarily aquatic ecosystem impacts and ecotoxicology and not soils or cattle health. I have collated some information regarding the assessment of mobility of uranium is soils and the assessment of risk to grazing animals but I suggest that relevant experts in those areas be consulted. Also, I have looked at but not fully reviewed the NEPM measures for site contamination, likewise I have also only done a first pass of the available guidelines so conclusions for those need to be revisited.

Cheers,

Jason

Dr Jason Dunlop
Senior Environmental Officer
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Department of Science, Information Technology and Innovation

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Customers first | Ideas into action | Unleash potential | Be courageous | Empower people

Evaluation of the potential for contaminant export and potential impacts at Ben Lomond

Background

Ben Lomond is a uranium and molybdenum ore deposit owned by Mega Uranium (UMVI) that is in care and maintenance and not operating. Ongoing surface and groundwater monitoring undertaken as part of the requirements of the existing environmental authority has identified a high proportion (between 20-90%) of samples at monitoring locations are in exceedance of surface and groundwater triggers for a range of water quality indicators. The site is an area of natural mineralisation and has had historic mining and exploration activities undertaken on it. The potential contribution of contaminants from disturbed areas compared with natural areas was not known. As a result an Environmental Evaluation was issued to require an investigation of the source, cause and extent of contamination on the site. This study undertaken in behalf of UMVI found that the source of contaminants was largely natural. However, the report was not found to have adequately characterised the contribution from all potential sources. A field evaluation of the site found some additional sources not previously identified by UMVI. EHP requested an additional study be undertaken to evaluate longitudinal trends in water quality. That study was unable to identify the presence of either an increasing or decreasing trend in the concentrations of contaminants had occurred since the mid 1980s when historic mining activities were active. Local reference based water quality trigger values developed using the available historic monitoring data. These triggers showed that greater compliance with triggers for most sites with the exception of sites GWM6 and SWM22; however, the source of elevated concentrations at these sites was not able to be defined. A further study has since been undertaken by UMVI to evaluate the concentration of contaminants in both the unimpacted and disturbed areas. That study identified material excavated from historic mining was stockpiled and used to construct haul roads. In some instances this material had high concentrations of metals. This study indicated portal rock benches and haul roads were constructed of both mineralised rock from mining and local remnant soils with some material having eroded soon after construction. Following on from this, further studies have been undertaken by UMVI to survey the area and estimate the volume of material exported as a result of erosional processes and estimate the likelihood of further erosion occurring.

Given that there are a number of sources of contaminants on-site, there is currently a need to understand what hazard this represents to the environment. Where there is a genuine threat to the environment, UMVI have agreed to rehabilitate the site. The information presented here seeks to define the requirements to assess the risk associated with elevated concentrations of contaminants in soils. The receptors considered here are a) risk to aquatic ecosystems in surface water, b) risk to sediment biota in stream channels, c) losses to groundwater, and d) uptake by cattle as a result of grazing on contaminated land.

Mobility and potential impacts of uranium

Areas disturbed as a result of historic mining and exploration activities include the adit apron, haul road, and waste rock dump (referred to as benches 1, 2 and 3). In addition, there are five areas of where elevated concentrations of uranium and other metals have been found (referred to as areas A – D). The XRF Characterisation Report (UMVI, 2015) shows the concentration of metals present in the surface layer of soils at each of those locations. The XRF survey has shown that disturbed areas can have relatively high concentrations of a range of metals. Dominant metals include U, Pb, and As. The potential mobility and environmental effects of contaminants from disturbed areas have not been characterised.

The conceptual model in Figure 1 shows a range processes that are likely to influence the mobility of contaminants and indicates the likely environmental receptors. Most metals (including uranium) have a strong affinity to bind with particulates and organic matter. Although metals are likely to bind with particulates, under some circumstances they may be soluble in water and can enter surface waters as overland flow or alternatively may percolate into soils and enter groundwater. It is thought that most water that percolates through the soil at this site and may return to the surface at seepage points downslope from disturbed areas. Where the landform is stable and not eroding, metals bound to particulates may remain on-site. As the lease is subject to grazing, it is possible that metals present in soils may accumulate in grasses and pose a risk to cattle and human consumers. Metals bound to particulates may be transported from disturbed areas due to natural weathering and erosion processes. This material can enter streams where it may settle out and pose a risk to sediment biota. Under some conditions, contaminants may desorb from particulates making stream sediments a potential source of contaminants also.

