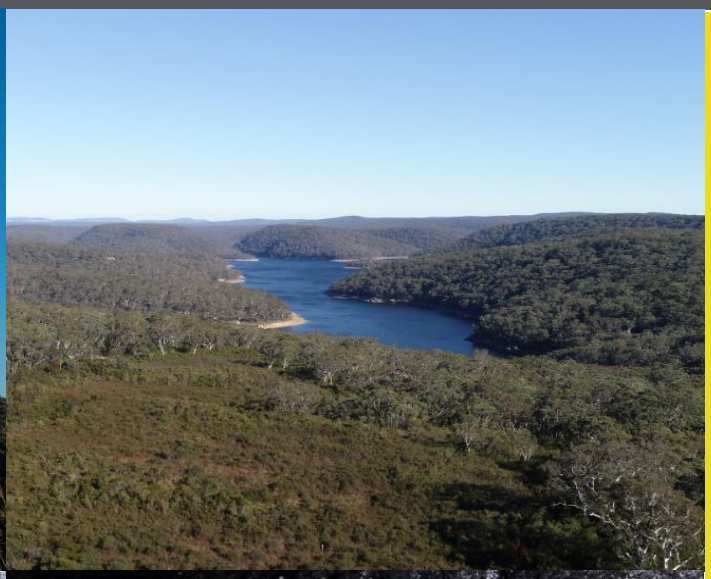
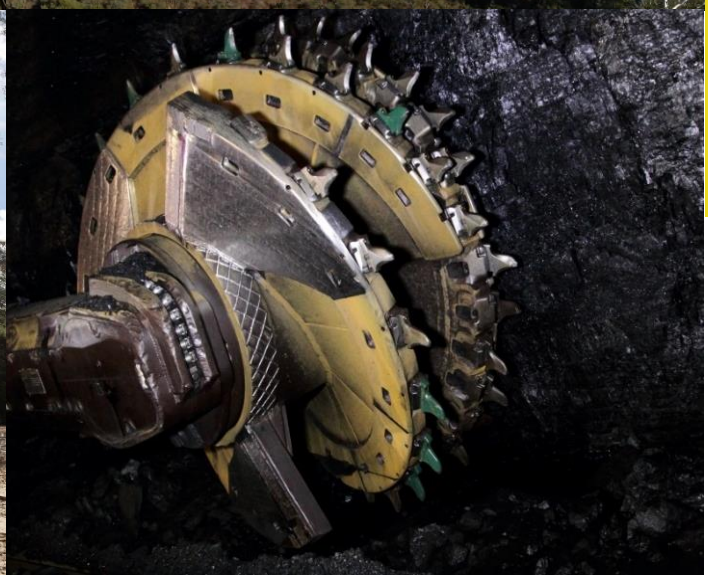
SOUTH32 Illawarra Metallurgical Coal





APPIN MINE - ENVIRONMENTAL RESEARCH PROGRAM

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DOCUMENT REVISION LOG

Persons authorising this Plan

NAME	TITLE	DATE
Gary Brassington	Manager Approvals	6 May 2021

Document Revisions

REVISION	DESCRIPTION OF CHANGES	DATE
0	Original document	19 September 2012
1.0	Update document and use of South32 template	28 January 2021
1.1	Addition of Table 3 and minor updates	6 May 2021

Persons involved in the review of this Plan

NAME	TITLE	COMPANY	EXP (YRS)	DATE
Gary Brassington	Manager Approvals	South32 IMC	25	January 2021
Nicola Curtis	Principal Mining Approvals	South32 IMC	7	January 2021
Chris Schultz	Lead Environment	South32 IMC	24	July 2020

1. INTRODUCTION

Appin Mine includes underground mining and surface support operations which extract coal from the Bulli Seam, including the West Cliff Coal Preparation Plant (WCCPP) and Coal Wash Emplacement Area (CWEA). Appin Mine is located approximately 25 kilometres north-west of Wollongong in New South Wales. Appin Mine is owned and operated by Endeavour Coal Pty Ltd, a subsidiary of Illawarra Coal Holdings Pty Limited (ICHPL), wholly owned subsidiary of South32 Limited. Appin Mine, Cordeaux Colliery and Dendrobium Mine (and associated facilities) collectively operate as South32 Illawarra Metallurgical Coal (IMC).

In September 2009, ICHPL submitted an Environmental Assessment (EA) for its Bulli Seam Operations (BSO) Project to the NSW Department of Planning and Infrastructure (DoPI) for the continuation of existing underground coal mining operations for Appin Mine and West Cliff Mine. In October 2010 ICHPL submitted a Preferred Project Report (PPR) to the Director General of the DoPI requesting that the North Cliff, Area 2 and the majority of the Area 3 mining domains be removed from the BSO Application. This resulted in removal of most of the proposed mining beneath the Dharawal State Conservation Area and all 226 upland swamps previously identified within the Application Area.

ICHPL received Project Approval 08_0150 (the Bulli Seam Operations approval) from the NSW Planning Assessment Commission (as delegate to the Minister for Planning) on 22 December 2011 for current and proposed mining of the BSO for 30 years, and production of up to 10.5 million tonnes per annum of run of mine (ROM) coal. This approval incorporates underground mining, transport and coal wash emplacement activities undertaken 24 hours a day, seven days per week.

1.1 Program Objectives

The purpose of this Environmental Research Program (ERP) is to provide the framework of IMC's subsidence related environmental research across its BSO in accordance with Conditions 9 and 10, Schedule 3 of the BSO Approval. The scope of the ERP includes the following mining areas:

- Appin Area 3;
- Appin Area 7;
- Appin Area 8;
- Appin Area 9;
- West Cliff Area 5;
- Previous mining areas; and
- Other mining areas where they have applicability to BSO mining areas.

The objectives of the ERP are to:

1. Improve understanding and prediction of subsidence impacts by:

a) testing (including core testing and in situ testing) to further define the mechanical, hydrogeological and geochemical properties of rock strata within each longwall domain, including:

   i. testing and validation of assumptions regarding regional continuity of modelled hydraulic properties (including mass porosity and permeability);

   ii. identifying hydraulic properties of rock strata close to water-dependent ecosystems; and

   iii. identifying the presence and distribution of iron-bearing minerals that might contribute to surface water quality impairment;

b) installation of a regional network of deep pore pressure monitoring bores with vertical arrays of pore pressure transducers to assess and quantify the height and impacts of subsurface fracturing;

c) a census of boreholes which may be impacted by subsidence, the gathering of relevant borehole and groundwater quality data and a regular monitoring program;

d) regular enhancement, calibration and verification of the project's regional groundwater model, and the further development of this model on a mining-domain scale; and

e) regular recalibration of methodologies and models used for subsidence effect and impact prediction, as they are applied within the project area.

