Reference list for water-related coal seam gas and coal mining research

Report 3: Australia, Canada, China, India, Russia, the United Kingdom and the United States of America, July 2012 to September 2013

This report is the third in a series of reference lists commissioned by the Department of the Environment on the advice of the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC). It was prepared by the Water Research Laboratory of the School of Civil and Environmental Engineering at UNSW Australia.

October 2014

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Addendum

Changes to government departments may have occurred since the finalisation of this report by the authors. Up-to-date information should be sourced from the relevant department.

On 1 January 2013, the Queensland Water Commission (QWC) ceased operations. The Office of Groundwater Impact Assessment (OGIA) retains the same powers as the former QWC under Chapter 3 of the *Water Act 2000* (Qld).

On 1 January 2014, New South Wales Catchment Management Authorities (CMA) joined with the Livestock Health and Pest Authorities and Department of Primary Industries agriculture extension to form Local Land Services. The Namoi Catchment Management Authority (Namoi CMA) has been absorbed into the North West Local Land Services.

Contents

Copyright ii
Acknowledgements ii
Disclaimer ii
Addendum ii
Contents iv
Summary xiv
Abbreviations xvi
Glossary xvii
1 Introduction 1
1.1 Scope 1
2 Method 4
2.1 Research project survey 4
2.2 Search for research organisations/researchers 4
2.3 Literature search 6
3 Overview of research projects 7
3.1 Research themes 7
3.2 Summaries by country 8
3.2.1 Australia 8
3.2.2 Canada 9
3.2.3 China 10
3.2.4 India 11
3.2.5 Russia 11
3.2.6 United Kingdom 12
3.2.7 United States 13
3.3 Centres of research 13
4 Research project profiles 19
4.1 Aquifer interconnectivity 19
4.1.1 Australia 20
4.1.2 United States 36
4.2 Disruption of surface water flow pathways 38
4.2.1 Australia 38
4.2.2 China 54
4.2.3 Russia 68
4.2.4 United Kingdom 69
4.2.5 United States 71
4.3 Co-produced water and salt management (CSG) and mine water and salt management (coal mines) 81

4.3.1 Australia 81
4.3.2 China 119
4.3.3 United Kingdom 134
4.3.4 United States 136
4.4 Seismicity 155
4.4.1 Australia 155
4.4.2 United States 157
4.5 Integrity of wells - installation, operation, decommissioning 164
4.5.1 Australia 164
4.5.2 China 167
4.5.3 United States 176
4.6 Hydraulic fracturing 183
4.6.1 Australia 183
4.6.2 Canada 185
4.6.3 China 187
4.6.4 United States 189
4.7 Quality and reliability of water supplies including environmental health 192
4.7.1 Australia 192
4.7.2 China 199
4.7.3 India 204
4.7.4 United Kingdom 208
4.7.5 United States 213
4.8 Water dependent ecosystems 227
4.8.1 Australia 227
4.8.2 Canada 241
4.8.3 China 243
4.8.4 United States 244
4.9 Cumulative impact assessments 251
4.9.1 Australia 251
4.9.2 Canada 264
5 Bibliography 265
Appendix A - Project survey 277
Appendix B - Project survey recipients 280
Appendix C - Literature search methodology 286
Appendix D - Project index 295

Tables

Table 1.1 Scope of reports commissioned by OWS regarding water impacts of coal mining and coal seam gas 2
Table 3.1 Distribution of projects by research centres 14

Table 4.1 Project 1: Groundwater monitoring report for April - May 2012, Angus Place and Springvale groundwater monitoring program 20
Table 4.2 Project 2: Conceptualisation of the Walloon Coal Measures beneath the Condamine Alluvium 21
Table 4.3 Project 3: Using hydrogeochemistry to understand inter-aquifer mixing in the on-shore part of the Gippsland Basin, southeast Australia 22
Table 4.4 Project 4: 2013 Annual Report: Surat underground water impact report 23
Table 4.5 Project 5: Integrated water model 24
Table 4.6 Project 6: Vertical hydraulic connectivity studies 25
Table 4.7 Project 7: New insights into the hydrodynamics of the Surat Basin 26
Table 4.8 Project 8: Connectivity between MNES Springs and Walloon Coal Measures (QGC, Santos, Australia Pacific LNG) 27
Table 4.9 Project 9: Groundwater Visualisation System (GVS): A software framework for integrated display and interrogation of conceptual hydrogeological models, data and time-series animation 28
Table 4.10 Project 10: Linking 3D geological modelling and multivariate statistical analysis to define groundwater chemistry baseline and inter-aquifer connectivity, Clarence-Moreton Basin, southeast Queensland, Australia 30
Table 4.11 Project 11: Observations of ground movements within the overburden strata above longwall panels and implications for groundwater impacts 32
Table 4.12 Project 12: Geotechnical centrifuge permeater for characterizing the hydraulic integrity of partially saturated confining strata for CSG operations 33
Table 4.13 Project 13: Leading practices for assessing the integrity of confining strata - Application to mining and coal-seam gas extraction 34
Table 4.14 Project 14: Impacts of longwall mining and coal seam gas extraction on groundwater regimes in the Sydney Basin 35
Table 4.15 Project 15: Surface water and groundwater interactions in an extensively mined watershed, upper Schuylkill River, Pennsylvania, USA 36
Table 4.16 Project 16: Criteria for functioning river landscape units in mining and post mining landscapes 38
Table 4.17 Project 17: Subsidence: an overview of causes, risks and future developments for coal seam gas production 39
Table 4.18 Project 18: Subsidence monitoring - technical background paper for NSW Chief Scientist and Engineer 40
Table 4.19 Project 19: Some interesting abandoned mine stabilization projects in Australia 41
Table 4.20 Project 20: Assessment of mine subsidence in an area with a major pillar crushing event - Newcastle, Australia 42
Table 4.21 Project 21: Seismic imaging of stressed pillars in abandoned coal mines - Case studies from Australia 44
Table 4.22 Project 22: Subsidence monitoring - technical background paper for NSW Chief Scientist and Engineer 46
Table 4.23 Project 23: Building new bridges on the hunter expressway over abandoned coal mines 47
Table 4.24 Project 24: Managing mine subsidence along railways and highway pavements in the southern coalfield 48
Table 4.25 Project 25: Continuous monitoring of mining induced strain in a road pavement using fiber Bragg grating sensors 49
Table 4.26 Project 26: Hunter Expressway, Australia: Dealing with poor ground and subsidence 50
Table 4.27 Project 27: Rail corridor mine remediation - from investigation to verification 51