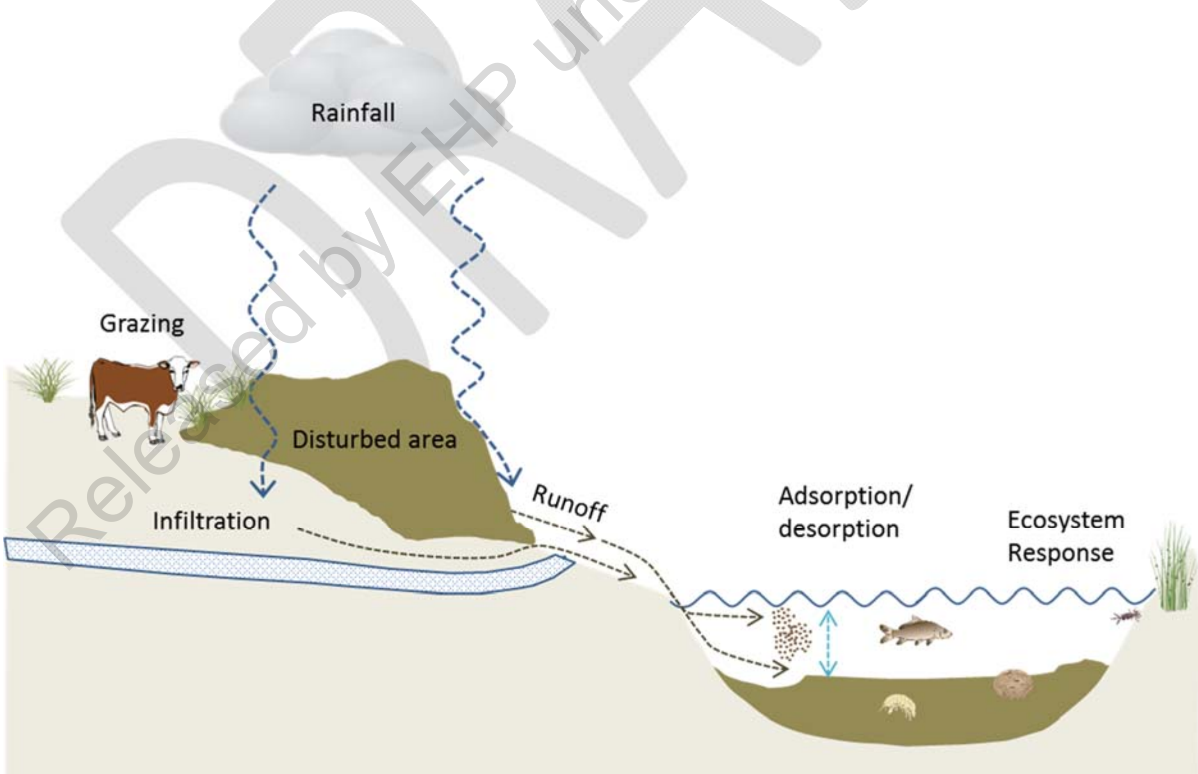

Figure 1. Conceptual model of contaminant fate and effects in the environment at Ben Lomond.

Assessment of contaminant mobility

The mobility of uranium and other metals present in disturbed areas at Ben Lomond has not been described. In order to characterise the hazard, there is a need to identify the factors influencing uranium mobility and to describe approaches that may be used to assess the risk.

Leaching potential

Uranium mobility is dependent on the physical and chemical attributes of the soil. Physical attributes affecting the movement of metals in soils include grain size, porosity and hydraulic conductivity. Chemical attributes affecting the movement of metals in soils include soil organic content, ionic strength (salinity) and cations present, soil pH and redox potential (Eh). The cation exchange capacity (CEC) provides an indication of the ability of soils to retain exchangeable ions. The soil water distribution coefficient (Kd) also provides an indication of the sorption capacity of soils. Increasing soil salinity has been found to mobilise U(VI) from soil exchange sites forcing it into solution (Rout et al. 2015) with the different ions known to have varying effects on mobility. The desorption capacity of cations is directly proportional to ionic radius (Ca^{2+} > Mg^{2+}> Na^{+}) (Rout et al. 2015).

The oxidation state of uranium has a significant effect on its mobility. Uranium can be present as U(IV), U(V), U(III), and U(VI). The dominant form of uranium in soils is the uranyl ion (UO_2^{2+}) Uranium(VI). Uranium(VI) is soluble and mobile under oxidizing to mildly reducing environments forming soluble complexes with carbonate anions in natural waters (Gavrilescu et al. 2009). Many studies have shown that carbonate complexing reduces adsorption of uranium leading to its release from soils (Gavrilescu et al. 2009). Uranium (IV) is comparatively very insoluble forming uraninite (UO_2) under reducing conditions (Gavrilescu et al. 2009). Uranium tends to occur in the solid phase at low Eh and predominance of dissolved uranium carbonate complexes at high Eh values (Gavrilescu et al. 2009). The presence of high concentration of NO_3^- in ground water also has the potential to mobilize the soil U(VI) by changing the redox potential of environment (Rout et al. 2015).

