AUGUST 2024

CURRENT PROJECTS

This report is a summary of current projects for the months May, June and July 2024

ACARP

ACARP CONTACTS

PROGRAM MANAGEMENT

Suite 23, Level 9
307 Queen Street
Brisbane Qld 4000
Phone: 07 3607 3824

Matt Fellowes
Executive Director
matt@acarp.com.au

Marilyn Keenan
Levy Administrator
accounts@acarp.com.au

PROJECTS MANAGEMENT

Level 12
167 Eagle Street
Brisbane Qld 4000
Phone: 07 3225 3600

Anne Mabardi
anne@acarp.com.au

Patrick Tyrrell
patrick@acarp.com.au

Nicole Youngman
nicole@acarp.com.au

RESEARCH COORDINATORS

Peter Bergin
Underground NSW
peter.bergin@icloud.com

Ashley Conroy
Technical Market Support
ashley@ashleyconroy.com.au

Cam Davidson
Open Cut – Mining
cam@cwrd.com.au

David Drakeley
Open Cut
ddrakeley@fieldcrew.com.au

Ben Gill
Coal Preparation
excaliburmining@outlook.com

www.acarp.com.au

UNDERGROUND

Coal Burst

C27020
Management of Coal Bursts and Pillar Burst in Deep Mines

University of Adelaide
Giang Nguyen
Murat Karakus

Value:	$380,240
Report Expected:	August 2024
Industry Monitor/s:	Coal Burst Task Group
ACARP Contact:	Peter Bergin

The draft final report has been submitted to the Industry Monitors for review.

C28012
Microfracture Analysis as a Trigger for Coal Bursts

SCT Operations
Winton Gale
Yvette Heritage

Value:	$498,000
Report Expected:	September 2024
Industry Monitor/s:	Coal Burst Task Group
ACARP Contact:	Peter Bergin

The project aims to identify the nature of micro fabric in coal around structures such as dykes and faults relative to 'normal' unstructured coal and the role of gas pressure in coal bursts. The project seeks to identify the mechanics of the process and provide a better understanding of risks, prediction and prevention of such coal burst events.

The overall objective of this project is to define the zones around dykes and faults in which the coal is structurally modified and capable of generating sufficient gas related energy to initiate a coal burst. This is aimed to be achieved through digital CT scanning of coal block samples which have been selected at various distances from dykes and faults mapped in coal mines.

The CT scanning has been completed and fracture distribution analysis has been conducted on selected samples. Some key outcomes of the CT scanning include:

- Away from the structures, samples show a typical microfracture work with identifiable fracture sets. Close to structure, particular dykes, the fracture sets are significantly less distinguishable or non-apparent.
- Samples closely adjacent to dykes show very high porosity (possible from brecciation or high absorption characteristics) and reduction in discernable microfracture frequency. A high risk zone of 3m on Dyke A and 5m on Dyke B is suggested by the results of the CT scanning.
- Fault CT scanning and fracture volume analysis shows variability in fracture network characteristics around the thrust fault. Variability in the following was observed:
  - distinguishable micro fracture sets,
  - fracture frequency and volume,
  - high absorption/porosity characteristics.
- This variability is being investigated further, and may be a driver in creating burst potential.

The relationship between the results of the CT scanning, the geotechnical environment and mining geometry is being investigated.

C29010
In-situ Stress Measurements using Cored Coal/Rocks for Coal Burst Management

University of Adelaide
Giang Nguyen
Murat Karakus

Value:	$228,600
Report Expected:	August 2024
Industry Monitor/s:	Coal Burst Task Group
ACARP Contact:	Peter Bergin

The draft final report has been submitted to the Industry Monitors for review.

C33014
Coal Burst Research Findings

SCT Operations
Winton Gale
Yvette Heritage

Value:	$388,000
Report Expected:	September 2024
Industry Monitor/s:	Coal Burst Task Group
ACARP Contact:	Peter Bergin

This project will examine and summarise the energy required to cause a coal burst in a range of seams. The energy may be derived from stored strain, seismic transmission and expansion of desorbed gas. The project objectives are to:

- Examine the threshold energy requirement to cause a coal burst for a number of coal seams cases based on a range of generic mined seams;
- Provide guidance as to the factors to be considered in a risk analysis; and to
- Provide an estimate of the threshold values associated with dynamic bursts for a range of coal.

Work to date:

- Modelling of both strain and gas induced bursts within a roadway has been assessed to determine the seismic signature of such an occurrence. The strain tensor of the seismic waveforms and energy of events

has been determined. In general strain induced bursts are well reflected in the seismic transmission however gas related bursts are not well reflected.

- Modelling and theoretical assessment of strain bursts has been undertaken. One of the key findings has been that the upper bound velocity of a strain burst associated with shear slip and overstressing can be defined. This allows burst severity and risk levels to be determined on the basis of stress conditions about the excavation.
- Simulations of bursts in a range of seam thickness and banding has been undertaken. The main control is the rib resistance to a burst event. This is being assessed and known to be related to seam height, clay bands, structure and degree of rib fracture during development.
- This has been completed and indicates that rib strength is reduced by:
  - an increase in rib height from 3m to 5m reduced rib strength,
  - the occurrence of weak clay rich bands reduced the strength,
  - the occurrence of two clay rich bands did not change the results markedly from that of only one band. However, it did significantly increase the velocity of ejection.
- A full discussion of these results will be made at the next project review meeting.
- A key outcome is that most instances of seismic event recordings record a combination of modes of failure. This is due to the fact that one form of failure (say shear slip on bedding) allows additional failure in the surrounding area due to reduced confinement. In that way the overall strain tensor is one which reflects both events and associated displacement.
- A definition of the change in strength of the ribside caused by claystone bands and rib height has been determined. The effect of gas pressure, gas volume and gas desorption rate has been assessed for a range of extraction heights and claystone bands.
- It has been found that the use of energy as a criteria for understanding of bursts allows a simple assessment of the risks of bursts irrespective of the cause. The energy required is constant although the generation of the energy is different albeit gas ,strain or seismic.
- A review of the strength of the coal ribside has been undertaken to define energy levels required to move the coal under the confining conditions which occur.
- This approach provides a clear view of the likelihood and risk of various types of bursts on the basis of the energy available to the system.
- The draft report will be submitted in August.

C35014
Investigation of Pre-Installation of Optic Fibre Cable in Exploration Holes for Longwall Weighting and Coal Burst Monitoring

CSIRO
Baotang Shen
Joey Duan
Matt van de Werken

Value:	$258,473
Report Expected:	June 2025
Industry Monitor/s:	Marc Henderson Tim Dean
ACARP Contact:	Peter Bergin

The project goal is to provide a new and more cost-effective approach for assessing the longwall caving progress and coal burst risk. The objectives are to:

1. Trial optic fibre cables pre-installed in geo-exploration holes for high accurate and cost efficiency longwall weighting and coal burst monitoring; and to
2. Conduct a field demonstration using both distributed fibre optic sensors (DFOS) and geophones and investigate the optimal monitoring configuration, data processing and interpretation methods for the DFOS system.

During the quarter the main activity was to install the DFOS network at Mine A. The field installation was delayed for about three weeks because of rain. The field work started in mid-July. As the longwall at Mine A has been mining much faster than expected, the DFOS network design was revised to accommodate the longwall progress. A new borehole was added for installation, whilst two boreholes were removed from the original plan because, by the time the network installation was completed, the longwall had already mined past those two boreholes. The focus of the monitoring will be the last 500m of the longwall panel. The DAS data is now being recorded and analysed.

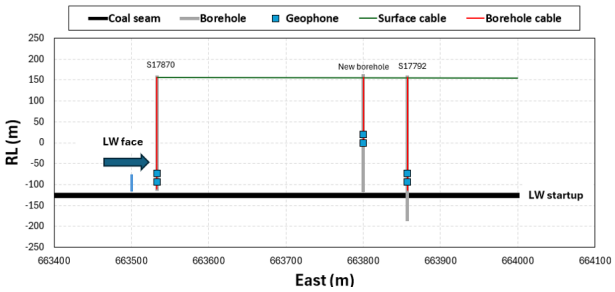


Figure 1. The installed DFOS network layout on the cross-section.

Detection and Prevention of Fires and Explosions

C28013
Use of Compressed Air Foams (CAFs) to Alter Goaf Air Circuits and Mitigate Spontaneous Combustion Events

Mines Rescue
Alaster Wylie
Clive Hanrahan
Dave McLean

Value:	$392,500
Report Expected:	September 2024
Industry Monitor/s:	David Webb Martin Mackinnon Owen Salisbury Paul Wild Peter Baker Sharif Burra
ACARP Contact:	Patrick Tyrrell

The project aims to provide an additional spontaneous combustion control technique for use by industry and to:

- Procure a full system ready for deployment in the Australian coal industry;
- Deploy the system in at least one underground longwall panel(s);
- Evaluate the cost and effectiveness of using CAFs to alter goaf 'micro ventilation circuits'; and
- The system will be retained by NSW Mines Rescue and maintained similarly to the Mine Shield for use by the New South Wales and Queensland industry as a tool to assist manage accelerated oxidation of coal.

A CAF unit was deployed at a New South Wales underground mine midway through 2021 to provide assistance in controlling a spontaneous combustion event in an active longwall panel.

Preliminary findings from the initial mine site trial suggested that CAF, when injected into the goaf acted as an effective 'dam', stopping the ingress of oxygen into the goaf and allowing the mines seam gas to fill the void and no air ingress was possible.

Since the initial mine site trial, the unit has been deployed to address other spontaneous combustion events at the same mine and one other. On both occasions the injection of foam and Nitrogen into the goaf has reduced oxygen ingress.

In the quarter, there has been no further testing undertaken, the CAF unit is currently located at Hunter Valley Mines Rescue Station. A draft project report is being prepared and will be available in the next quarter.

C29026
Investigation into the Thermal Ignition Caused by IS Power Supplies

Resources Safety & Health Queensland
Andre De Kock
Gareth Kennedy

Value:	$153,700
Report Expected:	December 2024
Industry Monitor/s:	Brad Lucke Jarod Chadwick
ACARP Contact:	Patrick Tyrrell

The objectives of this project are to:

- Determine the fault conditions arising in an intrinsically safe electrical circuit that could ignite combustible material on a mining machine;
- Determine the role and extent that combustible material accumulation can cause or contribute to the risk of equipment fires, when ignited by intrinsically safe power supplies; and to
- Determine the parameters to be considered in installing an intrinsically safe circuit in an area where they could be an accumulation of flammable materials.

The testing requirement and methodology are being refined through interactions with Mines Inspectors. The testing is planned to be undertaken in the next quarter.

Environment - Subsidence and Mine Water

C28004
Monitoring Hydrological Status of Complex Upland Heath Communities Using Canopy Conductance and Thermal Imaging

Queensland University of Technology
Andrew Fletcher

Value:	$230,964
Report Expected:	September 2024
Industry Monitor/s:	Gary Brassington Peter Corbett
ACARP Contact:	Patrick Tyrrell

No report received.

C33021
Pilot Scale Membrane Distillation Crystalliser (MDC) with Renewable Heat Source for Mine Water Brine Management

CSIRO
Ramesh Thiruvenkatachari

Value:	$969,195
Report Expected:	December 2025
Industry Monitor/s:	Michael Holzapfel Paul O'Grady Tim Kendrick
ACARP Contact:	Patrick Tyrrell

This project aims to undertake a mine site demonstration of the MDC system for treating saline and acid mine drainage mine impacted water under actual mine site conditions. The main objectives are to develop a modular MDC water treatment plant to mine site specifications, install at the mine site by integrating with onsite infrastructure and to demonstrate the mine impacted water treatment performance. Through this study optimum operating process parameters for AMD treatment will be obtained in maximising reusable water recovery with reduced volume of saturated concentrate.

Preparations are being made for onsite infrastructure development for the pilot setup and trial. Mine water intake and storage tanks have been installed. Other infrastructure such as compacting of site location where the test unit is to be installed, pipe works for mine water pumping, power supply etc are being installed. Suitable data and communication network management system has been purchased. Modifications to the MD design has been carried out. Membrane modules have been fabricated and tests are being conducted.

Pilot test unit is being constructed and is expected to be completed in the next quarter.

C35016
Rehabilitation Options for Ponded Areas Due to Longwall Coal Mining

University of Queensland
Louisa Rochford

Value:	$397,200
Report Expected:	May 2026
Industry Monitor/s:	Callum Gawne Jason Fittler Michael Moore Ned Stephenson
ACARP Contact:	Patrick Tyrrell

There has been limited research on the most appropriate options for rehabilitating land subsided by longwall mining in Australia. This project is investigating the implications of retaining ponded areas from longwall mining, including their contribution to environmental values. The approach is to select a study site and conduct the research at that location over a three-year period, providing a template for the assessments that are required to make decisions on rehabilitation options for ponded areas at other mines.

The second round of fieldwork (out of four rounds in total) was completed in the week of 13 to 17 May. The fieldwork involved the collection of water samples from ponded areas, vegetation surveys, bird surveys and camera trapping within the plots. The field team also visited a nearby mine to make observations of intermittent subsidence ponds formed more than ten years ago. Mine site representatives continue to record pond water levels using staff gauges in two ponds and are planning to install an additional staff gauge.

Laboratory analysis of water samples has been completed and the results will be plotted with historical data and compared to guideline values. A first draft of the report on the vegetation surveys has been completed and is currently under review. The bird survey data and fauna data from the camera trapping is being processed and will be added to the survey database.

The impact assessment is underway with the research team investigating adaptation of the causal network framework developed for the Bioregional Assessment Program for use at project scale and to assess both the risks and benefits of the rehabilitation scenarios to be assessed.

The next round of fieldwork is scheduled for October and will involve collection of water samples, bird surveys and camera trapping within the plots.

Maintenance and Equipment

C28010
Towards Better, Safer Mines - Optical Technologies for Software Defined Instrumentation

University of New South Wales
Francois Ladouceur
Lucy Chen

Value:	$704,974
Report Expected:	September 2024
Industry Monitor/s:	Ben McCamley Dave Young Ernest Baafi
ACARP Contact:	Peter Bergin

The current project work extends the original scope of the project where the participants have completed the design of an optically powered, intrinsically safe gas monitoring station (CH4, CO, CO2, O2). This certified system has been successfully deployed in situ and reliably collected data over a period of two months. The current project work now seeks to:

- Fix identified technical issues with the current system and proceed with its testing;

- Develop an improved system design, focussing on design for manufacture; and
- Provide the resources needed for its deployment and testing.

Work undertaken this quarter includes:

- Continued development of Android APP. Communication between mobile and GMS4 has been established and the APP displays readings of all sensors; and
- GMS4 has been tested, running on optical power for tens of days now and proved stability and power efficiency.

Work planned in the next quarter:

- Features like response time and time since calibration are to be implemented on the Gas Station and Android App, and network functions and serial RAM driver on the remote terminal unit (RTU);
- Ingress test (part of Intrinsic safety test) on the prototype enclosure;
- Fabrication of the final version of enclosures based on the test result of the prototype;
- System assembly and testing;
- Final report on the project to be submitted.

We foresee no important technical holdups but the final stage (fabrication and testing) may take longer than expected and field trial decision needs to be made.

C29009
Control of Touch Potential Transients During Switching

ResTech
Peter Stepien

Value:	$114,000
Report Expected:	September 2024
Industry Monitor/s:	Barrie Alley
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C33009
Ceramic Wall Flow Filter Commercialisation

PPK Mining Equipment
Bradley Drury
Greg Briggs

Value:	$888,778
Report Expected:	June 2024
Industry Monitor/s:	Andrew Esdaile Steve Coffee Trevor Hartley
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C33017
Specialised Instrumentation and Data Processing for Real Time FEA Condition Monitoring of AFC Chain

Vayeron
Ryan Norris

Value:	$185,000
Report Expected:	September 2024
Industry Monitor/s:	Brad Lucke Jarrod Sampson
ACARP Contact:	Patrick Tyrrell

Armoured face conveyor (AFC) chain failure causes serious production delays and associated costs for longwall operators, accounting for up to 27% of longwall failures. This project will develop instrumentation to wirelessly measure and transmit stress and strain information from chain joiners deployed within the AFC chain.

No progress was made during the quarter.

C33026
Prototype Battery Electric Load Haul Dump

3ME Technology
Greg Briggs
Justin Bain
Lewis Grainger
Martin Kime

Value:	$1,431,295
Report Expected:	August 2025
Industry Monitor/s:	Brad Lucke Dave Young Sharif Burra Tyrone Smith
ACARP Contact:	Patrick Tyrrell

The project objective is to design, build, and certify a high-performance battery for use in an Electric Vehicle (EV) system that meets Australian Hazardous Area requirements. Achieve Hazardous Area certification of a Ex battery and then integrate into an underground rubber tyred vehicle to operate in a hazardous area of an underground coal mine.

Key activities conducted to date:

- Certifying Body continued assessment against relevant standards;
- Feedback provided and responses prepared;
- Approval given to proceed to Stage Gate 2.

Key tasks to be conducted next quarter include:

- Continue testing process at Certifying Body;
- Continue detailed design of large scale battery for OEM platform; and
- Commence procurement activities for large scale battery.

Mining Technology and Production

C20033
Development of a Safer Underground Explosive

University of New South Wales
Andres Castro
Duncan Chalmers

Value:	$468,000
Report Expected:	September 2024
Industry Monitor/s:	Brad Elvy Paul Wild Russell Thomas
ACARP Contact:	Patrick Tyrrell

The primary objective of this project has been achieved in that a safer explosive has been developed that is suitable for delay firing in coal.

The team went to CIMFR Dhanbad, India where the operational test facility is situated. The explosives company supplied an explosive that met the specifications that were given to them as a suitable test subject. The main criteria were that the explosive provided less than 7.2GW from the 570g charge required for series 1 tests The explosive supplied theoretically delivered 5.2GW. Testing with this explosive commenced on 8th July and concluded on 18th July. Series 1, 2, 3. Conducted in the incendivity gallery in accordance with Testing Memorandum -2 and Series 4 using the type II cannon.

This explosive met the requirement of all tests. With no ignitions in the 30 incendivity tests and emulsion residue was found in the remnants of 26 valid tests in the deflagration (Type II) cannon.

Ongoing work will be to present the findings to the regulators in both New South Wales and Queensland, tidy up a few research questions with additional data and preparing the final report.

C28018
Longwall Floor Horizon Sensing

CSIRO
Andrew Strange
Zak Jecny

Value:	$269,680
Report Expected:	November 2024
Industry Monitor/s:	Jarod Chadwick
ACARP Contact:	Patrick Tyrrell

Effective horizon control is essential for both safety and productivity in underground longwall mining. The key to achieving this outcome is a reliable means of actively sensing the geological strata of the seam floor. This project will develop a ground penetrating radar (GPR) sensor for installation on a production longwall and long-term trial as a floor horizon sensor.

It was previously reported that the second protective skid base developed to house the GPR sensing system when installed on the longwall failed due to being crushed by a coal cobble. That skid base was fabricated from 10mm polycarbonate sheets. Several new non-metallic skid bases have been designed using thicker sheets of high-density polyethylene (HDPE) in an effort to provide more protection. After unexpected fabrication delays, these have been fabricated. They are about to be tested for suitability in operation (i.e. sensing system remains in contact with seam floor) then will be sent to the host site so that the trial can continue.

C29033
Alternative Flameproof Enclosure Protection Techniques

CSIRO
Peter Reid

Value:	$272,000
Report Expected:	September 2024
Industry Monitor/s:	Brad Lucke Colin Hoyle
ACARP Contact:	Patrick Tyrrell

The primary objective of this extension work is to design and produce a certified pressure sensing module capable of achieving Ex ia/ib certification. This module is intended to automatically and safely de-energize the payload promptly if the enclosure's internal atmosphere is compromised. The integration of this module into various existing enclosures aims to facilitate their certification as Ex P, elevating their protection levels.

The key project goals are:

- Semiconductor Independence:
  - reduce reliance on specific, currently challenging to procure semiconductors.
- Consolidation of Pressure Switches:
  - integrate the functionality of two separate pressure switches into a single board.
- Compliance with Standards:
  - address all necessary modifications to ensure compliance with 60079.2 and 60079.11 requirements.
- Design Optimisation:
  - redesign the module with a focus on enhancing manufacturability and cost-effectiveness.
- Manufacturer Selection:
  - identify and choose a suitable manufacturer for the production of these certified modules.
- Differential Pressure Sensing:
  - implement a differential pressure sensing configuration for enhanced functionality.

The project continues to progress, albeit with some recent setbacks. During the Ex.i certification process, thermal dissipation issues were identified, necessitating the development of a new design to address these concerns. The preliminary assessment of this revised design has been completed and approved.

Currently, a small batch of units incorporating the new design is being manufactured. Upon receipt, these units will undergo comprehensive thermal evaluation to ensure the issues have been effectively resolved.

Despite these challenges, it's worth noting that several working prototypes of the initial design of the system are now operational, and the software development is largely complete. These advancements provide a solid foundation for the project moving forward, once the thermal dissipation issues are fully addressed.

C34003
Self-Drilling Bolt Automation: Finalisation of Development

OKA Rock Bolt Technologies
Mark Levey

Value:	$2,357,744
Report Expected:	November 2024
Industry Monitor/s:	Roadway Development Task Group
ACARP Contact:	Patrick Tyrrell

The project objectives are to:
- Complete development of the chemicals, capsule and self-drill bolt;
- Complete the development of the adaptor, headplate and software such that an underground trial can take place;
- Carry out an underground trial.

Progress during the quarter is detailed below.

The adaptor:
- The 3D printed adaptor is working satisfactorily;
- Improvements are incorporated into the design of the current build of the second adaptor. Lid hold down issues are the main area for improvement.

The capsule and chemicals:
- The plastic capsules have been treated, assembled and filled with chemical for use as required.

The bolt:
- Over 120 bolts have been installed during the workshop test trials;
- The drill rig and support frame with grout tube has been functioning satisfactorily for the workshop trials to date.

General:
- Adjustments to the equipment and our assembly have been made as we progress the workshop trialling.

Current steps are:
- FRAS studies on the plastic capsule used in the system; and
- Urgently attempting to lock in a site for the underground trial.

C34015
Assistive Shuttle Car: Development of an Industry Ready Guidance System: Stage 3

CSIRO
Andrew Strange
Mark Dunn

Value:	$205,395
Report Expected:	September 2024
Industry Monitor/s:	Roadway Development Task Group
ACARP Contact:	Patrick Tyrrell

Most development operations in Australia utilise manual line-of-sight radio-controlled miners to cut roadways, and operator driven shuttle cars to transfer coal from the working face. These levels of technology are not able to achieve the goal of safe remote operation of roadway development. Two issues have been identified that inhibit progress in the domain of remote development:
1. Continuous miner self-steering technology to maintain desired roadway headings has not yet reached the required level of performance required for sustained remote operation; and
2. No automated options currently exist to guide shuttle cars while tramming through roadway systems and whilst avoiding ribs, cut-through corners and other infrastructure.

An assistive guidance system based on CSIRO's ExScan technology and simultaneous locating and mapping (SLAM) techniques has been developed to address these issues. In preparation for a site trial, the system was temporarily mounted onto one of the host site's shuttle cars currently being overhauled in the workshop to confirm the lasers and other electronics modules fit on the vehicle without impacting system operation. The conveyor boom was raised and lowered and all items were confirmed to be successfully mounted.

The system was also powered on to investigate the field of view (FOV) of the lasers. Unfortunately, a significant section of the SLAM system laser scanner's FOV (used to determine shuttle car position) was occluded by the conveyor boom which degrades the performance of the guidance system. Note that the guidance system was designed using two ExScans where one was utilised for SLAM position estimation but both ExScans are used for wall and target detection. To resolve this limited FOV issue, the team is modifying the software so that both laser scanners are used for the SLAM system. Once completed, functionality of the system will be reconfirmed and then taken to the host mine site to commence a pilot trial.

C34024
Effects of Rock Weathering on Life-of-mine Roadway Stability

University of Queensland
Zhongwei Chen

Value:	$312,534
Report Expected:	September 2024
Industry Monitor/s:	Brian Vorster Matt Tsang
ACARP Contact:	Patrick Tyrrell

The main project objectives are to:
- Identify the relevant weathering testing standards for assessing the process of rock degradation;
- Experimentally characterise and quantify the responses of rock properties to the weathering; and to
- Apply the laboratory results to assess the weathering impact on CMRR de-rating and its implications to support design practices.

In this quarter, the following tasks have been carried out:
- Rock mechanical and physical properties (e.g. UCS, BTS, sonic velocity etc.) have been characterised and comparatively analysed along with weathering timelines;
- Evolution and correlations of rock mechanical properties of four rock types in response to two heat and humidity conditions have been quantified. Preliminary models have been established to predict the time-dependent degradation of weathering rock;
- Rock mineralogy has been characterised by using the X-ray diffraction (XRD) test on eight samples from various depths;
- Rock surface properties (e.g. colour alteration) have been captured using a camera under controlled lighting conditions periodically on the planned weathering time points; and
- The non-distractive tests have been done for initial and weathering status with micro-CT, confocal laser scanning microscopy (CLSM) and scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDS).

The following activities are planned for the next quarter:
- The weathering tests for destructive test samples will be carried out for another four months, and the evolution and correlations of rock properties will be recorded periodically based on the testing schedule;
- The weathering tests for non-destructive samples will be carried out for another two months, and we will continue monitoring the surface colour alteration and microstructure evolution periodically based on the testing schedule.

C35004
Advancing Remote and Automated Capability for Longwall and Roadway Development

CSIRO
Andrew Strange
Jonathon Ralston

Value:	$2,517,000
Report Expected:	May 2025
Industry Monitor/s:	Roadway Development Task Group
ACARP Contact:	Patrick Tyrrell

This project responds to the industry need to accelerate remote and automated longwall and roadway development capability. The project utilises the flexible industry-directed project model to deliver research impacts to industry through well-scoped work packages.

Work Package #2 “Longwall Gate End Face Alignment” progressed such that a system to measure gate end alignment using ExScan and two reflective markers was developed, installed and tested at a mine site’s maingate in production conditions. LASC software was also updated to automatically merge the measured gate end alignment with the rest of the face. As a result of this successful outcome, the system has also been installed at the tailgate. This full system is currently operating in production conditions achieving the desired objective of full longwall face alignment.

Work Package #3 “Automated BSL Steering” progressed such that a new LASC module that controls longwall creep by integrating wedge cuts with LASC face correction profiles has been developed and deployed at the trial site. An initial trial of this system was completed whereby a PLC was used to automatically input a creep measurement into the new LASC BSL steering module. Partial creep correction (wedge) cuts were successfully merged with face straightening profiles and the BSL was steered as desired.

The stretch goal of full closed-loop BSL steering using creep measurements generated by an ExScan mounted on a BSL was implemented in the new LASC software. However, a trial of this approach was not undertaken as the creep measurements generated by the BSL ExScan were too variable. The team felt it was too risky to pursue this objective. It is expected the host mine will pursue this closed-loop trial in a future panel when the BSL ExScan can be repositioned to improve performance.

The technical development aspects of Work Packages #2 and #3 are complete. The Industry Working Group met to identify topics for Work Package #4. The group agreed that the next package will be targeted to RWD and the two topics that gained the most interest are:
- Continuous miner navigation (i.e. improve performance of offline drivage monitoring directly or through R&D of aiding technology); and

- Marker band detection of ribs and the face for horizon control.

The topic for WP4 will be chosen by the working group shortly with the expectation that WP4 will commence late August/early September.

C35009
Longwall Remote Operations – Face Mapping Robot – Phase 1

Quantum Engineering and Consulting Group
Luke Dyer

Value:	$170,000
Report Expected:	September 2024
Industry Monitor/s:	Duane Witkowski Jarod Chadwick
ACARP Contact:	Patrick Tyrrell

No report received.

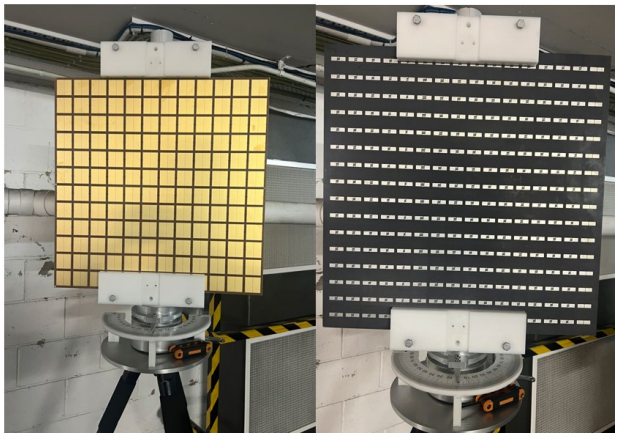
C36013
Planar Reflecting Radio Antenna (PRRA) for Underground Coal Mines

Roobuck
Dane Zielinski-Nicolson
Naing Ba
Tommy Chaung

Value:	$360,000
Report Expected:	February 2026
Industry Monitor/s:	Dave Young Jarod Chadwick Jonathan Harris Tyrone Smith
ACARP Contact:	Patrick Tyrrell

This project aims to simulate, manufacture, validate and test single/multi-band planar reflecting radio antenna in underground coal mines to extend network coverage with minimal cost/infrastructure.