Table 4.28 Project 28: Numerical modelling of mining subsidence in the Southern Coalfield of New South Wales, Australia 53
Table 4.29 Project 29: Study on regulations of coal mining under highway 54
Table 4.30 Project 30: Present situation of research on coal mining subsidence under highway in China 55
Table 4.31 Project 31: Effects of coal mining subsidence on the changes of soil nutrient in Shenfu-Dongsheng coal field 56
Table 4.32 Project 32: Changes of precipitation infiltration recharge in the circumstances of coal mining subsidence in the Shen-dong coal field, China 57
Table 4.33 Project 33: Dynamic monitoring of land subsidence in mining area from multi-source remote-sensing data - a case study at Yanzhou, China 58
Table 4.34 Project 34: Analysis on distribution characteristics of soil carbon pool in mining subsidence wetlands 59
Table 4.35 Project 35: The monitoring of ecological reclamation evolution and landscape ecology remodeling technology in mining subsidence area 60
Table 4.36 Project 36: Water quality variation of mining-subsidence lake during the initial stage: cases study of Zhangji and Guqiao Mines 61
Table 4.37 Project 37: Study on the deformation and stability of building foundations in mining subsidence areas 62
Table 4.38 Project 38: Surface subsidence prediction for the WUTONG mine using a 3-D finite difference method 63
Table 4.39 Project 39: Huge thick conglomerate movement induced by full thick longwall mining huge thick coal seam 64
Table 4.40 Project 40: Management of water quality information in mining subsidence waterlogged area 65
Table 4.41 Project 41: Quantitative prediction of mining subsidence and its impact on the environment 66
Table 4.42 Project 42: Highway construction across heavily mined ground and steep topography in southern China 67
Table 4.43 Project 43: Earth surface subsidence in the Kuznetsk coal basin caused by manmade and natural seismic activity according to ALOS PALSAR interferometry 68
Table 4.44 Project 44: Relationship between joint movement and mining subsidence 69
Table 4.45 Project 45: Numerical modelling of shallow abandoned mine working subsidence affecting transport infrastructure 70
Table 4.46 Project 46: Exploring the legacy effects of surface coal mining on stream chemistry 71
Table 4.47 Project 47: Templeton gap floodway levees, investigation and mitigation of mine subsidence 72
Table 4.48 Project 48: Enhanced subsurface subsidence prediction model that considers overburden stratification 74
Table 4.49 Project 49: Applications of DInSAR for measuring mine-induced subsidence and constraining ground deformation model 75
Table 4.50 Project 50: Mitigation and monitoring of structural distress in the Whitely Electrical Substation due to mine subsidence 76
Table 4.51 Project 51: Geotechnical aspects of a 16 m high steep embankment in Eastern Pennsylvania 77
Table 4.52 Project 52: Applications of surface and subsurface subsidence theories to solve ground control problems 78
Table 4.53 Project 53: Identifying root causes for subsidence over abandoned coal mine - A case study 80

Table 4.54 Project 54: Assessment of options for using coal seam gas water in the Central Condamine Alluvium - Business case 81
Table 4.55 Project 55: Coal seam gas, coal and agriculture - water implications 82
Table 4.56 Project 56: Chemicals associated with coal seam gas exploration: towards understanding their ecological risks 83
Table 4.57 Project 57: CSIRO's Water for a Healthy Country Flagship 84
Table 4.58 Project 58: Optimal reinjection strategies for the management of coal seam gas production water 85
Table 4.59 Project 59: Healthy HeadWaters coal seam gas water feasibility study 86
Table 4.60 Project 60: Assessment of salinity impacts of CSG water on landscapes and surface streams 87
Table 4.61 Project 61: Coal seam gas (CSG): What becomes of produced water? Regulation and strategies 88
Table 4.62 Project 62: Infrastructure options for delivering coal seam gas water to the Central Condamine Alluvium 90
Table 4.63 Project 63: CSG water use in the Central Condamine Alluvium: Substitution issues 91
Table 4.64 Project 64: Hydrochemical compatibility assessments of aquifer injection of treated coal seam gas water into Surat Basin aquifers 92
Table 4.65 Project 65: Injection of coal seam gas water into the Central Condamine Alluvium: Site prioritisation 93
Table 4.66 Project 66: Feasibility of injecting coal seam gas water into the Central Condamine Alluvium 94
Table 4.67 Project 67: Produced Water - technical background paper for NSW Chief Scientist and Engineer 95
Table 4.68 Project 68: Coal seam gas associated water treatment and management; opportunities and limitations 96
Table 4.69 Project 69: Coal seam gas and associated water: A review paper 97
Table 4.70 Project 70: Initial report on the Independent Review of Coal Seam Gas Activities in NSW 98
Table 4.71 Project 71: Modelling of drainage and salinity 99
Table 4.72 Project 72: Selective salt recovery trials 100
Table 4.73 Project 73: Brine injection 101
Table 4.74 Project 74: Selective salt recovery - brine management (QGC, Australia Pacific LNG, Arrow Energy) 102
Table 4.75 Project 75: Treatment methods for CSG production waters 103
Table 4.76 Project 76: Testing application of CSG production waters 104
Table 4.77 Project 77: Design of beneficial use schemes for disposal of treated CSG production water 105
Table 4.78 Project 78: Injection of coal seam gas water into the Central Condamine Alluvium: Field program design 106
Table 4.79 Project 79: Field trial to measure and model water use of range of forage crops to be irrigated by CSG water 2: Glasshouse trial to ascertain the root zone salinity tolerance of range of forage crops 107
Table 4.80 Project 80: Compatibility of injected concentrated brines with formation waters and their tendency for scaling 108
Table 4.81 Project 81: Algal growth and community structure in a mixed-culture system using coal seam gas water as the water source 109
Table 4.82 Project 82: Assessment of alternative use options for coal seam gas water proposed for Central Condamine Alluvium recharge schemes 110