2. Improve understanding and prediction of environmental consequences on significant natural features by:

   a) directed research into improving the prediction, assessment, remediation and/or avoidance of subsidence impacts and environmental consequences on significant natural features in the Project Area; and

   b) targeted genuine research, as opposed to implementing the matters required by this approval.

1.2 Environmental Management System

IMC has a comprehensive Environmental Management System (EMS) in place to minimise the impact of its operations on the local environment and community. The ERP is a component of the EMS which is certified to ISO 14001.

1.3 Consultation

In accordance with Conditions 9 and 10, Schedule 3 of the BSO Project Approval, the BSO ERP was provided to the Director-General (via the DoPI) on 19 September 2012.

The ERP was also provided to WaterNSW (previously Sydney Catchment Authority), Environment, Energy and Science Group (previously Office of Environment and Heritage) and the Resources Regulator (previously Department of Primary Industries - Resources and Energy) for feedback.

No feedback was received requiring modification of the ERP at that time.

2. ROLES AND RESPONSIBILITIES

The roles and responsibilities for the ERP are outlined below in Table 1.

Table 1: Roles and Responsibilities for the ERP

Role	Responsibilities & Accountabilities	Authorities
General Manager Mining Services	- Ensure that the IMC Approvals Team is adequately resourced to effectively implement the ERP	- Make or authorise changes to the ERP to ensure compliance with the BSO Approval - Liaise with Government authorities in relation to the ERP
Manager Approvals	- Implement research projects required by the ERP to a high standard that is consistent with company and government expectations - Develop research projects for inclusion in the ERP - Measure success of rehabilitation methods and trials - Coordinate independent reviews of the ERP with recommendations for subsequent trials and ongoing actions	- Make or authorise changes to the ERP to ensure compliance with the BSO Approval - Liaise with Government authorities in relation to the ERP - Undertake environmental assessments and gain appropriate approvals for research projects - Liaison with Government on the progress of research projects - Reporting on the implementation of the ERP
Superintendent Infrastructure Protection and Legacy Sites Survey Coordinator Principal Approvals	- Implement research projects required by the ERP to a high standard that is consistent with S32 and government requirements - Develop research projects related to subsidence and groundwater aspects for inclusion in the ERP	- Undertake environmental assessments and gain appropriate approvals for research projects - Liaison with Government on the progress of research projects - Reporting on the implementation and management of the ERP to Government authorities
Technical Experts	- Conduct the roles assigned to them in a competent and timely manner to the satisfaction of the Manager Approvals and formally provide expert opinion as requested - Converting monitoring and research data into analytical documents that can be published for wider application	- Authorise technical reports
Lead Community	- Ensure there are no community impacts resulting from ERP activities	- Liaise with community members in relation to the ERP

3. LEGISLATION AND PLANNING

3.1 Project Approval Conditions and Statement of Commitments

IMC operates under a number of statutory approvals, licences, leases and permits granted under NSW and Commonwealth legislation, including the BSO Approval. Table 1 outlines the environmental research requirements of the BSO Approval and references where the requirements have been addressed within the ERP.

Research activities described in the ERP will be undertaken in accord with the BSO Approval. The following approvals, licenses or permits may also be applicable to IMC's implementation of the ERP:

- Mining Leases and Consolidated Coal Leases;
- Environmental Protection Licence (EPL) 2504;
- Environmental Protection and Biodiversity Conservation Act approvals (EPBC 2010/5350 and EPBC 2010/5722);
- BSO Mining Operations Plan (MOP);
- Relevant WHS and HSEC approvals; and
- Any additional leases, licences or approvals resulting from the BSO Approval.

3.2 Relevant Legislation and Licences

Legislation that may be applicable to the conduct of the ERP includes the following:

- Mining Act, 1992;
- National Parks and Wildlife Act, 1974;
- Protection of the Environment Operations Act, 1997;
- Water NSW Act, 2014;
- Crown Lands Management Act, 2016;
- Fisheries Management Act, 1994;
- Water Act, 1912; and
- Water Management Act, 2000.

Relevant licences and approvals required under applicable Acts will be obtained as required.

Supplementary approvals may be required from Water NSW and National Parks and Wildlife to access some areas for activities within the Metropolitan Special Area, Woronora Special Area, O'Hares Creek Special Area and the Dharawal State Conservation Area in accordance with the requirements of the conditions of IMCs mining tenements.

4. ENVIRONMENTAL RESEARCH PROGRAM

IMC has committed to fund research to develop improved scientific understanding of subsidence impacts. The aspects considered for research were described in the BSO EA Section 5.6 (water) and Sections 5.7 to 5.9 (ecological).

IMC's commitments to research were outlined in Table SOC-2 of the BSO EA and included the following:

Swamps:

- The possible mechanisms for subsidence impacts on swamp hydrology across a range of swamp types, terrain and mining operations. The objective is to improve predictability of impacts on swamp hydrology.
- The relationship between changes in swamp hydrology and environmental consequences. The two key issues here are severity and duration of the hydrologic disturbance. Both are relevant to considering whether mitigation or remediation measures might play a role in management of mining impacts.
- The possibilities of using remediation techniques and the circumstances in which they may be applicable.
- Developing a suite of indicators that could form the basis of an accepted stratified approach to monitoring impacts and consequences on upland swamps.
- The value that the community places on catchment protection and conservation roles of upland swamps.

Streams:

- Non-systematic subsidence effects and associated environmental consequences in significant watercourses.
- Techniques for remediating stream bed fracturing.

Specific research projects previously supported, currently underway and planned by IMC are provided in Appendix 2. Further discussion on IMC's approach to addressing the BSO Approval requirements is provided below.

4.1 Improved Understanding and Prediction of Subsidence Impacts

Mining impacts are influenced by subsidence movements interacting with the overburden above and below the extracted coal seam. Understanding strata conditions and properties contributes significantly to the prediction of subsidence impacts through understanding the mechanisms causing impacts. Testing will be undertaken on overburden strata (core and in situ) during the exploration program to further define the mechanical, hydrogeological and geochemical properties of rock strata within each longwall domain. The following testing will be included in the program:

i. testing and validation of assumptions regarding regional continuity of modelled hydraulic properties (including mass porosity and permeability);

ii. identifying hydraulic properties of rock strata close to water-dependent ecosystems; and

iii. identifying the presence and distribution of iron-bearing minerals that might contribute to surface water quality impairment.

A regional network of deep pore pressure monitoring bores with vertical arrays of transducers has been installed to assess and quantify the height and impacts of subsurface fracturing. This network will be further developed as exploration programs are undertaken in new mining domains as well as regional programs further from mining operations.