Work completed over the quarter includes:
- Further design iterations to account for polarisation mismatch;
- Mine partner completion of scenario scoping questionnaires (mine sites 1 and 2);
- Mining scenario scoping questionnaire used to identify a set of key initial test case scenarios for underground testing. Tunnel geometry (height, width, length, corner angle, elevation variation) and desired WiFi coverage extension applications (single band 2.45Ghz WiFi PRRA) were considered;
- Initial proof of concept and testing system validation scenario was developed and planned for an initial onsite test at mine site 1;
- Manufactured initial project PRRA prototypes fit for initial key application scenarios (Two initial designs manufactured with characteristics ideal for different tunnel corner types identified in mining scoping questionnaire); and
- Lab based performance testing of both PRRA prototypes. Two designs were manufactured and tested (30/60, 45/45 - degree angle of incidence/degree angle of reflection);



  - initial testing of both PRRA designs in lab environment shows high potential for enabling significant signal gain around corners and down tunnels,
  - initial testing used signal generator to simulate AP behaviour with different gain scenarios,
  - beamforming observed in early stage lab testing seems to meet expected performance observed in simulations;
- Planned and organised date (early August) for initial partner mine site visit (mine site 1). This included preparation of -
  - testing scope of work to validate testing procedure and testing performance of both PRRA prototypes, and
  - apparatus list and other equipment (e.g. PPE).

Planned next steps:
- Underground test at mine site 1;
- Further research into anti-static coatings/enclosures that will minimise impact on RF gain;
- Further design revisions and simulations for single band PRRA (2.45Ghz); and
- Initial 5Ghz Single band prototyping.

C36014
Roof Support Location using Wireless Ranging

CSIRO
Matt van de Werken

Value:	$212,543
Report Expected:	September 2025
Industry Monitor/s:	Brad Elvy Tom Hudson
ACARP Contact:	Patrick Tyrrell

The project aim is to develop a prototype system for locating the roof supports in real time using wireless ranging, to alleviate the problem of roof support left behind.

During the quarter, commercialisation activities were initiated, with an NDA being drafted to enable collaboration to begin with potential partners. A presentation ready for sharing with potential partners was also prepared. Various development boards using different technologies were purchased and comparative evaluation began. A simulator for the longwall was written, including a messaging system and visualisation. Development of the localisation algorithm for the roof supports started.

Health and Safety

C24010
Proximity Detection Systems Specification for Underground Coal Mining Machines

Resources Safety & Health Queensland
Andre De Kock
Gareth Kennedy

Value:	$565,988
Report Expected:	October 2024
Industry Monitor/s:	Brad Lucke
ACARP Contact:	Patrick Tyrrell

The objectives of the project are to:

- Develop a proximity detection system specification and minimum acceptance criteria for the underground coal mining industry;
- Determine the gap between the specification from the coal mining industry and the performance of systems offered to the industry by proximity detection system manufacturers; and to
- Determine if future developments by the proximity detection manufacturers will address the specification from the coal mining industry.

Analysis of all interviews using NVivo was compiled during this quarter. During the next quarter the results and recommendations arising from the interviews and analysis will be completed. A draft final report will be prepared and submitted for review.

C28029
Personal Real Time Dust/Particulate Monitor (Direct Mass Based Measurement)

Lear Siegler Australasia
Peter Phaedonos

Value:	$1,521,730
Report Expected:	November 2024
Industry Monitor/s:	Brad Lucke Glenn Owens Ian Marshall
ACARP Contact:	Patrick Tyrrell

The PDM Real time dust monitor is a safety tool and a safety companion to the miner. At any point in the miner's working shift the PDM will display the exposure levels you will have and allow the operator to make decisions and withdraw to a safe area. Standards exist for limiting exposure to the respirable fraction of coal dust in most industrial settings, the PDM will provide the miner with the means to monitor and manage such exposer. It will have a very low detection limit that will meet or exceed current and anticipated exposure limits, and AS2985-2009 requirements for such continuous testing.

Project status with latest updates in bold:

- In the process of building the initial prototypes of the final versions for physical testing
  - All key modules have been ordered and being currently manufactured.
    - **Due to lack of availability of specific components there is a delay in delivery**
  - PCBAs and modules will start coming on hand in late May onwards with deliveries stretching into July.
    - **The components availability has had a cascading effect to the delivery of these PCBAs, which will now stretch into September/October.**
  - In coming months Modules will be made available to SIMTARS for physical testing which will lead us into the final IECEx physical testing and certification.
    - **This will most likely happen during third quarter of this year.**
- Final manufactured versions of the complete PDM will be ready in the second half of this year. Most likely in the 3rd Quarter.
  - These units will be made available to SIMTARS for their IECEx testing and,
  - To LSA for the testing and field calibration

C33001
Silica Analysis of Dust on PDM filters: Phase 2 Optimisation and Field Demonstration of the Developed Methodology

CSIRO
Hsin Wei Wu
Yonggang Jin

Value:	$516,700
Report Expected:	April 2026
Industry Monitor/s:	Andrew Lau Kevin Rowe Sharif Burra
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C33006
Breathing Zone Exposure Quantification and Respirators Performance – Review of Exposure Control Strategies

CSIRO
Rao Balusu

Value:	$329,450
Report Expected:	August 2024
Industry Monitor/s:	Andrew Lau Kevin Rowe Sharif Burra Tony Egan
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C33012
Respirable Dust Reference Testing Method and Dust Chamber Facility

Resources Safety & Health Queensland
Gareth Kennedy

Value:	$215,950
Report Expected:	December 2024
Industry Monitor/s:	Andrew Lau Kevin Rowe Sharif Burra Tony Egan
ACARP Contact:	Patrick Tyrrell

The aim of this project is to establish the methodology for the respirable dust chamber as a reference tool for cyclones and devices used in the coal mining industry. This will be achieved through three objectives:

- Establish that the respirable dust chamber conforms to international testing methodology and accuracy;
- Verify the methodology utilising a selection of respirable dust cyclones and impactor plate devices currently used in underground coal mines; and
- Compare the accuracy of the devices when using a different dust types and dust mixtures (stone dust, coal dust, silica).

The system's design has been modified based on observations made during Simtars March visit of NIOSH.

The re-design of the electrical, pneumatic and control systems was completed in June and the implementation of the systems is currently underway towards system commissioning. These design changes will make the system safer, more reliable and more ergonomic to use.

It is expected that the commissioning and testing requirements will be finalised in the next quarter.

C33069
New PDM filter for Direct-on-Filter Silica Analysis of Coal Mine Dust

CSIRO
Yonggang Jin

Value:	$298,240
Report Expected:	August 2024
Industry Monitor/s:	Andrew Lau Kevin Rowe Sharif Burra Tony Egan
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34006
Resilience and Mental Health in Mining Pilot Program

Macquarie University
Rebecca Mitchell

Value:	$476,099
Report Expected:	March 2025
Industry Monitor/s:	Sharif Burra
ACARP Contact:	Patrick Tyrrell

This project is on hold.

C34007
Evaluating Toxicity of Different Types of Respirable Crystalline Silica Particles to Lung Cells and Tissues

University of Queensland
Gordon Xu

Value:	$207,950
Report Expected:	September 2024
Industry Monitor/s:	Andrew Lau Kevin Rowe Sharif Burra Tony Egan
ACARP Contact:	Patrick Tyrrell

The project aim is to evaluate the toxicity and potential hazards of respirable crystalline silica (RCS) particles to lung cells and tissues. By developing three typical RCS particles (freshly generated, hydrated and aged) that the coal mine workers are typically exposed to, we investigate their biological impact on lung cells and tissues in vitro and examine their toxicity and potential hazards to lung tissues in a mouse model. The project outcomes will provide a comprehensive understanding of the varying levels of toxicity and risk posed by different RCS particle types to mine workers and help inform and direct health and safety strategies to reduce exposure to the most dangerous RCS particle types.

This quarter we have worked on preparation and writing the draft final report. This report summarises the collected and analysed data about the physicochemical properties and cytotoxicity level of the RCS particles as well as the observation in the animal model and will be submitted in September for review.

C34023
Advanced Breathing Apparatus with Gas Membrane Modules

Monash University
Victor Chang

Value:	$298,436
Report Expected:	January 2025
Industry Monitor/s:	Ken Singer Lee Earnshaw Paul Wild
ACARP Contact:	Peter Bergin

The main objective of the project is to develop a prototype for breathing apparatus which will replace the CO2 adsorption module with a light weight gas separation module.

The team has started the testings on the Ladder Polymer gas separation membrane on the performance and durability. The preliminary results indicated that one of the two proposed directions has significant potential to suit our needs. In addition, the surface modification on the gas separation membrane has demonstrated very good results in extending the operation time. Finally, the Drager's BG4 has returned back to the lab after servicing. The team will continue to examine the compatibility of the housing, membrane, and BG4 together.

C35017
Is Exposure to Illite Dust Linked to Pneumoconiosis?

University of Tasmania
Basil Beamish
Graeme Zosky

Value:	$302,428
Report Expected:	October 2024
Industry Monitor/s:	Andrew Lau Brad Lucke Frank Fulham Kevin Rowe Shane Apps Sharif Burra Tony Egan
ACARP Contact:	Patrick Tyrrell

Previous ACARP projects have identified illite in coal dusts as a potential driver of lung cell toxicity, which may be related to the risk of developing Coal Workers' Pneumoconiosis (CWP). The overarching aim of this project is to explore this relationship in more detail.

We have completed a systematic review of more than 4,000 articles and identified a significant gap in knowledge regarding the comparative health effects of dusts generated by potassium rich minerals in mining operations. We have also completed our cell studies. This included assessing the cell response to 44 coal samples obtained from operating coal mines in New South Wales and Queensland that cover a range of mineral constituents from low to high potassium alumino-silicates. These experiments have involved exposing epithelial cells (cells that line the airspaces in the lung) and macrophages (which engulf inhaled particles) to the dusts. We have also spiked low potassium coals with illite, muscovite or orthoclase and assessed the cell response. While we are still completing the analysis in preparation for submission of the final report, our preliminary analysis shows that illite is highly pro-inflammatory and exacerbates the coal induced cell response. Suggesting a potential causal role for illite in adverse lung responses to inhaled dust.

C36006
Advanced Lung Function Assessments for Diagnosis of Coal Mine Dust Lung Disease (CMDLD): The Next Step Towards a Better Health Surveillance Program

I-MED Radiology Network
Katrina Kildey

Value:	$186,832
Report Expected:	February 2025
Industry Monitor/s:	Andrew Lau Kevin Rowe Shane Apps Sharif Burra
ACARP Contact:	Patrick Tyrrell

The aim of this project is to evaluate the effectiveness of Lung Ventilation Analysis Software (LVAS), a radiomics-based software-as-a-medical device, to detect lung disease in workers assessed as 'at-risk' from the health surveillance program for CMDLD and compare to spirometry.

To date, the required human research ethics application has been submitted and approved; a database appropriate for the collection of the comparative lung function assessment data has been developed, reviewed and fine-tuned to ensure collection of all relevant available data; and patient identification and data collection has commenced.

At the present time, the work of the research team is focused on participant identification. The identification process involves retrospectively reviewing our repository of cases to identify all workers included in our repository (C27010) and health scheme database (C33010) who had a CT chest scan performed by I-MED since 2015. Each individual database entry is reviewed to select individuals that fulfil our selection criteria for this project; specifically coal workers who underwent a chest CT, as part of their respiratory review; the CT performed was a paired inspiratory/expiratory volumetric breath hold CT scan acquired in a supine position, with a slice spacing and slice thickness of ≤2.5mm) and have the required information available (i.e., spirometry results within 6 months of suitable CT). We have currently identified 12 individuals with a diagnosis of CMDLD that fulfill these requirements. The eligible DICOM image files of each CT chest scan have been located, de-identified and queued for transfer to 4DMedical for image analysis using LVAS to generate regional ventilation maps and metrics of lung health.

Roadway Development

C27076
Underground Coal Mine Gateroad Development Continuous Haulage System

Premron CHS
Mick Whelan

Value:	$9,773,528
Report Expected:	February 2025
Industry Monitor/s:	Roadway Development Task Group
ACARP Contact:	Patrick Tyrrell

This project aims to develop a Continuous Haulage System for mine gateroad development, utilising the closed conveyor system of the "Premron CHS" ©. The project builds on ACARP projects C22009, C23017 and C24023. Premron is awaiting a suitable host mine to complete the project objective, namely the performance in an underground trial. Work in this space is continuing and we have positive signs coming from industry.

The project encompass the following key objectives:

- Build and install a suitable Premron CHS Testing Track;
- Install Premron CHS Minibuild machine (nom 55m);
- Commission Premron CHS machine along with Sizer Feeder; and
- Trial test Premron CHS and Sizer Feeder including several open days for industry.

Premron have completed the steel test track and painting. The civil works are almost complete, but we have experienced some delays with the site stage two planning. This has meant we could install the Premron CHS Mini build, but in two halves. The Head Trolleys on the southern side of the test track and the tail at the opposite end. Our plan is, once the civils are complete for stage 2 work area, we can install the structure and monorail and bring the two halves of the machine together, completing belt splicing and termination of electrical. This has delayed completion of the machine until September. We intend to continue through to the project completion in December.

C33013
Light Weight Composite Conveyor Support Structures

University of New South Wales
Ganga Prusty
Serkan Saydam

Value:	$499,804
Report Expected:	March 2025
Industry Monitor/s:	Roadway Development Task Group
ACARP Contact:	Patrick Tyrrell

This project aims to advance the technology readiness level of lightweight composite conveyor support structure prototypes through a comprehensive field testing phase at a mining site.

This quarter several key activities were accomplished:

- Wear testing on the pultruded section specimens to assess the non-compliance with anti-static requirements has been completed. Wear studies were conducted using a tribometer with Alumina carbide antagonist and 4kg dead load. A wear track of 30mm was created on the specimen and tested for six hour, with the electrical resistance measured at two hour interval. The results showed an initial value of 18.74 kΩ before wear and 174.6 kΩ after complete wear. As per MDG3608 FRAS requirements the mean value of electrical resistance for polymeric materials shall not be greater than 300 MΩ. This test showed the pultruted section with Nylon protection can be compliant with the anti-static requirements even with a 10mm wide wear track.
- Three site visits were undertaken at a mine site in Lithgow. The first visit was conducted on 29/04/2024. During the first visit, three potential locations were surveyed for field trial. However, one location was finalised after evaluating the accessibility for resources and the ease of installation. In subsequent visits in May and June, placement of the composite support structures and dimensional measurements of the existing metallic mine frame were finalised.
- Four composite support structures are to be installed for field testing. The planning and designing of the composite support structures have been underway for the past three months. The design modifications include altering the dimensions, designing brackets, and adding a composite stringer. The design process is in the final stages, and currently finite element analysis (FEA) is being conducted to assess the composite structure's structural integrity.
- Sensing devices for field evaluation were procured. The manufacturing of the composite pultruted sections from Wagners Composite Fibre Technologies (Wagners CFT) is initiated and ongoing. In addition, the trough frames for rollers are also procured from TS Global in Newcastle.

In the next quarter, the design and FEA will be finalised. Simultaneously, the manufacturing and field installation of the composite frames will also be undertaken.

C33020
Floor Horizon Control for Roadway Development

CSIRO
Andrew Strange

Value:	$80,000
Report Expected:	December 2024
Industry Monitor/s:	Roadway Development Task Group
ACARP Contact:	Patrick Tyrrell

The overarching objective of this project is to develop a floor horizon control sensor suitable for installation on a production miner-bolter. The key outcome of this project is to install an enclosure that is capable of housing a floor horizon sensor (ground penetrating radar) on a production miner-bolter to ascertain how well a new non-metallic enclosure, along with the corresponding mounting bracket, can survive the roadway environment. The enclosure will not require certification because it will not contain a sensing payload.

The technical activities for this project have been completed. The draft report is almost complete and will be provided to the Industry Monitors shortly.

Strata Control and Windblasts

C28020
Optimising the Cablebolt Pre-Tensioning Practice to Control Roadway Roof Failure Using Advanced Combined Axial and Shear Testing Facility

Monash University
Hossein Masoumi

Value:	$165,000
Report Expected:	August 2024
Industry Monitor/s:	Brian Vorster Patrycja Sheffield Peter Corbett
ACARP Contact:	Peter Bergin

The draft final report has been submitted to the Industry Monitors for review.

C29014
Definition and Quantification of Long Term Stability of Coal Pillar Systems

University of New South Wales
Ismet Canbulat
John Watson

Value:	$230,000
Report Expected:	August 2024
Industry Monitor/s:	Peter Corbett Russell Thomas
ACARP Contact:	Peter Bergin

The draft final report has been submitted to the Industry Monitors for review.

C29019
Mechanical Assessment of Time Dependent (Creep) Behaviour of Coal and Coal Measure Rocks Under Uniaxial and Triaxial Conditions Based on Experimental and Analytical Methodologies

Monash University
Amin Heidarpour

Value:	$205,000
Report Expected:	September 2024
Industry Monitor/s:	Brian Vorster Elliot Tembo
ACARP Contact:	Peter Bergin

The project objective is to investigate the time-dependent behaviour of coal and coal measure rocks by conducting experiments under various timeframes ranging from a month to a year or more. Researchers will use creep loading frames in temperature and humidity-controlled conditions which replicate the underground mining environment.

During the quarter:

- Experimental design phases have been successfully completed;
- Short-term uniaxial compressive tests have been conducted on sandstone, marble, granite, and coal;
- Creep experiments on sandstone samples have been completed;
- Creep experiments on granite samples have been completed;
- Creep experiments on coal samples have been completed; and
- Creep experiments on marble samples are underway.

Finally, the creep behaviour of different rock types, prediction of their long-term strength and time to failure were examined. From the experimental results, a novel time-dependent failure model was introduced. In such an approach, the significant experimental scatter which is commonly observed during the time to failure test was mitigated resulting in a robust prediction of long-term strength of tested rocks.

C29022
Mechanical Investigation of Two Critical Standing Support Systems (Timber Chock and Pumpable Crib) in Underground Coal Mines

Monash University
Hossein Masoumi
Javad Hashemi

Value:	$295,000
Report Expected:	September 2024
Industry Monitor/s:	Bob Coutts Brian Vorster Dan Payne Patrycja Sheffield
ACARP Contact:	Peter Bergin

The main project objective is to characterise the mechanical behaviour of two standing support systems including timber chock and pumpable crib which are commonly utilised in underground in Australia.

To investigate the mechanical behaviour of timber chock structures, the study has been divided into three levels: component, contact, and global. For the global full-scale level study of timber chock structures, several tests were conducted using MAST, a cutting-edge loading frame, at Swinburne University of Technology. In this extensive testing program, factors such as aspect ratio and loading rate were quantified. Moreover, the behaviour of timber chocks under complex loading regimes that replicate the movement of mine roofs was evaluated. These complex loading regimes included combined test protocols: Combined-I tests applied a compressive load reaching 50% of the maximum load-bearing capacity of the timber chock, followed by a shear force until structural failure. Combined-II tests aimed to evaluate the behaviour of timber chocks under both compression and shear loading simultaneously after a compressive preload of 50% of the maximum load-bearing capacity of the structures. Subsequently, the experimental results were used to verify numerical simulations, which employed a sophisticated UMAT to simulate the real failure process in the numerical results.

To study the mechanical behaviour of pumpable cribs, a detailed approach was implemented. A crucial meeting with DSI Underground, the main supplier of the samples, provided valuable guidance that influenced the design and finalisation of a robust steel frame for the vertical transportation of the samples. The experimental setup includes nine long samples, each 3,250mm in height and 914.4mm in diameter, cast in cuttable bags. These samples will undergo combined shear and compression actions to simulate the stress conditions of a mine roof.

Following this, nine shorter samples, 2,500mm in height and 914.4mm in diameter, will be subjected to similar combined compression and shear actions. This comprehensive analysis will validate the performance of the cribs across different dimensions and stress scenarios. Simultaneously, short cubic samples will be

cast and prepared for numerical studies, as discussed with DSI Underground. This multi-faceted approach, integrating both physical experiments and numerical analysis, ensures a thorough understanding of the mechanical behaviour of pumpable cribs, significantly contributing to mining engineering and safety.

C33024
Improved Model Upscaling of Overburden Hydraulic Conductivity for Input into Groundwater Models

SCT Operations
Yvette Heritage

Value:	$230,000
Report Expected:	November 2024
Industry Monitor/s:	Bob Coutts Gary Brassington Peter Corbett
ACARP Contact:	Peter Bergin

The key objective for the project is to determine an upscaling method that bridges the gap of geotechnical model fracture conductivity at longwall panel detail, to groundwater model bulk conductivity input requirements. It has so far been a challenge across the geotechnical and hydrological disciplines to upscale these detailed fracture flow conductivity results to the groundwater models, whilst resulting in flows that are consistent with experience.

Collaboration with groundwater modelling consultants has allowed understanding of groundwater model inputs and limitations.

Investigations into upscaling methodologies have provided changes to mining induced hydraulic conductivity of only about 1 order of magnitude. These include local (mathematical averaging) and non-local (large detailed flow models) averaging techniques. However, to meet the observed groundwater impacts, groundwater modelers need to use mining induced overburden conductivity 3-5 orders of magnitude less than the modelled, measured and observed overburden conductivity.

This project proposes that desaturation is responsible for the significant reduction in relative conductivity. Understanding that running unsaturated groundwater models with current computing power is not practicable for timely and cost appropriate solutions to the client, this project is investigating a method for determining the site specific relative conductivity to use in groundwater models, based on the limiting conductivity layer at the top of the desaturated zone.

Site specific models are being run to support the proposed methodology of estimating overburden mining induced hydraulic conductivity. As part of the site specific modelling exercise, an improved technique of estimating virgin vertical hydraulic conductivity, based on an existing database of field measurements, is being investigated.

C34018
Carbolt – Pre Commercial Fixed Length Carbolt Prototype

Mining3
David John

Value:	$360,088
Report Expected:	September 2024
Industry Monitor/s:	Alex Wright Bob Coutts Peter Quinn
ACARP Contact:	Patrick Tyrrell

The project objectives are to:

- Develop a pre-commercial fixed-length carbon-fibre based roof bolt to provide tensile and shear strata support which will be designed to be installed in a manner similar to a standard rebar rock bolts and provide a non-corroding alternative to existing rebar roof bolts, which includes the ability to be re-tensioned;
- Develop a locking mechanism that locks the carbon fibre braid without damaging them; and to
- Characterise and statistically analyse the shear and tension load capacity of the Fixed Length Carbolt through a series of trials. Achieve comparable load performance to a steel rebar roof bolt.

The first set of 1.75m Carbolt samples was manufactured using the inner and outer moulds. These moulds were crucial for the resin setting process and for achieving the necessary rib and thread patterns similar to conventional metal rockbolts. The moulds were modified according to the geotechnical team's recommendations, resulting in samples that feature the ribbed section as shown in Figure 1. Adjustments to the braiding and mould curing techniques were necessary to ensure optimal rib-to-rib diameter and even resin distribution. The cast samples are being prepared for the performance testing, which will include pull-out, shear, and double-shear tests.

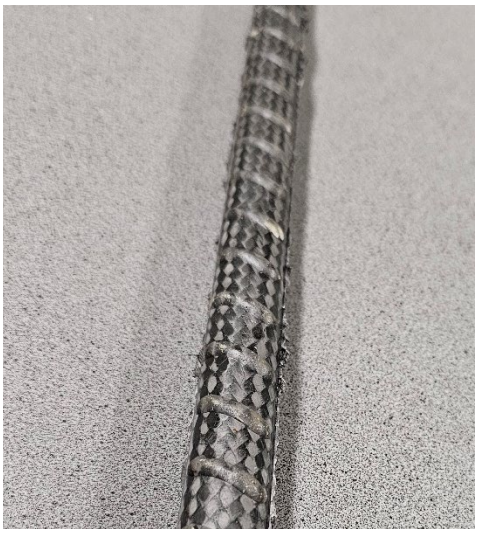


Figure 1. Ribbed section of the Carbolt sample providing the desired outer diameter and profile.

C34021
Roof Beam Support Assessment Tool

Resource Geotechnical
Terry Medhurst

Value:	$230,000
Report Expected:	May 2025
Industry Monitor/s:	Brian Vorster Roger Byrnes
ACARP Contact:	Patrick Tyrrell

Previous projects C22008 and C24015 funded the development of a roof support design approach that takes account of differing roof conditions, effect of support type and stiffness that can be used for mine design and in the strata management process. An analytical framework was developed for roadway development that provides a measure of both support load and roof convergence which can be matched and updated against roof monitoring data. It is based on beam-column principles and incorporates bending, immediate roof failure and shear. The model relies upon inputs from the Geophysical Strata Rating (GSR), roof bolt characteristics including pull-out stiffness/load, in-situ stress ratio and unconfined compressive strength (UCS). The current proposal is to now convert this method into a practical site-based software tool to accompany existing design methods.

A Windows based version has been developed that can be used to assess both development and longwall abutment loads. The beta version and user guide has been developed and shared with the Industry Monitors for evaluation. An extension has been granted to introduce additional options into the program following this initial evaluation. Work on this aspect is underway.

C34022
Risk Based Model for Forecasting Longwall Face Cavity Development

University of New South Wales
Chengguo Zhang
Ismet Canbulat

Value:	$173,200
Report Expected:	September 2024
Industry Monitor/s:	Bob Coutts Matt Martin
ACARP Contact:	Peter Bergin

Cavity development across the longwall face can cause substantial production losses and pose significant safety risks to mine workers during recovery operations. Previous research into longwall roof cavities has primarily focused on individual causes, such as equipment, shield pressures, geology, in situ stresses and geotechnical setting. In this project, researchers will adopt a holistic assessment of all causes that, in combination, can result in the formation of a roof cavity. The project aims to produce a risk based approach for assessing the likelihood of cavity development; a set of predetermined controls to mitigate the risk of cavity development; and a proposed hierarchy of longwall fall-of-ground severity linked to these controls, based on the escalating level of risk.

The main progress over the quarter is noted as follows.

Cavity prediction for the next cut:

- We had updated the cavity prediction on whether or it will happen in the next cut based on the historical LVA data from the case study mine A. The update is focused on the cavity labelling, where the cavity locations are changed from reading survey drawing to identify abnormally high TWAP. Performances improvements are observed on both prediction accuracies and recalls, with experiments on multiple active panels.
- We also identified that the models, once trained, are not effective to different panels, primarily due to the autoencoder module, which is used for feature extraction and compression. Train and test on different panels can produce unreliable predictions on cavity.

Cavity prediction for the cavity location:

- We have also been working on the improvement of the cavity location prediction based on the new prediction based on TWAP labels, primarily concerning on the shield numbers associated with the cavity. We are trading off on the precise prediction of shield numbers by grouping the shields to sections, for lowing the model complexity by reducing numbers of possibilities.

Further data collection:

- We are delayed in the process of further data collection. Mentors has been reaching other mine sites for more data but no feedback has been received. We are yet to receive new data sets, which impact the cavity prediction model and the numerical modelling of the cavity mechanisms.

C35008
Optimum Design of Pillars with Various Sizes and Shapes at Increasing Stress Environment

University of Queensland
Mehdi Serati
Paul Buddery

Value:	$172,000
Report Expected:	April 2025
Industry Monitor/s:	Brian Vorster John Grieves Peter Corbett
ACARP Contact:	Patrick Tyrrell

This project aims to develop a modified methodology for estimating pillar loads, enabling the optimal design of pillars of various sizes and shapes in increasingly stressful environments. The project will validate the design of

main pillars based on a load less than the tributary area load (TAT), potentially offering significant financial and operational benefits.

In the last quarter, several expanded Polystyrene foams, as well as five large-scale synthetic models (measuring 1.8m*1.2m*0.2m in size), were tested with the application of a 12 Mega-pixel stereo-DIC (digital image correlation) system and a 500kN servo-hydraulic loading portal (customised at UQ Civil for the project). The tests covered different configurations of pillar distribution, mining depth, and roof stiffness. The stress-strain correlation measured by DIC was first verified using benchmark UCS samples on both synthetic models and 100mm cylindrical standard specimens. Test results have demonstrated that the load applied on small pillars adjacent to large pillars could be up to 50% smaller than the TAT estimation as the panel length becomes smaller than the mine depth, meaning the TAT constantly overestimates the load on pillar at depths. The percentage of applied load to TAT load is influenced by roof condition, mining depth, and span. In the next stage, the numerical verification will be conducted based on the experimental results with consideration of horizontal stresses. Drafting of the final report is commenced and it is expected to be finalised by the end of this year for monitors review.

C35010
Causes for Swelling and/or Bearing Capacity Floor Failures in a Pillar System Under Varying Geological and Geotechnical Environments

University of New South Wales
Serkan Saydam

Value:	$298,300
Report Expected:	June 2025
Industry Monitor/s:	Brian Vorster Peter Corbett
ACARP Contact:	Peter Bergin

This project aims to investigate the conditions of swelling and bearing capacity floor failures through an experimental program, in-situ monitoring program, and analytical and numerical approaches and determine the timing of failure. Based on the learning from projects C26064 and C29041, an analytical model will be developed to evaluate the bearing capacity of soft floor strata in underground coal mines. The cutting-edge numerical modelling framework will be developed that will enable us to better understand the swelling failure mechanisms. The research team will develop a framework for the assessment and prediction of floor heave. This approach will provide comprehensive guidelines to assess and predict floor heave failures.

Up-to-date work includes the calibration of the data logger and laser sensor, which are critical for establishing the correlation between sensor readings and the axial displacement of the samples, has been finalised. We have been conducting swelling tests on Kaolin clay with varying dry densities and initial water contents to investigate their influence on the swelling mechanism. LoadTrac frame has been calibrated, and several tests have been conducted (Figure 1). Clay mineralogy analysis has been performed using X-ray diffraction tests on rock/clay samples collected from the site. Based on the initial test results, swelling clay mineral montmorillonite has been identified. ICP tests have determined the water chemistry, providing data that can be utilised for further research on the effects of groundwater on the swelling behaviour of rock.