Table 4.83 Project 83: Fracture delineation and monitoring of geothermal and coal seam gas areas using magnetotellurics 111
Table 4.84 Project 84: Evaluating the effect of bicarbonate in coal seam gas water on soil threshold electrolyte concentration relationships 112
Table 4.85 Project 85: Assessing impacts of CSG amended water application: soil chemistry equilibrium as influenced by solution volume and time 113
Table 4.86 Project 86: Coal seam gas water as a medium to grow Dunalliella Tertiolecta for lipid extraction 114
Table 4.87 Project 87: CSG water as a medium to grow microalgae for biofuel production 115
Table 4.88 Project 88: Renewed demands for mine water management 116
Table 4.89 Project 89: Spatial analysis of coal seam water chemistry 117
Table 4.90 Project 90: CSG water; desalination and the challenge for the CSG industry; developing a holistic CSG brine management solution 118
Table 4.91 Project 91: A treatment process for coal-bed-methane-extraction water 119
Table 4.92 Project 92: A treatment study of acid mine wastewater and the performance of electricity generation by coupling system using sludge anaerobic fermentation-sulfate reducing bacteria 120
Table 4.93 Project 93: A harmless treatment for coal bed methane produced water and its reuse 121
Table 4.94 Project 94: A pilot-scale demonstration of reverse osmosis unit for treatment of coal-bed methane co-produced water and its modelling 122
Table 4.95 Project 95: Design of water purification plant of micro-polluted source water in Shendong mine area 123
Table 4.96 Project 96: Underground direct treatment and recycle of coal mine water 124
Table 4.97 Project 97: National Science and Technology Major Project (No. 2011ZX05060-005) 125
Table 4.98 Project 98: Mine water treatment technology analysis 126
Table 4.99 Project 99: Mechanism and experimental research on treatment of coal chemical wastewater by external circular anaerobic reactor 127
Table 4.100 Project 100: Small experiment of high - efficiency intelligent coal mine water recycling equipment 128
Table 4.101 Project 101: Treatment of coal mine drainage with high turbidity, high iron and manganese in the use of coagulation and sedimentation process 129
Table 4.102 Project 102: A nitrogen foam fluid with low formation damage for CBM fracturing treatment 131
Table 4.103 Project 103: New technologies of purification and utilization on mine water 132
Table 4.104 Project 104: Comment on "identifying well contamination through the use of 3-D fluorescence spectroscopy to classify coalbed methane produced water" 133
Table 4.105 Project 105: Hydraulic performance assessment of passive coal mine water treatment systems in the UK 134
Table 4.106 Project 106: Mine water management post-closure 135
Table 4.107 Project 107: Potential for beneficial use of coal-bed methane produced water in western Alabama to augment water supplies during intense drought 136
Table 4.108 Project 108: Forward osmosis treatment of drilling mud and fracturing wastewater from oil and gas operations 138
Table 4.109 Project 109: Photo-induced graft polymerization of N-isopropyl acrylamide on thin film composite membrane: Produced water treatment and antifouling properties 139
Table 4.110 Project 110: Performance and microbial community dynamics of a sulfate-reducing bioreactor treating coal generated acid mine drainage 141

Table 4.111 Project 111: Radium and barium removal through blending hydraulic fracturing fluids with acid mine drainage 142
Table 4.112 Project 112: The role of ownership in environmental performance: Evidence from coalbed methane development 143
Table 4.113 Project 113: An estimate of the near-term electricity generation potential of co-produced water from active oil and gas wells 144
Table 4.114 Project 114: Disclosure of hydraulic fracturing fluid chemical additives: analysis of regulations 146
Table 4.115 Project 115: Geochemical and microbial community dynamics of a remediation system treating coal-derived acid mine drainage 147
Table 4.116 Project 116: Minerals and mine drainage 149
Table 4.117 Project 117: Deep subsurface drip irrigation using coal-bed sodic water: Part I. Water and solute movement 150
Table 4.118 Project 118: The effect of coal-bed methane water on spearmint and peppermint 152
Table 4.119 Project 119: Analysis of reserve pit sludge from unconventional natural gas hydraulic fracturing and drilling operations for the presence of technologically enhanced naturally occurring radioactive material (TENORM) 153
Table 4.120 Project 120: Shallow groundwater and soil chemistry response to 3 years of subsurface drip irrigation using coalbed-methane-produced water 154
Table 4.121 Project 121: Seismicity - technical background paper for NSW Chief Scientist and Engineer 155
Table 4.122 Project 122: Seismicity and induced earthquakes (background paper to NSW Chief Scientist and Engineer) 156
Table 4.123 Project 123: Introduction to this special section: Passive seismic and microseismic—Part 2 157
Table 4.124 Project 124: Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 Mw 5.7 earthquake sequence 158
Table 4.125 Project 125: Earthquake catalogues for New Mexico and bordering areas: 2005-2009 159
Table 4.126 Project 126: Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons 160
Table 4.127 Project 127: Enhanced remote earthquake triggering at fluid-injection sites in the Midwestern United States 162
Table 4.128 Project 128: Injection-induced earthquakes 163
Table 4.129 Project 129: Life cycle of coal seam gas projects: technologies and potential impacts (Report for the New South Wales Office of the Chief Scientist and Engineer) 164
Table 4.130 Project 130: Low cycle cement fatigue experimental study and the effect on HPHT well integrity 165
Table 4.131 Project 131: Anisotropic damage mechanics as a novel approach to improve pre- and post-failure borehole stability analysis 166
Table 4.132 Project 132: The "U-type" wells history of fuzzy ball drilling fluids for CBM drilling in China 167
Table 4.133 Project 133: A Mechanical model of borehole stability for weak plane formation under porous flow 168
Table 4.134 Project 134: Study on borehole stability of unconsolidated sandstone in depleted reservoir 169
Table 4.135 Project 135: Borehole stability analysis and its application in Xujiahe Formation of ZJ Block 170

