



Government of **Western Australia**
Department of **Mines and Petroleum**

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Economics and Industry Standing Committee
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Dear Dr Abernethie

INQUIRY INTO TECHNOLOGICAL AND SERVICE INNOVATION IN WESTERN AUSTRALIA - DMP SUBMISSION

Thank you for your letter of 26 June 2015 inviting the Department of Mines and Petroleum (DMP) to make a submission to the Economics and Standing Committee Inquiry into technological and service innovation in Western Australia.

I note that the Terms of Reference of the Inquiry relate to how technological and service innovation can be encouraged to expand and diversify the State's economy.

As the Committee will be aware, the Office of Science is the lead Western Australian Government agency responsible for the delivery and coordination of research and technological development programs across Western Australia.

DMP has a lead agency role in attracting investment in minerals and petroleum exploration and development (principally through the provision of geoscience information and a secure and equitable titles system), while also regulating the mining, petroleum and dangerous goods industries. Through these functions, DMP has an understanding of, and role in, scientific research and technological development as they relate to the State's resources sector.

In response to the issues raised by the Inquiry, the attached submission provides information on:

- major innovations of the Western Australian resources sector;
- facilitating resources sector innovation in Western Australia; and
- innovation needed for future resources development in Western Australia.

I trust the information contained in the submission will assist the Committee in its Inquiry.

Should the Committee require clarification on the issues raised in this submission or additional information, please contact DMP's General Manager of Policy and Coordination.

Yours sincerely

A handwritten signature in black ink, consisting of a stylized 'R' followed by a long, sweeping horizontal line that tapers off to the right.

Richard Sellers
DIRECTOR GENERAL

24 August 2015

Att: Submission of the Department of Mines and Petroleum to the Legislative Assembly Economics and Industry Standing Committee Inquiry into technological and service innovation in Western Australia



Government of **Western Australia**
Department of **Mines and Petroleum**

Submission

to the

Legislative Assembly
Economics and Industry Standing Committee

**Inquiry into technological and
service innovation
in Western Australia**

28 August 2015

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1. INTRODUCTION

Western Australia is one of the world's leading producers of mineral and petroleum resources.

It produced more than 50 different commodities valued at \$114.1 billion in 2014. This is up from \$28.5 billion in 2004, emphasising the sector's dramatic growth over the last decade. Iron ore was the State's highest value commodity in 2014, accounting for \$65 billion in sales, followed by liquefied natural gas (LNG) (\$15.6 billion), crude oil and condensate (\$9.5 billion) and gold (\$8.7 billion).

The State accounted for 37 per cent of total world iron ore, 13 per cent of alumina production, nine per cent of LNG (sea-borne trade), eight per cent of nickel, and six per cent of gold, in 2014.

Building on the opportunities and strengths provided by the State's natural resources endowment, and its status as one of the world's leading mineral and petroleum producers, Western Australia is at the forefront of global resources research and technological development. This expertise includes advanced mining technologies, advanced oil and gas exploration and recovery, and carbon capture and storage.

One of the keys to delivering major resources innovation in Western Australia has been effective collaboration between governments, universities, technical institutions and industry. Several examples of the power of cooperation to achieve meaningful results are provided in this submission. Data libraries and transparency are also emerging as key drivers of innovation.

Encouraging scientific research and technological innovation through collaboration will be crucial to addressing the challenges facing the State's resources sector. These challenges include fewer discoveries of world-class mineral deposits, increasingly complex and intensive mineral recovery and processing requirements and scientific research required to assist development of shale and tight gas resources.

Addressing these challenges will underwrite Western Australia's economic future. It also presents an opportunity for the State to be a stronger and more visible leader in resource-related research, and to develop into a global resources innovation hub.

2. MAJOR INNOVATIONS OF THE WESTERN AUSTRALIAN RESOURCES SECTOR

Examples of world-leading technology developed and operated by the resources sector in Western Australia include:

- advanced mining technologies such as automation, remote operations and robotics;
- advanced oil and gas exploration and recovery technologies such as floating liquefied natural gas (FLNG) facilities; and
- efforts to reduce greenhouse gas emissions through carbon capture and storage (CCS) technologies.