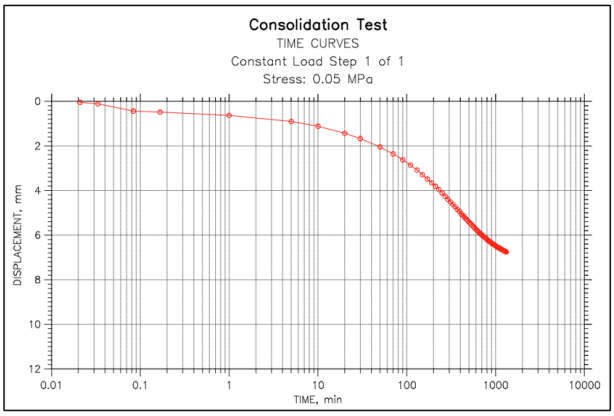


Figure 1. LoadTrac trial test under 0.05 MPa.

C35011
Revolutionising the In-Situ Stress Measurement Using a New Generation of Downhole Tools: DilaStress

University of New South Wales
Hamid Roshan
Ismet Canbulat

Value:	$184,500
Report Expected:	April 2025
Industry Monitor/s:	Brian Vorster Patrycja Sheffield
ACARP Contact:	Peter Bergin

The first prototype of DilaStress, an innovative downhole tool for in-situ stress measurement, has been recently completed, with its mechanical, flow, and electronic components successfully tested in a laboratory environment. This significant advancement has positioned DilaStress for its field trial. Currently, the DilaStress software is undergoing refinement, and the inversion algorithm testing has demonstrated reliable in-situ stress predictions in a simulated environment.

In the next quarter, our focus will be on refining the Finite Element model and its algorithm to enhance computational efficiency, ensuring DilaStress is at the forefront of industry technology.

C36010
Next Generation Fibre Glass (FG) Rock Bolts with Robust Shear Strength Properties to Replace Steel Rock Bolts

University of Southern Queensland
Ali Mirzaghorbanali

Value:	$147,998
Report Expected:	June 2025
Industry Monitor/s:	Dennis Black Peter Corbett
ACARP Contact:	Patrick Tyrrell

This project aims to enhance the shear strength properties of fiberglass bolts for strata reinforcement. Various prototypes will be manufactured using different Reinforcing Element architectures (RE1, RE2, and RE3). Special matrices will be created by mixing three types of Resin (R1, R2, and R3 – each with unique properties and characteristics) with Nylon 6 and graphene, which will increase the synthetic polymer's resistance to shearing forces. The prototypes will have nominal diameters ranging from 22 to 30mm. Initial shear strength testing will be conducted using a guillotine box, providing a quick determination of shear properties. The prototype with the highest shear strength will advance to the next phase, where load transfer mechanisms will be thoroughly investigated using double shear testing in 40 and 60 MPa strength host rocks.

The research team has reviewed current manufacturing practices for fiberglass bolts in collaboration with industry partners. It was concluded that epoxy, unsaturated polyester, and vinyl ester resins have been utilised as matrices in manufacturing fiberglass bolts, further demonstrating the significant potential of R1, R2, and R3 as matrices when mixed with Nylon 6 and graphene. Pultrusion and braidtrusion have been identified as common manufacturing methods to produce fiberglass rods, emphasising the importance of reinforcing element architecture in the axial and shear load transfer mechanisms of fiberglass rods and dowels. Hybrid fiberglass rods with steel cores and varying steel volume fractions have also been explored to improve bearing capacity and elastic modulus properties.

In addition, the research team is currently testing the shear strength properties of available fiberglass bolts (utilising a twisted RE architecture and epoxy resin as the matrix) using single and double shear testing methodologies for benchmarking purposes.

In the next phase, the team will manufacture various fiberglass prototypes based on RE1, RE2, and RE3 architectures, as well as R1, R2, and R3 matrices mixed with Nylon 6 and graphene. The produced samples will then be tested for shear strength properties and compared against available rock bolts.

Ventilation, Gas Drainage and Monitoring

C25072
New Approaches to Mine Gas Analysis and Ratios

Resources Safety & Health Queensland
Andre De Kock
Gareth Kennedy

Value:	$416,192
Report Expected:	September 2024
Industry Monitor/s:	John Grieves
ACARP Contact:	Peter Bergin

The project aim is to identify additional gases for the detection and monitoring of spontaneous combustion. This will be achieved through three objectives:

- Using a medium scale reactor, profile the gases evolved from the heating of a Queensland coking coal with a methane/ethane seam gas composition and a NSW coal with a carbon dioxide seam gas;
- Compare these gas profiles to the normal carbon dioxide seam gas and methane/ethane seam mine fingerprints identified in the first stage of the C25072 project and ACARP Project C10015; and
- Expand the current “Fire Ladder” to include additional alkanes below the ethylene point which can be used to give earlier warning of a developing heating/spontaneous combustion and incorporated into TARPs.

The work status is as follows:

- Aldehyde Data has been graphed/processed;
- Preliminary validation work has started on the X-Pid, targeting the identified aldehydes from the HPLC analysis;
- Literature review specifically targeting aldehydes evolved during coal spontaneous combustion is being revisited;
- Preparations for the third test have commenced with an anticipated start date of early September: installation and commissioning of the PID controllers for better control of the flange temperatures was completed;
- Micro GC methods are being reassessed based on the general gas data from the previous run; and
- The sample plan and temperatures have been established for the next test.

The following steps will be addressed in the next quarter:

- Graph/Process the VOC data from the GC-MS data;
- Finalisation of the General Gas data processing;
- Comparison of the volatile organic components from the general gas data with the GC-MS data;
- Preparation of the interim report, with tentative date for submission by the end of October;
- Data storage and reporting software update to improve reliability and flexibility is progressing with expected completion by end of August; and
- Finalisation of preparations for the third test and commence testing at the start of September.

C27035
Automatic Leak Detection for Tube Bundle Systems

Resources Safety & Health Queensland
Sean Muller

Value:	$220,000
Report Expected:	September 2024
Industry Monitor/s:	John Grieves
ACARP Contact:	Patrick Tyrrell

The objective of this project is to develop a fully automated prototype integrity testing system, based on information of the flow rates and pressures on tubes. This prototype will be able to be retrofitted to any tube bundle system, regardless of the supplier. The basis for the design of the automated system is Delta Automation's manual integrity testing system. The project comprises three phases. The first phase is the accumulation and evaluation of presently available information relating to flow rates, designs and pressures in tube bundle systems used in underground coal mines. During the second phase the specifications for automatic system prototype will be developed. The final phase will be to test the prototype using the Simtars Mobile Gas Laboratory (MGL) and then retrofit the prototype to a tube bundle system for a trial at the mine site.
Simtars is undertaking comprehensive testing using the Mobile Gas Laboratory (MGL), and adequate lengths of tube-bundle tubing to represent an actual scale of a mine site. The aim of these tests is to evaluate the following:

- Effectiveness of the prototype to undertake leak testing according to AS 2290.3 2018; and
- Ability and accuracy of the prototype to detect leaks and changes in tube integrity.

Testing has been completed and the final report is expected to be submitted in the next quarter.

C28027
Effect of Occlusions by Coal and Stone Dust on the Sensitivity and Time Response of Methane Gas Detectors in Underground Coal Mines

Ampcontrol
Gareth Kennedy
Ian Webster

Value:	$90,000
Report Expected:	September 2024
Industry Monitor/s:	John Grieves Ken Singer Patrick Tyrrell
ACARP Contact:	Peter Bergin

The two overall objectives for this project are:

- Establish the existing degrees of occlusion of real time methane sensors in service in underground coal mines by qualitative survey, and hence determine the potential compromise in performance; and
- Verify and quantify the susceptibility of real time methane detectors to occlusion by coal and stone dust by controlled laboratory testing of typical methane sensing devices.

During the quarter the following tasks were undertaken, or completed by Simtars, related to the second objective.

Equipment modifications:

- Test chamber and associated instrumentation were setup, commissioned and used to complete all laboratory testing.

Measurement undertaken:

- Measurements of detectors' response times and accuracies using Calibration Cups (OEMs and Simtars);
- Measurements of the effects of blockage on the gas detectors' response times and accuracies;
- Measurements of the effect of occlusion for four gas detectors under dust conditions within the purpose-built test chamber.

Laboratory Testing of Gas Detectors:

- Gas detectors' response times and accuracies using Calibration Cups (OEMs and Simtars) was completed;
- Gas detectors to determine the effects of blockage on the on the gas detectors' response times and accuracies was completed;
- Four gas detectors under dust conditions within the purpose-built test chamber was completed.

Reports:

- Draft report for the Comparison of Calibration Cups effects on the gas detectors' response times and accuracies was completed - final report being finalised;
- Draft report for the effects of blockages on the gas detectors' response times and accuracies was completed - final report being finalised;
- Draft report for testing of four gas detectors under dust conditions within the purpose-built test chamber in preparation.

The work schedule for the next quarter is as follows:

- Finalising all test reports; and
- Submission of combined final report to ACARP.

C29018
Evaluation of Explosion Resistant Ventilation Control Devices and Determining Explosion Risk Exclusion Zones

University of Wollongong
Alex Remennikov
Andre De Kock
Gareth Kennedy
Timothy Jackson

Value:	$562,560
Report Expected:	June 2025
Industry Monitor/s:	David Webb John Grieves Ken Singer Paul Wild Russell Thomas Tim Huston
ACARP Contact:	Peter Bergin

Work in this second stage aims to characterise the threat of projectiles from mine entrances through a systematic experimental and numerical approach. The following project tasks have been performed this quarter:

- The experimental program commenced with tests for the drift scenario completed. Tests were conducted with varying blast strength, incline of drift, type of objects (which includes generic shapes and typical objects at the mine with different shapes, sizes and mass), and position of objects relative to the exit (inside or outside the exit, and at the edge or centreline). Necessary data have been collected and compiled for further analysis—this includes blast overpressure, impulse, methane concentration at various locations of the Small-scale Advanced Blast Simulator (ABS), and dual high-speed camera recordings of projectiles in mid-flight.
- Motion analysis of flight trajectories has commenced. Professional motion analysis software is used to convert dual high-speed camera recordings of projectiles in mid-flight into coordinates within a 3D space, and subsequently extract their velocities and angles of trajectory. Software has been calibrated to accurately track projectiles along the Small-scale ABS.
- Results, preliminary findings have shown a clear relationship between blast strength, drift incline, the object's size, mass and position relative to the exit, and its resulting velocity and angle of trajectory. The velocity and angle of trajectory will be used in the development of safety distances and exclusion zones.

C33029
Review Longwall Face Ventilation to Mitigate Goaf Gas Emissions onto Walkways and Tailgate End

University of Wollongong
Ting Ren

Value:	$146,500
Report Expected:	August 2024
Industry Monitor/s:	Ventilation Task Group
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34010
Time Lapse In-Seam Seismic and Resistivity Measurements as an Integrated Component of a Smart Coal Seam Gas Pre-Drainage Practice: Literature Review

University of New South Wales
Hamid Roshan

Value:	$60,000
Report Expected:	August 2024
Industry Monitor/s:	Ventilation Task Group
ACARP Contact:	Peter Bergin

The draft final report has been submitted to the Industry Monitors for review.

C34011
Appraisal of Gas Indicators from Goaf Drainage Holes for Spontaneous Combustion and Explosion Risk Management: Stage 2

University of New South Wales
Guangyao Si

Value:	$223,254
Report Expected:	September 2024
Industry Monitor/s:	David Webb John Grieves Ken Singer Paul Wild
ACARP Contact:	Peter Bergin

The objectives are to:

- Develop CFD models to simulate intensive goaf drainage impact and interaction with longwall ventilation airflow. This will be calibrated and validated by a large amount of goaf gas drainage data collected from the Stage 1 project;
- Understand the migration pathways of leaked air from the face to individual goaf holes; and
- Evaluate the effect of goaf holes on pulling oxygen back and goaf fringe size, at various goaf drainage scenarios (completion depth, position, layout, suction pressure) and goaf natural characteristics.

In the last quarter, we aim to develop a matrix (Figure 1) with various parameters that affect oxygen migration in the goaf zone, which includes key contributors such as coal seam geometry, the number of active holes, suction pressure, goaf permeability, gas emission amount etc.

We conducted further analysis on the impact of goaf dipping angle and goaf compaction characteristics on the distribution of goaf atmosphere. Additionally, the process of numerical simulation is parameterised based on the software control panel, including model geometry setup, grid size, and site operating conditions (compaction characteristic, goaf dipping, borehole suction pressure, borehole position, goaf gas composition, etc). This simplifies the complicated modelling process into changing the parameter that fits the site conditions, allowing for swift implementation to the local geological condition and operating scenarios. This enables site operators to quickly update the model and repeat simulation results based on their site conditions.

Furthermore, the model is made compatible with HPC (High Performance Computing), which overcome computational limitations of standard desktop or workstation on simulating large scale model. With the support of HPC, the computation time is reduced from 72 hours to six hours, significantly shortening the time to obtain results for changes in operating conditions.

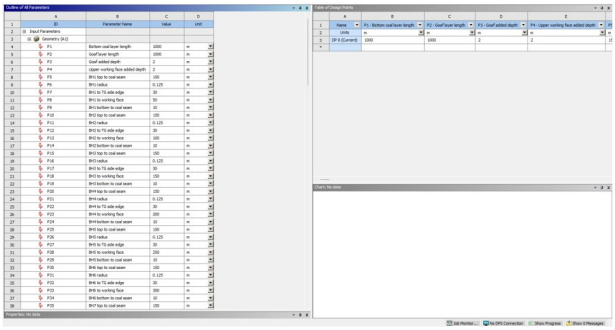


Figure 1 Parameter matrix to flex various contributors affecting goaf oxygen distribution.

C34014
Borehole Tools to Deal with Outbursting, Coal Bursting and Gas Drainage: Stages 1 and 2

Sigra
Ian Gray

Value:	$1,678,320
Report Expected:	September 2024
Industry Monitor/s:	Ventilation Task Group
ACARP Contact:	Patrick Tyrrell

The project aim is to produce a survey system for drilling, including a rock recognition system and a packer system to enable coal seam permeability and pressures to be determined. The project is multi-facetted as it involves drilling hardware, sensing equipment, downhole and at the drill rigs sensing and electronics. This is in both IS and flameproof form and it also involves a lot of software development.

Part of this project involves the modification of a drilling rig to record the operation of the chuck, rod gripper, drilling fluid flow, drill head position etc.

All the downhole equipment and the uphole equipment to test have currently been assessed by Simtars who have deemed that they cannot complete the IS approval and Sigra are now seeking another approving body. Sigra have also had to make three sets of equipment for this purpose. This will take some time. A project extension has been sought as it has become more expensive and complex than originally anticipated.

C35015
Studies of Coal Toughness and Gas Sorption Dynamics for Outburst Risk Management

University of Wollongong
Ting Ren

Value:	$275,000
Report Expected:	June 2025
Industry Monitor/s:	Ventilation Task Group
ACARP Contact:	Patrick Tyrrell

The objective of this project is to improve industry knowledge and management of potential outburst risks by conducting systematic studies of coal toughness, geo-mechanical properties and gas sorption dynamics with different coals sourced from underground coal mines in New South Wales and Queensland.

The following tasks have been completed:

- Sorption tests (including adsorption/desorption isotherms, sorption hysteresis, and rapid desorption testing at fixed gas content and gas pressure for both CO_2 and CH_4) are approaching completion. These tests are conducted on intact cores, coarse and pulverised coal samples placed into eight high-standard canisters with a maximum gas pressure of 5 MPa.
- Coal toughness tests are regularly conducted by using coal samples from four mine sites in New South Wales. These tests aim to establish a comprehensive database of the coal toughness test index (f), and the correlation between the coal toughness index and other parameters is analysed;
- The rapid desorption expansion energy is analysed for CH_4 and CO_2 desorption gas, including the gas expansion energy of the rapid desorption gas and the free gas, as well as the total initial gas expansion energy, with results shown in Figure 1 (a);
- 3D Micro-CT scans of tested coal samples have been conducted to determine micro-structural changes resulting from gas sorption, as compared to as-received coal samples, and deep machine learning techniques are used to quantitatively analyse the damage from gas rapid desorption and its relationship with gas pressure, as shown in Fig 1 (b);

- Preliminary analyses of CH_4 and CO_2 rapid desorption characteristics and Micro-CT scanning results were presented at the 10th International Conference on Energy, Resources, Environment and Sustainable Development (ERESD 2024) in China.

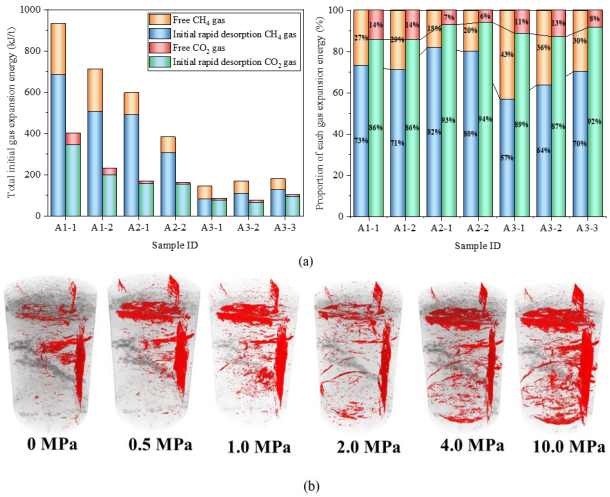


Figure 2 (a) A comparison of CO_2 and CH_4 gas expansion energy at fixed gas content; (b) CT scanning of intact coal sample micro-fractures subject to different CO_2 pressure.

C36003
Practical Implications of Oxygen Deficiency on the Determination of Graham's Ratio in Longwall Goafs

Resources Safety & Health Queensland
Gareth Kennedy
Sean Muller

Value:	$64,350
Report Expected:	November 2024
Industry Monitor/s:	David Webb John Grieves
ACARP Contact:	Patrick Tyrrell

Graham's ratio is a commonly used indicator for measuring the intensity of the oxidation of coal in underground mine atmospheres. The basis of Graham's ratio is the conversion efficiency of oxygen to carbon monoxide. Graham's ratio uses the nitrogen from a sample for the calculation of oxygen deficiency. This allows for dilution by methane and carbon dioxide seam gases. This calculation is made on the basis that nitrogen is an inert gas which is not consumed or created.

This project will investigate the practical implications for the interpretation of Graham's ratio and other indicators in the presence of an oxygen deficient atmosphere (due to natural processes and both added nitrogen or exhaust gases via inertisation). Mine data is currently being acquired for data review.

C36005
Optimisation of Goaf Management Strategies

CSIRO
Qingdong Qu
Rao Balusu

Value:	$1,443,557
Report Expected:	November 2027
Industry Monitor/s:	Ventilation Task Group
ACARP Contact:	Patrick Tyrrell

The objective is to develop optimum goaf management strategies to maximise goaf gas drainage, reduce oxygen ingress into the longwall goaf, and minimise fugitive emissions. The project's main focus is to:

- Obtain a fundamental understanding of goaf gas distribution; obtain an understanding of the impact of various geological, mining and operations parameters;
- Investigate the feasibility of various goaf gas drainage designs and strategies to maximise gas drainage and minimise oxygen ingress;
- Develop optimum inertisation strategies to minimise oxygen ingress on both maingate and tailgate sides of the longwall goaf; examine the impact of various additional goaf management strategies; and to
- Develop optimum adjacent goaf gas drainage strategies to minimise greenhouse gas emissions into the main return airways.

A comprehensive CFD model of the longwall goaf has been developed incorporating various features to carry out extensive investigations. Base-case modelling simulations were carried out to obtain goaf gas distribution patterns in the longwall goaf under different goaf gas emission and drainage conditions. Validation of the results of CFD models were carried out by comparing with field measured data. Several field measured parameters such as air velocity profiles at different sections across the face, pressure differentials, goaf gas distribution and gas drainage performance including gas composition in goaf holes were compared with the results of modelling simulations. The studies demonstrated that the results of base-case modelling simulations matched well with the field measured data.

Some of the base-case modelling conditions have been modified to suit field conditions at a greater number of mines. The next stage involves extensive parametric studies with variations in geological, mining and operational parameters.

C36012
Rotary Steering System Field Trial and Developments

Sigra
Ian Gray

Value:	$449,600
Report Expected:	April 2025
Industry Monitor/s:	Ventilation Task Group
ACARP Contact:	Patrick Tyrrell

This project is to enable field trials and necessary modifications to be made to the Sigra rotary steering system (RSS) tool that was developed as part of project C28022 and was completed in 2020 without an underground field trial. During this period a drilling trial was conducted using a civil engineering horizontal directional drilling rig and many changes have been implemented as a result of this.

The Sigra RSS is designed to replace down hole motors in underground in seam drilling and in particular to overcome problems faced with 'boggy ground'. The latter is caused by cuttings bed build up around the drill string. The rotary steering system involves the use of a rotating drill string with a non-rotating sleeve fitted with pads that deflect the drill bit. The rotating drill string has been shown, in oilfield use, to prevent cuttings buildup. The RSS should also permit greater power at the bit compared to downhole motors that are currently used underground. It is hoped that this will enable faster penetration rates when drilling through stone.

The system is currently at a coal mine for field trials. These are initially to determine whether the system will drill straight when in a neutral mode and to determine angular build up when being steered. No doubt there will be many other findings.

C36015
Intelligent Integrated Distributed Fibre Optic Sensing Technologies

CSIRO
Yi Duan

Value:	$568,317
Report Expected:	April 2026
Industry Monitor/s:	Peter Corbett Dennis Black
ACARP Contact:	Patrick Tyrrell

Temperature, strain and seismicity monitoring are crucial for geotechnical hazards (e.g., spontaneous combustion, pillar failure, strata instability) management in underground coal mines. This project aims to advance remote underground mining operation capabilities by targeting specific technology developments in areas of high strategic need and opportunity for industry. The key components of this project are:

- Continuous temperature profiling using distributed temperature sensing;
- Combined continuous pillar strain and microseismic measurement using optic fibre; and
- Real-time distributed acoustic sensing data processing based on deep learning pipelines.

During the quarter, the main activity for each key component include:

- Literature review on the applications of distributed temperature sensing is being conducted. Raman based distributed temperature sensing interrogator, single mode fibre optic cable and IS-approved ambient air temperature sensors are selected for the initial lab experiment to verify the temperature measurements. Supplier of the interrogator has been contacted to expand the number of channels of the interrogator for high quality loop back connection for temperature calibration.
- Pillar strain numerical models have been developed in a spreadsheet and transferred to MatLab code. Results indicate that mine scale strains, including strain on coal pillars can be recorded using optical fibre without the fibre breaking. The design of a scale model test rig has been completed and materials purchased for its construction.
- Distributed acoustic sensing data associated with longwall caving is being collected from a mine site. The monitoring focuses on the last 500m of the longwall panel and will provide sufficient quality data. The dataset is being reviewed and characterised for deep learning pipelines development. An initial database including seismic events and noise and a deep learning prototype model have been developed for seismic event discrimination. The model is being tested and calibrated as more new data is collected from the ongoing monitoring project.

OPEN CUT

Geology

C34020
Guideline for Standardising Structure Interpretation in ATV/OTV Logs

University of Queensland
Mojtaba Rajabi

Value:	$163,415
Report Expected:	September 2024
Industry Monitor/s:	Brian Vorster Euan Macaulay Matt Tsang
ACARP Contact:	Cam Davidson

This project aims to develop a guideline for processing, analysis, and interpretation of geological features in image logs. Such a guideline will significantly reduce the inconsistencies and misinterpretations through image log interpretations. To achieve this goal, we will combine a wide variety of data including core, ATV/OTV and company experts' knowledge to develop a guideline for standardisation of image log interpretation and nomenclature.

During the quarter all data analysis was completed. The team is in the final stage of report writing and expects to submit the draft report for review in August.

C34037
Statistical Analysis of Methods for selecting Lithology Boundaries from Density and Natural Gamma logs and assessing their ability to select Lithology Boundaries in Blast Holes

GeoCheck
Brett Larkin

Value:	$76,000
Report Expected:	August 2024
Industry Monitor/s:	Mark Laycock
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C35023
Recovery of Critical Minerals from Coal and Coal Production Waste

CSIRO
Clint McNally
Nerrida Scott

Value:	$154,000
Report Expected:	September 2024
Industry Monitor/s:	Andrew Lau Caroline Lang Shaun Booth
ACARP Contact:	Patrick Tyrrell

The objectives of the project are to determine the mineral associations of critical minerals (REE) and use this knowledge to inform the development of innovative recovery technologies of these metals form coal-based resources. Also to investigate technologies and processes to recover and extract these high value products in an economic and sustainable manner.

Characterisation of initial samples from a Queensland coal resource were completed and specific areas were identified for further investigation. From these focus areas, three larger samples were taken. Each sample was then split down into smaller size fractions for further beneficiation trials and additional characterisation work. Essentially by identifying the physical properties of the samples, it is possible to exploit the best separation options for the various minerals.

Beneficiation of the samples has commenced and from the physical separation outcomes, the recharacterisation will indicate the relative benefits of each beneficiation step. This work is expected to be completed by October and the final hydrometallurgical analysis phase of the work will be completed in tandem with each beneficiation step.

Samples are currently being tested with beneficiation trials and the hydrometallurgical extraction will commence in early September under expert guidance of the CSIRO Hydrometallurgy team. Resulting fractions will then be re-characterised to determine possible viable products and an assessment of the economic cost of recovery done.

C35025
CSR Predictions and Correlations Definition

McMahon Coal Quality Resources
Chris McMahon

Value:	$35,880
Report Expected:	May 2025
Industry Monitor/s:	Alison Burke Maurizio Tonelli Tomoaki Nagata
ACARP Contact:	Patrick Tyrrell

This project seeks to take the published equations, chart data (that can be converted to formulas), and data attained from MCQR's ACARP projects and estimators produced in those projects, and industry supplied data to compare against each other and define the effectiveness of each CSR predictor for product coals of varying coal quality characteristics. Several deposits/coal types will be evaluated.

To minimise standard error of outcomes (the chosen metric for precision/variability assessment), MCQR plans to test both historical data and MCQR attained data via a "proportional" coal quality approach. The "proportional" approach will allocate percentage contribution to each coal quality test from an optimisation engine process with the goal of minimising standard error outcomes. This approach is in contrast to almost all prior predictive models which were largely based on polynomial equations constructed to give the highest correlation coefficient for the coal quality tests examined.

At the start meeting a request for information memorandum was issued. One borecore database was received. Two other borecore databases, and three shipping databases were initially promised and repeatedly sought, with notice of rejection of the data requests being received recently due to market confidentiality issues.

Use of the one supplied borecore database and other borecore database(s) from McMahon Resources available data will be utilised for the review.

Commencement of data processing and review is scheduled to commence in October.

The outcomes of this project will be the definition of accuracy (precision and bias) information for varying CSR Estimators (both published and MCQR developed) with differing coal types. This will benefit the industry by providing predictive formulae and ranges of CSR outcomes for a range of coal types, and potentially add to correct resource representation and/or lower analysis costs. The outcomes then will provide a financial risk reduction and/or evaluation enhancement.

C35047
Real Time Prediction of Coal Top Through Guided Borehole Radar Wave Imaging for Open Cut Blast Hole Drilling Phase III

CSIRO
Matt van de Werken
Wayne Stasinowsky

Value:	$396,792
Report Expected:	April 2025
Industry Monitor/s:	Jack Woollett Troy O'Reilly
ACARP Contact:	David Drakeley

The objectives are to:
- Develop a fully functional real-time coal top guidance system prototype suitable for field demonstration trials where it is fitted to a blast rig drilling production holes;
- Extend and mature the technology and engineering developed in Phase II; and to
- Develop a prototype to the stage that the technology is ready to engage a commercial partner.

Progress during the quarter:
- All components of prototype 2 have been manufactured and assembled;
- Lab testing of the assembled system has confirmed a working prototype ready for a TRL 7 trial;
- Final testing to optimise the antenna design and configuration is currently underway; and
- A mine site has been approached for a TRL 7 mine trial to be conducted in September. Timing will depend on drill rig and mine personnel availability.

C36022
Validation of LIBS Technology for Downhole Resource Evaluation

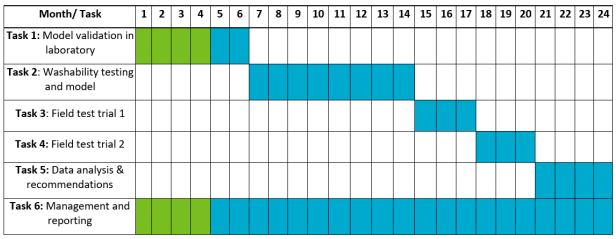
CSIRO
Joe Perkins

Value:	$276,020
Report Expected:	April 2026
Industry Monitor/s:	Jason Schumacher Mark Laycock Sudipta Nag
ACARP Contact:	David Drakeley

The project aims to further validate Laser-Induced Breakdown Spectroscopy (LIBS) as a rapidly deployable technology through expanded lab testing and field trials; following on from project C34029.

The project aims to:
- Using state-of-the-art laboratory LIBS hardware and multivariate analytical methods, build upon the preliminary findings of project C34029 to develop a comprehensive coal core derived calibration model;

- Integrate LIBS spectral information into washability models using processed core samples; and to
- Conduct field testing using a prototype/pre-commercial LIBS downhole tool to determine the potential and challenges of optimising LIBS technology specifically for the evaluation of coal resources.