Table 4.136 Project 136: Wellbore stability analysis of coal seam based on Hoek-Brown Criterion 171
Table 4.137 Project 137: Discrete element model for coal wellbore stability 172
Table 4.138 Project 138: Analysis of failure criterions on wellbore stability prediction 173
Table 4.139 Project 139: Study on borehole stability in Haita Basin 174
Table 4.140 Project 140: Effect of pore pressure variation on borehole stability of drilling in sandstone reservoir 175
Table 4.141 Project 141: Environmental risk arising from well construction failure: Difference between barrier and well failure, and estimates of failure frequency across common well types, locations and well age 176
Table 4.142 Project 142: Identifying well contamination through the use of 3-D fluorescence spectroscopy to classify coalbed methane produced water 178
Table 4.143 Project 143: Modeling reveals hidden conditions that can impair wellbore stability and integrity 179
Table 4.144 Project 144: What are we going to do with all these wells then? 181
Table 4.145 Project 145: Historical analysis of oil and gas well plugging in New York: Is the regulatory system working? 182
Table 4.146 Project 146: Environmental regulation of hydraulic fracturing in Queensland 183
Table 4.147 Project 147: Link between rocks, hydraulic fracturing, economics, environment, and the global gas portfolio 185
Table 4.148 Project 148: Effect of interface defects on shear strength and fluid channeling at cement-interlayer interface 187
Table 4.149 Project 149: Community-based risk assessment of water contamination from high-volume horizontal hydraulic fracturing 189
Table 4.150: Project 150: History and development of effective regulation of hydraulic fracturing; the genesis of Colorado Rule 205A 190
Table 4.151 Project 151: Opportunities and challenges to coal bed methane production in Australia 192
Table 4.152 Project 152: Toxicity and eco-toxicity testing for stimulation chemicals and flowback waters 193
Table 4.153 Project 153: Ecological assessment of areas requiring remediation and stabilisation within East Wolgan and Narrow Swamps at Angus Place and Springvale Coal Mines, Newnes Plateau 194
Table 4.154 Project 154: The potential impacts of coal seam gas on biodiversity 195
Table 4.155 Project 155: The National Harmonised Regulatory Framework for natural gas from coal seams 196
Table 4.156 Project 156: Literature review: coal seam gas impacts on water resources 197
Table 4.157 Project 157: Vulnerability of aquifers to coal seam gas water extraction 198
Table 4.158 Project 158: Stable isotope and water quality analysis of coal bed methane produced water in the southern Qinshui Basin, China 199
Table 4.159 Project 159: Ecological restoration of abandoned mine land in China 200
Table 4.160 Project 160: Variational characteristics of water quality of produced formation water in coalbed methane production area 201
Table 4.161 Project 161: Hydrogeochemical evolution of Ordovician limestone groundwater in Yanzhou, North China 202
Table 4.162 Project 162: Assessment of water quality around surface coal mine in India 204
Table 4.163 Project 163: Environmental geochemistry and quality assessment of mine water of Jharia coalfield, India 205
Table 4.164 Project 164: Multivariate statistical analysis for assessment of groundwater quality in Talcher Coalfield area, Odisha 206