A significant benefit from the development and application of cutting-edge resources technology is the opportunity to expand the State's international economic footprint and share its knowledge globally.

Moreover, the State's resources sector capabilities and expertise provide a new economic opportunity for Western Australia, which is not dependent on mining. It also has the potential to drive technological and knowledge transformation in other sectors of the economy. For example, knowledge in automated technologies and process control systems can be used in non-resource industry sectors to deliver productivity improvements.

Home-grown research and development expertise and facilities also provides an excellent training ground to accelerate science, technology, engineering and mathematics education in the State.

2.1 Advanced mining technologies

Rio Tinto has a Remote Operations Centre in Perth. Established in 2010, this centre provides a real-time perspective of the company's Western Australian iron ore supply chain including 15 mines, 31 pits, four port terminals and a 1600 kilometre rail network. It increases efficiency and improves reliability and stability, while also allowing the identification of performance improvements across the supply chain.

Similarly, BHP Billiton's Integrated Remote Operations Centre provides a comprehensive, real-time view of the company's entire Western Australian iron ore operations. It allows centralised scheduling, planning and control from pit-to-port. It has assisted in increasing the availability, utilisation and productivity of the company's assets throughout its Pilbara supply chain.

Rio Tinto is developing and deploying a fleet of autonomous transport and robotics systems at its Pilbara iron ore operations. The company's autonomous trucks have reportedly travelled approximately four million kilometres and moved 200 million tonnes of material since they were deployed in 2012. The company also has a series of remotely controlled blast hole drilling systems. These innovative technologies were driven by the company's challenges of attracting staff at the height of the investment-driven expansion of the resources sector, and have resulted in improved productivity and safety standards.

Rio Tinto is currently trialling an autonomous 1600 kilometre heavy haul, long-distance rail system at its Pilbara operations that is expected to be deployed later in 2015, as well as leading the development of a robotic haul truck wheel changer and the use of unmanned aerial vehicles to survey mine sites.

Several other resources companies, including BHP Billiton, Fortescue Metals Group and Hancock Prospecting, are developing or trialling autonomous and robotics systems. Woodside is also proposing to test remote operation systems for its future FLNG facility.

2.2 Advanced oil and gas exploration and recovery technologies

FLNG is a new technology and the Prelude project in the Browse Basin off the Western Australian Kimberley coast will be the first large scale deployment of the technology. This technology marks a significant change in the way that natural gas fields can be developed, making economically viable those gas reserves located in remote and distant offshore locations. It represents a major opportunity for Western Australia, which has significant remote offshore gas fields under development and consideration.

Driven by a decrease in the number of near-shore hydrocarbon discoveries and the extension of operations further offshore, complementary technologies to enable offshore oil and gas exploration and production in deeper waters are also being developed in the State.

2.3 Carbon capture and storage (CCS)

Western Australia is a world leader in the development of CCS technologies. CCS is a developing technology that offers prospects of reducing to near-zero the greenhouse gas emissions of fossil fuel burning in power generation and other industrial processes such as alumina production. The world's largest CO₂ injection and storage project, the Gorgon CO₂ project, is located in Western Australia's North West. This project will sequester up to four million tonnes per annum of CO₂ from the Gorgon LNG project during its estimated 60-year life. CO₂ will be injected and stored into a deep reservoir unit, known as the Dupuy Formation, more than two kilometres beneath Barrow Island.

The South West Hub CCS project is also underway and is based in the Harvey area of Western Australia. It is Australia's first flagship CCS project with the aim to reduce carbon emissions from industrial processes. It is supported by the recently completed National Geosequestration Laboratory, a \$48.4 million facility to assist research and new technological developments in CCS across Australia (discussed as an example of successful collaboration in Section 3.4).

2.4 Resource services sector

Driven by Western Australia's extensive mining and oil and gas experience, the resource services sector has developed technically advanced products and

services to promote efficiencies in resources exploration, development and production.

The service sector is well supported by the extensive research efforts of the State's diverse range of research centres and facilities.