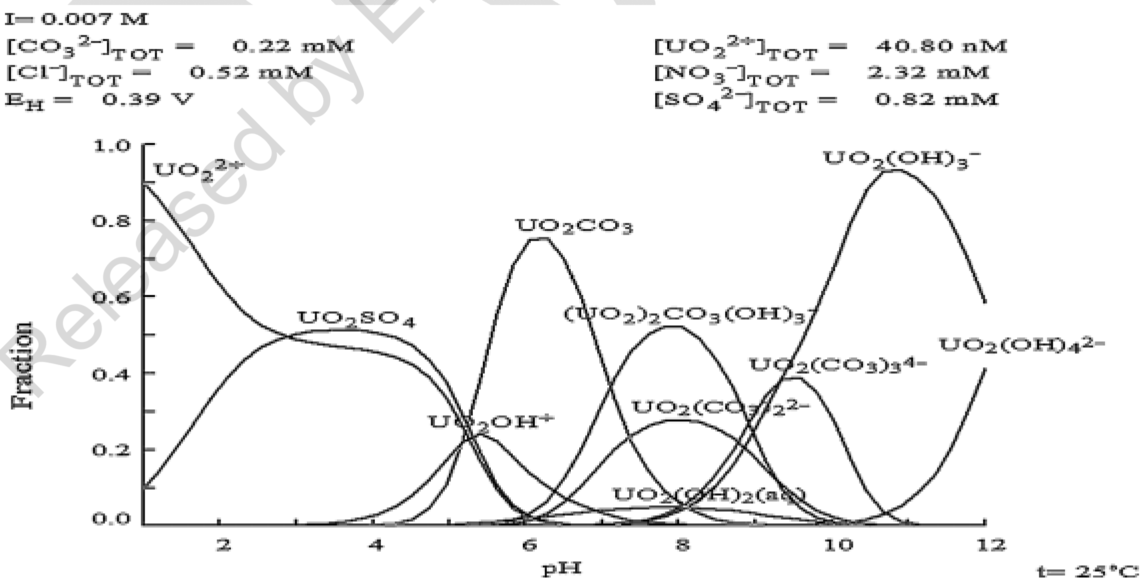

Figure 2. Speciation of U(VI) in soil solution

Leachate studies

A useful approach to determine the proportion of uranium and other metals that are likely to be soluble is to undertake leachate studies. Leachate studies are undertaken by passing a solute through a sample of soil collected from the site and analysing the chemical composition of the leachate. This approach provides a direct measure of the likely solubility of metals taking into account the soils chemical and physical properties that occur on site. An appropriate sample collection techniques, study design and chemical analysis should be used that comply with the relevant standards including AS4439.1 (1999), AS 4439.2 (1997) and AS 4439.3 (1997) for the preparation of leachates including.

To gain a full understanding of how mobility is affected by soil chemistry, it would be worthwhile describing the proportion of uranium present in each oxidation state. This would show for example the % present as U(VI) that is mobile as compared with the immobile fraction of U (IV). In addition, it would be worthwhile identifying what fraction of uranium (as % of total) is associated with organic matter, clay minerals, and carbonates compared with the proportion exchangeable.

It is also possible to model the proportion of metals likely to be soluble. A model can provide an indication of the likely mobility of contaminants under relevant chemical and physical conditions. Examples of models include PHREEQC. Programs such as Geochemist workbench can also be used to provide an indication of the likely speciation of compounds under varying conditions.

Erosion, transport and deposition of metals associated with particulates

Metals including uranium that are associated with particulates can be transported via hydraulic and geomorphic processes. A study by ETS Geotechnical (2015) on behalf of UMVI indicated that fill batters have been eroding during the 30 year life and display signs of instability. In that study, batters were considered largely stable under normal conditions though it was noted that they are prone to instability during periods of intense rainfall. The report by Resource and Exploration Mapping (REM 2015) undertaken on behalf of UMVI provides estimates of the volume of material lost from drill pads and the haul road from surveys of the estimated original and current landform. An estimated 298 m^3 of material has eroded from the three benches and haul road.

It is likely that some of this material has been deposited in Bog Hole Creek and is being transported within the stream. However, at this time there is no information available describing the chemical composition of sediments in Bog Hole Creek. Although much of the uranium associated with particulates would remain adsorbed to particulates in the sediments, it is possible that under some conditions it may desorb from sediments, though there is not much information available describing the release of uranium from contaminated sediments. Uranium present in stream sediments may pose a risk to sediment dwelling biota though at this stage the concentration of metals in Bog Hole Creek have not been determined.

Assessing the effect of uranium and other metals in water and stream sediments

Uranium can exhibit impacts in both the aqueous and solid phases hence it is important to understand the potential risk to both aquatic and benthic fauna. Isotopic ratios can be used to determine the faction of uranium likely to be present in each phase with the proportion present in the aqueous phase posing greater risk to aquatic biota. A study by Siddeeg et al. (2015) found that ^{234}U is expected to be more abundant in water relative to ^{238}U, and ^{238}U is expected to be more abundant in sediment.

Uranium can exhibit both radiological and toxicity effects. However, a study by Mathews et al. (2009) showed that the risks to the environment from uranium's chemical toxicity generally outweigh those of its radiological toxicity. Accordingly, the direct toxicity effects are likely to provide the focus for ecological risk assessment. Uranium can be toxic above certain thresholds, though it is comparatively less toxic than other metals (Goulet et al. 2011). It does not biomagnify but is known to accumulate in bone, liver, and kidney tissue (Goulet et al. 2011). There is potential for uptake of uranium via the gill, though diet and/or sediment may be the major route of uptake, and may vary with feeding strategy (Goulet et al. 2011).

A range of toxicity assessment studies may be undertaken using aquatic or sediment biota. There are many factors that can influence the toxicity of uranium including the presence of calcium, magnesium, carbonates, phosphate, and dissolved organic matter (Goulet et al. 2011; and Goulet et al. 2015). It is also possible to monitor the concentration of metals present in resident biota. A study by (Bollhöfer 2011) provides an example where lead isotopes present in freshwater mussels were used to estimate the contribution of uranogenic lead associated with mining.