Table 4.165 Project 165: Effect of mining on geochemistry of groundwater in Permo-carboniferous Gondwana coalfields: Raniganj Basin, India 207
Table 4.166 Project 166: Modified multi-phase stability diagrams: An AMD case study at a site in Northumberland, UK 208
Table 4.167 Project 167: Science project SC030136/SR41 209
Table 4.168 Project 168: Flow dependent water quality impacts of historic coal and oil shale mining in the Almond River catchment, Scotland 210
Table 4.169 Project 169: Geochemical tracing of methane from unconventional gas production 212
Table 4.170 Project 170: Advanced characterization of coalbed methane produced water quality in the Rocky Mountain region, USA for consideration as a potential water resource 213
Table 4.171 Project 171: Stream reconstruction under SMCRA burning star #4: A case study 215
Table 4.172 Project 172: Assessing different mechanisms of toxicity in mountaintop removal/valley fill coal mining-affected watershed samples using *Caenorhabditis elegans*: e75329 216
Table 4.173 Project 173: Analyses of geological and hydrodynamic controls on methane emissions experienced in a Lower Kittanning coal mine 217
Table 4.174 Project 174: Water chemistry in areas with surface mining of coal, West Virginia, USA 219
Table 4.175 Project 175: Geochemical and stable isotopic analysis of the Tongue River and associated tributaries in the Powder River Basin: An analysis of the cause of annual elevated salinity in spring runoff 220
Table 4.176 Project 176: Carbon isotope characterization of Powder River Basin coal bed waters: Key to minimizing unnecessary water production and implications for exploration and production of biogenic gas 222
Table 4.177 Project 177: Spatial variability of coalbed natural gas produced water quality, Powder River Basin, Wyoming: Implications for future development 225
Table 4.178 Project 178: Guidelines for establishing ecologically sustainable discharge criteria in seasonally flowing streams 227
Table 4.179 Project 179: Reducing the impact of longwall extraction on groundwater systems 228
Table 4.180 Project 180: Impact of multi-purpose aquifer utilisation on a variable-density groundwater flow system in the Gippsland Basin, Australia 230
Table 4.181 Project 181: Upscaling hydraulic processes and properties to assess impacts on groundwater from coal seam gas abstractions 231
Table 4.182 Project 182: Simulating the impact of coal seam gas water production on aquifers 232
Table 4.183 Project 183: Great Artesian Basin water resource assessment 233
Table 4.184 Project 184: Coal seam gas water - river discharge: context matters 234
Table 4.185 Project 185: Direct toxicity assessment 236
Table 4.186 Project 186: Condamine River seep investigation 237
Table 4.187 Project 187: Literature and science review of coal seam gas and coal mining impacts on water-related environmental values 238
Table 4.188 Project 188: Condamine River gas seep investigation 239
Table 4.189 Project 189: Stage One Report: Development of ecosystem protection trigger values For sodium sulfate in seasonally flowing streams of the Fitzroy River Basin 240
Table 4.190 Project 190: Groundwater protection and unconventional gas extraction: the critical need for field-based hydrogeological research 241

Table 4.191 Project 191: The hydrogen and oxygen isotope characteristics of drainage water from Taiyuan coal reservoir 243
Table 4.192 Project 192: How many mountains can we mine? Assessing the regional degradation of Central Appalachian Rivers by surface coal mining 244
Table 4.193 Project 193: Spatial variability of ecological and water quality impacts of acid mine drainage in an alpine wetland 245
Table 4.194 Project 194: Unconventional gas resources in the USA 246
Table 4.195 Project 195: Effects of coal mining on freshwater mussels in the New River Basin; a test using Corbicula as biomonitors 248
Table 4.196 Project 196: Effects of coal mining on survivorship and taphonomy of the Asian clam 249
Table 4.197 Project 197: Effects of mountaintop mining on fish distributions in Central Appalachia 250
Table 4.198 Project 198: Coal seam gas – Toward a risk management framework for a novel intervention 251
Table 4.199 Project 199: Energy from the food bowl: an uneasy coexistence 253
Table 4.200 Project 200: Cultivating collaboration: Lessons from initiatives to understand and manage cumulative impacts in Australian resource regions 254
Table 4.201 Project 201: CSG water use proposals in the QMDB (assessing the impact on aquatic ecosystems) 255
Table 4.202 Project 202: Assessing the cumulative impact of mining scenarios on bioregional assets in the Namoi Catchment 256
Table 4.203 Project 203: General Purpose Standing Committee No. 5 Inquiry into coal seam gas 257
Table 4.204 Project 204: An analysis of coal seam gas production and natural resource management in Australia Issues and ways forward 258
Table 4.205 Project 205: Managing cumulative risks to assets from mining 259
Table 4.206 Project 206: Underground water impact report for the Surat Cumulative Management Area 260
Table 4.207 Project 207: Regulating coal seam gas in Queensland: Lessons in an adaptive environmental management approach? 261
Table 4.208 Project 208: Namoi Catchment Water Study independent expert interim final report 262
Table 4.209 Project 209: Modeling the impact of revegetation on regional water quality: A collective approach to manage the cumulative impacts of mining in the Bowen Basin, Australia 263
Table 4.210 Project 210: Legitimizing industry and multi-sectoral regulation of cumulative impacts: A comparison of mining and energy development in Athabasca, Canada and the Hunter Valley, Australia 264

Figures

Figure 3.1 Distribution of research themes 7
Figure 3.2 Relative proportion of projects by country and research theme 8
Figure 3.3 Distribution of research themes in projects from Australia 9
Figure 3.4 Distribution of research themes in projects from Canada 10
Figure 3.5 Distribution of research themes in Chinese research projects 11
Figure 3.6 Distribution of research themes in projects from the United Kingdom 12
Figure 3.7 Distribution of research themes in projects from the US 13

Summary

This reference list is the third in a series of reports commissioned by the Department of the Environment on the advice of the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC). It includes summaries of research projects relating to the impacts of coal seam gas and coal mining developments on water resources, currently being undertaken or completed, in Australia, Canada, China, Russia, India, the United Kingdom (UK) and United States of America (US) during the period July 2012 to September 2013.

The objective of the reference list series is to provide a resource for the Department of the Environment's Office of Water Science (OWS) and the IESC to fulfil their respective functions in delivering the bioregional assessments, identifying research priorities and delivering research products, and providing advice on coal seam gas and coal development proposals to Australian Government regulators.

The reference list will also provide others, including state regulators and industry, with project and citation information, which will enable improved understanding of the water-related impacts of coal seam gas and coal mining.