A census of boreholes which may be impacted by subsidence will be undertaken as part of the development of Extraction Plans for all mining areas. The data gathered will include relevant borehole characteristics from drilling records as well as any information available from landholders. Groundwater level and quality monitoring will be undertaken.

A regional groundwater model has been developed for the BSO. The model will be updated regularly to include any enhancements, calibrations and verifications. The regional groundwater model will be used to assess each mining area during the development of Extraction Plans, rehabilitation and closure planning.

The BSO groundwater model is a 3D mathematical model developed using Modflow-Surfact software. During the development of each Extraction Plan the model and methodologies used for subsidence effect and impact prediction as they are applied within the project area will be reviewed and any identified improvements will be implemented.

The Annual Review would describe updates to the groundwater model, groundwater level monitoring results and comparisons of predicted and actual groundwater flows into the workings.

4.2 Improve Understanding and Prediction of Environmental Consequences

IMC will implement targeted research to improve the understanding and prediction of environmental consequences on significant natural features resulting from subsidence impacts. The research will be directed at improving the prediction, assessment, remediation and/or avoidance of subsidence impacts and environmental consequences on significant natural features in the Project Area. This research program will add to the understanding of subsidence impacts which will develop from the routine monitoring required by the BSO Approval.

The following significant features will be targeted for research:

i. Rivers, streams and riparian areas;

ii. Groundwater, including Dependent Ecological Communities such as upland swamps; and

iii. Cliffs, overhangs and steep slopes.

4.3 Research and Industry Partners

IMC will work cooperatively with research and industry partners, including Government Agencies where appropriate.

The Australian Coal Association Research Program (ACARP) was formed by the Australian Coal Association to develop and adopt technology and mining practices that improve the industry. Industry funding for this program is reviewed and considered on a five-year cycle. Research programs are developed and prioritised by technical committees responsible for project selection. IMC is represented on ACARP Committees and actively supports research projects investigating subsidence impacts in the Southern Coalfield. Research into the impacts of subsidence has received considerable funding through this program. IMC's investment in research will be leveraged with this and other sources of additional funding to optimise the results for IMC, the industry and other stakeholders.

4.4 Expenditure

Research expenditure required under Condition 10 of Schedule 3 will be tracked and reported throughout the program as directed by the Department of Planning, Industry and Environment (DPIE). Expenditure included is that directed at research into improving the prediction, assessment, remediation and/or avoidance of subsidence impacts and environmental consequences on significant natural features in the Project Area. Expenditure will occur over the period of the ERP, as relevant research projects are identified.

The costs of data collection to meet approval conditions will not be included in the costs of implementing the ERP, unless such data collection is directly informing research for the ERP. The costs of research undertaken as part of the Dendrobium Mine Swamp Rehabilitation Research Program (SRRP) are not included in the costs of implementing the ERP, unless such research is directly informing research for the ERP.

Expenditure details are provided in Appendix 2, Table 2.

5. REPORTING AND REVIEW

5.1 Review and Audit

IMC environmental management strategies, plans and programs are developed to comply with legislative, South32 and ISO 14001 certification requirements. The ERP will be subject to regular auditing and review in accordance with Condition 9 of Schedule 6 of the BSO Approval.

In accordance with Condition 5 of Schedule 6 of the BSO Approval, strategies, plans and programs will be reviewed within three months of:

i. the submission of an annual review (under Condition 4 of Schedule 6);

ii. the submission of an incident report (under Condition 7 of Schedule 6);

iii. the submission of an Independent Environmental Audit report (under Condition 9 of Schedule 6); and

iv. any modification to the conditions of the Appin Mine Approval (unless the conditions require otherwise).

This ERP will be reviewed in conjunction with the above and any revisions will be made to the satisfaction of the Secretary.

5.2 Access to Information

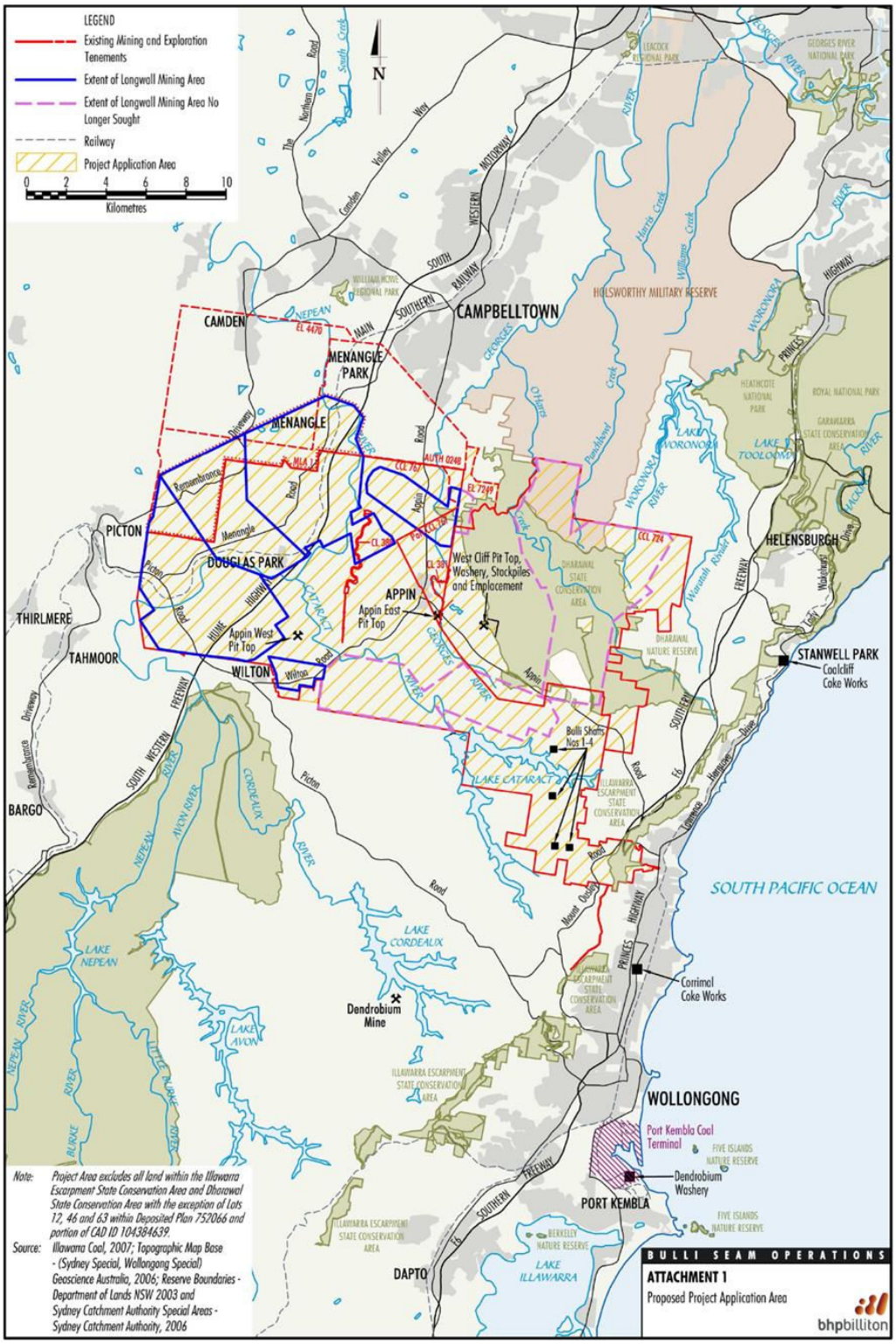
In accordance with Condition 11 of Schedule 6, IMC will have the ERP publicly available on its website:

https://www.south32.net/our-business/australia/illawarra-metallurgical-coal/documents.

Reporting of ERP results will be through established mechanisms required by the BSO Approval, including the Annual Review, available on the South 32 website.

6. PLANS

Figure 1 Appin Mine Locality Plan



7. APPENDICES

Appendix 1

Table 1 - BSO Approval Conditions

Clause	Requirement	Document / Section
Condition 9 of Schedule 3	The Proponent shall prepare and implement a program to improve its prediction and understanding of subsidence impacts (in particular sub-surface impacts and impacts on groundwater resources), to the satisfaction of the Secretary. This program must be prepared in consultation with DRE and be submitted to the Secretary for approval by 30 September 2012 and must include proposals for: a) testing (including core testing and in situ testing) to further define the mechanical, hydrogeological and geochemical properties of rock strata within each longwall domain, including: i. testing and validation of assumptions regarding regional continuity of modelled hydraulic properties (including mass porosity and permeability); ii. identifying hydraulic properties of rock strata close to water-dependent ecosystems; and iii. identifying the presence and distribution of iron-bearing minerals that might contribute to surface water quality impairment; b) installation of a regional network of deep pore pressure monitoring bores with vertical arrays of pore pressure transducers to assess and quantify c) a census of boreholes which may be impacted by subsidence, the gathering of relevant borehole and groundwater quality data and a regular monitoring program; d) regular enhancement, calibration and verification of the project's regional groundwater model, and the further development of this model on a mining-domain scale; and e) regular recalibration of methodologies and models used for subsidence effect and impact prediction, as they are applied within the project area.	This Plan Section 4 Appendix 2
Condition 10 of Schedule 3	The Proponent shall prepare and implement a Research Program to the satisfaction of the Secretary and allocate $1,000,000 in total to this program for expenditure over a period of seven years from the date of the program's approval. This program must be prepared in consultation with OEH, WaterNSW and DRE, be submitted to the Secretary for approval by 30 September 2012, and be: a) directed at research into improving the prediction, assessment, remediation and/or avoidance of subsidence impacts and environmental consequences on significant natural features in the Project Area; and b) targeted at genuine research, as opposed to implementing the matters required by this approval.	This Plan Section 4 Appendix 2

Appendix 2

Table 2 - Research projects previously supported, currently underway and planned by IMC

RESEARCH PROJECT TITLE AND ID	OVERVIEW	TIMING
1. Subsidence Modelling and Predictive Tools		
a) Incremental Subsidence Profile Model	The Incremental Subsidence Profile Model was developed by MSEC for the Southern Coalfield. IMC contributes significant amounts of the empirical data for the continued calibration of the model.	This model is routinely updated based on subsidence survey data provided by IMC
b) Upsidence and Closure Model	The ACARP Upsidence and Closure Model was developed by MSEC for the Southern Coalfield. IMC contributes significant amounts of the empirical data for the continued calibration of the model.	This model is routinely updated based on subsidence survey data provided by IMC
c) Effects of Geology on Upsidence and Closure Movements and Impacts in Valleys	This ACARP C18015 project aims to provide more appropriate upsidence and closure predictions and impact assessments near valleys, provide probabilistic predictions and improve the accuracy and level of confidence in predictions. IMC is a significant contributor to this project, supplying the majority of empirical data being analysed.	Completed in 2014
d) Anomalous Subsidence Review	A review of known anomalous events over the last 20 years from IMC mining areas and research into the mechanisms contributing to these events.	Completed in 2014
e) The Influence of Geology and Lineaments on Subsidence Movements and Impacts	Research program to develop techniques for improved understanding of the effects of lineaments and geological structures on the ground movements (i.e. subsidence) above longwall mines.	Ongoing (2018-2020)
f) The Role of Basal Shear on Strata Permeability	The presence of natural and mining induced bedding plane shears, also referred to as basal shear horizons, are recognised to have potential to increase the lateral hydraulic conductivity of the rock strata between adjacent water reservoirs and the mine. As part of a program to investigate this potential, IMC drilled two boreholes to intersect three basal shear horizons previously observed during inclinometer monitoring at Sandy Creek Waterfall and to review the packer testing data from these holes.	Completed in 2019
g) The Influence of Steep Slopes on Subsidence Movements and Impacts	A study has commenced on trial sites above Appin Area 7 and on the foothills of the Razorback Range above Appin Area 9. The objective is to better understand the influence of steep slopes on subsidence movements and potential impacts.	Appin Area 7 Q1 2012 till Q3 2016 - present

RESEARCH PROJECT TITLE AND ID	OVERVIEW	TIMING
	Engineering services provided by GHD and MSEC, survey and spatial data expertise provided by IMC.	
2. Groundwater Response to Mining		
a) Reducing the Impact of Longwall Extraction on Groundwater Systems	The objective of this ACARP project (C18016) was to develop and demonstrate an integrated hydrogeological assessment approach with supporting tools, and to enhance industry's ability to predict the hydrogeological response to longwall mining. IMC contributed significantly to this project with Dendrobium Mine being one of the key case studies	Completed in 2012
b) Connective Fracturing Research Project	Project aims to investigate the connective fracturing above proposed longwall panels and the potential impacts on connected water systems, including swamps. This project researched the impact of Longwall 9 in Dendrobium Mine, Area 3B and has involved diamond core holes drilled at key locations to provide information on the following: • Pre-mining hydraulic characteristics; • Hydraulic conductivity of the fractured rock mass and connectivity of fractures using packer testing, down hole flow testing and cross-hole tracer tests. The overall objective of this study is to characterise the groundwater system in the Triassic strata above proposed longwall mining operations, and specifically to identify inherent horizontal and vertical flow paths related to connected fractures and other flow paths, prior to mining. The study included repeat investigations after the longwall passed through the area, in the post-mining environment.	Completed 2012-2015
c) The Influence of Geology and Lineaments on Mine Inflows (Water Fingerprinting)	Lineaments (mapped or inferred geological structures such as faults or dykes) have the potential to propagate impacts such as groundwater drawdown and/or cause mine inflow. A spatial correlation analysis was carried out at Dendrobium mining areas and for each of the four parameters (EC, Cl, Na/Cl and tritium) to determine the relationship between the parameter value and the proximity to each feature type, including faults, lineaments, igneous dykes, and disturbed or cindered coal.	2019 - 2020
d) The Influence of Geology and Lineaments on piezometer responses	Lineaments (mapped or inferred geological structures such as faults or dykes) have the potential to propagate impacts such as groundwater drawdown and/or cause mine inflow. A spatial correlation analysis was carried out at Dendrobium mining areas on piezometers that are located within strata near or within lineaments.	2019 - 2020