We have met with industry monitors several times to discuss specific coal quality measures to target during this project. The acquisition of coal core samples has also been discussed in preparation for Task 2 (washability testing and lab model development). It was decided that proximate analysis, CV derived from ultimate analysis, sulphur, and phosphorus would be the primary targets for the lab-derived models. CSIRO expects to obtain coal core samples in August to commence LIBS core scanning. The project leader presented on this project at the BBGG event in Rockhampton in July.

Drilling and Blasting

C27024
Evaluation of Production Trials of HP Explosives

Mining3
Andrew Kettle

Value:	$477,920
Report Expected:	September 2024
Industry Monitor/s:	Andrew Lau Brett Domrow
ACARP Contact:	Cam Davidson

The objective of this project is to demonstrate the on-site on-demand manufacture and delivery of Hydrogen peroxide (H_2O_2)/oil-based emulsion-style explosive using a specialised Mobile Processing Unit (MPU) and evaluate blast performance in surface mine-site operations with increasing scales of production. This project progresses the research plan for H_2O_2-based emulsion explosives from confirmation of first viable formulations meeting sleep-time and detonation performance (reported in C27023) towards implementation and adoption by focussing on on-site on-demand manufacture and delivery procedures to meet mine-site operational requirements with a central and critical focus on safety.

Work undertaken during the quarter:

- Due to the delay in execution of this project, advancements within the parallel project C35028 (project update in this quarterly report) will be utilised in this project. A prototype continuous static mixer, being developed in C35028 by Sydney-based Elquip, is designed to produce fifty kilograms of emulsion per minute. This advance now makes redundant the batch vortex mixer approach for manufacture that was initially intended and tested in within this project in 2022. However, the progress that was made in this project during field trials of the batch mixer are transferable to the field trials in C35028.
- The continuous mixer approach has won further support and interest from potential commercialisation company partners. For continuation of this project, an international blasting company partnership is finalising licencing agreements and exploring Mining3's commercialisation roadmap. It is intended that this project will be additionally utilised to embed competencies within the commercialisation company.

Of note, this project is required to be completed to progress into project C33041 to enable the continuation of blast demonstrations with larger volumes of material.

C33041
Production Trials in Two States of HP Explosives with Custom MMU

Mining3
Andrew Kettle

Value:	$342,034
Report Expected:	August 2025
Industry Monitor/s:	Andrew Lau Brett Domrow
ACARP Contact:	Cam Davidson

The objective of this project is to utilise a prototype Mobile Production Unit (MPU), built within project C27024, and C35028, to expand the blast demonstrations of on-site on-demand Hydrogen peroxide (H_2O_2)-based explosives. Through executing these displays, across state jurisdictions, engaging both the Queensland Explosives Inspectorate and SafeWork NSW, in two mine site locations, further technical confidence in the blasting agent will result. This new H_2O_2-based emulsion technology has passed product stability testing in C27023, and authorisation testing in C27024.

In preparation for this project:

- The potential blasting company collaborating with this project is finalising the licencing agreement of this technology and exploring Mining3's commercialisation roadmap.
- We will then determine hazard studies and risk assessments through internal company capability and finalise further in-kind support from the host company. This will be a component shared within project C27024 and duplicated here with modification for the larger blasts and duplicate sites.

Due to the delay in execution of this project, advancements within C35028 (see project update in this quarterly report) will be utilised making redundant the batch vortex mixer approach for manufacture that was initially intended. A prototype continuous static mixer has been developed that is targeted to produce fifty kilograms of emulsion a minute.

This project requires the completion of blasting in project C27024 and is a stage two of the blasting capability demonstrations.

C35018
Reactive Ground Testing

Queensland Magnetic Research
Alastair Torrance
Gary Cavanough

Value:	$250,000
Report Expected:	January 2025
Industry Monitor/s:	Andrew Micallef Mark Laycock
ACARP Contact:	David Drakeley

The project objective is to evaluate and introduce a new testing method for assessing reactive ground.

Experiments conducted last year showed that coal is an effective inhibiter if the coal and reactive sulphide contents were of the approximate same proportions. For example, when 20% coal is mixed with highly reactive black shale the AEISG screening test result is not reactive. This quarter, the mechanism whereby coal inhibits a reaction between sulphide and nitrates was investigated with no clear mechanism being identified. It was noted that coal is hydrophobic and the ability of coal to inhibit reactivity may be due to the coal particles decreasing the access of water the surface of the sulphide (with water being essential for a reaction to occur).

The project focusses on analysis of previous instances of reactions and spontaneous detonations with consideration to the finding of this project. It was identified that several events at coal mines that were designated as caused by reactive ground have clear indications the event was caused by burning coal. Therefore, it may be likely that the use of inhibited product will not prevent these events from occurring in the future.

The project has identified that a possible pathway to detonation due to heat energy is via a hot top layer forming after decomposition of the ammonium nitrate. During the next quarter research will focus on the composition of the layer.

C35028
Mining Explosive Sensitisation using Chemical Free Methods

Mining3
Andrew Kettle

Value:	$297,256
Report Expected:	September 2024
Industry Monitor/s:	Andrew Lau Brett Domrow
ACARP Contact:	Cam Davidson

The project objective is to further enable and improve bulk hydrogen peroxide (H_2O_2)-based emulsion mixtures. This project investigates unique sensitisation methods of H_2O_2-based emulsion mixtures. Success of this project will lead to improved H_2O_2-based explosive performance, reduced material costs, and an in-line reactor for an on-bench, on-site, on-demand emulsion manufacture process within a mobile production unit (MPU).

Over the quarter, we have worked on the following:

- In the Elquip workshop, a major milestone (2) was achieved! When all the reactor components were finally acquired and assembled (see photographs) the preliminary proof-of-principle tests for the sensitisation material process has been successful! A considerable delay was experienced in this project due to delayed equipment components from Germany that were compliant to Australian Standards. This delay was an unforeseen complication in the unit design and due to this the test window for field trials have been bumped.
- With successful preliminary sensitisation material testing completed, the entire system is being assembled. Adding compatible controls to a novel sensitisation system and prototype manufacture method are proving challenging. The Elquip project-deployed engineers are continuing to investigate compatible-to- H_2O_2 in-flow monitoring equipment. Additionally, system pressure rating and back-pressure forces generated in the system are being addressed.
- Unit field trials continue and a new test window in November 2024 has been confirmed. We have abandoned the August test dates.
- Whilst not directly funded in this project, Mining3 has submitted patent protection of the sensitisation method, confident with the recent testing success.

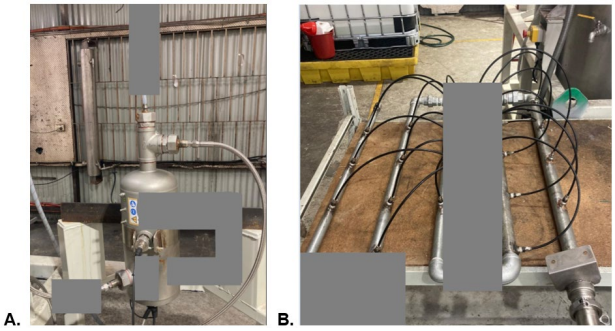


Figure 3. A & B. In Elquip's workshop: the complete reactor (A) installed into the prototype manufacturer

system (B) following successful initial testing of the reactor. Components and labels of the reactor and manufacture system has been blocked out for protection of intellectual property and patent protection. [Image acknowledgement: Otto Lambe, Elquip].

Environment

C29049
Saline Pit Lakes as Aquatic Ecosystems: A Design Manual for Closure

Edith Cowan University
Mark Lund

Value:	$1,089,226
Report Expected:	November 2024
Industry Monitor/s:	Andrew Lau John Watson
ACARP Contact:	David Drakeley

In Australia, many community members and regulators expect that final voids will be backfilled. However, a lack of backfill materials combined with prohibitive costs ensures that pit lakes will be a permanent feature of most post-mining landscapes. Pit lakes are considered the 'greatest legacy of open cut mining' due to the potential for safety issues, ground and surface water contamination, and in-lake toxicity. Additionally, pit lake science has struggled to find a foothold in mainstream literature, limiting wider scientific exposure to the issue of pit lakes and holding back advancement of the development of remediation and closure approaches. Therefore, the broad objective of our proposed research is to understand the biophysical processes in unrehabilitated saline pit lakes and investigate options for enhancing ecosystem services in the Hunter Valley and Bowen Basin.

Salinity is a key water quality issue with many Australian pit lakes. Many natural lakes are saline and have valuable ecosystem values. Understanding the role of catchments and nutrient inflows in maintaining salinity within useful ranges and driving ecosystem processes is therefore important to determine the range of future uses for these pit lakes. These future uses may include as aquatic ecosystems, recreational areas, and for aquaculture.

The overall project approach has two main components: 1) In situ component: Continuing the monitoring of four saline pit lakes (Hunter Valley and Bowen Basin) for a broad range of water chemistry, physical and biological parameters from C27043. We have added an additional four pit lakes in the Bowen Basin to the monitoring program in 2021. Based on findings from the C27043 monitoring program, we have introduced some refinements for 2021 that include improved replication of water quality data, and consistent numbers of macroinvertebrate and diatom samples between sites. We will sample each lake twice yearly. Using instrument chains, installed in all lakes we collect hourly data on stratification and salinity levels.

2) Experimental component to examine rehabilitation options: Carbon (in the form of terrestrial organic matter) determines the nature of the aquatic food web and creates important habitat. In C27043, using tank mesocosms (1000 L) on site, we tested the effects of adding coarse, low-cost organic matter on lake water and sediments on biophysical and chemical endpoints (as measured in the lake). Based on the positive improvements recorded, in this project we will reset the mesocosms and test both organic matter phosphorus additions. Low phosphorus concentrations were recorded in all the pit lakes studies in C27043, and additions should stimulate primary production, creating more food for macroinvertebrates.

Littoral areas are well-established as the most important areas for biodiversity in lakes and yet also represent the most expensive component of pit lake rehabilitation (due to the earthmoving requirements to create these areas). We will conduct detailed sampling at a small rehabilitated saline pit lake to investigate the influence of water depth on biodiversity to determine the littoral area requirements of pit lakes for creating productive aquatic environments. As shown in C27043, organic matter additions can enhance biodiversity in saline pit lakes. Experimentally we will move from mesocosms to a pit lake to test organic matter additions in situ. Artificial floating islands of vegetation will be tested as a source of carbon and propagules that could assist in pit lake development during filling.

We are currently in the process of writing up the results from the study and preparing the Design Guidelines.

C33043
Best Practice Management and Performance Assessment of Biodiversity Offset Areas

Eco Logical Australia
May-Le Ng
Rachel Murray

Value:	$335,540
Report Expected:	August 2024
Industry Monitor/s:	Mark Nolan Nigel Charnock
ACARP Contact:	David Drakeley

The draft final report has been submitted to the Industry Monitors for review.

C33046
Rationale for the use of Paired Continuous Real Time Noise Monitors to Reduce Uncertainty in the Quantification of Noise from Open Cut Coal Mines

Umwelt (Australia)
Steve Lyons
Tim Procter

Value:	$125,000
Report Expected:	August 2024
Industry Monitor/s:	Ned Stephenson
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C33047
Best Method for Determining Atmospheric Stability for the Assessment of the Acoustic Environment in the NSW Coal Mining Industry

Umwelt (Australia)
Steve Lyons
Tim Procter

Value:	$276,000
Report Expected:	October 2024
Industry Monitor/s:	Ned Stephenson
ACARP Contact:	Patrick Tyrrell

No report received.

C34025
New Landscape Evolution Model for Assessing Rehabilitation Designs

University of Newcastle
Greg Hancock

Value:	$875,391
Report Expected:	March 2025
Industry Monitor/s:	Chris Quinn Jason Fittler
ACARP Contact:	Patrick Tyrrell

The project objectives are to:

- Test and develop the newly developed SSSPAM landscape evolution model and SIBERIA (LEM) so that they can be used easily to evaluate both constructed and proposed post-mining landforms. The models will be tested across a range of sites in Queensland and New South Wales.
- Develop a database of parameters that can be used by the industry across a range of sites, materials and climates.

A laboratory weathering assessment of waste materials has developed material specific weathering parameters that can be used in the SSSPAM model to predict erosion reduction and pedogenesis. This work demonstrates that for some sites weathering is rapid and is not a major influence on landscape evolution. It also confirms the robustness of the weathering model in SSSPAM. A journal paper has been accepted in the journal Geomorphology.

Model input parameters have been developed for several sites in Queensland and the Hunter Valley with validated sets of parameters available. Continued testing and development of the SSSPAM model continues. A focus at present is on the Hunter Valley where high quality LiDAR data has allowed the identification of erosion features such as rills and gullies. This data is being used to parameterise and evaluate both the SIBERIA and SSSPAM models. Recent outputs include an assessment of DEM grid spacing needed to reliably capture erosion features as well as above ground features such as contour drains. A new capability in the SSSPAM model has been the inclusion of a landscape uplift capacity.

C34027
Microalgae Cultivation as a Low Cost Method for Desalinating Void Water and Generator of Post Mining Bioeconomic Activity from Final Voids

University of Queensland
Ben Hankamer
Leigh Trevaskis

Value:	$2,159,848
Report Expected:	March 2025
Industry Monitor/s:	Andrew Lau Jason Fittler John Watson Trudy Mazucco
ACARP Contact:	Patrick Tyrrell

This stage 2 of the project will:

- Confirm pilot scale microalgae production and desalination performance;
- Assess effective microalgae harvesting, determine biomass composition and processing methods;
- Validate and characterise pilot scale salt extraction;
- Optimise process control based on pilot scale system performance;
- Refine technoeconomic simulations for guiding pre-commercial cultivation and biorefinery process delivery for an anticipated pre-commercial stage; and
- Develop a valid commercialisation pathway and value chain to market.

During this quarter, the project has conducted the following work:

- Optimised media in mine void water at lab scale: Lab scale optimisation of void water with N, P and microelements resulted in a 3-fold higher Na uptake by microalgae than non-optimised media. Optimised conditions resulted in ~15% EC reduction.
- Pilot trials: Artificial mine water was made using sea water and fertiliser grade chemicals. The autumn 4000L pilot scale run was conducted in batch and

continuous modes using the microalgae mine isolate A10-A6 (Lobochlamys sp). In the 13-day batch mode experiment the average biomass productivity was 17 g m2 d-1 (ranging from 10 to 29 g m2 d-1). This productivity is higher than sugar cane (14g m2 d-1). The final EC was reduced by 7.4% compared to the start. As ion removal is dependent on many factors the following items are being analysed in more detail:
  - void/synthetic void: The use of void water rather than synthetic void water may influence ion removal,
  - salt/biomass: Ion removal is influenced by biomass productivity and so improved biomass production processes could improve this,
  - ion extraction: While lab scale experiments showed a ~15% EC reduction, this reduction accounted for evaporation. In the pilot scale there was evaporation which was difficult to account for and so could masked ion removal. We are currently evaluating ion uptake in the dried biomass to provide a direct measure of desalination.
- Product/process development: The A10-A6 cell line produces extracellular polymeric substances (EPS) which can act as useful hydrogels and ion exchangers. The project has identified EPS as being of interest as a potential contributor to ion uptake and for downstream product development.
- Pond experiments: The project has postponed open pond experiments to Q4 so that we can conduct them with mine void water rather than synthetic void water for desalination trials (spring/summer) seasons.
- Commercialisation pathway: The project has found it challenging to engage with Government to clarify regulatory constraints.

C34035
High Interest Native Plant Pittosporum Angustifolium for Mine Rehabilitation: Key Strain Identification and Germplasm Propagation Investigation

RNA Environmental Services
Ryan Anderson

Value:	$197,401
Report Expected:	September 2024
Industry Monitor/s:	Andrew Lau Andrew Micallef
ACARP Contact:	Patrick Tyrrell

Pittosporum angustifolium is a drought resistant plant found in semi-arid regions on highly weathered skeletal sandy soils. Pittosporum angustifolium is an ethno-pharmaceutical plant species reputed to have beneficial properties for prostate cancer patients. It also has potential as a mined land rehabilitation species. Two known parent plants have been identified in the Bouldercombe region of Central Queensland. This project will produce Pittosporum angustifolium tubestock suitable for field implementation. Researchers will develop a robust practical methodology for successful propagation of the species and assay anti-cancer properties of phytochemical active ingredients.

All field work is complete and most of the lab work is done. We have been waiting on the genetics lab, AGRF, which lost many samples so we had to re-sample and they have had a backlog of work and has been delayed. We expect lab results very soon which will let us finish off the report. Depending on lab, we are hopeful of completing and submitting a draft report within August.

C35021
Delineating Water Tables and Flow Pathways Inside Spoil Piles to Support Water Quality Predictions

University of Queensland
Mansour Edraki
Neil McIntyre
Thierry Bore

Value:	$297,420
Report Expected:	August 2025
Industry Monitor/s:	Andrew Lau
ACARP Contact:	David Drakeley

The aim of the project is to detect the spatial and temporal distribution of major flow pathways and water table(s) inside spoil piles with the level of confidence required for the progressive rehabilitation of spoil piles and prediction of water balance and water quality of final voids, in particular predictions of spoil seepage quality.

During the quarter, the focus has been on two activities:
- A geophysical survey was conducted at the site and profile data were collected for the selected spoil pile;
- A conceptual model has been developed based on the drill hole data provided by the site. This will be combined with geophysical data to develop a hydrological model.

The case study site located in the Gloucester Basin is preparing to finish coal extraction in 2024 and will transition to closure upon completion of mining operations.

C35026
Management Strategies for Invasive Leucaena on Coal Mine Sites

University of Queensland
Shane Campbell

Value:	$531,528
Report Expected:	December 2026
Industry Monitor/s:	Andrew Lau Morne van Zyl Cian Morgan Dominique Taylor Craig Bushell
ACARP Contact:	Patrick Tyrrell

The primary objective of this project is to develop strategies to effectively manage the invasive species leucaena (Leucaena leucocephala) in rehabilitation on coal mine sites in Queensland. Leucaena is a leguminous tree introduced to Australia for use as a forage for livestock production, but it has also become an environmental weed in sub-tropical and tropical regions, including on several coal mine sites in central Queensland.

A fire trial that was due to be initiated near Rockhampton between April and June in collaboration with the Department of Environment and Science has been delayed due to prolonged wet conditions, with initial burning now planned for completion in August. A foliar experiment was established at the University of Queensland (Gatton Campus) in April/May to evaluate ten herbicides for their ability to control leucaena. A brown-out assessment was carried out in June with most herbicides demonstrating the ability to fully defoliate leucaena plants. The first efficacy assessments will be undertaken three months after treatment in August and then on a quarterly basis for at least 12 months. A glasshouse trial to investigate the efficacy of Dazomet (Basamid®), a soil fumigant, in reducing the viability of leucaena seeds in the soil has been established at the Ecoscience Precinct in Brisbane. One month (August) after the application of Dazomet all seeds will be retrieved from the soil and viability testing undertaken to determine if this fumigant is effective at depleting leucaena soil seed reserves. Discussions are underway regarding the potential to monitor leucaena control activities on mine site 1 and mine site 2 using either on-ground, remote sensing and/or aerial imagery. Monitoring of a residual herbicide trial has also continued, entering its sixth month, whereby ten herbicides are being evaluated for their ability to prevent seedling recruitment of leucaena from the soil seed bank.

C35029
Renewable Energy as Post Mining Land Use

University of Queensland
Claire Cote

Value:	$186,628
Report Expected:	September 2024
Industry Monitor/s:	Morne van Zyl Jason Fittler Raymond Howard Ned Stephenson
ACARP Contact:	David Drakeley

A baseline assessment of post mining land use in Queensland concluded that in the Bowen Basin and Surat Basin, renewable energy produced by solar and wind had vast potential, but the pathway to implementation is not clear. This project aims at examining how renewable energy projects can be set up on a mine and be accepted as post-mining land use by regulators and stakeholders.

The review of legal acts and planning approval processes led to the identification of four potential regulatory pathways, two of which are relatively straight-forward, though effort-intensive. It is the nature of the tenure for the underlying land that will dictate which pathway needs to be followed.

The potential for implementing renewable energy projects on mine sites was tested by applying a multi criteria analysis to land use data collated from three case study sites. Land use data was compiled from Progressive Rehabilitation and Closure Plan spatial data sets. Scores were assigned to land tenure, land use, distance to specific features (e.g. electrical grid) and local site-specific factors (e.g. subsidence areas). Results from the multi-criteria analysis were used to determine the surface areas that could be dedicated to renewable energy, along with the associated generation capacity that could be installed.

Net Present Value of solar and wind farms was calculated, based on capital costs (derived from information provided in the Electricity Generation Map database); capacity factors (% of hours the renewable energy facility will be operating); costs of batteries (compiled from a range of sources, including reports from the Renewable Energy Laboratory in the USA); operational and maintenance costs; and revenue streams through sale of electricity on the National Energy Market. Results indicate that wind farms are unlikely to be suitable, despite yielding positive NPV within ten years, as the extent of land available on a single mine is not sufficient to support installation of several wind turbines. Solar farms are suitable, but financial returns are uncertain. Facilities with a small generation capacity can yield a positive NPV, but they would need to be operated by providers experienced in generating maximum revenue from variations in the electricity spot price.

Results are being compiled in a draft report describing the costs and benefits of implementing renewable energy projects on mine sites, along with regulatory pathways and options for stakeholders' engagement. Knowledge transfer has commenced, with main outcomes presented to the Central Queensland Mining Rehabilitation Group.

C35030
Erosion and Sediment Control Framework for Queensland Mines – Calibration and Validation

University of Queensland
Robynne Chrystal

Value:	$347,196
Report Expected:	March 2026
Industry Monitor/s:	Andrew Lau Jason Fittler Tim Kendrick
ACARP Contact:	Patrick Tyrrell

A framework for Erosion and Sediment Control Plans (ESCP) for Queensland coal mine sites was developed during project C29046. The ESCP framework uses a GIS-based RUSLE tool that was developed to quantify soil loss on site, assist with identifying erosion risks and with selecting, designing, and implementing controls on site. This work also provided guidance on the key steps for sediment basin design. This project aims to verify that the soil loss rates calculated using the GIS-based RUSLE tool accurately represent site conditions at different catchment scales and land uses and that the guidance provided in project C29046 is applicable and reflects approaches that ensure compliance.

Site 1 will be revisited in August to inspect installed sediment fences. Additional fences will be installed in a catchment with recently finished dump reshaping. The site visit to mine site 2 to select final locations for sediment fence and height marker installation was undertaken in May, with contractors scheduled to do the installation this month. All preliminary catchment-based RUSLE models have been completed. Available erosion studies are currently under review to assess key gaps in our understanding of soil erodibility on Queensland mine sites and inform laboratory and field experiments.

C36018
Predicting the Long Term Erosional Behaviour of High Walls

University of Newcastle
Greg Hancock
Sue Henderson

Value:	$443,980
Report Expected:	March 2026
Industry Monitor/s:	Andrew Lau Chris Quinn Jason Fittler
ACARP Contact:	Patrick Tyrrell

The objectives are to:
- Better understand the process and rates of mine highwall erosional failure; and
- Develop parameters for input into numerical models for high wall erosional failure and
- Calibrate and validate a predictive model (SIBERIA) for the erosional of highwalls.

Discussions with mines have commenced and permission given for use of existing DEMs that the team have.

One site has committed to providing materials and landscape data for analysis. Former trial site data has also been supplied. The data is now being processed with needs for additional data being prepared. Additional field and GIS data needs are now being determined. The Research Fellow is developing high level knowledge of Landscape Evolution Models and the management of large spatial data sets.

C36020
Semi Autonomous Bulldozers for Mine Site Rehabilitation

University of Queensland
Carl Hendricks
Eric Reiners
Jason Pagnotta
Ross McAree

Value:	$498,218
Report Expected:	April 2025
Industry Monitor/s:	Andrew Lau Brian Neilsen Jonathan Miln Ned Stephenson Phillip Enderby Simon Zillman Teo Di Pasquale
ACARP Contact:	Patrick Tyrrell

The SATS (Semi-Autonomous Tractor System) is a technology marketed by Caterpillar that allows D11 bulldozers to operate semi-autonomously with remote mission planning, aiming to optimise material movement and reduce manual intervention. This project aims to develop and demonstrate semi-autonomous bulldozers

based on SATS to significantly reduce emissions and costs associated with mined land rehabilitation. The objectives of the project are:

- Specification and Design: Capture knowledge that will support the development of a semi-autonomous dozing capability for mined land rehabilitation. This involves using a use case framework to capture the entire process of mined-land rehabilitation and employing a systems theoretic process analysis (STPA) approach to determine and control potential losses and risks, ensuring the system is functionally safe.
- System Development: Develop an autonomous mission planning system that extends the Caterpillar SATS to effectively execute land rehabilitation material movement activities.
- System Evaluation: Assess the benefits of the semi-autonomous dozing system by measuring potential improvements in productivity, fuel savings, and reduction in emissions.

Progress has been made on the use case analysis and STPA for rehabilitation scenarios, providing a detailed understanding of operational procedures and potential risks. Adaptations to the SATS system are underway, with initial simulations showing promising results. The development of the Bulk Movement Planner is advancing, aiming to optimise material movement rates. We are also actively working with Thiess to identify suitable locations and timing for field trials, focusing on a baseline study and a subsequent study incorporating the STAMP planning system.

C36042
Validation of a Landform Design and Management System for Sloped Grazing PMLU

Valarion
Leigh Trevaskis

Value:	$688,080
Report Expected:	February 2027
Industry Monitor/s:	Andrew Lau Morné van Zyl
ACARP Contact:	Patrick Tyrrell

The project's primary objectives are to:

- Characterise the impact livestock behaviour has on stability indicators for sloped grazing PMLU in the Bowen Basin;
- Provide statistical confirmation of an adaptive grazing management system for maintaining the stability of sloped grazing PMLU;
- Obtain evidence that justifies the use of stability indicators for the approval of grazing PMLU rather than a slope gradient ceiling;
- Assess the feasibility of using integrated behavioural, landform elevation, and sustainability indicator data for developing a grazing PMLU landform evolution model;
- Use stability indicator data from replicated treatments to evaluate recommendations from previous grazing PLMU studies;
- Publish a best-practice guide for managing livestock on sloped grazing PMLU.

In this quarter, the following work was undertaken:

- Surveyed three mine sites to identify a grazing PMLU landform with slopes > 15%;
- Undertook slope analysis and designed paddock layouts for two prospective mine site partners;
- Collaborated with researchers and a virtual fencing company to clarify opportunities for the integration of this approach to moving livestock within the study;
- Received Animal Ethics approval from the Department of Agriculture & Fisheries Animal Ethics Committee undertake the study; and
- Supported the most promising mine site location in moving forward with the implement grazing treatments prior to the next growing season in the Bowen Basin.

C36043
Using Large Floating Islands to Promote Aquatic and Terrestrial Biodiversity in Pit Lakes

Edith Cowan University
Mark Lund

Value:	$697,290
Report Expected:	March 2027
Industry Monitor/s:	Andrew Lau John Watson Ned Stephenson
ACARP Contact:	David Drakeley

Previous projects C27043 and C29049 have demonstrated that closure of pit lakes as aquatic ecosystems is likely a viable, sustainable, and economically responsible option for post-mining land use. Riparian vegetation and littoral areas are critical ecosystem components that cannot be established before the lake is full.

Artificial floating islands (AFIs) can provide habitat for waterbirds and other fauna. Therefore, AFIs may be used to encourage waterbird usage, create habitat for fauna (including turtles, fish, frogs, macroinvertebrates, and terrestrial organisms) and as a source of plant propagules, and general habitat for fauna (aquatic and terrestrial) in pit lakes. Waterbirds are particularly important to aquatic biodiversity because they are vectors of plants, invertebrates, bacteria, fish eggs, and major sources of nutrients (N and P) through excreta. Propagules from AFIs can continually seed the pit lake during filling, potentially removing the need for companies to return after the lake fills to plant a riparian zone, especially as the upland vegetation is normally well-established by then limiting access to the shore.

The broad goal of this project is to develop the use of large-scale AFIs as a tool that can deployed by miners to

develop or improve biodiversity in their pit lakes making them suitable for closure as aquatic ecosystems or demonstrating improvement for NUMAs.

We will investigate the effectiveness of AFIs by testing pairs of pit lakes across Western Australia, New South Wales and Queensland. In each pair, one lake will be treated with an AFI and the other left as a control. Using previous data collected at the sites in projects C27043 and C29049 and extending this monitoring in this project we can test the effectiveness of AFIs using a Before/After/Control/Impact (BACI) study design.

Current project activities:

- Field trips to install the island are organised for August;
- We presented on findings generated from our recent ACARP work at the 2024 IMWA conference.

Geotech

C29005
System for Rock Fall Analysis Field Trial

CSIRO
Marc Elmouttie
Peter Dean

Value:	$321,268
Report Expected:	September 2024
Industry Monitor/s:	Matt Tsang
ACARP Contact:	Cam Davidson

Systems to detect, monitor and analyse rock-falls in open pit mining operations have the potential to improve operational safety, improve calibration of rock fall simulators (restitution coefficients), and importantly provide quantitative data to justify current standoff designs. A monitoring system that can accumulate a large database of rock fall events across the full strike length of highwalls is required. The use of existing monitoring systems (radar, vision, lidar) as well as knowledge of the wall geometry, geology (rock mass types) and structural characteristics (defect orientations and intensities) has potential to support detection of events (potentially in real-time) and detect rock fall movements accurately enough for determination of trajectories (bounce kinematics), impact locations and final resting positions. This project will field trial a prototype system which will consist of software and computing hardware to integrate data from radar, vision and microseismic monitoring systems.