Some of service sector's capabilities include:

- remote control technologies and automation system solutions;
- high-speed and remote data communications;
- airborne and ground geophysics, and GPS positioning;
- exploration and 3D mine design software, including mine production management and control, and data management solutions;
- metallurgical, mineral and chemical process design, development and engineering;
- drilling and blasting services, including drilling fluids and down hole instrumentation; and
- logistics management, analytical services, and mine maintenance.

3. FACILITATING RESOURCES SECTOR INNOVATION IN WESTERN AUSTRALIA

Resources science and technology in Western Australia has been successfully delivered through effective collaboration and collective research efforts between government, universities, technical institutions and industry.

The following diagram demonstrates the collaborative pathways currently supporting resources sector research and innovation in Western Australia.

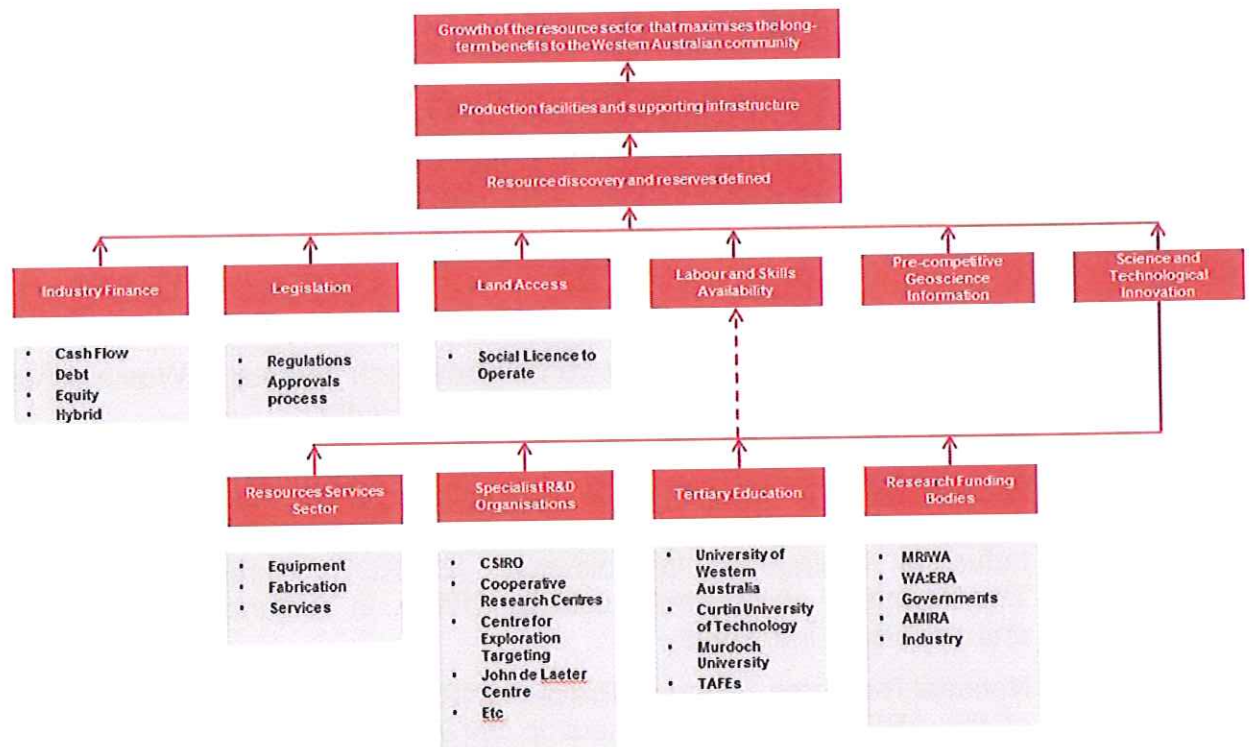


Figure 1. Collaborative pathways supporting resources sector research and innovation in Western Australia.

Initial support from the State and Commonwealth Governments has been instrumental in building expertise and providing essential infrastructure in Western Australia as well as fostering these collaborations.

The Department of Mines and Petroleum (DMP) has played a significant role in the establishment of collaborative research centres and facilities that deliver on the science needs of the resources sector.