RESEARCH PROJECT TITLE AND ID	OVERVIEW	TIMING
e) Groundwater Model Review, Enhancement and Calibration	Installation of groundwater monitoring equipment in the BSO area, including between mining and the Nepean River. Multilevel piezometers and permeability testing in the bores is undertaken to enhance and calibrate the BSO groundwater model. The model is regularly updated with new data collected.	Ongoing
f) Measuring the Height of Fracturing above Extracted Longwalls	ACARP Project C28026. The objective of the project is to measure by geotechnical means the height of rock fracturing and compare this height to the 'height of depressurisation' of groundwater determined by various models, such as the Tammetta (2013) model. The project involved data provision and drilling a fully packer and geotechnically tested hole. Seven in-situ 3D stress tests were undertaken in the borehole to provide data for modelling.	2019 - 2020
3. Impact Monitoring and Prediction Tools		
a) GIS Methods for Subsidence Impact Assessment	The objectives of this ACARP project (C14031) were to develop and demonstrate practical decision support methodology for the assessment of the impacts of mining subsidence on natural features. The decision support tools were developed within the flexibility of the Geographic Information System (GIS) environment and uses relevant case studies to demonstrate the usefulness of GIS tools. The project included analysis of a number of case studies, including Dendrobium and Appin Mines.	ACARP completed May 2007 with continuing development of the techniques by IMC, including developing automated subsidence monitoring tools
b) The Effect of Longwall Mining on Vegetated Environments	The aim of ACARP C15013 was to develop methods and tools to assist the coal mining industry to better monitor the consequences of subsidence on surface environments. The project focus was to improve monitoring quality through the incorporation of high- resolution remotely sensed data into subsidence monitoring programmes. A major component of this research was related to upland swamps within IMC mining areas.	ACARP component completed January 2010 with continuing development of the techniques by IMC
c) Monitoring Surface Condition of Landscape Features Subject to Mining Subsidence with Very High Resolution Imagery	This ACARP C20046 project is researching the use of unmanned aerial vehicles to capture high resolution imagery of upland swamps with the intention of comparing and calibrating this data with traditional ground based survey techniques.	2012-2014
d) Swamp Eco-hydrology Study	This research was undertaken by IMC and Parsons Brinckerhoff and is seeking to provide a quantitative assessment of swamp ecohydrology. The key outcomes of the study included: • Quantify vegetation condition within Swamp 15a • Characterise water sources used by plants	Stage 1 Proof of Concept, completed in 2013

RESEARCH PROJECT TITLE AND ID	OVERVIEW	TIMING
	• Distinguish between climatic and anthropogenic stresses. The approach by Parsons Brinckerhoff involved two main methods: • Isotopic characterisation of plant xylem water and potential sources of plant water. Continuous monitoring of plant stem moisture and soil moisture.	
e) Change Detection in Complex Vegetation Communities	This ACARP Project C25056 develops and demonstrates methods to introduce UAV sourced remote sensing products for monitoring and reporting change in complex vegetation communities, including Upland Swamps. IMC provided substantial data to support this research.	Completed 2019
f) Measuring Subsidence using g) Remote Sensing (ALS, drone, photogrammetry)	The objective of the project was to determine if remote sensing methods could produce sufficiently precise measurements to replace/supplement traditional ground survey techniques for the purposes of subsidence management. Additional Appin ALS was flown, and the data manipulated to extract subsidence contours. Several types of drone targets were also trialled in an attempt to generate survey-like precision from drone/photogrammetric techniques.	2017- present
h) Swamp hydrology numerical modelling for advancing rehabilitation planning and management - extension	The project (ACARP Project C27059) will extend understanding and capability to predict the impacts of mining and climate on the hydrology and vegetation of Temperate Highland Peat Swamps on Sandstone (THPSS). Data will be supplemented by additional monitoring at one site at the Dendrobium Mine, and calibration of the Sentek soil moisture sensors in use at Dendrobium. Soil sampling for calibration of soil moisture instrumentation in swamps also undertaken.	Field work undertaken in 2019. Additional fieldwork planned (part of ACARP extension) for March 2020 however postponed due to COVID-19 travel restrictions.
i) Reservoir Water Balance	Develop water balance model for Avon Reservoir Catchment and assess the relative scale of the components. Recommendations made about whether mining-related seepage is likely to be a significant factor in reservoir hydrology, and whether it is possible to refine certain inputs to improve this modelling and analysis. Work undertaken by Weatherford and SCT Operations.	2019 - 2020
4. Subsidence Impact Mitigation and Rehabilitation		
a) Damage Criteria and Practical Solutions for Protecting River Channels	This ACARP Project C12016 investigated the nature of the disturbances that occur in the base of river channels, the potential impacts of these disturbances on water flow paths as well as the range of practical strategies available for the assessment, mitigation and remediation of these impacts. IMC provided substantial data to	Completed May 2009