CSIRO on-site trials of the vision-based sub-system have begun and site trials are being organised. It is planned that a site investigation will occur in the next quarter in preparation for field deployment.

C33040
Machine Learning for Rockfall Analysis

University of Newcastle
Anna Giacomini
Klaus Thoeni
Marc Elmouttie

Value:	$342,240
Report Expected:	November 2025
Industry Monitor/s:	Matt Tsang
ACARP Contact:	Cam Davidson

The project proposes using machine learning (ML) for rockfall analysis. The objective is to identify a rapid and reliable method for estimating the location and energy of rockfall events at the base of a highwall, effectively mitigating the associated risks without the need to run specific rockfall simulations. The main outcome for the industry will be an ML-based tool to manage rockfall hazards at the base of highwalls.

In the quarter, the performance of several different machine learning (ML) models was evaluated. The models analysed included Artificial Neural Network (ANN), K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Random Forest (RF), Extreme Gradient Boost (XGB), and Symbolic Regression (SR). The predictions from these models were compared with the Linear Regression (LR) predictions from Stage 1. Among all the ML models tested, the LR and the SR are the only ones that produce a formula that can be easily used by engineers. The results obtained with the ML models are summarised in Figure 1, which displays the goodness of fit (R2 score) ranging from zero to one, with one indicating a perfect fit of the data. E1 represents the total kinetic energy in Joules at the first impact on the floor, d1 represents the distance in meters from the position of the first impact to the toe of the wall, and df represents the runout in meters. The results in Figure 1 showed that the ANN model was the best performer in predicting energy, while the RF model best predicted the distances. Additionally, Figure 2 illustrates a comparison of the prediction versus simulation using LR and RF. However, the results showed a minor improvement only, indicating that incorporating more site-specific information might be necessary to achieve better predictions. To address this, considerable effort has been dedicated to identifying the material layers in the 3D models of the highwalls. Data provided by the sites, such as borehole data, is used to assign the material layers. Furthermore, the Python scripts developed in the previous quarter were adapted to extract 2D profiles with material layers. These scripts and masked walls will be used in the next quarter to generate a refined dataset that incorporates the new information.

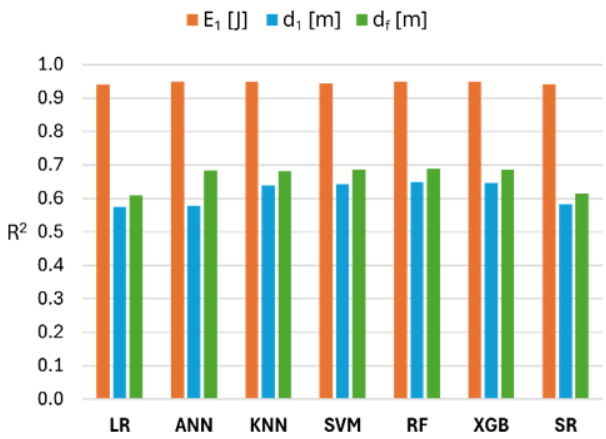


Figure 1. Comparison of different ML models using R2 score.

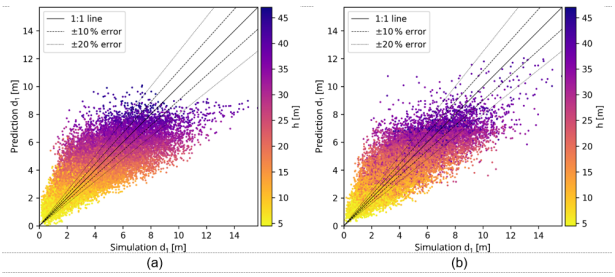


Figure 2. Example of results for d1 using (a) Linear Regression (Stage 1) and (b) Random Forest. Results are coloured by height to the seeder (i.e. release height).

C35022
Quantifying Hoek-Brown Disturbance Factor (D) for Coal Measures Through an Integrated Laboratory and Numerical Modelling Approach

University of Queensland
Italo Onederra
Zhongwei Chen

Value:	$355,776
Report Expected:	May 2025
Industry Monitor/s:	Adrienna Robotham Matt Tsang Peter Chern
ACARP Contact:	Patrick Tyrrell

The main objective of the project is to construct a comprehensive and generalised estimation method for the Disturbance factor (D) in coal measure strata. This mainly includes the quantification of the variation of D in response to blast-induced damage and scale effects to establish an effective guide for the definition of D in slope stability analysis.

In this quarter, the proposed empirical model for predicting the blasting-induced damage zone and the assignment of the D factor was evaluated using full-scale geometric data from a mine site. A small section of the high wall slope at the mine site was selected as the area of interest, along with a group of blastholes of varying lengths, stemming lengths, and dip angles. The proposed empirical model was then applied to map peak particle velocity (PPV) to define damaged zones and determine the D factor.

In this preliminary analysis, the overburden rock mass was assumed to be homogeneous, and each blasthole contained only one deck. The evaluation considered various primer positions (bottom, middle, and top initiation). Based on the predicted PPV contours, a simplified D factor assignment profile was determined and proposed as a practical method.

The next stage will focus on evaluating a heterogeneous overburden with bedding structures using multi-decked blastholes. Additionally, the project will also focus on the determination of p-wave velocity changes within the identified damaged zone using experimental and modelling data.

C36017
From Open Pit to Pumped Hydro Energy Storage, a Focus on Low Wall Stability

University of Newcastle
Anna Giacomini
Jubert Pineda
Olivier Buzzi

Value:	$405,500
Report Expected:	October 2026
Industry Monitor/s:	Andrew Lau Shaun Booth Troy O'Reilly Tyron Domenici
ACARP Contact:	David Drakeley

The objectives of the project are to identify the fundamental failure mechanisms of a low wall in the context of pumped hydro energy storage, and provide guidance to mitigate the geotechnical failure risks.

In the quarter, we have:

- Produced criteria for success for transitioning from Phase 1 to Phase 2 for the project.
- Identified one possible site to get data and materials from (some data have been provided but we are still waiting to get materials). The discussion is ongoing, two visits took place by the research team. Some logistical difficulties are imposing delays to get the material to the laboratory and proceed with the planned experimental program and investigations.
- Conducted some preliminary reduced scale experiments on the erosion of the spoil pile due to wavelets.
- Analysed the piezometer data and started processing the 3D spoil models to quantify possible deformations between surveys.

Preliminary reduced scale experiment on erosion:

- A portion of the water engineering flume of the civil engineering laboratory was used to create a basin in which four different reduced scale spoil piles were created (see Figure 1) using a rockfill material (clayey

gravel) quarried from the south coast of New South Wales. Particles larger than 19mm were sieved out. The piles were 30cm high, 50cm wide, with a batter slope of 15°, 25°, 35° and 45°. The piles were separated by a Perspex sheet. The water level was increased to mid pile height and a fan was used to create wavelets. The experiment was left to run for three days. After three days, clear erosion was observed on the steepest spoil pile, some minor erosion occurred on the 35° pile; no erosion occurred on the two flattest piles. This preliminary experiment confirms that it is possible to address the erosion risk by lowering the batter slope. The use of Digital Image Correlation is being trialled to quantify the extent of erosion. The mechanics of slope erosion by a wave is also being reviewed to understand the interplay between particle size, wave size/frequency and pile size.

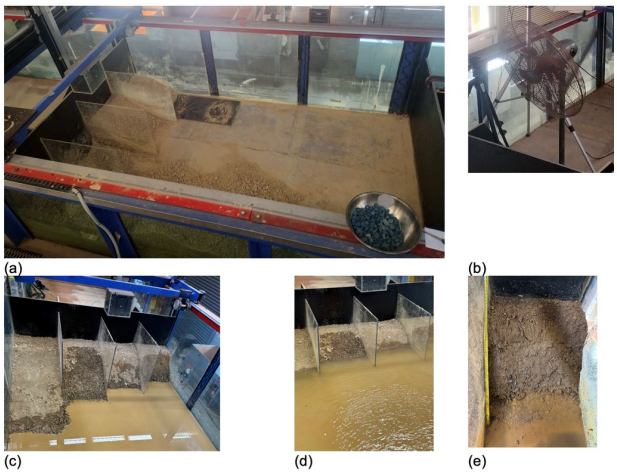


Figure 1: (a) view of the portion of the flume used to conduct the test, (b): fan used to create wavelets, (c): 4 spoil piles with raising water level, (d); view of two central piles with established water level and wavelets, (e): steepest spoil pile after erosion.

C36021
Measuring the Tensile Strength of Thin Units in Coal Measure Rocks using a Comminution Approach

University of Queensland
Dion Weatherley
Karina Barbosa
Katerina Savinova

Value:	$214,100
Report Expected:	July 2025
Industry Monitor/s:	Andrew Lau Jianping Li Matt Tsang
ACARP Contact:	David Drakeley

While testing for strength is typically done by compression, there is a need to measure intact tensile strength to develop site-dependent properties. A solution can be borrowed from comminution with the potential to derive rock tensile strength from drill chips (i.e., crushed rocks) and drilled mini-core (<20mm in diameter and at 1:1 ratio of width to height) of a representative sample and applied to the mining/geotechnical sector. The project aims to demonstrate the utility of the Short Impact Load Cell (SILC) instrument for testing coal measures overburden rock types, including sandstone, siltstone, and tuff, and link this information to geological variability, texture and mineral composition. This project will also develop a refined methodology for coal measures, particularly around sample selection, preparation, and testing, to provide reliable indices for translation into reasonable approximations of intact rock properties for tensile strength.

Work to date:

- Several consultation meetings have taken place with the Industry Monitors;
- Literature review of tensile strength measurements, appropriate sample preparation methodologies and breakage tests with the SILC device;
- Received two overburden intervals (several different lithologies) of drill core for detailed logging, sample preparation and conducting breakage tests;
- Employed three vocational students to help with sample preparation;
- Prepared a nearly-complete set of samples for the sandstone interval (280 cylinders) that are ready for breakage tests. These include mini-core with diameters of 6mm, 8mm, 10mm, and 15mm drilled perpendicular and parallel to bedding.

Work planned for the next quarter:

- Continue with sample preparation and drilling mini-core from tuffaceous siltstone/siltstone;
- Further investigation into tensile strength of different rock types;
- Ongoing consultations with the Industry Monitors;
- Continue investigating and assessing geotechnical properties of the interpreted rock types/geological domains of interest. If possible, investigate results of the more common geotechnical tests, such as slaking, plasticity and rock strength; and
- Start analysing results of the SILC breakage tests.

C36023
"SCANDY" - A handheld Imaging System for Real Time Spoil Categorisation

University of New South Wales
Simit Raval

Value:	$178,050
Report Expected:	April 2025
Industry Monitor/s:	Adrienna Robotham Ned Stephenson Tim Vangsness
ACARP Contact:	Patrick Tyrrell

The project aims to establish a user-friendly system for coal spoil characterisation employing computer vision and advanced deep learning networks to enhance real-time accuracy.

Thousands of coal spoil piles smartphone images, captured from mines in New South Wales and Queensland under previous project C29048, were utilised to construct Explainable AI (XAI) models (Fig). Data from the mining sites was curated and labelled to ensure a thorough spread across all the four coal spoil categories. A variety of deep learning models, including vision transformers, convolutional, and residual networks, were devised. Diverse data partitioning approaches were also employed to guarantee the robustness and generalisability of the model. Training and testing were carried out on each site's data independently as well as collectively to assess the performance and interpretability. Current testing is yielding over 70% accuracy in the characterisation. Further investigation is underway to develop the optimum model that works on the handheld device.

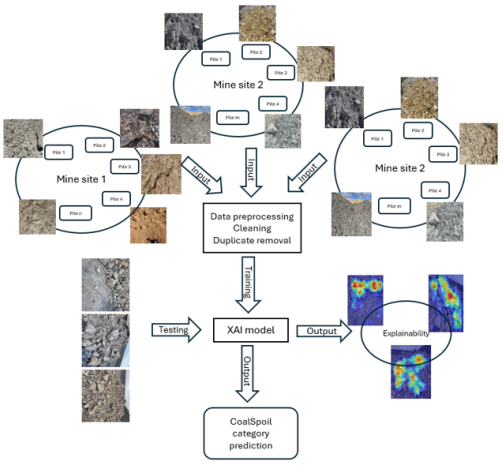


Fig. Overall data pipeline and architecture.

Maintenance and Equipment

C26020
Preventing Fatigue Cracking Via Proactive Surface Dressing

Bureau Veritas AIRS
Simon Krismer

Value:	$126,940
Report Expected:	October 2024
Industry Monitor/s:	Shane Saunders
ACARP Contact:	Patrick Tyrrell

Condition monitoring mining equipment and structures for fatigue cracking is costly. Proactively dressing surfaces susceptible to fatigue cracking could be significantly cheaper than condition monitoring in terms of labour costs and downtime. This project will assess the effectiveness of using surface linishing to remove accumulated fatigue damage. Surface linishing is a cheap, readily accessible technique that requires no special tooling. The lab testing phase is almost completed, with just a few additional samples to run to provide statistically significant data.

The results of the lab testing so far have confirmed the premise of this research project, that it is possible to significantly extend fatigue life and prevent fatigue cracking by removing a thin layer of material from the surface. Work has commenced on drafting the final report, which should be completed by end of September.

C33034
Dozer Suspension Seat to Reduce Body Vibration

University of Queensland
Danellie Lynas

Value:	$83,107
Report Expected:	September 2024
Industry Monitor/s:	Shane Apps Tim Gray Troy O'Reilly
ACARP Contact:	Cam Davidson

The project objective is to evaluate the effectiveness of an innovative passive vibration and movement cancelling seat prototype in reducing dozer operator exposures to excessive whole-body vibration during normal operation at surface coal mines. This project extends C23022 and C26026 through an evaluation of a potential engineering control. Previous project data indicates dozers are associated with whole-body vibration levels that frequently exceed the upper limit of the Health Guidance Caution Zone defined by ISO2631.1. Project C26026 provided the technology to allow continuous remote monitoring of floor and seat accelerations, as well as simultaneous GPS data.

An innovative passive suspension system has been patented and successfully tested in lab-based experiments recreating vertical vibration exposures from several different types of commercial vehicles and in a field-based experiment evaluating an on-road truck application. The design was found to reduce whole-body vibration exposures by 50% compared to conventional, commercially available mechanical and air-suspension seats. Based on these preliminary results, the seat suspension design appears to have the potential to substantially reduce operator exposure to whole-body vibration. Field testing of the prototype seat has been completed. Analysis of the results is almost complete. The draft final report is being drafted for submission.

C33036
Radar Tyre Monitor System

CSIRO
Luke Powell
Pat Humphries

Value:	$132,382
Report Expected:	September 2024
Industry Monitor/s:	Brendan Wilkins Rob Fraser Tim Gray
ACARP Contact:	Cam Davidson

Underinflation and/or overloading of mine truck tyres causes undue cyclic stress to the internal steel cords,

causing them to fatigue. "Zipper" failures can occur when such damaged tyres are reinflated, potentially causing serious injury or fatality. This project is undertaking the development and trialling of a monitoring system for haul truck tyres to identify tyre fatigue. The proposed system would consist of a continuous monitoring sensor combined with software analytics that will seek to identify and characterise significant changes in the tyre structure that correlate with incipient failure modes.

The project is currently in the final stage nearing completion, with the report almost ready for submission to the industry monitors for review. Some final data processing is being completed to aid in knowledge transfer, assisting with formatting the data in such a way that is suitable for presentation in report format.

C34031
Reducing Noise Emitted by Heavy Vehicles in Open Cut Coal Mines

University of Technology Sydney
Mahmoud Karimi

Value:	$231,645
Report Expected:	August 2024
Industry Monitor/s:	Brendan Wilkins Tim Gray
ACARP Contact:	David Drakeley

The draft final report has been submitted to the Industry Monitors for review.

C36019
In-situ Slew Bearing Scanner for Shovels

Ascribe Engineering
Matthew Robinson

Value:	$150,000
Report Expected:	February 2025
Industry Monitor/s:	Brendan Wilkins Tim Gray Tyson Burkitt
ACARP Contact:	Patrick Tyrrell

The aim of the project is to:

- Develop an in-situ scanner that can examine the slew bearing rails on a shovel for damage and hence provide mine sites with an accurate assessment of the condition, remnant life and replacement strategy; and to
- Undertake a trial scan of a shovel slew bearing using the developed scanner as a proof of concept.

The PCB boards were manufactured and have been assembled with the various sensors and other instrumentation. The data logger has been coded and the overall system has undergone preliminary bench testing. Some progress has been made on the sensor support structure design, but further finalisation of some aspects is needed. The work planned for the next quarter includes:

- Finalisation of the support structure design;
- Manufacture of the scanner support structure;
- Final bench testing of the scanner; and
- Trial fitment within a shovel slew bearing.

Health and Safety

C36033
Live Monitoring of Workplace Exposures In Surface Mobile Equipment

SafeOperate
Andrew Westaway

Value:	$152,000
Report Expected:	March 2025
Industry Monitor/s:	Shane Apps
ACARP Contact:	Patrick Tyrrell

The project objectives are to:

- Manufacture and installation of seat and cab vibration monitoring hardware into eight haul trucks at Mine1;
- Develop alerts for whole body vibration monitoring for actioning through site TARP systems;
- Develop display of GPS located data and provide regular reports for haul road performance assessment.

The project status:

- Manufacture of required hardware has been significantly delayed due to lead time for key electronic components, with parts forecast at this stage to arrive during August/September, hardware installation likely to be completed in October with implementation of remaining objectives targeted to be complete prior to end of 2024.

COAL PREPARATION

Maintenance and Equipment

C35036
Autonomous Stockpile Dozing: Quantifying Viability

University of Queensland
Ross McAree

Value:	$352,797
Report Expected:	September 2024
Industry Monitor/s:	Chris Huth Chris Jackson Frank Mercuri Jimmy Pollack Peter Shumack
ACARP Contact:	Patrick Tyrrell

This project explores the feasibility of using semi-automated bulldozers for managing coal stockpiles. Bulldozers are essential for constructing and maintaining these stockpiles, distributing and repositioning material from the piles created by stackers to extend the stockpile, and returning material to the reclaim valves. A significant hazard in these operations is the risk of bulldozers and their operators being engulfed by sudden material collapses near reclaim valves. To mitigate this risk, the project aims to implement unmanned, semi-autonomous bulldozers that can autonomously navigate and manage material movements, adapting to dynamic supply-demand conditions.

The primary goals of this project are to:
- Assess the technical feasibility of semi-autonomous bulldozers in performing stockpile management tasks efficiently, effectively, and safely; and to
- Evaluate the business implications by analysing the cost of technology implementation against its operational benefits.

During this quarter, the project has focused on analysing data from a field campaign conducted over a three-week period in the previous quarter. This analysis aims to understand the operational efficiencies and identify potential improvements that semi-autonomous bulldozers might bring. Some periods of data loss occurred for unknown reasons, and workarounds are being developed to accommodate these losses using redundancy in the data Simultaneously, we have continued the development and testing of semi-autonomous planning based on insights gained from the data analysis.

C36028
Continuous Stockpile Cavity Warning System - Feasibility Assessment

CSIRO
Wayne Stasinowsky

Value:	$191,600
Report Expected:	April 2025
Industry Monitor/s:	Kevin Rowe Michael Booth Naresh Racha
ACARP Contact:	Ben Gill

The project objectives are to:
- Conduct a feasibility assessment for a system that will allow the mine to monitor the stockpile continuously in real time and give real-time warning of a developing void to the dozer operator;
- Model the responses numerically to determine that there is sufficient resolution to detect dangerous voids; and to
- Test the technique using scale models.

Progress during the quarter:
- Scale model testing has continued with positive results suggesting that a cavity of 2m diameter may be detectable in a dry coal stockpile;
- Scale model testing will continue to determine the limits of detectability for both dry and wet coal;
- Numerical modelling is underway with open-source modelling software, GPRmax. Parameters are currently being modified as needed to determine if numerical models will match scale model results; and
- Radars with different frequencies are currently being sourced to enable a test of signal penetration through a full-size stockpile.

Dewatering

C27016
Eriez HydroFloat in Plant Evaluation

Eriez Magnetics
Darren Mathewson
Liam Davis

Value:	$155,600
Report Expected:	October 2024
Industry Monitor/s:	Han Hooi
ACARP Contact:	Ben Gill

The Eriez HydroFloat is a small footprint, high capacity, coarse particle flotation technology capable of recovering coal from a fine (eg -2.0 +0.25mm) material stream using both density and surface chemistry properties of the feed. This hybrid technology combines the capacity and throughput of a density separator, with the selectivity of flotation.

The yields from 19 tests on the TBS feed stream at the first site were very high at an average of 97.1% (ad) at low average product ashes of 8.8% (ad). The tailings ashes were high at an average of 75.4% (ad) and the combustibles recoveries were extremely high at an average of 99.2% (ad). As expected, the greatest variation in yield was in the +1.4mm size fraction, which ranged from 79 to 96.3% (averaged 89.4%) (ad). The yield of the other size factions was >95% (ad), on all but one occasion. The Organic Efficiency for the -2.0+0.25mm fraction was up to 99.7%.

The Whiten equation was curve fitted and showed cutpoints between 1.80 and 2.20 RD with -2.0+0.5mm Eps of between 0.087 and 0.166 for the four best tests. Due to the higher than expected cutpoints, there is often only one, or zero, float-sink fractions above the calculated cutpoint, so the curve-fit is significantly overestimating the cutpoint and the Ep. Being the very first Australian HydroFloat trial, it was also expected that some results would be sub-optimal.

Testing at a second site was delayed and then circuit changes precluded test work at that site. A test work plan is being developed with an alternate site.

C29060
Tailings Management - Dewatering Flume Site Trials

University of Newcastle
Craig Wheeler

Value:	$278,500
Report Expected:	October 2024
Industry Monitor/s:	Kevin Rowe Peter Shumack
ACARP Contact:	Patrick Tyrrell

The objective of this project is to further refine and conduct site trails of a dewatering flume developed in C27067. The aim of the flume is to increase the solids content of the tailings entering the tailings dam and recover water before it is deposited in the tailings dam. The recovered water would be recycled back to the CHPP as process water, thus limiting the volume of water stored in the tailings dam and reduce, or eliminate, the use of secondary flocculant in the tailings dam.

Original onsite testing is complete and further testing at a new site is progressing under a project extension. New feed material is currently being tested over a range of concentrations and flowrates to optimise solids recovery.

C33049
Emerging Pulsed Power Technology for Dewatering Mineral Tailings

University of Queensland
Mansour Edraki

Value:	$277,630
Report Expected:	August 2024
Industry Monitor/s:	Dan Delahunty Jack Lauder
ACARP Contact:	Ben Gill

The draft final report has been submitted to the Industry Monitors for review.

C33050
Dewatering Efficiency of Fine Flotation Concentrates by De-Aerating Froth Products - Plant Demonstration

University of Queensland
Yongjun Peng

Value:	$627,923
Report Expected:	September 2024
Industry Monitor/s:	Frank Mercuri Naresh Racha Shivank Vijayakumar
ACARP Contact:	Ben Gill

The objectives of this project are to:

- Develop large demonstration-scale mechanical and vacuum deaerators which are fully automated and can run continuously in plants;
- Identify optimum operating conditions and control strategies through continuous plant trials;
- Evaluate and optimise equipment stability, wear, maintenance requirement and operational costs; and to
- Identify equipment size and key parameters for future full-scale operation in plants.

During this quarter, UQ researchers and DADI engineers have been actively engaged in installing the vacuum deaerator at Mine Site 1. As shown in Figure 1, the vacuum deaerator has been successfully installed and trialled at this site.

During the trial, different vacuum pressures were tested to study their impact on stable froth deaeration. Additionally, two different froth collection systems, suction and inflow types, were tested to investigate their effect on stable froth deaeration. The results indicated that vacuum pressures below -40 kPa could achieve over 98% froth reduction with the froth inlet speed increasing as vacuum pressure decreased. The suction froth collection system was found to be able to handle a larger mass of froth but with a higher water content. In contrast, the inflow froth collection system could achieve the same level of froth reduction with less water intake, indicating it more energy-efficient for froth deaeration.

After the froth deaeration treatment on top of the thickener, the subsequent filtration efficiency of the flotation concentrate was also improved during the plant trial. Based on the plant trial, the optimum control strategy involves maintaining vacuum pressure between -60 kPa and -80 kPa and using the inflow froth collection system. Therefore, the vacuum deaerator can not only efficiently break the stable froth on top of thickeners in the plant, but also improve the subsequent dewatering efficiency.

Figure 1. Vacuum deaerator installed on site 1

C33051
Hybrid Microwave Technology for Dry Stacked Tailings Applications

University of Queensland
Christian Antonio

Value:	$121,335
Report Expected:	October 2024
Industry Monitor/s:	Frank Mercuri Kevin Rowe Naresh Racha
ACARP Contact:	Ben Gill

One of the most pressing challenges facing the mining industry today is the increasing frequency of catastrophic tailings dam collapses. Such events are known to cause significant environmental damage as well as loss of life. There is a strong industry push to move away from wet tailings dams to drier and safer options. A viable alternative to tailings storage in dams is Dry Stack Tailings (DTS) technology. This project proposes a new approach that could reduce tailings moisture contents to levels required for dry stacking – the use of Hybrid Microwave (MW) Technology. This approach combines microwave treatment with conventional dewatering techniques. This method could bridge the moisture content gap between conventionally dewatered material and Dry Stack Tailing requirements.

The project aims to evaluate the feasibility of a continuous process and measure the energy requirements to achieve different product moisture content. Finally, it will provide a concept for a microwave-assisted dewatering process for future research studies.

Progress during this quarter includes:

- Energy calculations from the experiments are on-going and an external consultant is assisting with the techno-economic analysis of the process;
- Additional experiments were conducted to fill in gaps in data;
- Results analysis and report writing is ongoing.

C34051
Cost Effective Approach for Coal Tailings Dewatering using Semi Inverted (SIV) Hydrocyclones

University of Queensland
Christian Antonio

Value:	$174,500
Report Expected:	September 2024
Industry Monitor/s:	Jenny Goh Naresh Racha Tom Wilson
ACARP Contact:	Ben Gill

The application of coagulation, flocculation, and mechanical dewatering units such as belt press filters (BPF), centrifuges, and horizontal belt filters (HBF) is currently used by industry as a practical approach for dewatering coal tailings. However, there are still challenges that limit dewatering of coal tailings which affects the performance of these dewatering processes. These include the presence of clay materials, elevated fines and ineffective coagulation and flocculation methods, amongst others.

This project aims to develop a technologically and economically viable approach to reduce moisture content and capture fine clay particles in tailings to improve tailings dewatering outcomes, by using Semi-Inverted (SIV) Hydrocyclone Technology, followed by coagulation, and flocculation. The study aims to use the SIV to split a tailings sample into a coarse stream (underflow product), with reduced moisture content, and a clay-rich fines stream (overflow product). This will enable targeted processing of the two streams that could consequently improve the efficiency of downstream dewatering units. A potential tailings sample has been received for evaluation for use in this project.

Progress during this quarter include:

- Trials on coal tailings samples with different % solids content was undertaken on the semi-inverted cyclone at different cyclone angles (100-130˚), operating pressures (60-130kPa) and spigot size (45-60mm);
- Samples of the overflow and underflow were taken for each of the runs for % solid content analysis, particle size distribution and for coagulation/flocculation testing. Figure 1 shows the effect of spigot size on the % solids of the overflow (O/F) and underflow (U/F).

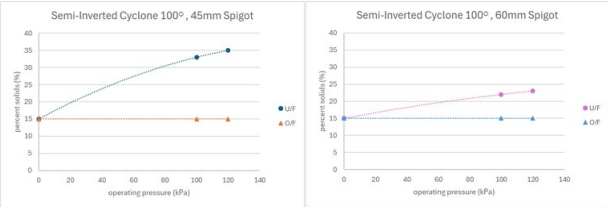


Figure 1: The effect of spigot size on the % solids of the U/F and O/F products

C35032
Improving the Dewatering of Fine Coal Tailings by Minimising Micro-Nano Bubbles

University of Queensland
Yongjun Peng

Value:	$238,470
Report Expected:	January 2025
Industry Monitor/s:	Han Hooi Naresh Racha Tom Henshaw
ACARP Contact:	Ben Gill

The objectives of this project are to:

- Understand how micro-nano bubbles are stabilised in fine coal tailings and evaluate their effects on the settling, filtration/centrifugation and compaction of solid suspensions;
- Evaluate physical and chemical methods in collapsing micro-nano bubbles in enhancing the settling, filtration/centrifugation and compaction of solid suspensions; and to
- Demonstrate the benefit of breaking micro-nano bubbles to fine coal tailings dewatering.

During this quarter, researchers investigated the effect of chemical deaeration on dewatering to address the second project objective. A range of oily and water-soluble anti-foamers and surfactants, which modify liquid surface tension and solid wettability, were examined in the context of tailings dewatering using the centrifugation method. The results indicated that traditional anti-foamers and surfactants had minimal or negative impacts on the dewatering efficiency. However, a superwetting oily surfactant, which effectively reduced microbubbles in stable froth, was found to enhance the centrifugation efficiency of the tailings significantly.

The effects of both physical and chemical deaeration on particle sedimentation were investigated. The findings revealed that both physical and chemical deaeration increased the sedimentation efficiency of the tailings.