There are currently no national uranium guidelines for aquatic ecosystems in ANZECC/ARMCANZ (2000) or for sediments Simpson et al. (2005) that are applicable at the national level in Australia. There are Canadian Guidelines for uranium in waters (Canadian Council of Ministers of the Environment 2011). Those guidelines are 15 µg/L uranium (total recoverable) long term exposure, and 33 µg/L uranium (total recoverable) short term exposure. A study by (Sheppard et al. 2005) indicated a NOEC for uranium that is protective of freshwater plants was 0.005 mg/L and 0.005 mg/L for freshwater invertebrates. Sheppard et al. (2005) also proposed Predicted No Effect Concentrations (PNECs) of 100 mg/kg dry sediment for uranium was protective of freshwater benthos. Such values may be used as a basis for initial assessment of risk, though consideration of local species and water quality conditions would provide the most accurate results.

Effect of uranium and other metals on grazing cattle

It is difficult to assess to the risk associated with beef cattle grazing. A study by (Lottermoser 2011) evaluated plant uptake of metals on pots mined land at the Mary Kathleen mine in Queensland. That study showed *Calotropis procera* accumulated sufficient concentrations of Ca, K, Mg and S in its tissue to potentially cause harmful effects on stock and wildlife feeding on it. However, the species studied, *C. procera* is a non-native perennial shrub and may not be representative of potential uptake in native grasses found on site. This study did not assess uranium risks as there is no known maximum acceptable threshold concentration that are protective of beef cattle (Nrc 2005).

Accordingly, there may be a need to assess the risk of update by cattle that may occur as a result of grazing as part of a localised study that analyses the concentrations present in local grasses and considers the potential uptake in cattle. Such a study would provide useful information to describe this risk. Alternatively it may be possible to adopt a value for a surrogate species or to adopt soil guidelines though such an approach may not be protective.

In lieu of such information it may be possible to utilise the information from Sheppard et al. (2005) that suggested terrestrial plants (250 mg/kg dry soil, and other soil biota 100 mg/kg dry soil. In addition there are soil guidelines by the (Canadian Council of Ministers of the Environment Canadian Guidelines (CCME, 2007) for uranium. Those guidelines state a PSQGHH of 23 mg/kg uranium for Agricultural areas, 33 mg/kg uranium for commercial and 330 mg/kg uranium for Industrial land. As there are large differences between these values there is a need to further evaluate their source and relevance. A study by (Sheppard et al. 2005) suggested maximum thresholds for uranium to be protective of terrestrial plans and soil biota. The Predicted No Effect Concentrations (PNECs) protective of terrestrial plants was 250 mg U/kg dry soil and 100 mg/kg dry soil for other soil biota.

Approach to assess and manage risk

As uranium and other contaminants have been identified in elevated concentrations above background, the possibility of impacts to the environmental cannot be excluded. In such a circumstance it may be worthwhile implementing strategies to contain contaminants and prevent potential impacts. Strategies would require input from relevant experts but may include removing and covering material or implementing erosion and sediment control practices to stabilise soils material and capture material in runoff and leachate. It may also be possible to limit or prevent stock and wildlife accessing contaminated areas. Where there is a desire to evaluate the risk and determine the need for remediation, there is likely to assess the risks to the environment. The diagram in Figure 3 provides an indication of a process that may be followed to assess the risks and determine the need for remedial actions.