Partnerships enable access to talent and facilities beyond the capacity of a single body. They can tackle larger problems and deliver more significant outcomes. Pooling financial and intellectual capital resources also greatly enhances the ability to attract and deliver large research infrastructure projects. A high level of cooperation exists between all the players in Western Australia's resource sciences space.

The success of this approach makes it a useful model to encourage further research and technological innovation in the resources sector and for consideration in other parts of the Western Australian economy.

Another approach to stimulate innovation in the resources sector is through building relevant data sets containing spatially-referenced data and information with open and easy access. Properly designed, such systems open up access to data which can be analysed and applied in new ways, by other cross-disciplinary researchers with diverse backgrounds and interests. This leads to improved decision-making and better service delivery.

For example, building an open system of data and knowledge on the environment and cultural heritage can assist in making better decisions and reduce duplication of data collection efforts to protect Western Australia's globally unique biodiversity, scarce water resources and important cultural heritage. DMP has already taken some steps to build a model data library of environmental and cultural heritage information.

3.1 Research centres

Key examples of successful joint venture research centres in Western Australia with initial financial support from governments include:

- Australian Resources Research Centre (ARRC) – this was established through seed funding of \$26 million from the Government of Western Australia, and developed with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Curtin University, and The University of Western Australia (UWA), in conjunction with the mining and petroleum industries;
- National Resource Sciences Precinct (NRSP), which builds on the foundation of the ARRC and is a partnership between CSIRO, Curtin University and UWA that operates as a 'one-stop-shop' for the technology, and education and training, needs of resources companies;
- Western Australian Energy Research Alliance (WA:ERA), which was established through a grant of \$20 million from State Government. It is an alliance of CSIRO, Curtin University, UWA, Woodside, Chevron and Shell;
- Centre for Exploration Targeting, which was established in 2005 by UWA, Curtin University and the exploration industry with initial funding support of \$2.1 million from the Government of Western Australia through the Centres of Excellence Program; and
- Centre for Offshore Foundation Systems at UWA, which hosts a unique simulator modelling the effect of cyclonic conditions on seabed sediment and oil and gas pipelines. It was established in 2007 with \$1.5 million in funding over five years from the State Government through the Centres of Excellence Program.

Through this project, innovative geoscientific data, interpretations, understanding and exploration targeting technologies are being developed. All this enables easier identification of the mineralogical and geochemical signatures of major ore bodies which will assist in discovering the mines of tomorrow. It is focused on the Capricorn area in Western Australia's southern Pilbara and Gascoyne regions, which are poorly explored areas of the State with potential mineralisation obscured by thick cover that poses a significant disincentive to commercial investment in exploration.

Advanced Spaceborne Thermal Emission and Reflection map

Another outstanding example of the cooperative approach to geoscience in Western Australia is the world-first Advanced Spaceborne Thermal Emission and Reflection, or ASTER, map. GSWA contributed \$300 000 to the project through the EIS and CSIRO's Centre for Three Dimensional Mineral Mapping Centre of Excellence developed software and computing capabilities to piece together 14 different surface-composition maps of various mineral suites. It also involved the National Aeronautics and Space Administration or NASA, the United States Geological Survey and Japan Space Systems.

This project has produced the largest satellite-derived geoscience map ever produced. New information is now available about the composition of the surface rocks and soils of Western Australia, helping explorers to target areas for intensive exploration.

Mineral system studies

GSWA has a partnership with the Centre for Exploration Targeting and the John de Laeter Centre for Isotope Research to deliver innovative mineral system studies. The study of a mineral system, as opposed to an actual deposit, offers explorers a much larger target. Once a mineral system is discovered, exploration for deposits can commence with a higher likelihood of success.

This approach results in a mineral exploration effort which is more rigorous and economically justifiable. This collaboration has already produced an innovative prospectivity study of the east Kimberley.

UNCOVER

GSWA is involved in another collaborative initiative known as UNCOVER. This is a partnership with other Australian geological surveys, exploration and mining companies, resource services providers, and research groups. It aims to integrate efforts in current technology research and pre-competitive data, and is working to further stimulate collaborative partnerships between government, researchers and industry, to meet the objective of improving exploration performance in Australia.