Main findings

- A total of 210 projects were identified from Australia, Canada, China, India, Russia, the UK and the US between July 2012 and September 2013, completed by 125 research organisations and companies.
- The dominant research theme on which projects have been focusing was co-produced/mine water (93), followed by water supplies (60) and disruption of surface water (45).
- Compared to reports 1 and 2 in this reference list series, the number of research projects being undertaken or completed has increased for all research themes (excluding the water dependent ecosystems theme, which remained steady).
- Of the 210 projects identified, 99 originated from Australia.
    - In report 1 of this series, which covered January 2000 to June 2012, 30 research projects were identified from Australia, compared to the 99 identified during this review (July 2012 to September 2013), demonstrating an increase in research into the water-related impacts of coal mining and coal seam gas in Australia.
    - The theme of co-produced/mine water (44 projects) dominated the research into water-related impacts of coal mining and coal seam gas in Australia, followed closely by water supplies (34 projects).
    - Of all the countries reviewed, Australia was involved in more research projects on almost every research theme, with the following exceptions:
        - the US was involved in the most research regarding seismicity (6 projects) and water dependent ecosystems (13 projects)
        - China was involved in the most research regarding well integrity (9 projects).

  - In Australia, the universities most involved in the research were found in Queensland:
    - Queensland University of Technology, Brisbane (5 projects)
    - University of Queensland, Brisbane (10 projects)
    - University of Southern Queensland, Toowoomba (4 projects)
  - In Australia, Origin Energy (commercial/company; 8 projects) and CSIRO (Australian Government; 10 projects) have also been involved in research.
- A total of six projects originated from Canada and Russia; this included:
  - five projects from Canada
  - one project reviewed from Russia.
- Of the 210 projects identified, 43 originated from China.
  - In Report 2 of this series (12 year period, January 2000 to June 2012), 47 research projects were identified from China, which also indicates an increase in research into the water-related impacts of coal mining and coal seam gas in China.
  - This review found 25 research organisations involved in related research in China. The universities leading research in China are:
    - China University of Mining and Technology, Beijing & Xuzhou (8 projects)
    - China University of Petroleum, Beijing (5 projects)
  - The China University of Mining and Technology was dominant among the research organisations in China; however, research from China University of Petroleum only began appearing in the literature during the financial year 2012/13.
- A total of four projects originated from India.
  - The Central Institute of Mining and Fuel Research, Dhanbad was the most prolific of the research organisations and also completed one research project during the July 2012 to September 2013 period.
- A total of eight projects originated from the UK.
  - The University of Newcastle, Newcastle upon Tyne, the Coal Authority and the University of Edinburgh were each involved with two research projects each during the July 2012 to September 2013 period.
- A total of 50 projects originated from the US.
  - The US Geological Survey completed more research projects (5) than any of the other 32 identified research groups involved in related research in the US during the July 2012 to September 2013 period, followed by the University of Wyoming (4 projects).

Abbreviations

General abbreviations	Description
2D	Two dimensional
3D	Three dimensional
ACARP	Australian Coal Association Research Program
APLNG	Australia Pacific Liquefied Natural Gas project
BC	British Columbia
CBM	Coal Bed Methane
CCSG	University Queensland's Centre for Coal Seam Gas
CMA	Catchment Management Authority
CMM	Coal Mine Methane
CSG	Coal Seam Gas
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DERM	Queensland Government Department of Environment and Resource Management (ceased operations in 2012)
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GDE	Groundwater Dependent Ecosystem
IESC	Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development
IMWA	International Mine Water Association
OWS	Office of Water Science
UK	United Kingdom
UNSW	University of New South Wales, Australia
UQ	University of Queensland
USA	United States of America
WOS	Web of Science
WRL	Water Research Laboratory of the School of Civil and Environmental Engineering at the UNSW Australia

Glossary

Term	Description
Aquifer	rock or sediment in formation, group of formations or part of a formation, that is saturated and sufficiently permeable to transmit quantities of water to wells and springs.
Aquifer connectivity	the degree to which groundwater can transfer between two adjacent aquifers or to the surface.
Aquifer injection	the injection of liquid (for example, H_20) or gas (for example, CO_2) into an aquifer. Commonly used in Managed Aquifer Recharge schemes or groundwater remediation.
Aquitard	a saturated geological unit that is less permeable than an aquifer and incapable of transmitting useful quantities of water. Aquitards often form a confining layer over an artesian aquifer.
Bore/borehole	a narrow, artificially constructed hole or cavity used to intercept, collect or store water from an aquifer, or to passively observe or collect groundwater information. Also known as a borehole, well or piezometer.
CO_2 sequestration	the process of capture and long-term storage of atmospheric carbon dioxide.
Co-produced water	the water that is pumped out of coal seams in order to extract coal seam gas. Also referred to as produced water and associated water. Over time, the volume of produced water normally decreases and the volume of produced gas increases.
Coal bed methane	(CBM) See coal seam gas.
Coal seam	sedimentary layers consisting primarily of coal. Coal seams store both groundwater and gas and generally contain saltier groundwater than aquifers that are used for drinking water or agriculture.
Coal seam gas	a form of natural gas (generally 95-97 per cent pure methane, CH_4) typically extracted from permeable coal seams at depths of 300–1000 m.
Cone of depression	occurs in an aquifer when groundwater is pumped from a well. The pumping of groundwater lowers the watertable immediately around the bore, causing a dimple, called the cone of depression, to form in the watertable around the well. The cone of depression grows larger as the pumping rate is increased and wider as the length of time a well is pumped increases. But once pumping stops the watertable will eventually return to its original shape, although the water quality may have changed.
Fracking	see hydraulic fracturing.
Groundwater	water occurring naturally below ground level (whether in an aquifer or other low-permeability material), or water occurring at a place below ground that has been pumped, diverted or released to that place for storage. This does not include water held in underground tanks, pipes or other works.