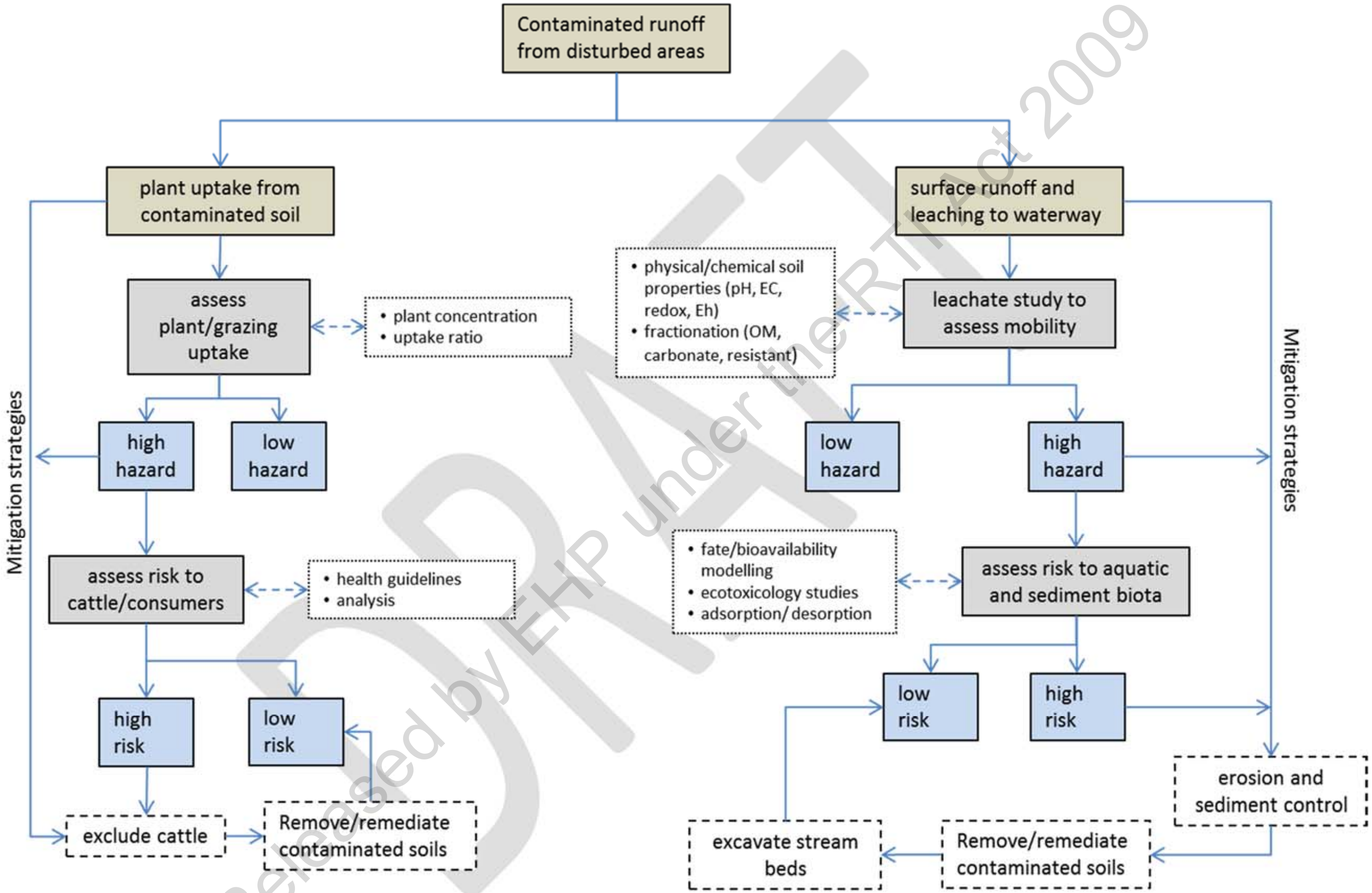

Figure 3. Assessment process for disturbed areas on the Ben Lomond lease area.

References

[note: the following references will be placed in alphabetic order in final draft]

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TROCCAZ Catherine

From: WALLACE Andrew
Sent: Tuesday, 30 June 2015 1:05 PM
To: DUNLOP Jason
Cc: CONNOLLY Niall
Subject: Ben Lomond - contaminated leachate
Attachments: UMVI XRF Characterisation Report May 2015.pdf; ES1418038_0_COA.PDF

Hi Jason,

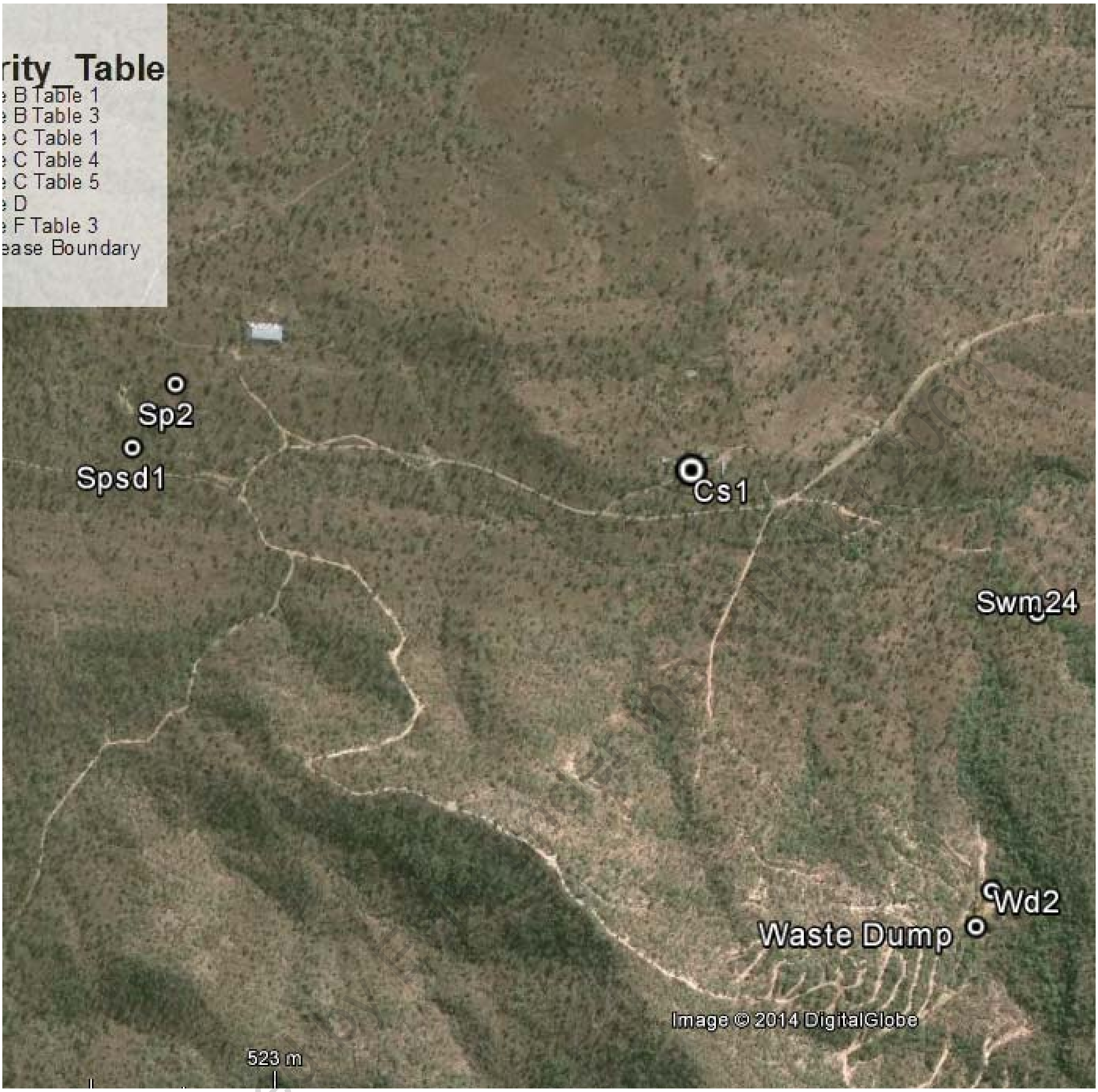
As discussed, EHP has received new information on the location and level of contaminated areas at the Ben Lomond site.
There has been a concern raised that the contaminant areas may be a source of contaminants to surface and groundwater.