3.4 South West Hub

The successful partnership between government, research organisations and industry is a hallmark of the South West Hub project, and a key to its ultimate success.

The project is jointly funded by the State Government (\$11.7 million) and the Commonwealth Government (\$52 million).

It is being led by DMP, in an alliance with Alcoa Australia, Perdaman Chemicals and Fertilisers, Electricity Generation Corporation (Synergy) and Premier Coal, in partnership with the National Geosequestration Laboratory.

DMP has established the legislation and regulations for the injection and storage of greenhouse gases in onshore areas, and is currently managing the research and data collection phase of the project. This involves a program of collecting and analysing data and samples from the Lesueur sandstone formation in the southern Perth Basin to test its commercial feasibility as a carbon dioxide reservoir. DMP has completed a deep stratigraphic well, 2D and 3D seismic surveys, and recently finished a three-well drilling program.

Researchers from CSIRO, Curtin University and UWA, through the National Geosequestration Laboratory, are assessing and testing the results of the seismic survey and drilling program.

Industry partners are expected to commence the commercial aspects of the project following the completion of this investigation phase.

3.5 Facilities

Partnerships between government, research centres and industry have been instrumental in the delivery of a host of major research infrastructure projects and state-of-the-art facilities in Western Australia that are enabling research and innovation for the mining and petroleum industries.

Advanced Resources Characterisation Facility

The Advanced Resource Characterisation Facility provides a step-change in advanced minerals characterisation that will offer previously unseen levels of analytic precision, accuracy, sensitivity and spatial resolution to improve the success of exploration in challenging environments. It draws on investments from the Australian Government's Science and Industry Endowment Fund and the NRSP foundation partners, CSIRO, Curtin University and UWA. Locating such a major facility in Western Australia would not have been possible without the culture of collaboration between these major research institutions.

Pawsey Supercomputer Centre

The Pawsey Supercomputer Centre is the most powerful public research super computer in the southern hemisphere. The centre provides the resources sector and researchers with access to a system that can assist in investigating and developing new and enhanced techniques to find and recover mineral and

petroleum resources. It was made possible through a partnership between CSIRO, Curtin University, Edith Cowan University, Murdoch University and UWA, as well as financial support from the State and Commonwealth governments.

John de Laeter Centre for Isotope Research

The John de Laeter Centre for Isotope Research is a collaborative venture involving CSIRO, Curtin University, UWA and GSWA. It features world-class modern analytical facilities that contribute to the development of the minerals and petroleum sectors in Western Australia such as ion microprobes, mass spectrometers, noble gas mass spectrometers, thermochronology facilities, and laser ablation and solution instruments.

One of the most important outputs of the Centre is accurate isotopic dating of Western Australia's very old geological units and mineral deposits.

National Geosequestration Laboratory

The recently opened National Geosequestration Laboratory in Perth, which brings together world-leading technology and equipment to analyse rocks and their contained fluids for the long term storage of carbon, is a collaboration between CSIRO, Curtin University and UWA. The centre was funded by a \$48.4 million Australian Government Education Investment Fund contribution and was made possible through WA:ERA and support from the Western Australian Government.

3.6 Data management and transparency

Making information and data easily accessible and usable by the public can drive improved service delivery and productivity, innovative insights, ideas and employment.

Department of Mines and Petroleum initiatives

DMP continues to promote its longstanding commitment to data transparency through:

- the enormous quantity of exploration reports and data submitted by mineral and energy explorers after a period of confidentiality, which becomes pre-competitive information for subsequent tenement holders;
- developing a model State Environmental Data Library to enable public access to environmental, water and cultural heritage spatial and attribute data retained by State Government agencies. These agencies comprise DMP, the Department of Aboriginal Affairs, the Department of Parks and Wildlife, the Department of Environment Regulation, the Department of Water, and the Office of the Environmental Protection Authority. Such a model promotes better decision making and avoids duplication of data collection activities; and
- supporting the 2015 Unearthed Hackathon and GovHack 2015.