Term	Description
Hydraulic fracturing	also known as ‘fracking’, ‘fraccing’ or ‘fracture simulation’, is the process by which hydrocarbon (oil and gas) bearing geological formations are ‘stimulated’ to enhance the flow of hydrocarbons and other fluids towards the well. The process involves the injection of fluids, gas, proppant and other additives under high pressure into a geological formation to create a network of small fractures radiating outwards from the well through which the gas, and any associated water, can flow.
Seismicity (induced)	refers to typically minor earthquakes and tremors that are caused by human activity that alters the stresses and strains on the Earth's crust.
Shale gas	a natural gas found in shale formations.
Solute	the substance present in a solution in the smaller amount. For convenience, water is generally considered the solvent even in concentrated solutions with water molecules in the minority.
Subsidence	usually refers to vertical displacement of a point at or below the ground surface. However, the subsidence process actually includes both vertical and horizontal displacements. These horizontal displacements, in cases where subsidence is small, can be greater than the vertical displacement. Subsidence is usually expressed in units of millimetres (mm).
Unconventional gas	a term used to encompass gas production methods apart from conventional natural gas production, including shale gas, coal bed methane and underground coal gasification.
Underground coal gasification	an underground, in-situ process carried out on un-mined coal seams in which oxidants are injected to convert carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide.
Water quality	the physical, chemical and biological attributes of water that affects its ability to sustain environmental values.
Well	a human-made hole in the ground, generally created by drilling, to obtain water (also see bore).

1 Introduction

The extractive nature of coal mining and coal seam gas (CSG) operations has the potential to result in significant impacts on water resources and water-dependent ecosystems. Environmental impacts may include: disruption of surface water pathways caused by mining, including mining-induced subsidence; aquifer contamination caused by fracking chemicals; and groundwater and ecological impacts from enhanced aquifer connectivity.

An expert scientific committee (now named the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC)) was established under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in November 2012 to provide independent, expert scientific advice to decision-makers on the water-related impacts of coal seam gas and large coal mining development. The Office of Water Science (OWS) within the Department of the Environment supports the IESC, including by commissioning research to address some of the critical gaps in the scientific understanding of water-related impacts associated with coal seam gas and large coal mining activities.

This report is the third in a series of reference list reports commissioned by the Department of the Environment on the advice of the IESC. The complete reference list series will include summaries of research projects relating to the impacts of coal seam gas and large coal mining developments on water resources, currently being undertaken or completed, in a number of countries including (but not limited to) Australia, the United States of America (US), Canada, China, India, Russia and the United Kingdom (UK) since January 2000.

The objective of the reference list series is to identify relevant research projects to:

- support targeted approaches to future research - that address critical gaps in the scientific understanding of water-related impacts associated with coal seam gas and large coal mining activities
- provide a resource to build the scientific capability of the OWS to effectively deliver bioregional assessments, research and support the IESC in the provision of advice on development proposals to regulators.

The reference list series will also provide others, including state regulators, with project and citation information, which will enable improved understanding of the water-related impacts of coal seam gas and coal mining.

1.1 Scope

This report (Report 3 in Table 1.1) includes summaries of research projects relating to the impacts of coal seam gas and coal mining developments on water resources, currently being undertaken or completed, during the period July 2012 and September 2013 from Australia, Canada, China, India, Russia, UK and the US.

Table 1.1 Scope of reports commissioned by OWS regarding water impacts of coal mining and coal seam gas

Report	Country included in review						
	Australia	**United States**	**Canada**	**China**	**India**	**Russia**	**United Kingdom**
Report 1: 2000 – June 2012	✓	✓	✓				
Report 2: 2000 – June 2012				✓	✓	✓	✓
Report 3: July 2012 – September 2013	✓	✓	✓	✓	✓	✓	✓
Report 4: October 2013 – September 2014	✓	✓	✓	✓	✓	✓	✓

The research themes identified by the Department of the Environment in the scope of this report were:

R1. aquifer interconnectivity:

- baseline information (water quality and quantity)
- field-based and modelling approaches for assessing connectivity
- groundwater flow and solute transport dynamics

R2. disruption of surface water flow pathways:

- subsidence
- mine cone of depression
- stream diversions
- infrastructure

R3. co-produced water and salt management (CSG) and mine water and salt management (coal mines):

- aquifer injection and/or water treatment (technologies, relative cost benefit)
- effect on land and water resources (including irrigation)
- effect on water dependent ecosystems (streams, rivers, floodplains, wetlands, groundwater-dependent ecosystems (GDE), peat swamps)

R4. seismicity

R5. integrity of wells - installation, operation, decommissioning

R6. hydraulic fracturing:

- chemical - surface and groundwater quality
- physical - aquitard disruption, borehole collapse

R7. quality and reliability of water supplies, including environmental health:

- mine site and gas field remediation, including well decommissioning and post-mining voids
- long-term impacts, including timescales for water levels to return to pre-development levels (quality/quantity)
- chemical migration and toxicity
- managing salt and heavy metals

R8. water dependent ecosystems:

- prediction of potential impacts to water dependent ecosystems (streams, rivers, floodplains, wetlands, GDEs, peat swamps)
- response and tolerances of water dependent ecosystems to changes in water regime (surface and groundwater quantity, seasonal patterns, variability, interactions) and water quality
- mitigation measures
- monitoring techniques

R9. cumulative impact assessments.

In undertaking this research project it was recognised that research undertaken in related extractive/resource industries (e.g. CO_2 sequestration, underground coal gasification or shale gas) may sometimes inform water and water dependent ecosystem knowledge gaps in the coal seam gas and coal mining sectors. For example, CO_2 sequestration researchers have been significantly more active in the examination of water well integrity and reservoir ‘seals’. However, research from such industries was outside the scope of this project.