EHP is seeking to identify the specific requirements needed to determine the level of contaminant export from the identified areas. These may form part of formal request for action in the future.
Specifically, EHP is seeking to understand:

- geochemical reactions, mobilisation processes and transformations for the potential contaminants;
- the likely factors affecting bioavailability of contaminants; and
- testing requirements

I have attached a pXRF report which identifies contaminant levels present, and maps of the areas (see below) and corresponding EHP sampling results.
We are happy to meet to discuss further as required. Note that Niall is on leave until the 13th of July.

Kind Regards, Andrew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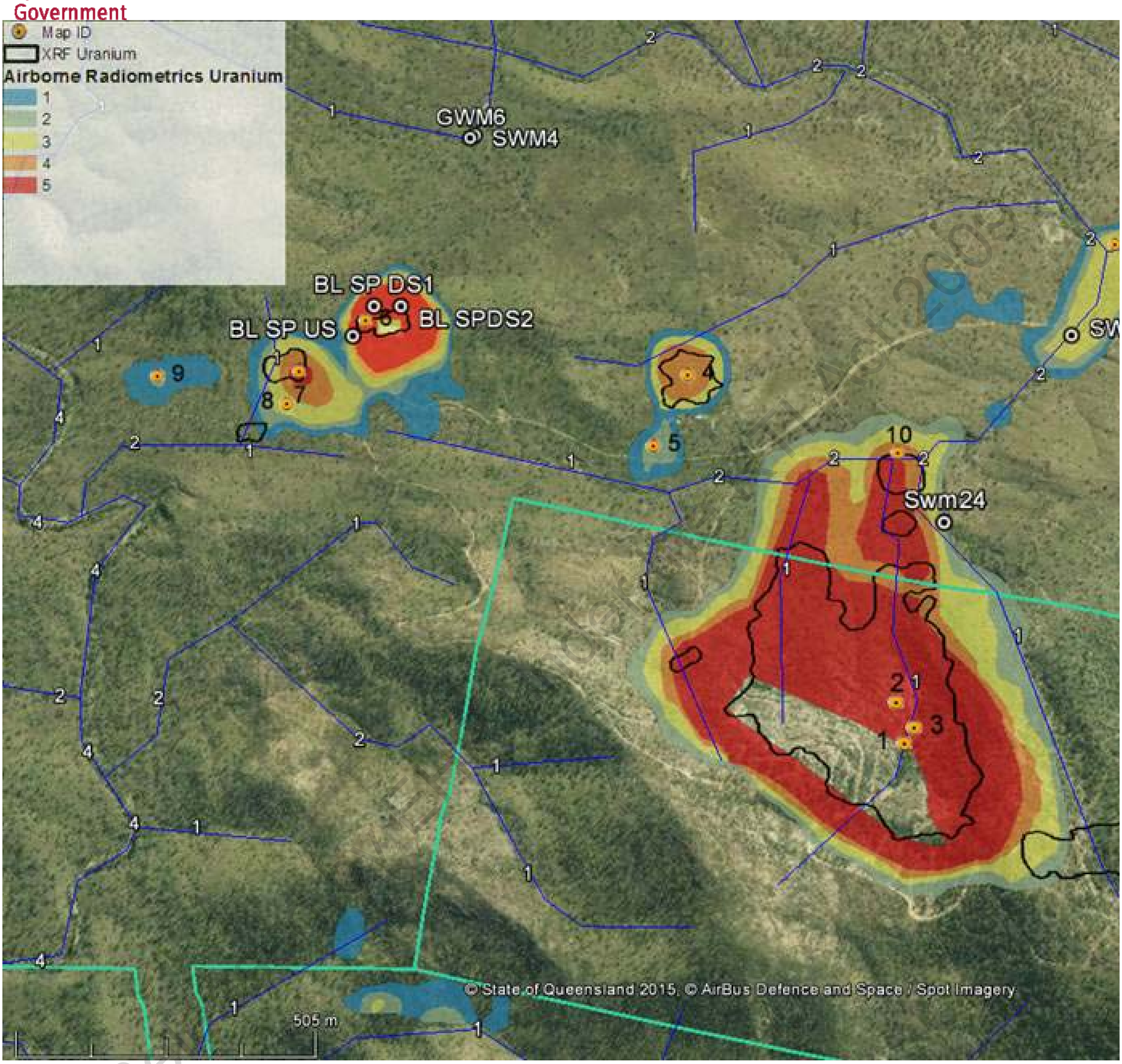
Queensland Government



Andrew Wallace
Senior Environmental Officer
North Queensland Compliance | Environmental Services and Regulation
Department of Environment and Heritage Protection