4. INNOVATION NEEDED FOR FUTURE RESOURCES DEVELOPMENT IN WESTERN AUSTRALIA

The future growth and prosperity of Western Australia's resources sector relies on meeting a number of challenges through greater knowledge and development of technologies.

Scientific research and technological development has been successfully delivered through joint ventures between government, universities and industry. Challenges facing technological development in the State's resource industry will be best addressed through the encouragement and facilitation of further collaboration. The delivery of innovation could also be made more effective through increased interaction with the resource services sector.

Initial and ongoing support from the State and Commonwealth governments is also likely to remain important for overcoming these challenges.

4.1 Minerals exploration and production

Exploration is the life-blood of the resources sector. However, exploration success is increasingly harder to achieve in Western Australia as many of the easy to find resources have already been discovered and new resources are buried beneath significant soil or rock cover.

As the depth and geotechnical complexity of economic mineral and hydrocarbon deposits increases, the risk of non-discovery increase and the costs of exploration and production increase. Resource production involves greater technical risks, higher energy intensity, and higher capital and operating costs.

If solutions to these issues are not developed, the State risks diversion of investment to jurisdictions where resource discovery and extraction present lower risks and costs.

The risks and costs of finding minerals can be mitigated through new knowledge and exploration technologies that can be applied in deeper and more geotechnically challenging environments. The recovery of mineral resources can be aided through more efficient and optimised technologies that can be applied at deeper geological depths, in lower grade ores and more complex geological settings.

To develop these solutions, DMP recommends ongoing support from government for MRIWA. Future commitments to research and development activities in the resources sector by government, universities and industry should also be guided by the MRIWA Research Priorities Plan. This plan was developed through a highly consultative process, and is available at: <http://meriwa.wa.gov.au/research/research-priority-plan-summary-and-wamri-policy>.

DMP also considers that the 16 high priority activities identified by the UNCOVER Roadmap, which is available from AMIRA International, should help

inform future research and the development of technical solutions to unlock Western Australia's hidden resource potential and find new ore deposits.

4.2 Shale and tight gas

DMP supports development of a better technical understanding of the scientific needs and knowledge gaps in relation to shale and tight gas activities in Western Australia.

It is estimated that Western Australia has up to 280 trillion cubic feet of potential shale and tight gas in the Canning and Perth Basins. This represents approximately twice the amount of gas held in the State's offshore areas.

Through the Interagency Working Group for Shale and Tight Gas, several State Government agencies are cooperating to develop a robust regulatory framework for shale and tight gas. Through this Group, these agencies are also cooperating to identify the scientific needs and knowledge gaps that might impact development.

Increased understanding of the technical challenges related to shale and tight gas development in Western Australia has the potential to unlock these resources. This is in the best interests of the State as shale and tight gas can play a significant role in future economic growth and energy security by increasing the total availability and diversity of energy sources.

5. SUMMARY AND RECOMMENDATIONS

Western Australia is a major centre of resources science and technology. It hosts research centres and facilities which are achieving major innovations through a culture of collaboration, partnerships and collective efforts involving government, universities, technical institutions and industry.

DMP has had a significant role in establishing, supporting and partnering with a suite of research centres and facilities delivering innovation for the resources sector in the State.

Scientific research and technological innovation, addressing the future needs of the resources sector will contribute to the expansion of the Western Australian economy.

While the resources sector has been identified as one of the State's five priority areas for scientific research, future government funding will need to be considered within the context of the other priority areas, as described in the Western Australian Government's Science Statement.¹

Nevertheless, DMP recommends that the State's research and technology needs for the resources sector should be guided by the MRIWA Research Priorities Plan and informed by the UNCOVER Roadmap.

Encouraging such research and innovation in the future will involve:

- government funding support for and fostering of, partnerships between governments, universities, mining and petroleum industries, and the resource services sector;
- support for MRIWA to collaborate with research centres, universities, resources companies, and the mining, equipment and technology services sector;
- support for the EIS to accelerate GSWA's ability to provide leading geoscience knowledge, concepts and tools that encourage minerals and petroleum exploration; and
- improving libraries of data and scientific knowledge as well as data management, transparency and openness.