RESEARCH PROJECT TITLE AND ID	OVERVIEW	TIMING
	support this research, including the Georges River Grouting and Marhnyes Hole Slot case studies	
b) Effects of Surface Topography on Mining Subsidence Damage to River Channels	This ACARP Project C15025 investigated the potential to provide more effective and substantially smaller barriers by better understanding the mechanics of the processes that cause horizontal subsidence movements. The report presents current understanding of the mechanics of mining induced horizontal ground movements and the opportunities available to design protection barriers based on this understanding. IMC contributed significantly to this research, including provision of subsidence data for assessment of DinSAR monitoring.	Completed April 2011 with IMC continuing to research DinSAR monitoring techniques
c) Feasibility Study of Subsidence Control using Overburden Grout Injection Technology	This ACARP C12019 project aimed to assess the feasibility of significantly reducing longwall mining subsidence by applying the overburden grout injection technology originally developed and used in China. A key task of the project was to develop a cost-effective and flexible overburden grout injection system for Australian conditions. IMC contributed significantly to this project with monitoring data and West Cliff Mine was a key study site for this project.	Completed August 2005
d) Subsidence Control Using Coal Washery Waste	This ACARP C16023 Project aimed to provide technical knowledge to support a trial of overburden grout injection technology to control mine subsidence in an Australian mine. The project included comprehensive pre-trial feasibility studies at three targeted mines, including West Cliff Mine by means of field monitoring, laboratory simulation and numerical modelling	Completed March 2010
e) Technical and Economic Evaluation of Underground Emplacement of CHPP Rejects, Appin Complex	This report contains a technical and economic evaluation of CHPP rejects emplacement into existing underground mine workings within the Appin Mine Complex. The study has utilised the joint skills and expertise of both Mine Advice as the geotechnical and mining engineering contributors.	Completed in 2019
f) Southern Coalfield Coal Washery Reject (CWR) Characterisation and Classification, including management strategies for applications in Civil Engineering.	ACARP Project C29016. This research project seeks to promote the beneficial use of CWR, providing a robust data set that supports the environmental and geotechnical merits of existing and new applications in civil engineering, including mine site rehabilitation, back-filling quarry voids and placement beneath groundwater.	2019/2020
g) Swamp 15B, 1A, 1B and 5	Swamp 15B was impacted by Longwall 8 in Dendrobium Mine, Area 3A. Swamps 5, 1A and 1B were impacted by Longwall 9 in Dendrobium Mine, Area 3B.	2016 - 2024

RESEARCH PROJECT TITLE AND ID	OVERVIEW	TIMING
	Rehabilitation techniques such as sealing of rock fractures, injection grouting and knick point control are to be assessed as part of the Dendrobium Mine Swamp Rehabilitation Research Program (SRRP). Alternate Project proposed after swamp grouting was forgone as a research activity. IMC sponsoring UNSW swamp water balance study over the next 5 years.	
h) Monitoring and Data Collection (formerly Swamp 1A and 1B Project)	Monitoring has been installed to investigate whether the methods trialled to rehabilitate swamps contribute to the restoration of groundwater levels and groundwater recharge behaviour. Swamp water balance project has replaced swamp grouting trials in agreement with DPIE and WaterNSW. Project details in SRRP Section 5.12.	2016 - 2024
i) Littlejohns Tree Frog	Field research to determine the impact longwall mine subsidence may be having on Littlejohns Tree Frog populations.	2017 - present
j) Giant Dragonfly	Giant Dragonfly research undertaken to date has contributed to identifying impacts at the local population level and seeks to expand this level of investigation to enable a regional understanding of the context and cumulative impact of the Dendrobium Mine.	2018 – present
k) Swamp Resistivity	Electrical resistivity imaging techniques used in this study are based on the measurements of physical rock and soil properties, and electrical resistivity. The measured apparent electrical resistivity (measured as potential difference between a set of electrodes for a known current) depends on soil moisture content, salinity, porosity and temperature. The aim of using repeated surveys was to understand the changes in moisture content in the swamp and shallow sandstone as a result of underground mining. This was undertaken by tracking the soil and rock resistivity changes on the same transects across and along the swamp extent.	2018 - present
l) WC21 Rehabilitation Trial	WC21 was impacted by longwall operations in Area 3B. The following rehabilitation techniques will be trialled at WC21: sealing of rock fractures and injection grouting. The trials will commence following appropriate approvals to undertake the work are in place. Trial findings will be applied to subsidence remediation activities at Georges River.	Planned to commence in 2020
m) Upper Georges River Catchment Modelling	IMC and WSP Australia undertook a project to develop a water balance model of the Upper Georges River Catchment.	Stages 1 and 2 completed 2019

RESEARCH PROJECT TITLE AND ID	OVERVIEW	TIMING
	Stage 1 involved developing a pool water balance model of the Upper Georges River pool and rockbar system and assessing the performance of proposed measures to remediate mine subsidence impacts to the system. Stage 2 involves expanding the pool water balance model developed in Stage 1 to include the water management system for West Cliff surface operations, as well as incorporating a mass balance into the model to simulate water quality in licensed releases and the Georges River. The Upper Georges River Catchment Model will support further research and monitoring of proposed rehabilitation.	
n) Additional Georges River Rehabilitation Research	Monitoring provides key data when determining any requirements for mitigation or rehabilitation. Baseline data is compared with monitoring results during and following mining to determine any remediation that may be required. Monitoring has been installed to investigate whether the methods to rehabilitate impacts to the Georges River restore surface flow and pool holding capacity. The monitoring data will be assessed against pre-mining (where available), post mining and post rehabilitation levels. Additional monitoring will be installed as required for specific rehabilitation research projects. A schedule for rehabilitation, development of work plans, and ongoing reporting will be undertaken as required by the Georges River Rehabilitation Plan. The rehabilitation activities will commence following appropriate approvals to undertake the work are in place.	Determined from specific rehabilitation requirements
o) Water bore impact mitigation and remediation method development	Optimising water extraction to manage observed yield changes in groundwater bores associated with the effects of mining.	The project has been progressively developed and implemented (subject to landholder access) throughout 2019 and 2020.
p) ACARP Research Contributions via a voluntary levy	IMC contributes to various ACARP Research programs relating to Conditions 9 and Conditions 10 of the BSO Approval. Several key projects relating to mine subsidence impacts have been developed to improve the prediction, control, mitigation and measurement of mine subsidence impacts. IMC is an active contributor and sponsor (direct payments and in-kind support) of these projects.	2012-present

Table 3 - Expenditure on research projects undertaken by IMC

Project ID	Expenditure Relevant to the BSO ERP	Expenditure Relevant to Dendrobium SRRP	Other Expenditure	Details	Relevance
1(a)	$188,900			Development since BSO Approval in 2012. At each End of Panel Report and each new SMP/EP Application all survey data that results in high quality strain measurement is used to update and improve the MSEC model/assessment, based on analysis of probability. MSEC attribute 50% of their time to review of new data for each end of panel reporting round. A component of subsidence consultant costs and IMC data acquisition therefore, is relevant to improving the prediction of subsidence impacts. Relevant survey data collection costs (5% only): $22,500 per year MSEC subsidence model review in BSO 2012-2019 (30% only): $31,400	This development is fundamental to understanding subsidence. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
1(b)				Main body of work completed prior to 2012, however work has continued since 2012 to collect and provide data to develop the subsidence modelling capability. At each End of Panel Report and each new impact assessment (SMP/EP Applications) all survey data that results in high quality measurement is reviewed to update and improve the upsidence and closure model/assessment, which in turn develops prediction of impacts. A component of MSEC costs and data acquisition, is therefore relevant. Costs are attributed in 1(a).	This development is fundamental to understanding subsidence. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
1(c)	$35,000			This ACARP research project ran from 2009 to 2013. In-kind donation $100,000 (calculated as $25,000 for the recordable period (25% only)) IMC provided resources (as noted in the ACARP report) including Survey Data, Geological advice, Expert review	This research stems from projects 1(a) and 1(b) and is fundamental to understanding subsidence prediction in the Project Area. Condition 10 (a) - Improving the