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CERTIFICATE OF ANALYSIS

Work Order	: **ES1418038**	Page	: 1 of 8
Client	: **QUEENSLAND DEPARTMENT OF ENVIRONMENT AND HERITAGE PROTECTION**	Laboratory	: Environmental Division Sydney
Contact	: MR ANDREW WALLACE	Contact	: Client Services
Address	: GPO BOX 5391 TOWNSVILLE MC QLD, AUSTRALIA 4810	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
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Telephone	: +61 07 47225353	Telephone	: +61-2-8784 8555
Facsimile	: +61 07 47225351	Facsimile	: +61-2-8784 8500
Project	: BEN LOMOND	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: 133161	Date Samples Received	: 14-AUG-2014
Sampler	: AW	Issue Date	: 02-SEP-2014
Site	: BEN LOMOND		
		No. of samples received	: 8
Quote number	: BNBQ/082/14	No. of samples analysed	: 8

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics
Shobhna Chandra	Metals Coordinator	Sydney Inorganics
Wael Saleh	Creation & Committal Coordinator	Sydney External Subcontracting

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG020: It has been confirmed by re-digestion and re-analysis that total Zinc concentration is less than dissolved for sample ES1418038-004.**
- **Radiological work undertaken by ALS Laboratory Group (Ceska Lipa) under CAI accreditation No. L1163. Report No. PR1444416 . NATA and CAI accreditations' are both recognised under ILAC.**