C36025
Green and Effective Reagents for Centrifugal Dewatering

University of Queensland
Liguang Wang

Value:	$198,982
Report Expected:	December 2025
Industry Monitor/s:	Chris Denyer Naresh Racha Jenny Park
ACARP Contact:	Ben Gill

The objectives of this project are to:

- Screen and develop green reagents for dewatering of coals and tailings over a broad size range to achieve low product moisture level and high solids recovery; and to
- Provide a guide for reagent selection in dewatering of Australian black coals and tailings.

The research team is currently in the process of securing reagent samples and coal slurry samples and analysing their properties.

Environmental Improvement

C29042
Tailings to Topsoil

University of Newcastle
Ken Williams

Value:	$765,300
Report Expected:	September 2026
Industry Monitor/s:	Bill Baxter Paul O'Loughlin Phillip Enderby
ACARP Contact:	Patrick Tyrrell

The original project commenced in 2020 to develop a co-utilisation and soil improvement program that addresses the environmental challenge of tailings management for mining operations. This transformational alternative for tailings management research optimises existing technologies for dewatering, delivery, and soil remediation processes into an integrated "pit to paddock" mobile plant emplacement and cultivation system. An extension of this project (Stage 2) began in September 2023.

A plant growth field trial at Mine 1 commenced earlier in the year and is currently being monitored (Figure 1). TDR-315N sensors have been placed at Mine 1 (Figure 2.) for real time monitoring of volumetric water content and soil temperature. A second plant growth field trial site has been identified at Mine 2 and planning for the trial is currently underway.

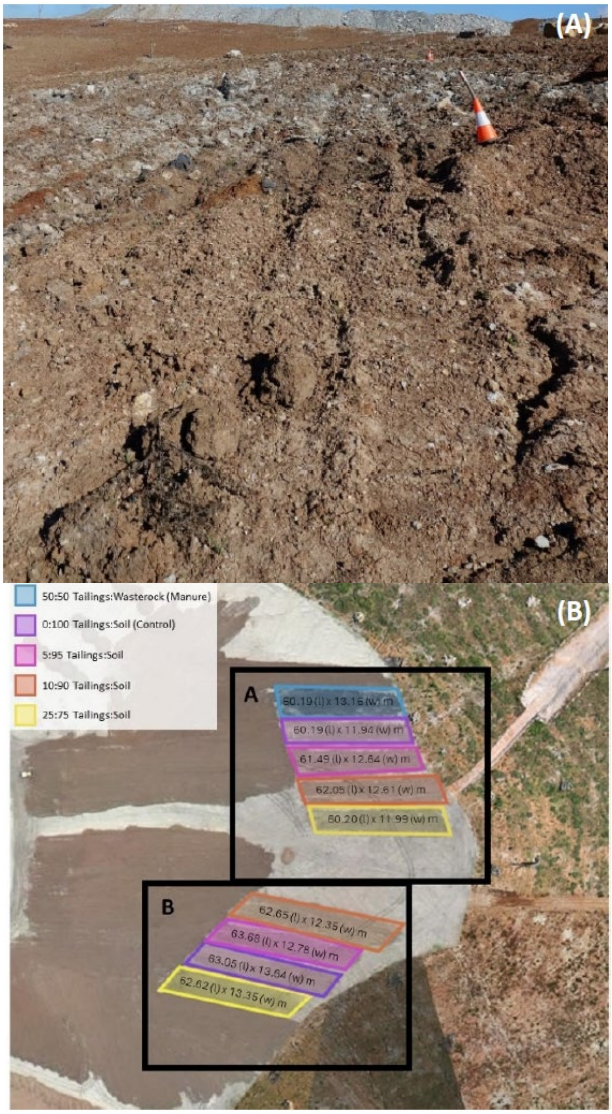


Figure 1: (A) Early-stage photo of field trial site at Mine 1. Orange cones demarcate plots. (B) Overview of field trial plots.

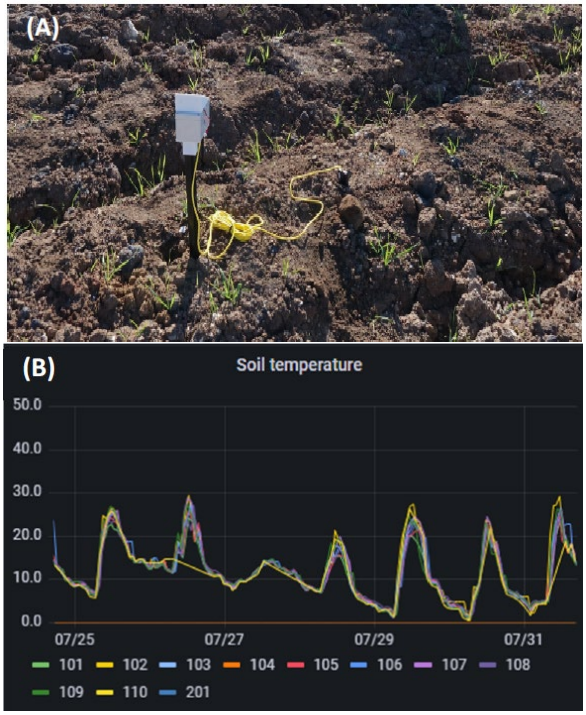


Figure 2: (A) Photo of TDR Sensor at Mine 1 and (B) screenshot of soil temperature recorded from sensors in real time.

C35019
Utilisation of Coal Mining Tailing in Australian Cement Production

Central Queensland University
Hassan Baji

Value:	$277,017
Report Expected:	October 2024
Industry Monitor/s:	Kevin Rowe Luke Dimech Shaun Booth
ACARP Contact:	Patrick Tyrrell

This project proposes a new framework of the circular economy and sustainable development by incorporating coal mine tailings as an alternative raw material in cement and concrete production instead of being a source of risk in polluting the environment. The project, which is in partnership with Holcim Australia and Cement Australia, has two major parts:

- the use of treated coal tailings as a supplementary cementitious material (SCM) will be investigated
- the feasibility of using coal tailings as a raw material in producing Portland cement will be explored.

Following is a summary of activities completed in the quarter.

Coal tailings as SCM: This work plan has been completed. In the final stage of this plan, the water demand and workability of blended cements made with 20% coal tailings treated at 850°C and 80% Portland cement were investigated. Extra water was added to the blended cement mortar samples to match the flow of the control sample. The results are summarised in Table 1.

Table 1: Workability and strength of blended cements with adjusted water to match flow of control sample.

	cement	coal tailings	water	sand	Flow	Compressive	Strength	(MPa)
Mix	g	g	g	g	%	3-day	7-day	28-day
Control	450	0	225	1350	101	34.51	44.06	55.85
Site 1 850 °C	360	90	260	1350	102	22.06	31.68	47.14
Site 1 850 °C	360	90	265	1350	103	23.48	30.88	46.71
Site 1 850 °C	360	90	265	1350	98	25.38	34.38	47.83

The results show that less than 20% extra water is needed for the blended cement samples to achieve flow of control sample satisfying the AS 3582.4 standard. Sites 1 and 3 coal tailings mixes produce a 28 day compressive strength of about 0.85% of that of the control mix, rendering as grade 1 pozzolans as per AS 3582.4 standard. For Site 2, it can be classified as grade 2 pozzolan with a strength activity index of 84%.

Coal tailings in clinker production: Several trials of clinker mix were prepared and tested. Free lime in all clinker mixes was controlled under the Australian standard requirements. Using one of the coal tailings sites, cement was successfully produced and tested for compressive strength, soundness, setting time, and fineness. The cement satisfied all the standard requirements.

Cost-benefit analysis: Cost analysis has been completed to determine the cost of producing concrete using treated coal tailings and compare it with that of conventional concrete. The results show that the cost of producing one tonne of blended cement with treated coal tailings is comparable to that of conventional Portland cement, and in some cases, lower.

The draft report is under preparation for submission in September.

C35033
Non-invasive and Real Time Monitoring of Slurry Tailings Density and Velocity in the Transmission Pipeline using Electrical Resistance Tomography Method

University of Queensland
Chenming Zhang
David Williams

Value:	$259,000
Report Expected:	March 2025
Industry Monitor/s:	Angus Morrison Naresh Racha Peter Shumack
ACARP Contact:	Patrick Tyrrell

The objectives of the project are to:

- Develop a resistivity inverse model that converts the longitudinal and cross-sectional resistivity tomography of coal slurry to its density and velocity, accounting for the effects of temperature, EC, air content and coal tailings mineralogy;
- Test the system at a coal transmission pipeline for in situ and real-time monitoring of the slurry transport conditions; and to
- Verify the monitored results with those obtained using concurrent technologies.

During the quarter:

- For coal tailings settling tests are carried out in the 1m long, 0.2m in diameter large column. Process water varies between 1.33 and 7.38 mS/cm. Each test lasted for about seven days. It is found that electrical resistivity tomography (ERT) can well capture the increase of settled coal tailings density over time.

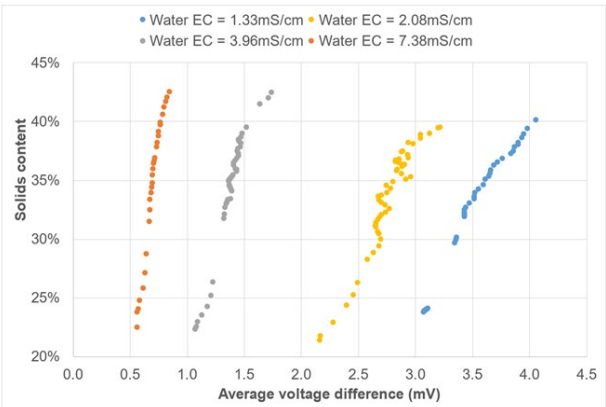


Figure 1 Correlation between solids content and average voltage difference measured by the ERT device

- The change in the conductivity domain over time during settling experiments were analysed.

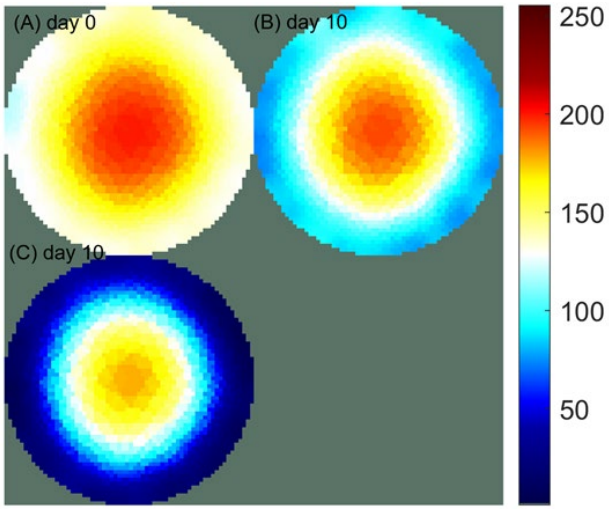


Figure 2 changes in the conductivity domain over time

Figure 3 Location of the trial site

- A mine site visit was carried out on 30 July. During the visit:
  - the potential location for deployment was identified,
  - the power supply for the monitoring system was planned,
  - the system will use 4G to deliver data to an online dashboard in real time,
  - the system installation will be carried out during times when the site is not in operation, which occurs once per month;
- The pipeline is constructed and the experiments can be started, once the slurry samples are received from the site.

Figure 4 set-up of the pipeline test

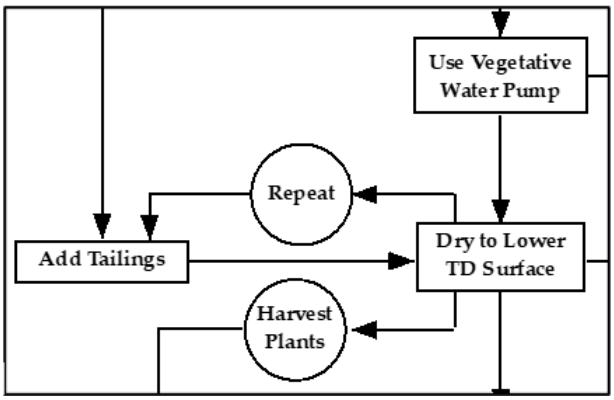
C35048
Cost Effective Rehabilitation of Tailings Dams

CSER Research
Carmen Castor
Mike Cole

Value:	$973,580
Report Expected:	March 2027
Industry Monitor/s:	Andrew Lau Brooke York Shaun Booth
ACARP Contact:	Patrick Tyrrell

This project develops the research undertaken in C27009 and C29041 and incorporates the final stages of C34030 towards cost-effective rehabilitation and closure of tailings dams. It aims to assist in developing a final land use plan with each mine and further test tailings amelioration techniques to maximise success for the native vegetation used. In addition, we will work to maximise plant and soil biodiversity of the dams and their surrounds.

Planning continues for the tailing's dams in New South Wales and Queensland. There is considerable interest in applying the cyclic part of the model (extract below) to potentially increase the dam capacity, perhaps by up to 40%, whilst providing a more stable base to the dam at closure. The use of cyclic filling will allow the determination of final land use to be delayed until the latter phases once the stable base has been formed.



A Queensland site has been selected for further work and preliminary substrate analysis and watershed analysis are being planned. The process to be applied at that site will be determined in the landscape planning that will follow collection of baseline data.

Germination experiments continue under temperature-controlled conditions. We have now tested several of the less common species which will be incorporated into the surrounds of the dams. The testing evaluates different storage times and seed treatments appropriate for the species used. This information helps with the long-term planning of sites in general towards rehabilitation as seed supply is limited for some species. This work aims to optimize seed resource usage for ecological rehabilitation outcomes.

Fine Coal

C29061
Improving Flotation Recovery and Throughput with a Combined Method

University of Queensland
Liguang Wang

Value:	$199,000
Report Expected:	August 2024
Industry Monitor/s:	Clinton Vanderkruk Doug Field-Akred Kevin Rowe
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C29065
Wash Plant Fines Testing Methods Enhancement

McMahon Coal Quality Resources
Chris McMahon

Value:	$197,330
Report Expected:	August 2024
Industry Monitor/s:	Frank Mercuri Jason Schumacher
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34002
Full Scale Beneficiation of Coal Fines by Novel Agglomeration

University of Newcastle
Kevin Galvin

Value:	$3,283,000
Report Expected:	November 2024
Industry Monitor/s:	Jason Schumacher Jenny Goh Kevin Rowe Luke Dimech Paul Sainsbury
ACARP Contact:	Patrick Tyrrell

The objective of this project is to investigate the scale-up of a novel fine coal agglomeration technology through a study at full-scale. The project involves the design, commissioning and operation of the novel agglomeration technology. The feed source is expected to be a fine coal tailings stream suitable for the thermal market. The study will quantify the scale-up at 500m^3/h in terms of yield, ash, moisture and economic benefits. The novel agglomeration technology offers the prospects of a low capital investment for processing the fine coal tailings stream normally sent to the thickener.

This project involves a substantial scale-up from a 25mm diameter pipe configuration to a 350mm diameter pipe system requiring the flow of the slurry and binder through a single hole in an orifice plate to produce agglomerates. The emulsion was successfully produced at full scale using the air sparging column, and its performance verified through bench scale tests. However, the emulsion formed using salt water from the process water via an RO system was also less robust than the traditional NaCl salt-based binder used in the past, hence it was necessary to base the design on a pressure drop at the lower end of the usual range, at about 50 kPa. The recent work on the full-scale plant demonstrated the difficulty of utilising a single, 100 mm diameter, hole in the orifice plate, with poor agglomeration observed. The results suggested that the system does not scale directly, and that the collision efficiency with the emulsion binder is impacted negatively.

In the most recent work at full scale, the strategy was to identify the hydrodynamic conditions necessary to ensure agglomerates could be produced, and to then reduce the binder dose to lower levels using the conditions identified. This approach delivered for the first-time high combustible recoveries (~80%) and low product ashes (~10%) based on a lab separation of the downstream flow. The volumetric feed rate was lower than the targeted level due to the high pressure drop. The conclusion reached is that the technology does produce the rapid separation, but the process is inefficient at the current pipe size of 350mm diameter.

Additional funding was secured to develop further understanding of the scale-up of the technology. The current standard pipe configuration, with a diameter of 350mm, will be replaced by a new design based on a 100mm diameter pipe configuration. New design work is under way to develop this system covering a much broader range of conditions. We anticipate stronger performance at this reduced scale. The performance should also be improved by introducing better conditioning of the binder prior to the main pipe, via dilution with an inline mixer. The new work will also permit a higher salt concentration for the binder, and a more viscous binder. Our goal will be to secure the best possible economic binder dose for producing the agglomerates, and to also establish peak performance for a binder like that used previously. Simultaneously work is proceeding on the design for upscaling the 100mm pipe into a ten-pipe bundle arrangement ahead of a further trial at full scale.

C34040
Optimising the Diesel Droplet Size in Coal Preparation Plants

University of Queensland
Yongjun Peng

Value:	$231,157
Report Expected:	September 2024
Industry Monitor/s:	Albert Blom Han Hooi Jason Schumacher
ACARP Contact:	Ben Gill

The objectives of this project are to:

- Develop full-scale emulsification systems incorporating the online droplet size measurement;
- Determine the optimal diesel droplet sizes in representative coal preparation plants varying with coal type, water salinity and diesel dosing through statistically designed ON/OFF trials;
- Identify the most efficient and economic diesel dispersion system to achieve each optimal droplet size; and to
- Develop the most suitable diesel dispersion strategy for each representative plant through an assessment of flotation improvement, reduction of diesel consumption, hurdles to implementation (e.g. safety, ease of installation and conversion, ease of operation) and capital and operating costs.

The emulsification device requires some electrical adjustments to meet the long-term operational requirements at the site when it was tested in a plant. Site engineers have scheduled a qualified electrician to perform the necessary adjustments in August. Upon achieving site compliance, UQ researchers will continue to evaluate the emulsification device in the plant with a specific focus on generating optimal droplet sizes.

C34041
Coal Spiral for the 2020s

Mineral Technologies
Ian Mangelsdorf
Wendy Nutt

Value:	$199,646
Report Expected:	August 2024
Industry Monitor/s:	Dan Delahunty Naresh Racha Phillip Enderby
ACARP Contact:	Ben Gill

The draft final report has been submitted to the Industry Monitors for review.

C34043
In Plant Demonstration of the Next Generation Flotation System

University of Queensland
Liguang Wang

Value:	$258,347
Report Expected:	November 2024
Industry Monitor/s:	Kevin Rowe Nic Roberts
ACARP Contact:	Ben Gill

The objectives of this project are to:

- Build a prototype of the next-generation flotation system with low energy and maintenance requirements for coal preparation; and to
- Demonstrate the prototype in a coal preparation plant.

The prototype system is in transit to UQ and expected to arrive in mid-August. It will then be assembled and tested before being inspected by the Industry Monitors. A novel sparging system recently constructed at UQ will also be integrated into the prototype system. Preparation work focusing on ensuring mechanical and electrical safety will then be done prior to in-plant testing.

C34045
Real Time Automatic Measurement of Frother Distribution in a Coal Preparation Plant

University of Queensland
Liguang Wang

Value:	$124,560
Report Expected:	November 2024
Industry Monitor/s:	Chris Denyer Peter Shumack
ACARP Contact:	Ben Gill

The objectives of this project are to:

- Build a prototype for real-time automatic measurement of frother concentration; and to
- Evaluate and demonstrate the prototype at a participating site to maximise coal recovery and prevent the overfrothing ('froth out') problem.

The construction of the prototype for the automatic frother concentration measurement device is in progress. During this quarter, we added several hardware components, which are now ready to use. Further work is on track to increase the safety feature of the measuring tool, including installation of a sensor for detecting a solvent, a key ingredient of the formulated liquid. It is expected the prototype unit will be ready for initial testing by the end of next month.

A short site visit is planned for the next quarter to streamline the installation and testing of the prototype unit. During this visit, we will discuss with engineers at the participating site to address any remaining safety concerns and align experimental plans to maximise possible benefits for the participating site.

C35024
Froth Flotation Predicted v Actual Definition

McMahon Coal Quality Resources
Chris McMahon

Value:	$41,360
Report Expected:	March 2025
Industry Monitor/s:	Jason Schumacher Jenny Goh Mel Robbins
ACARP Contact:	Patrick Tyrrell

This project seeks to collate and evaluate data in froth flotation raw ash and product yield/ash outcomes from borecores and actual coal handling and preparation plants. Several froth flotation methods from borecores, including the pseudo-density method (with efficiency factors trialled to fit data) will be evaluated against actual data. Several deposits will be evaluated.

At the start meeting information was requested and further requests were made in February 2024, May 2024 and July 2024, with just one database received to date. Data processing has commenced but no outcomes are yet available for review. A further request for information will be made in August with one further database expected imminently, and a final database being pursued, though without further response to date from initial agreement of supply in September of 2023.

The outcomes of this project will be the definition of accuracy (precision and bias) information for varying coal types, in yield and product ash, with notes on methods relevant to the accuracy of outcomes. This will benefit the industry by providing a guide for use and defined accuracy of outcomes for the data and methods evaluated, and potentially saving very expensive mine, coal handling and preparation plant design and resource misrepresentation. The outcomes then will provide a financial risk reduction and/or evaluation enhancement.

C35031
Demonstrating Better Classifying Cyclones

Elsa Consulting Group
Andrew Swanson
Andrew Vince

Value:	$377,475
Report Expected:	April 2026
Industry Monitor/s:	Clinton Vanderkruk Jack Lauder Jenny Park Jimmy Pollack
ACARP Contact:	Ben Gill

The overall objective of this project is to leverage off the significant past ACARP research on better classifying cyclones, to build and demonstrate the industrial benefits of the new Flat Bottomed Classifying Cyclone Concept (FBCCC) at an appropriate scale, namely 380 mm

diameter cyclone. Specifically, coal-independent performance efficiencies will be determined using: 1. Size separation partition curves and related characteristic parameters α, d50 and Rf 2. Size-by-size Tromp curves and related characteristic parameters d50 and Ep. These will then be used as benchmarks to compare against such curves generated by existing technologies.

The first stage was to determine how small-detail FBCCC design adjustments impact on capacity/pressure/metallurgical performance characteristics prior to unit construction and testing. Western Sydney University (Centre for Infrastructure Engineering, School of Engineering) has developed and used a discrete element model (DEM), and the results of using said model suggest that unexpectedly high alpha values can be expected. Simulations have been used to identify dimensions for a 380 mm unit that is currently under construction by a well-established OEM.

Parallel work has established a suitable source of feed stock for testing the unit, the testing and analytical procedures to be followed, and the set up for the pilot plant testing.

The newly constructed FBCCC has been received and preparations being finalised to test a bulk sample of raw deslimed coal at pilot scale.

The project remains on schedule.

C35034
Working Effectively with Swelling Clays in Fine Coal Flotation to Improve Product Quality and Recovery

University of Queensland
Anh Nguyen
Ngoc Nguyen

Value:	$200,304
Report Expected:	March 2025
Industry Monitor/s:	Ed Provan Jack Lauder Jason Schumacher Luke Dimech
ACARP Contact:	Ben Gill

The project objective is to investigate effective measures (clay suppressants and wash water) to reduce ash (clay) content and increase recovery of fine coal flotation. Specific aims include:

- Characterise clay types and compositions in coal flotation feed, clay-coal liberation, and surface properties;
- Screen (design) and test clay suppressants to remove clay slime coatings;
- Design and conduct experiments to evaluate the effect of wash water hydrodynamics on reducing clay entrainment;
- Conduct experiments using mechanical cell, Microcel, and Jameson cell for evaluating and benchmarking effective of clay and ash removals. The ultimate goal is to deliver higher-quality products and opportunities to increase overall plant recovery by avoiding high ash/clay entrainment.

In this quarter we have completed testing the clay depressants for the samples from one mine site. The outcomes have been communicated and discussed with the Industry Monitors at a review meeting in June. The Industry Monitors are very interested in the results and committed to send more site samples to UQ for further test works. The UQ team is waiting for new samples from sites. Once we have received new samples, test works will be carried to provide systematic understanding of the clay depressants on coal flotation.

C35035
3D Particle Surface Composition Analysis for Flotation Using Micro CT

University of Newcastle
Rohan Stanger

Value:	$81,730
Report Expected:	October 2024
Industry Monitor/s:	Araz Ejtemaei
ACARP Contact:	Ben Gill

This project aims to characterise a suite of plant flotation samples using microCT surface analysis. The technique involves determining the composition (vitrinite, inertinite, mineral content) at each particles surface interface. The project will focus on +38um material for this technique development to suit this microCT instrument resolution.

Work in this quarter has revolved around the consolidation of results and final report preparation. The second suite of flotation samples have been taken and are being sent to the University of Newcastle. Once arrived, the intention is to treat these samples as a trial for commercial analysis.

C36026
Side-by-Side Analysis of Coal by Automated Micro-CT and Commercial Laboratory Testing

University of Newcastle
Rohan Stanger

Value:	$167,432
Report Expected:	April 2025
Industry Monitor/s:	Mel Robbins Michael Saxby Tom Wilson
ACARP Contact:	Ben Gill

This project aims to trial an automated sample carousel for a laboratory micro-CT instrument and compare data with standard testing for float/sink and petrographic analysis. The intention is to determine the speed and accuracy of micro-CT derived coal tests. If successful, it will provide an automated 3D analytical test method with

faster turn-around times and potentially lower costs. This automation trial will develop the work-flows needed to test the automated scanning, image reconstruction, particle recognition and analysis.

The current progress is that the automated stage has now arrived and is undergoing preliminary testing. A series of prototype 3D printed sample containers are being tested to align samples within the X-ray window (see Figure 1). The intention is to ensure that all samples fit within the analytical "Region of Interest" for downstream image analysis automation.

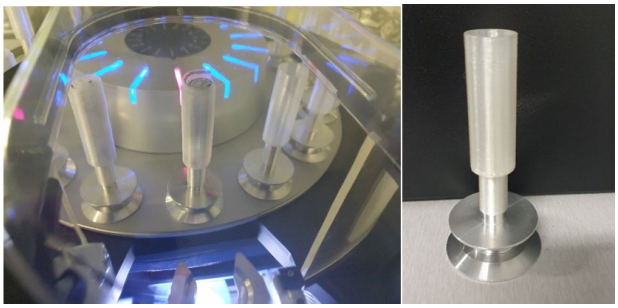


Figure 1. Photograph of automated sample carousel on micro-CT unit (left) with 3D printed sample containers allowing for direct connection with base mounts (also shown right).

Gravity Separation

C34046
Clay Type Effect on Magnetite Medium Properties in Dense Medium Cyclones

CSIRO
Clint McNally

Value:	$155,488
Report Expected:	September 2024
Industry Monitor/s:	Chris Denyer Frank Mercuri
ACARP Contact:	Ben Gill

The aim of this project is to examine how the clay component in a dense medium influences the performance and functioning of dense medium cyclones. It has been observed that when different types of clay are mixed into slurries with identical solid percentages, the resulting viscosities can vary markedly based on the type of clay used. Such variability has potential implications for the operation of dense medium cyclones.

A literature review was conducted to identify the types of clays found in Australian coal seams. Dense medium samples from various mines were collected and analysed for their Magnetite content and the type and quantity of clay present. These samples underwent Davis tube processing and X-ray diffraction (XRD) analysis, and the results applied to constructing synthetic dense mediums. The samples were also tested for settling rate and viscosity at RTP.

The constituent parts of the dense medium (different clay types and magnetite size grades) were tested to prepare various combination mediums for performance testing in the small dense medium circuit at QCAT. Synthetic (non-mine) dense medium samples, representing different clay characteristics, were also tested in a 150mm pilot plant DMC circuit at CSIRO QCAT to assess their influence on DMC operation.

The Small DMC circuit underwent commissioning, including sensor upgrades and refurbishment. The experimental program to investigate the effects of different clay types has been completed.

Data analysis is now underway, and the final report writing has commenced.

C34048
Using Clay Stabilised Medium for the Separation of Small Coal in a Dense Medium Cyclone

CSIRO
Andrew Taylor

Value:	$204,432
Report Expected:	October 2024
Industry Monitor/s:	Chris Denyer Frank Mercuri
ACARP Contact:	Ben Gill

The objective of this project was to demonstrate to the industry that small coal (2.0mm +0.1mm) can be processed in a DMC with good cut point control, good magnetic recovery and high yields when compared with spirals processing. The intent was to construct from this a business case for the introduction of small coal DMC circuits in Australian Plants.

From past ACARP work it has been determined that the effect of non-magnetics in the coal medium influences the stability of cyclones at low relative density cut point targets. While overseas, fine coal dense medium cyclones are used extensively (China, South Africa), in Australia, they are far less prevalent.

Work to date has involved the construction of the pilot plant circuit and testing of operating parameters, test work on deslimed coal through the hydrocyclone and spiral and part of the data analysis. There is more test work to be completed to compare a DSM DMC to the other two types of processing equipment and establish a comparison. Currently we are seeking additional plant feed sample to further the test work, however we will continue to analyse the existing data and continue the write up in the meantime.

Process Control

C33057
Foreign Contaminants Detection on Conveyor Belts Using Digital Imaging Processing Techniques and Coal Penetrating Sensors

Mincka Engineering
Fidel Gonzalez

Value:	$365,000
Report Expected:	August 2024
Industry Monitor/s:	Dan Delahunty Dave Young Kevin Rowe Phillip Enderby
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34039
Soft Sensor for Predicting Dense Medium Cyclones Performance

University of Queensland
Gordon Forbes

Value:	$189,300
Report Expected:	November 2024
Industry Monitor/s:	Araz Ejtemaei Peter Shumack Rick Jeuken Sam Rynne
ACARP Contact:	Ben Gill

This project aims to develop a soft sensor for predicting dense medium cyclone performance. The soft sensor will build on current state of the art DMC models, with the aim of including a wear model, as well as data driven machine learning models to better characterise the feed and pump operating regime. The soft sensor will provide site personnel with estimates of process parameters which cannot be directly measured.