Project ID	Expenditure Relevant to the BSO ERP	Expenditure Relevant to Dendrobium SRRP	Other Expenditure	Details	Relevance
				of report, Supervision and escort onsite (full time field officer was engaged). A conservative estimate for this time cost is $10,000 per year.	prediction, assessment, remediation and/or avoidance of subsidence impacts.
1 (d)	$90,000			The body of work commenced in response to the condition of approval in 2012 and was completed in 2014. ERP Consulting Fees $40,000 Additional Investigatory Works $60,000	This research is fundamental to developing subsidence predictive tools. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
1(e)	$91,952			Research included a geological structures comparison investigation to evaluate geological features and the potential for surface subsidence to affect subsidence above and outside the mining area in the Southern Coalfield: Review of data /reporting $81,782 Peer Review of Lineament Report $10,170	This research is fundamental to understanding subsidence prediction in relation to geological structures. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts
1(f)	$369,724			Research into the mechanism of basal shear from subsidence. Two boreholes were drilled for this purpose and analysed: Borehole Drilling costs (S2442A and S2443) $331,570 Packer testing for both holes $30,154 Review of borehole data $8000	This research is fundamental to understanding subsidence prediction in relation to geological structures. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
1(g)	$86,000			Research into the interaction of steep slopes and subsidence: 60 epochs of survey data were collected over 2 sites for Area 7 $36,000 Survey data review, collation and reporting $50,000	This research is fundamental to understanding subsidence prediction in relation steep slopes within the Project Area. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.

Project ID	Expenditure Relevant to the BSO ERP	Expenditure Relevant to Dendrobium SRRP	Other Expenditure	Details	Relevance
2(a)				Main body of work completed prior to 2012, however work has continued since 2012 to collect and provide data to develop the subsidence modelling capability.	
2(b)		$736,230		As per the Dendrobium SRRP	Relevant to the Dendrobium SRRP.
2(c)	$80,000			Isotope and chemical analysis for BSO borehole samples over two years $80,000	This research is fundamental to understanding subsidence prediction in relation to impact of subsidence within the Project Area. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
2(d)	$18,876			Research included assessment of correlation between groundwater fingerprinting and known geological features, and correlation between piezometer (in strata) response and lineaments HGEO technical Report (Spatial analysis of piezometer responses and Spatial analysis of mine water fingerprinting) $18,876	This research is fundamental to understanding subsidence prediction in relation to impact of subsidence within the Project Area. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
2 (e)	$238,976			Water monitoring boreholes for Area 9 Harris Creek Cliff line (S2280 and S2281) to analyse response on groundwater from mining: Drilling Costs: $104,798 Packer/Piezo/Geophysical testing: $129,178 Site Prep/Rehab: $5000 Ongoing monitoring - TBC	This research is fundamental to understanding subsidence prediction in relation to impact of subsidence on features within the Project Area. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.

Project ID	Expenditure Relevant to the BSO ERP	Expenditure Relevant to Dendrobium SRRP	Other Expenditure	Details	Relevance
2(f)	$282,925			ACARP Project C28026 - Borehole S2486 directly above the chain pillar between two extracted longwall panels to investigate the post-mining condition of the overburden strata via a series of overcore measurements in this hole to determine the residual stresses between two extracted longwall panels. Drilling costs were paid by IMC to support the research: Site costs: $5000 Drilling: $186,607 SCT perm testing: $27,845 Datalogger and weather track: $13,473 SCT review of data: $20,000 IC piezometer monitoring (direct costs as per ACARP commitment) $30,000	This research is fundamental to understanding subsidence prediction in relation to impact of subsidence within the Project Area. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
3(a)	$30,000			ACARP Project C14031 completed May 2007 with continuing development of the techniques by IMC. IMC has continued to develop the techniques to monitor subsidence impacts on natural features using UAV. Project included: UAV work - $5000 Fieldwork (2 people) - $25,000 (based on pp cost of $500 per day)	This research is fundamental to developing subsidence assessment within the Project Area. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
3(b)				ACARP Project C15013 component completed January 2010 with continuing development of the techniques by IMC.	This ACARP research was the first place IMC used ALS data to create ground strikes – which is now used for IMC subsidence bowl monitoring. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.

Project ID	Expenditure Relevant to the BSO ERP	Expenditure Relevant to Dendrobium SRRP	Other Expenditure	Details	Relevance
3(c)	$90,000			ACARP Project C20046 is researching the use of unmanned aerial vehicles to monitor subsidence: Cash support to ACARP $20,0000 Work committed in the ACARP Proposal: - Seasonal monitoring – 4 times annually using UAV, Ground Observation of abundance and condition of dominant species in plots (20 plots on 3 or 4 swamps) - Calibration of observers is required to ensure that observations made by different observers, UQ based field ecologists will work with IMC environmental staff to calibrate values and methods as required to maintain accuracy - Illawarra Coal environmental staff contribute to field observation and vegetation assessments - In kind support (site access, supervision and data). ACARP proposal estimated the in-kind value at $70,000	This research is fundamental to understanding and predicting subsidence within the Project Area. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
3(d)				As per the Dendrobium SRRP	Relevant to the Dendrobium SRRP
3(e)	$13,000			As a sponsor site for ACARP Project C25056, IMC committed to support this project with support staff and other in-kind contributions. In 2017, IMC provided field ecological staff and UASs through local capacity, hire or outsourcing to collect remotely sensed data: Minimum 22 days for: Field ecology data collection, Imagery collection, Field data handling, Imagery processing, Analysis, Seasonal monitoring. Field team costs - $11,000 ($500 per day) UAS cost - $2000 ($1000 per day) In undertaking the project more significant resources were provided (e.g. all previous swamp monitoring data).	This research is fundamental to understanding subsidence assessment within the Project Area. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
3(f)	$65,000			Additional ALS flights above what is required for IMC operations $20,000	This research is fundamental to understanding subsidence