Greater technical understanding of the scientific needs and knowledge gaps in relation to shale and tight gas development in Western Australia will also be important in supporting responsible development of such resources.

¹ A Science Statement for Western Australia – Growing Western Australia, published by the Department of the Premier and Cabinet, Office of Science, in April 2015

3.2 Minerals Research Institute of Western Australia

Building on the work of the former Minerals and Energy Research Institute of Western Australia, the Minerals Research Institute of Western Australia (MRIWA) was established in 2013 as a statutory authority by the Western Australian Government with initial funding of \$7.5 million provided over three years.

It collaborates with Australian and worldwide research centres, universities, resources companies, and the mining, equipment and technology services sector, in mineral-related scientific research and technological development.

MRIWA has a scholarships program for PhD candidates and final year students' Honours projects. It also supports the start-up and accelerator communities, such as Uearthed, which aids the growth of new companies and innovative products through seed funding in exchange for equity and linkages with industry mentors.

To date, MRIWA has committed \$4.1 million to minerals research projects, including significant investments in:

- Distal Footprints of Giant Ore Systems project through \$2.6 million in funding (discussed in greater detail in Section 3.3); and
- Cooperative Research Centre for Optimising Resource Extraction II, through \$0.6 million in funding, which is a major national research initiative involving industry and the Commonwealth Government. It is focused on bridging the gap between research and industry and fostering the development and commercialisation of new technologies that will improve the efficiency and cost-effectiveness of mineral extraction.

3.3 Geological Survey of Western Australia (GSWA)

GSWA, a division of DMP, encourages exploration by providing new geoscience data and knowledge that reveal new exploration opportunities, reducing the technical and economic risk for minerals and energy companies. In recent years this role has received additional support through the Exploration Incentive Scheme (EIS).

GSWA strategically invests in collaborative projects involving the use or generation of pre-competitive geoscience information that will better reveal the State's potential for mineral and energy resources. These projects are typically with Geoscience Australia, CSIRO, universities and industry and leverage collective funding sources and expertise.

It also maintains a digital library of geoscience information in Western Australia that can be searched spatially, providing access to very large volumes of structural data for industry and researchers. This library is a key source of data for collaborative projects involving GSWA.

Exploration Incentive Scheme

GSWA's participation in collaborative technologically innovative projects has been in part assisted and accelerated by the EIS. The Scheme is currently supported through State Government funding of \$10 million per year to June 2017, by which time the government's total contribution to the EIS since April 2009 will be over \$130 million.

An independent economic impact assessment of the Scheme has shown that the State Government has received a return of \$10.3 million in exploration activities and 12.5 full time jobs for every \$1 million it has invested. The potential impact of new discoveries and subsequent commercialisation is a further \$13.4 million and 35 full time employees per \$1 million. Examples of new discoveries the program has led to include:

- Nova-Bollinger nickel project in the Fraser Range east of Norseman
- Tropicana East Gold Mine project north-east of Kalgoorlie
- Handpump gold discovery in the West Musgrave region
- Gruyere gold deposit in the Yamarna greenstone belt
- Webb Diamond Project in the Gibson Desert
- Oxley potash project near Three Springs
- Camelwood nickel project north-east of Leinster
- Yeneena copper project in the Paterson Province
- MacIntosh graphite project in the East Kimberley
- Lake Mackay uranium project in the Lake Mackay region
- Speewah vanadium-uranium project in the East Kimberley.

Ongoing support for the EIS is considered critical to the ability of GSWA to provide cutting edge geoscience information, concepts and tools that encourage minerals and petroleum exploration.

Distal Footprints of Giant Ore Systems project

The Distal Footprints of Giant Ore Systems project is a ground-breaking project and an excellent example of a team approach to collaborative geoscience research and technological innovation in Western Australia.

This project has a total value of \$16 million and is supported by funding from the Science and Industry Endowment Fund, MRIWA, GSWA (through the EIS) and industry. It is a collaboration of CSIRO, Curtin University, UWA and the Australian Research Council Centre of Excellence for Core to Crust Fluid Systems.

This project takes advantage of the massive geophysical databases maintained by GSWA.