The development of the initial Excel based soft sensor for the primary and secondary DMCs is complete. This allows for the modelling of the circuit, adjusting to changes in washability when different coal types are processed. The model runs by solving for four parameters (washability scaling, primary screen efficiency, primary pump speed and secondary pump speed) to identify a solution that best matches the observed measurements from instrumentation.

The root cause of a previously identified offset between the modelled primary pump values and the operational data for the pump has been identified and rectified. The DMC wear model has been included into both python and Excel versions of the soft sensor. Further refinement to the Excel and python versions of the soft sensor have been made to improve performance and prepare for the delivery of the soft sensor to site.

Discussions with site have regarding the availability and delivery of data for validating the soft sensor model have progressed. The validation data is expected to be delivered soon. Once initial calibration of the soft sensor has been completed, the Excel version of the soft sensor will be delivered to site. Feedback from site will be utilised to undertake final model adjustments and modifications.

C34044
Real Time Monitoring and Control of Froth Flotation

University of Queensland
Liguang Wang

Value:	$262,437
Report Expected:	August 2025
Industry Monitor/s:	Albert Blom Angus Morrison Chris Denyer Chris Huth Josh Kowalczuk Rick Jeuken
ACARP Contact:	Ben Gill

The objectives of this project are to:

- Further evaluate and demonstrate a simple, cheap and fast sensor for monitoring the efficiency of multiple flotation cells;
- Develop remote control strategies corresponding to the sub-optimal operation identified by the sensor.

The latest field testing results have been communicated with the participating sites. The updated sensor holder and drag sensor demonstrated robustness and sensitivity in monitoring mass-pull and showed superior performance. We also discussed the upcoming long-term site testing with the site. It will involve testing multiple drag sensors with different designs at two flotation cells to evaluate sensitivity, durability, and maintenance requirements. Based on the testing results, we are now enhancing the design of the sensor and its holder to further improve the performance of flotation monitoring.

This project aims to combine drag sensor and AI-based machine vision for monitoring and controlling flotation yield and product ash content, we collected some froth image and flotation efficiency data from the participating site during the latest field testing. Further data collection will be carried out in the upcoming site work.

C34050
Hand Held Sensor for Real Time Measurement of Fluorine Mineral Contamination in Coal

University of Adelaide
Nigel Spooner

Value:	$261,215
Report Expected:	August 2024
Industry Monitor/s:	Jack Lauder Jenny Park Mel Robbins Rick Jeuken
ACARP Contact:	Ben Gill

The draft final report has been submitted to the Industry Monitors for review.

C34052
Simulation Enabled Digital Twin for the Control, Design and Optimisation of a Teeter Bed Separator

University of Queensland
Kym Runge

Value:	$232,531
Report Expected:	January 2025
Industry Monitor/s:	Albert Blom Chris Denyer Chris Jackson
ACARP Contact:	Ben Gill

Up to a fifth of in-plant material in Queensland metallurgical coal preparation plants is too fine to be efficiently upgraded using a dense medium cyclone and too coarse to be separated using froth flotation. This middling fraction (typically -2+0.35mm) is processed using hydraulic classifiers, such as teeter bed separators. In this project, researchers will use a combined experimental and simulation-based approach to develop a computational model that can be used as the basis of a performance-maximising advanced control strategy for the teeter bed separator (TBS).

Work to be performed will involve site surveys of full-scale TBS units, laboratory fluidisation test work, regression modelling of site survey data and development and validation of a CFD model.

This quarter, circuit survey campaigns were conducted at two coal processing plants as a follow on from the industrial site work which completed in the previous quarter. All site work has been completed and it has involved 80 surveys of industrial TBS units. These surveys were performed of three different designs of TBS fed six different feed types at two different coal processing plants operated under different operating conditions. Experimental data from the surveys, once received, will be used to:

- Perform regressions to determine drivers of TBS performance;
- Calibrate and validate a CFD simulation methodology that has been developed in the project to predict TBS performance.

Six feed samples were collected during the campaign and transported to JKMRC for ore characterisation and fluidisation test work. Processing of these samples has commenced. Washability analysis of the feed will provide the density distribution to input into the CFD model simulations. Fluidisation test work will be used to calibrate and validate the CFD modelling approach that has been developed to simulate full-scale industrial units.

General

C28061
Quantitative Based Structural Integrity Evaluations Using Modal Parameters Estimation

Mincka Engineering
Fidel Gonzalez

Value:	$363,651
Report Expected:	October 2024
Industry Monitor/s:	Chris Jackson Kevin Rowe Peter Shumack Phillip Enderby
ACARP Contact:	Patrick Tyrrell

The objectives of the project are to:

- Develop a technique for reliable, cost effective and objective structural condition assessments of mining infrastructure used in coal mining;
- Eliminate the subjectivity and conservative structural condition assessments; and to
- Enable data driven decision making and increased the reliability of structural condition assessments.

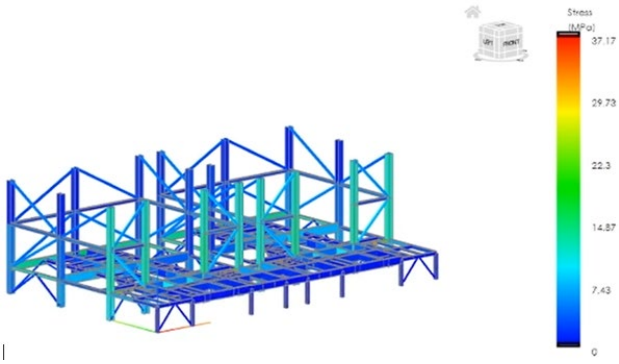


Figure 4. Stress distribution using 3D visualisation of the asset.

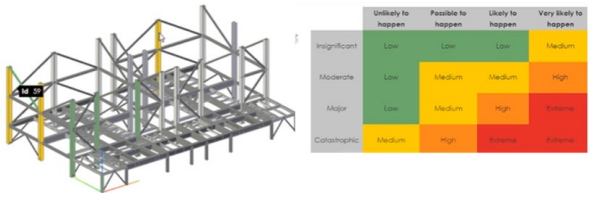


Figure 5. Risk analysis tool using 3D visualisation of the asset.

Commissioning of the monitoring system included verifying strain gauge and accelerometer outputs, commissioning a Python algorithm to send data to a relational database in AWS, acquiring data, and sending it to the RDB. It was also identified that a satellite internet supplier is needed to improve the reliability of the current internet provider. Additionally, the backend will be modified to store the data from the sensors locally.

TECHNICAL MARKET SUPPORT

Metallurgical Coal

C34054
Design of Cokes from Biomass Coal Blends for Sustainable Blast Furnace Ironmaking: Scoping Study

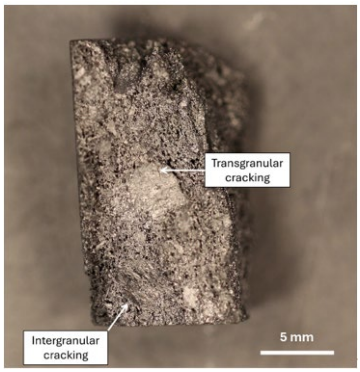
University of New South Wales
Pramod Koshy

Value:	$181,700
Report Expected:	October 2024
Industry Monitor/s:	Shaun Booth Stephen Brant
ACARP Contact:	Ashley Conroy

This project is focussed on understanding the impact of biochar addition and coal type on determining the quality of cokes for ironmaking. The aims of the present work are:

- Understand the impact of biomass addition (up to 10wt%) and base coal properties on the macrostructural and microstructural characteristics and room-temperature and high-temperature (1100°-1400°C) strengths after gasification of the resultant cokes;
- Correlate the mineralogical, microstructural, microtextural, bonding and fracture characteristics of these cokes with strength measurements at room and high-temperature; and
- Compare the properties using standard coke quality indicators such as CSR/CRI to determine optimal addition levels.

New cokes containing finer particle size fraction of biochar were fabricated. Fractographic analysis was carried out on samples of coke which were pre-gasified and then compressive strength tested under ambient conditions. Fractography of the coke without biochar (figure following) indicated that the coke was relatively strong and had a high fracture toughness. The sample with 2.5wt% biochar appeared more crumbly but showed a similar extent of mosaic cracking to the sample with no biochar. Therefore, it is assumed that the biochar at this addition rate is not significantly affecting fluidity development during cokemaking.



C34055
Factors Underpinning the Reactivity of Coke RMDC and IMDC

University of Newcastle
Hannah Lomas

Value:	$171,436
Report Expected:	August 2024
Industry Monitor/s:	Morgan Blake Sean Flanagan
ACARP Contact:	Ashley Conroy

The draft final report has been submitted to the Industry Monitors for review.

C34063
International Round Robin for Coke Reactivity Index, Coke Strength after Reaction and I600

CSIRO
Lauren Williamson

Value:	$77,800
Report Expected:	September 2024
Industry Monitor/s:	Caroline Lang Graeme Harris
ACARP Contact:	Ashley Conroy

The main objectives of this project are to:

- Update the understanding of the consistency of practice with regards to CSR and CRI across a group of international laboratories by conducting a round robin using two cokes produced in a pilot scale coke oven; and to
- Investigate the extent of use of I_{600} in coke testing laboratories and determine its potential as a standard test.

During the quarter the following activities have been completed:

- Two coal blends have been coked in the moveable wall oven at CSIRO-QCAT;
- Coke samples have been crushed and subsampled for despatch;
- Samples have been sent to 17 participants from six countries, noting that freight delays have been experienced;
- Results have been received from 12 participants;
- Report is being finalised and is expected to be issued in late August.

C35037
Examination of Contraction Pre and Post Resolidification using a High Temperature Dilatation Rig

University of Newcastle
David Jenkins

Value:	$99,250
Report Expected:	September 2024
Industry Monitor/s:	Cameron Tasker Graeme Harris
ACARP Contact:	Ashley Conroy

Project objectives are to:
- Measure the dilatation and contraction behaviour of a range of coals, both pre- and post-resolidification, using the UoN dilatation/contraction test rig;
- Develop a mathematical model of the configuration used in the dilatation/contraction test rig and calibrate with experimental results; and to
- Utilise the combined results from experiment and modelling to understand the key processes of dilatation and contraction of coal particles at coke oven feed size, particularly in the region around re-solidification.

All work for the project has been completed and a draft report has been prepared and will be submitted after internal checks have been is completed.

C35038
Microalgae Blending for Low Carbon Metallurgical Coke Production

University of Newcastle
Arash Tahmasebi

Value:	$172,000
Report Expected:	November 2024
Industry Monitor/s:	Nick Andriopoulos Stephen Brant
ACARP Contact:	Ashley Conroy

This project aims to evaluate the impact of microalgae blending on the coking behaviour, coke properties, and coke gasification performance of selected Australian coals to determine the tolerable microalgae addition level and carrying capacity of Australian coals. Specific objectives are to:
- Analyse the influence of microalgae on the thermoplastic and thermal decomposition behaviour of Australian coals;
- Evaluate the coking behaviour and pressure generation of coal/microalgae blends at different addition levels;
- Determine the optimal microalgae addition rate and study the carrying capacity of Australian coals in blend with microalgae from coke property analysis;
- Evaluate the impact of microalgae on coke microstructure and microtexture and coke quality indices;
- Explore the fate of alkali species during the coking process; and
- Evaluate high-temperature reactivity of bio-cokes.

Progress in the quarter:
- CT image analysis of plastic layer samples prepared in the 4kg oven has been completed. The impacts of algae addition on plastic layer microstructure were analysed;
- 16 coke samples were prepared in the UoN 8kg coke oven. The CSR/CRI testing was completed in this quarter. The results were used to determine the carrying capacity of coals in blends with microalgae;
- TGA carbonisation tests of coal-algae blends were conducted with data analysis currently underway; and
- Biocoke gasification reactivity tests in TGA and biocoke microtexture analysis are currently underway.

C35039
Impact of Coal Grain Composition and Macerals Association on Fluidity Development in the Plastic Layer of Australian Coals

University of Newcastle
Arash Tahmasebi

Value:	$141,600
Report Expected:	September 2024
Industry Monitor/s:	Graeme Harris Stephen Brant
ACARP Contact:	Ashley Conroy

The project aims to understand the impact of grain composition and maceral associations on the thermoplasticity of Australian coals from different coal measures. The project utilises the coal grain analysis (CGA) capability at CSIRO, rheometry and micro-CT expertise at UQ, and in-situ coking, plastic layer characterisation, and micro-CT analysis expertise at UON. Specific objectives are to:
- Improve the mechanistic understanding of the thermoplastic behaviour of Australian coals;
- Explore the differences in vitrinite and inertinite size distribution and the degree of association between reactive and non-reactive macerals in coals sourced from different measures;
- Analyse thermoplastic behaviour of selected coals using the permeability/dilatation and the 4kg coke oven test facilities at UON and the rheological testing at UQ using the coke oven feed size;
- Develop correlations between coal grain composition and fluidity development in the plastic layer; and to
- Analyse micro-CT images of quenched plastic layer samples to determine the difference between the “real” plastic range of coals and those measured by standard tests.

Progress in the quarter:

- The rheology (UQ), in-situ coking tests (UoN), and micro CT image analysis (UoN) of the remaining coal samples were completed;
- The analysis of coal grain compositions and in-situ coking test results (rheometry, dilatation, and plastic layer micro-CT analysis) was completed;
- Project findings to date show strong evidence that the composition and degree of association between coal macerals influence the development of fluidity; and
- Drafting of the final report is underway with submission expected to be in August.

C35040
Changes in Combustibility of Coal when Co-Combusted with Hydrogen Rich Fuels in PCI

University of Newcastle
Liza Elliott

Value:	$218,367
Report Expected:	June 2025
Industry Monitor/s:	Cameron Tasker Caroline Lang Oliver Scholes
ACARP Contact:	Ashley Conroy

With the steel industry under pressure to reduce CO_2 emissions, there are several possible changes to the steelmaking process that could be adopted. The first and easiest step in improving sustainability is the introduction of a material with high hydrogen content via tuyere injection. This injectant could be coke oven gas, waste plastics, biomass materials or hydrogen and hydrogen containing gases. However, as most of these materials have lower coke replacement ratios, most steelmakers will be looking to introduce these fuels along with coal. It is unclear, however, what the impact of co-combustion has on the possible injection rate.

This project aims to determine the impact on coal reactivity of co-combustion of hydrogen rich fuels: biomass, plastics, coke ovens gas, ammonia, and hydrogen. Two techniques will be used: the combustibility of solid fuels will be assessed using the Drop Tube Furnace technique developed in project C19049, that compares the combustion behaviour of coals in a set standard condition. Then a TGA (Thermo-Gravimetric Analyser) will be used to measure the reactivity of these materials individually and when co-combusted with coal. This will show changes in behaviour expected due to reduction of oxygen concentrations caused by the consumption of the hydrogen rich fuel.

All samples required for this project have been sourced and prepared for testing. Drop Tube Furnace tests and TGA analysis are all underway. The Drop Tube Furnace has been activating a circuit breaker when at temperature. Replacement of the main circuit breaker, flow switch and thermocouple did not overcome the issue. It was later found that furnace had been hardwired incorrectly, which has been rectified. During this period the water-cooling treatment had been changed without notice and upon restart it was found the water-cooling system was filled with grit due to corrosion of the furnace body. The system has been flushed but the furnace can no longer achieve the same water flow rate which will limit cooling. Assessment of the limit of operation resulted in automatic shutoff by the overtemperature controller, which caused the furnace muffle to rupture and break the graphite element. We are presently waiting for a replacement element.

Initial issues with the TGA experiments seem to have been overcome, and experiments are continuing, but access is limited due to demand for the equipment. The methodology for assessing the TGA data has been found to be inaccurate when multiple reactions are occurring, and alternate methods are being considered.

Unfortunately, the TGA to be used in this study has been found to allow feed gas to fill the electronics chamber and it was therefore decided that ammonia combustion was unsuitable for this machine. An alternate TGA has been found for tests utilising ammonia, but an exhaust needs to be fitted and sensors/alarms installed in the room. The cost of these alterations were excessive and alternate options are being considered. Safety reviews required for the alternate TGA are also needed.

C35041
Effect from the Co-Combustion of Coal and Biomass on Production of Fine Particles (<PM10)

University of Newcastle
Liza Elliott

Value:	$228,531
Report Expected:	August 2025
Industry Monitor/s:	Cameron Tasker Caroline Lang Oliver Scholes
ACARP Contact:	Ashley Conroy

Many power stations are looking to reduce their CO_2 emissions with the addition of biomass to the feed coal for combustion. Biomass is an overarching term to describe organic material derived from plants and is considered CO_2 neutral as the CO_2 emitted during combustion is equivalent to the CO_2 absorbed during the plant's growth. However, biomass generally has much higher contents of Na and K than coal, and these elements are associated with the organic structure of the plant. In bituminous coals these elements are generally associated with minerals that may be liberated during milling. The proximity of the alkalis to carbon increases the chance of vaporisation during combustion.

Project C29075 has shown that the proportion of PM10 particles produced during combustion of relatively refractory ashes is much higher than expected. When co-combusted with biomass, the PM10 produced would be

expected to increase dramatically as the alkalis associated with the biomass would be expected to report predominantly to the fine particle fraction of the particle size distribution, though a high ash load associated with the coal ash may limit this. It is unresolved where other species within the biomass would report. The source of PM10 from co-combustion materials must be understood if the value of coal is not to be undermined.

This project aims to assess the scope of fine particle emissions produced during combustion of biomass and the interactions expected between biomass and coal when these fine particles are forming during co-combustion.

The samples for this project have been sourced and prepared for testing. Combustion of the coal in coal only tests is complete, with collection of the ash including the ultrafine portion. Combustion of biomass-coal blends is underway. Analysis of the ash from the coal only tests has started. A new feeder box was unexpectantly required due to heat failure, which has been produced and fitted. Chemical fractionation of the biomass samples is complete. TIMA analysis of the coal is underway. Unfortunately, the drop tube furnace has experienced an electrical fault and will no longer heat to temperature. Replacement electronic components are being sourced to fix the fault. This has caused an unexpected delay.

C35042
Physical and Chemical Interactions Between Charcoal and Coal During Coking

University of Queensland
Karen Steel

Value:	$135,694
Report Expected:	December 2024
Industry Monitor/s:	Graeme Harris Morgan Blake
ACARP Contact:	Ashley Conroy

This project addresses the demand from coke makers to add high proportions of biomass to cokemaking blends whilst not compromising on coke strength. It has been recognised for some time that addition of biomass decreases coke performance in terms of the both CSR and CRI. One of the major adverse effects is reduced fluidity. It has been established that converting biomass to charcoal at high temperature (800°C) in the first instance reduces the adverse effect. Given that oxygen content decreases as charring temperature increases, it is strongly suspected that high temperatures are preferred due to the loss of oxygen from the char; oxygen is already well known to decrease fluidity through condensation reactions.

This project investigates the blending of biomass with high fluidity coals to deliberately interact with biomass at low temperature, thereby mitigating the adverse effects caused by biomass and preserving the function of the prime coking coal. The project involves studying three high fluidity coals, three biomass types (sugar cane bagasse, bamboo, and Jarrah), and two coking coals.

Following a meeting with monitors in May to discuss results and identify suitable blend designs for larger scale test work we proceeded with the first of two rounds of larger scale test work to examine the effects of charcoal on internal gas pressures and CSR/CRI. That test work is almost complete - we are awaiting the CSR/CRI results. Once complete, we will schedule a meeting to discuss results and plan for the second round of larger scale test work. In addition to this, we have been developing a knowledge base on the behaviour of charcoals made from bagasse, bamboo and jarrah, identifying three major effects that charcoal has on the fluidity of coal. In addition to oxygen and mesopores in chars destroying fluidity we have also observed that chars having both low oxygen and low mesoporosity can still destroy fluidity by destabilising the bubble interface and causing volatiles to vent. Therefore, in addition to the chars needing to have suitable properties for blending, it also appears that the coal's properties influence carrying capacity.

We are on track to complete test work by end of November.

C35043
Abrasion Resistance of Coke Under Hydrogen Reduction Blast Furnace Conditions

University of Newcastle
Hannah Lomas

Value:	$159,416
Report Expected:	December 2024
Industry Monitor/s:	Nick Andriopoulos Oliver Scholes Stephen Brant
ACARP Contact:	Ashley Conroy

The hydrogen enriched blast furnace (BF) is emerging as a viable alternate technology to reduce the carbon footprint of BF ironmaking, during which injected hydrogen reduces the ferrous burden, generating water vapour as a by-product. It is thus important to understand how the degradation of coke under such conditions differs in comparison with conventional ironmaking, and thereby identify the impact of a hydrogen enriched BF on coke quality requirements.

This project will focus on the impact on coke abrasion resistance. Six RCO cokes were selected. Project objectives include:

- Evaluate the impact of reaction conditions that simulate both the conventional and the hydrogen reduction BF on coke abrasion resistance through high temperature tribological testing of samples pre-gasified to 15 to 25% carbon conversion.
- Develop correlations between conventional coke quality indices and abrasion resistance measured using tribological testing.

- Relate results to the microtextural components, and the rank and maceral composition of the parent coals.

In the last quarter, a system was developed to introduce steam to the RDI furnace located at CIMR, University of Newcastle. This was to allow pre-gasification of 25mm diameter coke cores with either steam or CO_2 at 950°C to 15 to 25% carbon conversion. Pre-gasification and high temperature tribological testing of samples using Zhengyi Jiang's instrumentation at University of Wollongong is 90% complete. 3D laser scanning microscopy of the generated wear tracks to examine their depth and width as a function of microtexture, microstructure, parent coal properties, and pre-gasification environment, has been completed.

In the next quarter, analysis of the data will be completed. SEM imaging followed by quantification of the wear mechanisms and severity of the abrasion will be carried out. Results will then be compared to industry measures of abrasion.

We expect to submit the final report at the end of November.

C35044
What We Now Know about Coking Coals and Coke

CSIRO
Lauren Williamson

Value:	$96,284
Report Expected:	January 2025
Industry Monitor/s:	Lauren North Morgan Blake
ACARP Contact:	Ashley Conroy

The main objectives of this project are to:

- Integrate the findings from ACARP projects completed since 2014, with other, primarily Australian, research into an overall picture of what makes a coke "good" and what is a good coke;
- List new findings that research has established that are useful to industry;
- Review the effects of adding biomass and hydrogen into the iron making process.

Work on reviewing 56 reports that have been completed is nearing completion. The project team is currently working to prepare the draft project report.

C35045
Impacts of Chemical Structure Transformation in the Plastic Layer on the Microtexture Development during Coking

University of Newcastle
Soonho Lee

Value:	$158,900
Report Expected:	November 2024
Industry Monitor/s:	Morgan Blake Nick Andriopoulos
ACARP Contact:	Ashley Conroy

The primary aim of this project is to explore the fundamental mechanisms contributing to microtexture development during the formation of the plastic layer, using bireflectance analysis and Synchrotron Infrared Microspectroscopy (IRM). We've selected plastic layer samples with distinct layered structures, including particulate coal, the plastic layer, and coke/semi-coke. We've chosen five coal samples with varying properties in terms of rank, maceral content, and fluidity to investigate their impacts on microtexture development, using IRM to interpret the underlying chemistry.

Throughout this quarter, we've developed analysis methods for batch IR spectrum. Each 100x100-micron area of IR mapping, with approximately 1.75-micron stepping resolution, resulted in a total of 3000 IR spectra per spot. Each spectrum underwent various analyses, such as spectra integration and deconvolution, to semi-quantify various chemical structural parameters such as Aar/Aar and CH2/CH3, which represent aromaticity and the branching degree of aliphatic structures. Distribution of these values across the selected spot is presented as a contoured chemical map.

Microtexture evolution results suggest that for the rank set, mid to higher rank coal evolved into a higher proportion of longer carbon structures such as ribbon and lenticular structures from the plastic layer to the early stage of semi-coke, while the lowest rank mostly evolved as circular structures. For the maceral and fluidity set, higher fluidity with the highest vitrinite content coal evolved into a higher proportion of ribbon and lenticular structures, forming the highest ribbon structures in the semi-coke region.

Looking ahead to the next quarter, our primary focus will be on the chemistry behind these evolution trends by examining chemical structure transitions of vitrinite and inertinite macerals from initial softening, intermediate, and resolidification regions, using the IRM chemical maps mentioned above. These correlations will be used to better interpret coke strength/reactivity test values such as CSR, CRI, Micum indices, and I600.

C35046
Gasification Reactivity and Degradation of Coke Lumps Under Simulated Conventional and Oxygen Rich Blast Furnace Processes

University of Newcastle
Apsara Jayasekara

Value:	$98,500
Report Expected:	September 2024
Industry Monitor/s:	Lauren North Nick Andriopoulos
ACARP Contact:	Ashley Conroy

The project aims to explore the differences in coke reactivity, microstructure and microtexture evolution, and coke degradation during gasification reactions relevant to simulated conventional and oxygen-enriched blast furnace conditions.

The objectives are:
- Assess the gasification reactivity of different coke samples under simulated conventional and oxygen blast furnace conditions;
- Investigate the influence of varying oxygen enrichment levels (ranging from 21% to 100% O2) in the input gas on the evolution of coke microstructure and microtexture, and coke degradation;
- Compare the post-gasification strength of coke samples under conventional and oxygen blast furnace conditions;
- Establish correlations between oxygen content and coke degradation; and
- Establish connections between coke qualities and coke reactivity under oxygen-enriched scenarios.

In the previous quarter, Micro-CT image analysis to understand the evolution of pore coke microstructure has been completed. Samples were prepared for microtexture analysis at Pearson Petrography, Canada.

Progress in this quarter includes:
- Completion of post-reactivity image registration;
- Completion of microtextural analysis;
- The final report is expected to be submitted to the monitors by the end of August.

C36004
Physical and Chemical Structure Characterisation of Biomass for Biocoke Production

University of Newcastle
Arash Tahmasebi

Value:	$54,100
Report Expected:	September 2024
Industry Monitor/s:	Cameron Tasker Lauren North Morgan Blake Nick Andriopoulos Shaun Booth Stephen Brant
ACARP Contact:	Ashley Conroy

The project aims to conduct a scoping investigation to better understand the impacts of parent species and pre-treatment methods on the physical and chemical structures and properties of biomass. A selection of woody, crop waste and algal biomass species will be used and characterised using a range of analytical instruments. Specific objectives are to:
- Conduct a comprehensive compositional evaluation of microalgae and lignocellulosic biomass species aiming to identify key differences;
- Prepare and analyse the physical and chemical properties of torrefied and pyrolysed char samples from a range of woody and crop waste biomass species;
- Study the impact of biomass type and pre-treatment method on thermal decomposition behaviour;
- Provide input into the selection of biomass samples for biocoke preparation in the RCO pilot oven for use in detailed biomass related projects proposed to ACARP. We plan to select biomass samples with distinctly different properties and structures to allow a meaningful comparison in the detailed biomass evaluation projects; and to
- Select suitable biomass samples to gain maximum compatibility between the detailed biomass-related projects.

Progress in the quarter:
- Preparation of torrefied and char biomass and sample characterisation including TGA, SEM, FTIR, and elemental and ash chemistry have been completed;
- Update results were provided in May;
- The repeat BET surface area tests in a second instrument are underway to confirm previous measurement results; and
- Drafting of the final report is underway.

C36031
Structural Optimisation and Reactivity Evaluation of Ferro Coke Produced using Australian Coals

University of Newcastle
Arash Tahmasebi

Value:	$167,000
Report Expected:	November 2025
Industry Monitor/s:	Cameron Tasker Graeme Harris Nick Andriopoulos Stephen Brant
ACARP Contact:	Ashley Conroy

The project aims to examine the suitability of Australian coals for ferro-coke production and to develop a new understanding of the mechanism of microstructure formation and reactivity of ferro-coke. The specific objectives are to:

- Evaluate the coal properties and blend strategies suitable for ferro-coke production;
- Explore the use of high-fluidity Australian coal as a binder during ferro-coke decarbonisation;
- Analyse the impact of iron ore addition level on thermal decomposition behaviour and thermoplasticity development in coal blends;
- Evaluate the impact of iron ore on microstructure development during the carbonisation of ferro-coke;
- Improve the understanding of factors underpinning the reactivity of ferro-coke under simulated blast furnace reaction conditions; and
- Identify the governing factors driving the strength and reactivity of ferro-coke.

Progress during the quarter:

- A new Shimadzu AGS-X 50kN has been commissioned at NIER and will be used for the preparation of ferro-coke pellets and mechanical strength testing;
- The coal and iron ore samples were received in June;
- Standard characterisation of the coal samples is underway;

Next quarter will involve preparation of the ferro-coke samples and mechanical testing, as well as thermal decomposition behaviour tests in TGA.

C36032
Impact of Biomass on Coke Microstructure Evolution and Gas Diffusion During CO2 Gasification

University of Newcastle
Arash Tahmasebi

Value:	$169,000
Report Expected:	April 2026
Industry Monitor/s:	Graeme Harris Lauren North Morgan Blake Nick Andriopoulos Sean Flanagan Shaun Booth
ACARP Contact:	Ashley Conroy

A previous project revealed limited success in biomass blending due to the negative impacts on coke quality, and recommended further research on optimising species, biomass pre-treatment, coking technology, and coal blend design. This project forms part of an integrated program of research to improve the knowledge of the impacts of biomass addition on the coking performance and quality of coke generated from Australian coals. The aim of this project is to examine the impacts of biomass addition on the mechanism of carbon conversion during CO2 gasification and to evaluate the changes in coke microstructure during gasification reactions. This new knowledge will contribute to the understanding of how biocoke can be effectively utilised in blast furnace ironmaking.