Analytical Results

Sub-Matrix: DI WATER LEACHATE (Matrix: WATER)			Client sample ID	SD1	SP2	BL WASTE DUMP	BL WASTE DUMP 2	----
			Client sampling date / time	19-AUG-2014 12:00	19-AUG-2014 12:00	19-AUG-2014 12:00	19-AUG-2014 12:00	----
Compound	CAS Number	LOR	Unit	ES1418038-001	ES1418038-002	ES1418038-007	ES1418038-008	----
EG020W: Water Leachable Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**1.00**	**0.33**	**0.19**	**0.11**	----
Antimony	7440-36-0	0.001	mg/L	**0.001**	<0.001	<0.001	<0.001	----
Arsenic	7440-38-2	0.001	mg/L	**0.002**	**0.006**	**0.003**	**0.002**	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Barium	7440-39-3	0.001	mg/L	**0.431**	**0.319**	**0.284**	**0.071**	----
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
Chromium	7440-47-3	0.001	mg/L	<0.001	**0.003**	<0.001	**0.001**	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Copper	7440-50-8	0.001	mg/L	**0.003**	**0.003**	**0.001**	**0.001**	----
Lead	7439-92-1	0.001	mg/L	**0.005**	<0.001	<0.001	<0.001	----
Lithium	7439-93-2	0.001	mg/L	**0.002**	<0.001	**0.001**	<0.001	----
Manganese	7439-96-5	0.001	mg/L	**0.003**	**0.010**	<0.001	<0.001	----
Molybdenum	7439-98-7	0.001	mg/L	**0.002**	<0.001	**0.001**	<0.001	----
Nickel	7440-02-0	0.001	mg/L	<0.001	**0.001**	<0.001	<0.001	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Strontium	7440-24-6	0.001	mg/L	**0.005**	**0.009**	**0.003**	<0.001	----
Thallium	7440-28-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Tin	7440-31-5	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Uranium	7440-61-1	0.001	mg/L	**0.017**	<0.001	<0.001	<0.001	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
Zinc	7440-66-6	0.005	mg/L	**0.203**	**0.098**	**0.055**	**0.027**	----
Boron	7440-42-8	0.05	mg/L	**0.44**	**0.21**	**0.31**	**0.14**	----
Iron	7439-89-6	0.05	mg/L	**0.45**	**0.19**	**0.12**	**0.06**	----
EG035W: Water Leachable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SD1	SP2	CS1	SWM6DS1	BL WASTE DUMP
			Client sampling date / time	30-JUL-2014 15:00	30-JUL-2014 15:00	30-JUL-2014 15:00	30-JUL-2014 15:00	30-JUL-2014 15:00
Compound	CAS Number	LOR	Unit	ES1418038-001	ES1418038-002	ES1418038-003	ES1418038-006	ES1418038-007
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	9.5	2.1	----	----	<1.0
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	7110	5730	----	----	2710
Boron	7440-42-8	50	mg/kg	<50	<50	----	----	<50
Iron	7439-89-6	50	mg/kg	6540	9880	----	----	9810
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	6.3	37.0	----	----	158
Selenium	7782-49-2	1	mg/kg	<1	<1	----	----	<1
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	----	----	0.1
Barium	7440-39-3	0.1	mg/kg	82.0	45.8	----	----	10.2
Thallium	7440-28-0	0.1	mg/kg	0.1	<0.1	----	----	0.3
Beryllium	7440-41-7	0.1	mg/kg	1.0	0.7	----	----	<0.1
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	----	----	<0.1
Bismuth	7440-69-9	0.1	mg/kg	0.2	0.1	----	----	<0.1
Cobalt	7440-48-4	0.1	mg/kg	1.9	3.6	----	----	<0.1
Chromium	7440-47-3	0.1	mg/kg	1.8	1.3	----	----	0.6
Copper	7440-50-8	0.1	mg/kg	4.7	3.3	----	----	12.7
Thorium	7440-29-1	0.1	mg/kg	4.5	2.9	----	----	9.5
Manganese	7439-96-5	0.1	mg/kg	66.8	249	----	----	21.0
Strontium	7440-24-6	0.1	mg/kg	14.6	9.5	----	----	6.3
Molybdenum	7439-98-7	0.1	mg/kg	2.7	0.4	----	----	104
Nickel	7440-02-0	0.1	mg/kg	6.0	5.7	----	----	0.9
Lead	7439-92-1	0.1	mg/kg	20.8	13.4	----	----	23.0
Antimony	7440-36-0	0.1	mg/kg	0.7	0.7	----	----	4.6
Uranium	7440-61-1	0.1	mg/kg	125	0.6	----	----	11.4
Zinc	7440-66-6	0.5	mg/kg	27.8	22.9	----	----	9.5
Lithium	7439-93-2	0.1	mg/kg	4.4	5.3	----	----	0.5
Vanadium	7440-62-2	1	mg/kg	3	3	----	----	2
Tin	7440-31-5	0.1	mg/kg	2.6	0.2	----	----	0.7
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	----	----	<0.1
EN60: Bottle Leaching Procedure								
Final pH	----	0.1	pH Unit	8.3	8.0	----	----	8.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SD1	SP2	CS1	SWM6DS1	BL WASTE DUMP
			Client sampling date / time	30-JUL-2014 15:00	30-JUL-2014 15:00	30-JUL-2014 15:00	30-JUL-2014 15:00	30-JUL-2014 15:00
Compound	*CAS Number*	*LOR*	*Unit*	ES1418038-001	ES1418038-002	ES1418038-003	ES1418038-006	ES1418038-007
Radionucleides / Activity								
Gross alpha	----	500	Bq/kg DW	**5630**	**1360**	**670**	**3050**	**17300**
Gross beta	----	500	Bq/kg DW	**2980**	**980**	**1210**	**1580**	**5770**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**BL WASTE DUMP 2**	----	----	----	----
			Client sampling date / time	30-JUL-2014 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1418038-008**	**----**	**----**	**----**	**----**
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	**1.2**	----	----	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**2940**	----	----	----	----
Boron	7440-42-8	50	mg/kg	<50	----	----	----	----
Iron	7439-89-6	50	mg/kg	**7500**	----	----	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	**111**	----	----	----	----
Selenium	7782-49-2	1	mg/kg	<1	----	----	----	----
Silver	7440-22-4	0.1	mg/kg	<0.1	----	----	----	----
Barium	7440-39-3	0.1	mg/kg	**13.0**	----	----	----	----
Thallium	7440-28-0	0.1	mg/kg	**0.2**	----	----	----	----
Beryllium	7440-41-7	0.1	mg/kg	**0.1**	----	----	----	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	----	----	----	----
Bismuth	7440-69-9	0.1	mg/kg	<0.1	----	----	----	----
Cobalt	7440-48-4	0.1	mg/kg	**0.2**	----	----	----	----
Chromium	7440-47-3	0.1	mg/kg	**0.7**	----	----	----	----
Copper	7440-50-8	0.1	mg/kg	**17.4**	----	----	----	----
Thorium	7440-29-1	0.1	mg/kg	**8.9**	----	----	----	----
Manganese	7439-96-5	0.1	mg/kg	**26.3**	----	----	----	----
Strontium	7440-24-6	0.1	mg/kg	**6.9**	----	----	----	----
Molybdenum	7439-98-7	0.1	mg/kg	**38.4**	----	----	----	----
Nickel	7440-02-0	0.1	mg/kg	**1.8**	----	----	----	----
Lead	7439-92-1	0.1	mg/kg	**19.1**	----	----	----	----
Antimony	7440-36-0	0.1	mg/kg	**2.7**	----	----	----	----
Uranium	7440-61-1	0.1	mg/kg	**15.8**	----	----	----	----
Zinc	7440-66-6	0.5	mg/kg	**12.0**	----	----	----	----
Lithium	7439-93-2	0.1	mg/kg	**0.6**	----	----	----	----
Vanadium	7440-62-2	1	mg/kg	**1**	----	----	----	----
Tin	7440-31-5	0.1	mg/kg	**1.3**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	**0.1**	----	----	----	----
EN60: Bottle Leaching Procedure								
Final pH	----	0.1	pH Unit	**8.5**	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**BL WASTE DUMP 2**	----	----	----	----
			Client sampling date / time	30-JUL-2014 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1418038-008**	----	----	----	----
Radionucleides / Activity								
Gross alpha	----	500	Bq/kg DW	**9800**	----	----	----	----
Gross beta	----	500	Bq/kg DW	**4000**	----	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SWM24	GWM16	----	----	----
			Client sampling date / time	30-JUL-2014 15:00	30-JUL-2014 15:00	----	----	----
Compound	CAS Number	LOR	Unit	ES1418038-004	ES1418038-005	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.95**	**7.09**	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**568**	**532**	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.011**	**0.024**	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	**0.003**	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	**0.002**	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.001**	**0.003**	----	----	----
Uranium	7440-61-1	0.001	mg/L	<0.001	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.059**	**0.076**	----	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.020**	**0.028**	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.001**	**0.007**	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	**0.012**	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.001**	**0.004**	----	----	----
Uranium	7440-61-1	0.001	mg/L	<0.001	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	**0.227**	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----