Project ID	Expenditure Relevant to the BSO ERP	Expenditure Relevant to Dendrobium SRRP	Other Expenditure	Details	Relevance
				2 x Drones purchased $15,000 IMC staff costs during trial periods and data analysis $30,000	prediction in relation to impact of subsidence within the Project Area. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
3(h)	$5,000			As a sponsor site for ACARP Project C27059, IMC provided field assistance, vehicles and supervision.	This research is fundamental to understanding subsidence prediction in relation to impact of subsidence within the Project Area. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
3(i)	$25,900			Development of model understanding of mining related seepage from reservoirs Data collection $11,900 Geotechnical Review $14,000	Development of understanding subsidence prediction in relation to impact of subsidence within the Project Area. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
4(a)					Prior to BSO Approval (2012)
4(b)	$16,000			Continuing work resulting from ACARP Project C15025 into DinSAR monitoring techniques to develop Automated Subsidence Monitoring tools: - Automated tool written to undertake the ALS based subsidence bowl analysis (40 hours). A tool to aid the Environmental team produce detailed watercourses from the ALS (24 hours). - A tool to automatically map upstream catchment areas from a given weir location (16 hours). A tool to isolate vertical and horizontal movement of house roofs from	This research is fundamental to understanding subsidence prediction in relation to impact of subsidence within the Project Area. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.

Project ID	Expenditure Relevant to the BSO ERP	Expenditure Relevant to Dendrobium SRRP	Other Expenditure	Details	Relevance
				ALS in Appin (80 hours). Data Analyst work = $100p/h $16,000	
4(c)					Prior to BSO Approval (2012)
4(d)					Prior to BSO Approval (2012)
4 (e)			$144,000	Technical study $144,000	Requirement of another BSO approval condition.
4(f)			$40,000	Cash contribution $40,000	Requirement of another BSO approval condition.
4 (g)		$500,000 (over next 5 years)		As per the Dendrobium SRRP	Relevant to the Dendrobium SRRP
4 (h)		$465,168		As per the Dendrobium SRRP	Relevant to the Dendrobium SRRP
4 (i)		$573,000		As per the Dendrobium SRRP	Relevant to the Dendrobium SRRP
4 (j)		$275,770		As per the Dendrobium SRRP	Relevant to the Dendrobium SRRP
4 (k)		$296,080		As per the Dendrobium SRRP	Relevant to the Dendrobium SRRP
4 (l)	$27,000			Development of trial rehabilitation method, with applicability to Georges River rehabilitation and associated fieldwork: $7,000 Research to select grouting product, method and associated fieldwork: $20,000	Fundamental research and development for planned remediation for subsidence impacts. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
4 (m)	$82,236.50			Model developed to support rehabilitation evaluation of the Georges River, to better understand hydrogeological parameters and develop rehabilitation methods: 100% of Stage 1 ($34,888) +75% of Stage 2 ($49,798) was related to Georges River System (25% WTP) Total = $72,236.5 Field surveys ~$10,000	Fundamental research and development for planned remediation for subsidence impacts. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.

Project ID	Expenditure Relevant to the BSO ERP	Expenditure Relevant to Dendrobium SRRP	Other Expenditure	Details	Relevance
4 (n)	$30,000			Monitoring for pre-rehabilitation baseline post subsidence impacts, regular inspections of monitoring points and data collection, processing and interpretation of data, and installation and upkeep of monitoring equipment and boreholes to inform rehab approach/success. Conservative estimate of: $30,000	Fundamental research and development for planned remediation for subsidence impacts. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
4 (o)	$125,402.4			Four pilot projects of previously impacted bores aimed at re-optimising water extraction to develop tools to manage observed yield changes in groundwater bores associated with the effects of mining. 4 x $69,351.20	Fundamental research and development for planned remediation for subsidence impacts Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.
4(p)	$370,000			IMC has voluntarily contributed over $2.94 million to ACARP research programs between September 2012-2019. During this period, several key projects relating to mine subsidence impacts have been developed with a total value of $1.24 M in ACARP sponsorship. IMC has been an active in-kind contributor/monitor on the below projects which directly relate to subsidence at IMC operations: - Impacts of Longwall Mine Subsidence on Threatened Ecological Communities C22019 ($93,680) - Monitoring Surface Condition of Landscape Features Subject to Mining Subsidence with Very High Resolution Imagery C20046 ($278,191) -Change Detection in Complex Vegetation Communities C25056 ($274,700)	ACARP projects support research into underground mining impacts including specific projects targeting Subsidence. These projects develop industry knowledge in regard to subsidence. Condition 10 (a) - Improving the prediction, assessment, remediation and/or avoidance of subsidence impacts.

Project ID	Expenditure Relevant to the BSO ERP	Expenditure Relevant to Dendrobium SRRP	Other Expenditure	Details	Relevance
				- Effects of Geology on Upsidence and Closure Movements and Impacts in Valleys C18015 ($300,000) - Monitoring hydrological status of complex upland heath communities using canopy conductance and thermal imaging C28004 ($200,264) - Swamp Hydrology Modelling for Advancing Rehabilitation Planning and Management C27059 ($319,500). Based on IMC's level of involvement as a sponsor and the timing of the project (between 2012 and 2019), IMC is claiming a conservative 30% (only) of research investment, where directly related to the applicable Approval Conditions and only where IMC was an in-kind contributor to that research. This represents only 13% of the direct contributions from IMC to ACARP during this period of research. Its demonstratable IMCs direct payments to ACARP to conduct research at IMC sites relevant to the applicable Conditions was far greater than what is being claimed under the applicable Conditions.	
TOTAL	**$2,361,891.9**	**$2,346,248**	**$184,000**		

Mr Gary Brassington
Manager Mining Approvals
Illawarra Metallurgical Coal
South32
PO Box 514
UNANDERRA NSW 2526

13/05/2021

Dear Mr Brassington

Bulli Seam Operations (MP 08_0150)
Environmental Research Program

I refer to the Environmental Research Program that was submitted in accordance with Conditions 9 and 10 of Schedule 3 of the approval for the Bulli Seam Operations Project (MP08_0150-PA-40).

The Department has reviewed the document and is satisfied that it includes a number of studies to improve Illawarra Metallurgical Coal's (IMC's) prediction, assessment, remediation and/or avoidance of subsidence impacts and consequences.

Accordingly, the Planning Secretary has approved document titled *Appin Mine – Environmental Research Program* (Version 1.1 dated May 2021). Please ensure that the approved plan is placed on the project website at the earliest convenience.

If you wish to discuss the matter further, please contact Rose-Anne Hawkeswood on 9274 6324

Yours sincerely

Stephen O'Donoghue
Director
Resource Assessments
As nominee of the Planning Secretary