Work hasn't started yet due to delays in the provision of coke samples.

C36034
Sugar Coated Coal: Determining if Glucose Addition Can Improve Coke Quality of Coal-Biomass Blends

ACIRL
Callum Mainstone

Value:	$111,622
Report Expected:	October 2024
Industry Monitor/s:	Caroline Lang Graeme Harris Lauren North Morgan Blake Nick Andriopoulos Sean Flanagan Shaun Booth
ACARP Contact:	Ashley Conroy

This project seeks to determine if sugar (dextrose monohydrate) can be blended with coal to produce coke at higher concentrations than other forms of biomass. Two coal samples will be tested, one high ash coking coal (17.5% ash db) will be used to determine the ability of glucose to reduce ash content of the coke and a thermal

coal with no fluidity (0 dd/min) will be used in an effort to produce a competent coke utilising the properties of sugar.

Over the quarter, 11/14 bench-scale coke blends were completed. It was demonstrated that weak coke could be produced from the thermal coal with a dextrose concentration of 20%, producing a coke with a yield of 70.8%, CRI of 33.4 and CSR of 10.0.

At the project review meeting in June it was decided to exclude coke fines, molasses and lignosulphonate from further testing due to weak coke strength, handleability and high ash content respectively. Replacing these additives, biochar derived from prickly acacia wood was included at concentrations of 5 and 10% for both coals. Laboratory analysis on each blend was further added to the project.

C36037
Exploring the Effects of Bio-char and Torrefied Biomass Addition on the Microtexture of Bio-coke

University of Newcastle
Soonho Lee

Value:	$155,000
Report Expected:	January 2026
Industry Monitor/s:	Graeme Harris Lauren North Morgan Blake Nick Andriopoulos Sean Flanagan Shaun Booth
ACARP Contact:	Ashley Conroy

The project goal is to investigate the chemical interactions between bio-char/torrefied biomass and coal macerals in bio-coke microstructures using Pearson's anisotropy quotient colour-coded reflectance mapping technique (AQ mapping). This project also aims to develop a code-based image analysis method to quantify these interaction. This will be used to better understand the impact of biomass properties, distinct pre-processing methods, and coal properties on bio-coke quality.

To examine chemical/physical structure interactions between altered/non-altered macerals and bio-char/torrefied biomass, we will employ AQ and bireflectance mapping. This allows us to identify various types of carbon forms across the bio-coke microstructure and analyse pore structures from the obtained microscopic images.

Throughout this quarter, two types of biomass, softwood (sugar cane bagasse) and hardwood (acacia), were chosen to produce biochar and torrefied biomass via suppliers. Two Australian coking coals with similar MMVR ~1.2 but different vitrinite contents (~60% and 75%) were blended with the processed biomasses at a 10% blending ratio (weight basis) to produce bio-cokes from the 400kg pilot-scale recovery coke oven (RCO) at QCAT. We requested CSR lump-sized sub-bio-coke samples for AQ mapping.

Looking ahead to the next quarter, our primary focus will be on processing the CSR lump samples for AQ mapping, involving resining and polishing. Preliminary AQ map data will be used to develop a code for boundary analysis, aiming to quantify chemical interactions between biomass particles and surrounding carbonised coal macerals.

C36038
Effects of Ash Minerals on Coke Reactivity under Hydrogen Injection, Low CO2 Blast Furnace Conditions

University of Wollongong
Raymond Longbottom

Value:	$51,290
Report Expected:	April 2025
Industry Monitor/s:	Cameron Tasker Nick Andriopoulos
ACARP Contact:	Ashley Conroy

The primary objective of this project is to quantify the impact of mineralogy on the reactivity of metallurgical coke using a coke analogue at temperatures of 1100°C and higher using H_2 containing gas mixtures.

To assess the mineral effects on coke reactivity with H_2-containing gases, selected cokes and coke analogues containing targeted minerals will be reacted at temperatures from 1100-1600°C under blast furnace conditions representing H_2 injection, low CO_2 operation. These results will then be compared against the reactivity of coke with CO-CO_2 gas mixtures, helping to evaluate the effect of changing from traditional to H_2 injection blast furnace operation on coke performance.

The outcomes will directly improve the understanding of the impacts of hydrogen on coke quality requirements and coke performance in the BF in H_2 injection, low CO_2 operation.

Preparation of the coke analogue samples for the reactivity testing is on-going. Characterisation of the unreacted coke and coke analogue samples is underway.

C36039
Alternative Thermal Processing of Coal Pilot Extruded Coke and Supercapacitor Demonstration

University of Newcastle
Rohan Stanger

Value:	$157,178
Report Expected:	April 2025
Industry Monitor/s:	Graeme Harris Lauren North Morgan Blake Nick Andriopoulos Peter Austin Sean Flanagan Shaun Booth
ACARP Contact:	Ashley Conroy

This project aims to conduct pilot trials on our extrusion system to produce a final "annealed" coke product; suitable for CSR evaluation. The project will also continue development of our coal-based supercapacitor to produce a larger proto-type system for energy storage. Specific to the pilot extrusion system, the test work will involve an evaluation of final annealing temperature and the addition of "bio-fluids" to the feed mixtures (as opposed to biomass derived solids like biochar).

This project has now sourced and obtained a high temperature furnace capable of 1600°C continuous operation. We are currently having custom parts made to connect the extrusion unit and the furnace.

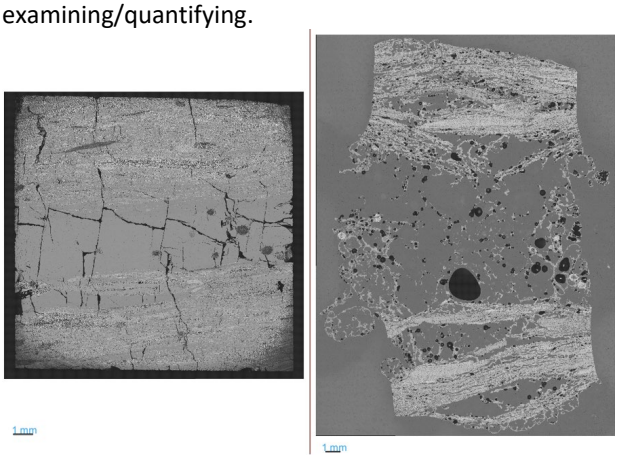
C36040
Tracking the Carbonisation Performance of Vitrinite Macerals

University of Queensland
Karen Steel

Value:	$108,664
Report Expected:	April 2025
Industry Monitor/s:	Lauren North Oliver Scholes
ACARP Contact:	Ashley Conroy

This project builds on previous research where different vitrinite maceral subgroups were examined before and after pyrolysis/carbonisation using optical microscopy. While the pyrolysis product of collotelinite bands comprised large spherical pores with thin pore walls, the pyrolysis product of collodetrinite was markedly different, comprising smaller pores and thicker pore walls. Given that pore structure influences coke quality indices, knowledge on the specific vitrinite properties that give rise to the best quality coke would be beneficial for coke makers developing blend formulations. The objective of this project is to apply the 'before vs after' technique developed by Tara Congo to examine coals of different rank and from different Australian coal measures. Additionally, we aim to characterise molecular structure using XPS and 13C NMR and relate this to the observations made. This work addresses the research priority to relate coke performance to coal property information.

During this quarter we have studied three coals, all of which have a low rank of 0.8-0.9. For each coal we have undertaken a macroscopic examination of many coal lumps received to select samples that are representative of the majority. We have prepared coal blocks, polished one face, undertaken petrographic analysis to identify the different macerals, coked the sample, and then set the coke sample in resin for re-examination. One sample is shown below. These low rank coals were found to undergo considerable expansion and all demonstrated different behaviour which we are currently examining/quantifying.



Work for the next research quarter will involve studying each new sample as it arrives. In parallel we are carrying out rheometry analysis, XPS and 13C NMR on the vitrinite taken from the thick bands and on the whole coal block.

C36041
Quantifying Biochar Interactions with Coal for Coke Making

CSIRO
Lauren Williamson

Value:	$141,683
Report Expected:	July 2025
Industry Monitor/s:	Graeme Harris Lauren North Morgan Blake Nick Andriopoulos Sean Flanagan Shaun Booth
ACARP Contact:	Ashley Conroy

The objectives of this project are to:

- Prepare cokes for consistent analysis of different aspects of biomass addition (including coke standard coke quality determinations) for use across a suite of biomass related projects commencing in 2024 and retain material for future projects in the ACARP Coal Bank;
- Quantifying the relationship between biomass char surface area, size distribution and their impact on coke properties.

Coke making and testing on the 100% cases has been completed and sub samples provided to researchers for projects C36032, C36036 and C36037. The production of biomass is in progress and once complete, will be prepared for coke making. It is estimated that the remaining coke making will take place in the final quarter of the 2024 calendar year. These samples will then be supplied to the related projects requiring cokes.

Thermal Coal

C34058
Strength Development in Fouling Deposits

University of Newcastle
Liza Elliott

Value:	$213,600
Report Expected:	September 2024
Industry Monitor/s:	Caroline Lang Oliver Scholes
ACARP Contact:	Ashley Conroy

Deposition within the convective pass of boilers can significantly affect gas and heat flows and alter boiler performance. Regular cleaning is required to ensure optimal boiler efficiency and ease of ash removal. Timeframes required for cleaning depend on the time it takes for strength to develop in the ash deposits, which can build-up in temperature regions well below the ash melting temperature. At present, to assess a coal ash's behaviour, a boiler operator will compare the ash fusion temperature (AFT) to those of coals with known performance in their boiler. But AFT has no correlation with strength development at sintering temperatures, instead is related to the surface tension of liquid phases present.

This project aims to produce a model for the development of strength in ash compacts to be able to predict the optimum time required for cleaning boiler walls. To do this the project will:

- Determine a correlation for the sintering temperature of Australian thermal coal ash;
- Gain an understanding of strength development in these coal ashes by assessing the impact of particle size and ash chemistry.

Fourteen fly ash samples have been collected and analysed for chemistry and particle size. The sintering temperature of each fly ash has been measured, along with the sintering temperature of blends of the selected fly ash samples. Additional tests to determine the impact of particle size have shown that the sintering temperature is not impacted by the size of the particles and is solely a function of chemistry. Modelling of the sintering temperature based on the ash chemistry using a neural network is complete. Figure 1 shows the model predictions compared to the measured values.

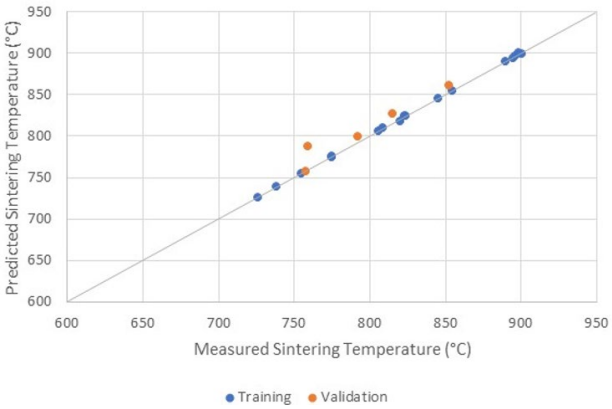


Figure 1: Model predictions of sintering temperature compared to measured values.

Sintered compacts have been produced. Measurements of the closed porosity have been completed by measuring the open porosity using pressure drop measurements of gas flowing across the compact. Previous calculations using Endo's equation were found to be flawed and so a modified Rose equation was utilised. The shear strength of the compacts has also been measured. Figure 2 shows the relationship between the closed porosity and shear strength.

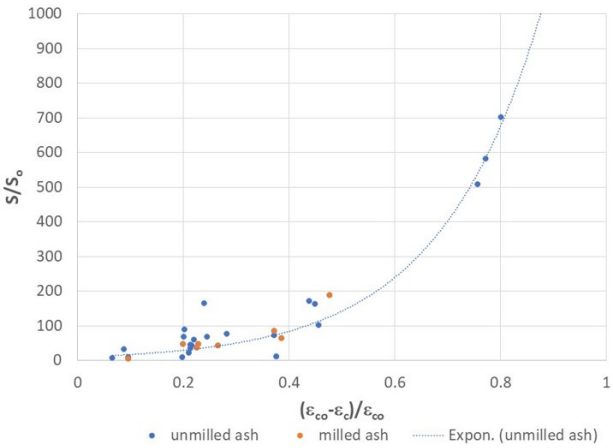


Figure 2: The relationship between Shear Strength of fly ash compacts and the ratio of the closed porosity and the original closed porosity.

As the sample begins to sinter, shown by the change in the closed porosity, (εco-εc), the ratio of shear strength of the sintered compact, S, compared to the shear strength of the unsintered ash, So, increases.

If we choose a strength ratio (S/So) where strength has not developed significantly, such as 90, ie a porosity ratio, (εco-εc)/εco, of 0.4, using Frenkel's equation of sintering due to viscous flow, the time of sintering can be calculated for the temperature experienced by the ash. The time required to reach a set strength is a function of the temperature experienced by the ash, T, the sintering temperature (solely a function of chemistry), Ts, and the particle size of the ash, dpm, as shown in Figure 3. Sintering occurs faster for ash of smaller average particle size.

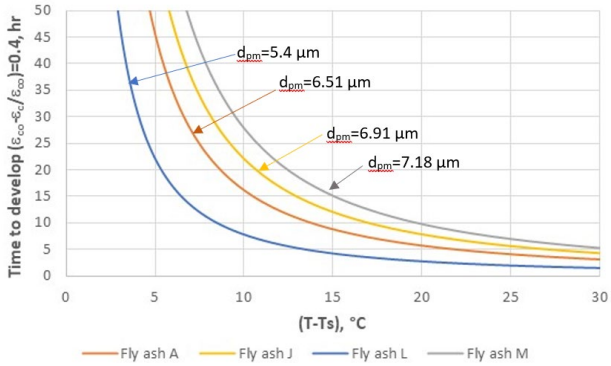


Figure 3: The time required to develop a strength ratio of 90.

Some ashes never reach the prescribed strength, predominantly due to the ash particle size, with more strength developed in finer particles. Figure 4 shows the calculation of porosity ratio of the same ash if the particle size varies. The larger the average particle size the smaller the porosity ratio that is achievable, and hence the lower the developed strength.

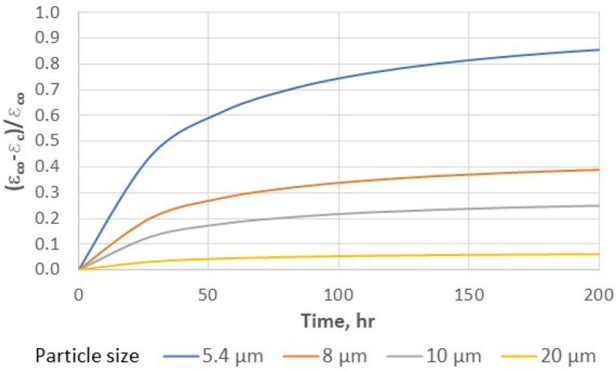


Figure 4: The impact of particle size of the porosity ratio achievable during sintering.

Finalisation of the draft report is being completed, with submission expected soon.

C35005
Feasibility Study, Upgrade and Commissioning of ALS-ACIRL Pilot Scale Combustion Test Facility

ACIRL
James Bottle
Luke Beattie

Value:	$591,250
Report Expected:	March 2025
Industry Monitor/s:	Caroline Lang Greg Wickman Jane Lawson Oliver Scholes
ACARP Contact:	Ashley Conroy

The overall objective of this project is to upgrade ALS-ACIRL's existing pilot scale coal combustion test facility so that it can more accurately simulate current and emerging coal fired combustion technology.

- Stage 1 – complete.
- Stage 2 – The upgrade of the Pilot Scale Combustion test facility is nearing completion, with the upgrade complete excluding one final component – the new gas analyser. The gas analyser arrived at ALS in June as expected, however the analyser was faulty, requiring it to be returned to the manufacturer in Japan. ETA for the return on the analyser is August.
- Stage 3 – The commissioning phase of the project will also be delayed due to the delay with Stage 2. In the interim, coal and biomass products required for the commissioning phase are being sourced, ready for preparation once the gas analyser is installed and commissioned for use. Once the gas analyser issue is resolved, ALS will still aim to meet January's deadline for the commissioning stage.

General

C25053
Coal Sample Bank

CSIRO
Lauren Williamson

Value:	$451,801
Report Expected:	November 2024
Industry Monitor/s:	Technical Market Support Committee
ACARP Contact:	Ashley Conroy

The objective of this project is to make coal and coke samples available to researchers and to enhance the systematic provision of the samples for research projects funded by ACARP.

To date, 98 coal samples have been delivered, stored at -18°C and their details recorded in a database, there are also 39 cokes, 5 biomasses and 1 fly ash stored. Of the coal samples stored coal quality data has been provided by coal producers for 79 of the samples.

In this quarter biomass samples are in the process of being sourced for a suite of projects (C36004, C36032, C36035, C35036, C36037 and C36041) related to the use of biomasses in coke making blends. 10 coal samples have been supplied for projects C35042, C36031 and C36040. Seven coke sample have been provided to projects C36032, C36036, C36037 and C36041. Five further coal samples have been requested for C36040 and are being sourced from producers.

C26003
Management of SA and ISO Coal Technical Committees Work Programs

Carbon Connections Consulting
Barry Isherwood

Value:	$391,150
Report Expected:	October 2024
Industry Monitor/s:	Graeme Harris Kevin Rowe Lauren North
ACARP Contact:	Anne Mabardi

This project is a continuation of support for the management and input into Australian and ISO Coal Sampling, Preparation and Analysis Standards.

During the quarter numerous discussions were held with SA Management and project proponents on the ISO MOD process for revising Australian Standards and the inherent copyright issues with ISO. For the Froth Flotation Standards in question, it was resolved to just publish a new AS version from scratch the using the results and work done as part of an ACARP project.

The new EU position on the reporting of methane emissions associated with coal and coal mining was the subject of a Dutch proposal for a Guide/Standard to be developed by our TC27 Committee. This was initially rejected as outside of our scope but following feedback from MCA and ACARP this will be revisited as there is already an AS Guide which potentially could be developed into an ISO version and assist the Australian coal industry with exports.

A revision of ISO Guide 84 – Addressing Climate Change in Standards is underway.

The Dutch are proposing a new Guide/Standard on the slumping of coal stockpiles, but this is being resisted as very problematic to define and impractical to implement.

ASTM who oversee production of the world's reference HGI calibration Standards, advised that they have appointed a new supplier and within Australia some technical issues have been encountered. Our concerns have been expressed to ASTM and follow-up is necessary to ensure that the calculated HGI values of Australian (and international) coals are not incorrectly reported.

ISO succession planning continues for TC27 and its SCs with the Chair of TC27 and each of its four SC's to be replaced over the next three years, at the expiry of their allowed terms. This will require careful management to ensure the necessary transition.

Further discussions were held with India regarding the next TC27 meeting to be convened in September 2025 in India and for which a preliminary notice of meeting needs to be issued soon.

A review was carried out on 15 ISO and 9 ASTM Standards revisions and ballots returned.

C26037
Australian Participation in Development of ISO Methods for Sampling, Analysis and Coal Preparation and National Technical Committee Support

Standards Australia
Ben Russell

Value:	$390,370
Report Expected:	August 2024
Industry Monitor/s:	Graeme Harris Kevin Rowe
ACARP Contact:	Anne Mabardi

SA support for Australian Mirror Committee—Schedule of meetings.

MN-001 (Coal and Coke)—Mirror Committee for ISO/TC27
Chairman: Barry Isherwood
Last meeting: 20 July 2023 (Zoom meeting)
Next meeting: 8 August 2024 (Venue: TBC)

MN-001-01 (Coal analysis) —Mirror Committee for ISO/TC27/SC3 and SC5
Chairman: Barry Isherwood
Last meeting: 21 March 2024 (BHP Office, Brisbane with Zoom Option--Hybrid)
Next meeting: 8 August 2024 (venue: TBC)
Meeting objective: Review ISO/TC27/SC5 & SC3 documents including systematic reviews and finalise Australian mirror Committee position on ISO ballot (and comments).

MN-001-02 (Coal Preparation) —Mirror Committee for ISO/TC27/SC1 and SC4
Chairman: Darren Mathewson
Last meeting: 27 June 2024 (NIER or SGS Office, Newcastle)
Next meeting: 12 September 2024 (NIER or SGS Office, Newcastle)
Meeting objective: Review of ISO/TC27/SC1 & SC4 documents including systematic reviews and finalise Australian mirror Committee position on ISO ballot (and comments). Review update on national Standards and projects.

MN-001-05 (Coal Mining and Geology)
Chairman: No Chair
No meeting planned; Subcommittee has no work program.

MN-001-06 (Determination of Gas Content)
Chairman: No Chair
No meeting planned; Subcommittee has no work program since publication of AS 3980-2016.

C33065
Digital Petrographic Atlas of Australian Coals - Maintaining the Knowledge

University of Queensland
Joan Esterle

Value:	$197,537
Report Expected:	September 2024
Industry Monitor/s:	Graeme Harris Sean Flanagan
ACARP Contact:	Ashley Conroy

This project will create a Digital Petrographic Atlas of Australian Coals, their maceral and mineral composition at different ranks, linked into our current understanding of basin scale variation in rank, type and grade, highlighting case studies that assist with conceptual mine scale models for understanding and predicting coal quality variation. In addition to the atlas, a library of scanned petrographic images of product coals from different basins and formations, illustrating the variation in rank, grade and type will be developed. This can be used for reference, training and round robins.

The final report continues to be in preparation, noting that all the authors are on honorary positions this quarter. The photomicrograph plates illustrating the range of macerals in different coals of different ranks, as well as minerals are finalised. The current task is finalising the text for the report, including the contextualisation of the scanned samples for the different Queensland coal bearing basins. The report is focussed on Queensland coals.

During this quarter a presentation of the Atlas was made to the ACARP-BBGG biannual meeting in Rockhampton, and a workshop utilising the atlas is planned for the upcoming Sydney Basin Symposium to be held in Newcastle in August.

MINE SITE GREENHOUSE GAS MITIGATION

C28078
Technical Development Unit (TDU) for Catalytic Conversion of VAM

University of Newcastle
Michael Stockenhuber

Value:	$1,040,592
Report Expected:	September 2024
Industry Monitor/s:	Jim Sandford Russell Thomas
ACARP Contact:	Patrick Tyrrell

No report received.

C33068
Airbag Inspired Explosion Suppression System for Mitigation of VAM Explosions

University of Newcastle
Behdad Moghtaderi

Value:	$583,073
Report Expected:	April 2025
Industry Monitor/s:	David Webb Jim Sandford Russell Thomas
ACARP Contact:	Patrick Tyrrell

The principal vision in this project is to advance the development of a Rapid Action Inflating Nitrogen Bag Obstruction Explosion Suppression (RAINBOES) concept as an effective and ultra-fast suppression system for gas explosions. The project aims at proving the concept through a combined theoretical and experimental approach. Theoretical studies will involve both analytical assessments and CFD modelling aimed at gaining a deeper understanding of the fundamental science that governs the operation of RAINBOES and its key components. The experimental studies include large-scale demonstration system for assessment and concept validation.

Several essential and key tasks of phase II have been achieved in the second quarter of the project as follows:

- The concept design for a duct with a four meter diameter is currently 70% complete. All required port dimensions and configurations to fit the measuring accessories have been determined.
- The duct skid concept design is in progress. This skid will enable the duct and all its accessories to be transported to different sites.
- A fast-acting mechanical valve for inflating large-scale airbags has been identified. Hardware evaluation is ongoing.

C34008
Satellite Remote Sensing - A New Tool for Coal Mine Emissions Management

Zephyr Environmental
Damon Roddis

Value:	$816,725
Report Expected:	October 2024
Industry Monitor/s:	Andrew Lau Ben Klaassen Jim Sandford John Watson Ned Stephenson
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34066
Safe Operation of Catalytic Reactors for the Oxidation of VAM Operating Under Abnormal Reaction Conditions

University of Newcastle
Michael Stockenhuber

Value:	$406,740
Report Expected:	August 2024
Industry Monitor/s:	Jim Sandford Russell Thomas
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C35049
Optimisation of Operational Parameters of Catalytic Reactor for the Oxidation of Ventilation Air Methane

University of Newcastle
Michael Stockenhuber

Value:	$238,464
Report Expected:	August 2024
Industry Monitor/s:	Jim Sandford Russell Thomas
ACARP Contact:	Patrick Tyrrell

No report received.

C36001
Open Cut Fugitive Greenhouse Gas Emissions

Australian Coal Mining Consultants
Andy Self

Value:	$227,500
Report Expected:	August 2024
Industry Monitor/s:	Ben Klaassen David Webb De Nicholls Iain Hornshaw Jim Sandford Sandy Tickell
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C36002
Investigation into the Technical Feasibility of In-Pit Gas Capture for Open Cut GHG Mitigation

GeoGAS
Christian Boucher
Yvette Heritage

Value:	$404,000
Report Expected:	September 2024
Industry Monitor/s:	David Webb De Nicholls Iain Hornshaw Jim Sandford Sandy Tickell
ACARP Contact:	Patrick Tyrrell

The key objective of the project is to determine how open cut mining modifies the coal seam gas reservoir and how these changes could be leveraged to provide a more cost-effective way of capturing gas from within the operating pit for the purpose of fugitive emission mitigation.

During the quarter progress included presentation of reservoir and drainage modelling and development of agreed final reporting outputs with presentation packages being developed for:

- Operations providing guidance for evaluating in-pit mitigation options; and for
- Industry as a high level briefing document on the methodology development.

C36007
Assessment of Sensors and Airflow Modelling for their Suitability to Quantify Methane Emissions in Open Cut mines

University of New South Wales
Simit Raval

Value:	$534,880
Report Expected:	March 2026
Industry Monitor/s:	Ben Klaassen Iain Hornshaw Jim Sandford John Grieves Ned Stephenson Sandy Tickell
ACARP Contact:	Patrick Tyrrell

This project is aimed at forming an evidence-based guideline for the coal industry covering a selection of sensors, strategies for data capture, and influence of airflow modelling through to utilisation of machine learning based mathematical models to estimate total methane emissions. This will be realised through integration of following FIVE Work Packages (WP):

- WP-1: Prepare a comprehensive literature review on available sensors and methods to detect and quantify methane emissions;
- WP-2: Conduct experimental environment trials to test selected sensors, both active and passive, under varied gas releases and airflow conditions;
- WP-3: Build mathematical models and advanced machine learning models integrating the airflow to estimate the total volume of methane emission;
- WP-4: Develop an algorithm to reconstruct the plume in 3D from a distributed sensor network.
- WP-5: Evaluate the potential of modelling total methane yield from an example scenario using strategic UAV-based sampling.

A comprehensive literature review of ground-based continuous monitoring sensors for methene emission estimations is currently underway. The next quarter will be dedicated to progress the controlled release trail setup.

C36008
Low Cost Precious Metal Free Honeycomb Monolithic VAM Catalysts and their Catalytic Activity and Stability Under Water and Dust Bearing Conditions

CSIRO
Yonggang Jin

Value:	$352,820
Report Expected:	October 2026
Industry Monitor/s:	Jim Sandford Paul Wild Russell Thomas Victoria Longley
ACARP Contact:	Patrick Tyrrell

The objective of this project is to develop low-cost honeycomb monolithic catalysts (HMCs) based on the high-performance precious-metal-free catalyst material newly developed by CSIRO in C29069 and evaluate HMCs' catalytic activity and stability with a simulated VAM stream containing water vapour and simulated ventilation air dust. Success of the proposed project is a stepping-stone to progressing the development of low-cost high-performance VAM catalysts for the structured catalytic VAM mitigator.

The project team has completed Standard 11 training for coal mine access to conduct ventilation air shaft survey which is planned to be carried out in the next quarter. A suitable-size ceramic honeycomb monolith substrate was sourced for studying wash coating and HMCs preparation at CSIRO laboratories. A series of HMC samples were prepared by different approaches. The existing laboratory catalytic testing microreactor has been modified for evaluation of catalytic performance of the prepared HMCs. Catalytic testings are being conducted under various reaction conditions. In the next quarter, the effects of HMC preparation parameters including the particle size, the wash coating composition and amount, and the loading amount of the precious-metal-free catalyst on the catalytic performance will be investigated for HMCs optimisation. The characteristics of the dust in ventilation air methane correlated with the ventilation air condition inside the shaft and the longwall production status will be studied.

C37002
Methane Matters: Updates on Relevant Advances for Coal Mine Emissions

University of New South Wales
Simit Raval

Value:	$161,890
Report Expected:	May 2026
Industry Monitor/s:	Mine Site Greenhouse Gas Mitigation Committee
ACARP Contact:	Patrick Tyrrell

This project is aimed at keeping an eye on the advances related to methane emission estimates under following three broad categories:

- Sensors for the detections, including ground-based, airborne, and satellite-based systems;
- Models for the emission estimations, including attempts to reduce the involved uncertainties; and
- Policy frameworks that influence the monitoring protocols.

During the quarter a comprehensive search has been started through various sources including scientific literatures, white papers, workshops and news articles relevant to the methane emissions. A particular emphasis is placed on the applicability and significance of existing and emerging technologies and policies for the coal mining sector. The aim is to ensure keeping the track of the current landscape that may directly relate to coal mine methane emission debate by sourcing information from diverse and reliable platforms.