This report also does not include the following types of information:

- research outside of Australia, Canada, China, India, Russia, UK and US
- research not relevant to the impacts on water resources from coal seam gas and coal mining projects
- bibliographic database of completed research
- operational and compliance monitoring reports completed by mining and gas companies
- policy, regulatory and legislative material
- critical review of the collated material
- research completed prior to July 2012 and after September 2013.

2 Method

The key outcome of this work was to collate information about research and knowledge acquisition projects, without critical analysis of the material. Consequently, the following priorities for information acquisition were determined (in order of desirability):

1. project descriptions written by the project's principal investigators
2. project descriptions written in telephone or email consultation with principal investigators
3. project descriptions as documented on the websites of research organisations
4. project descriptions inferred from the reporting outputs (i.e. a report on a project)
5. project descriptions inferred from published literature outputs (i.e. journal papers, conference papers).

Based on the above hierarchy, a project survey was created for the project and sent out to all research organisations and authors of relevant literature. To obtain the contact information of research organisations and principal investigators it was necessary to use a variety of methods, including disseminating an information request through research networks, industry associations, embassies and social media, and literature searching using library databases. An iterative process was used as information gleaned from one method fed back into the other methods - for example, references found in a journal article that pointed to a particular research organisation active in the field of coal mining impacts on water.

The study methods are further described in Sections 2.1, 2.2 and 2.3.

2.1 Research project survey

Recognising that project descriptions obtained directly from principal investigators were likely to be the most accurate, a project survey form was created in Microsoft Word to email out to known researchers. A copy of the blank survey form is included at Appendix A. The survey form was also translated into Russian and sent to Russian contacts.

The survey was emailed out to clients with an introduction and followed up by telephone calls and a reminder email. A complete listing of survey recipients and their subsequent participation in the survey is included at Appendix B.

2.2 Search for research organisations/researchers

Research organisations and researchers were identified using a range of methods. These methods are outlined below.

- Connecting with research networks. The authors liaised within their own research networks to connect with national and international research organisations that are or have been engaged in relevant research. Industry, government and academic connections across Australia and the world were contacted and asked to pass on the contact details of relevant researchers and research organisations or forward the research project survey form to their contacts.

- Contacting partner universities. The UNSW Australia maintains a network of exchange partner universities. Each university website was visited to determine whether they maintain relevant disciplines. Where the contact details of individual researchers involved in water impact research could be obtained, they were preferentially contacted, otherwise Heads of Schools/Faculties or generic universities were contacted, sent the survey form and followed up with a telephone call.
- Internet searches. Google searches were used to find research organisations involved in water research in each country. Each website was then interrogated to determine whether they were involved in relevant research projects.
- Industry associations. A posting was listed on the International Mine Water Association (IMWA) LinkedIn group forum (see dot point below).
- Contacting embassies. The following embassies were telephoned to request the names of researchers or research organisations involved in researching the potential impacts of coal mining and coal seam gas on water and water dependent ecosystems:
  - Embassy of the People's Republic of China
  - Embassy of the Russian Federation in Australia
  - The High Commission of India in Australia

  Each embassy requested a copy of the survey form and additional information. By request of the Embassy of the Russian Federation in Australia, an official letter requesting information was sent to the Russian Ambassador.
- Social media/website. The authors called for interested parties to participate in the research project survey through the Water Resource Laboratory website on 31 March 2014 and via LinkedIn. The LinkedIn groups included:
  - Hydrogeology Forum of LinkedIn (14 033 members)
  - International Association of Hydrogeologists (1282 members)
  - Water Pros (37 933 members)
  - International Mine Water Association (1065 members[1])
- Interpreter services. Due to the difficulty of communicating with Russian researchers, a Russian interpreter and translator was hired for a day to translate the project survey form, search for Russian research organisations, make telephone calls and send out surveys to possible contacts.
- Literature searches. The research organisation websites of authors found through the literature review were investigated for further contacts and the authors directly contacted where possible. The reference list of each relevant article/report was further scrutinised for relevant literature and contacts. The literature search is described in more detail in Section 2.3.

[1] While membership to the IMWA LinkedIn group was requested 31 March 2014, membership was granted 23 April 2014 and thus the post was made on that day.

2.3 Literature search

The literature search was accomplished using the UNSW library database and electronic journal subscriptions systems, which are among the most comprehensive in Australia, in addition to contemporary search engine tools. This search resulted in over 30 000 references, which were then assessed for relevance.

The following databases were interrogated in the search for relevant literature and researchers:

- Researcher ID
- WOS (Web of Science)
- Scopus
- Science Direct
- Engineering Village
- OnePetroAustralian databases (Informit)

ProquestKeyword searches were derived from the key research areas (see Section 1.1). More detail regarding the literature search, including keywords used for searches is given in Appendix C.

As each piece of relevant literature was identified, its references were reviewed for further leads to relevant literature.

In addition to the database search, references provided in key government submission documents and publications produced by key national agencies were also reviewed in an attempt to source additional relevant literature.

3 Overview of research projects

A total of 210 research projects from Australia, Canada, China, India, Russia, UK and the US were found relating to the water-related impacts and coal seam gas/coal mining, either currently being undertaken or completed, in the period July 2012 to September 2013.

3.1 Research themes

The relative proportions of projects relating to each research theme are represented in Figure 3.1. Where a project was deemed to be associated with more than one research theme, it was included in the calculation of statistics for each research theme.

Research themes R3 (co-produced/mine water) and R7 (water supplies) were relevant to the majority of projects. These research themes are highly related topics in scientific research, as it is often mine water or co-produced water that is impacting on water supplies.

The research theme with the least associated projects was R4 (seismicity). While there were many research projects found relating to hydraulic fracturing and well integrity, very little of it was related to water impacts.

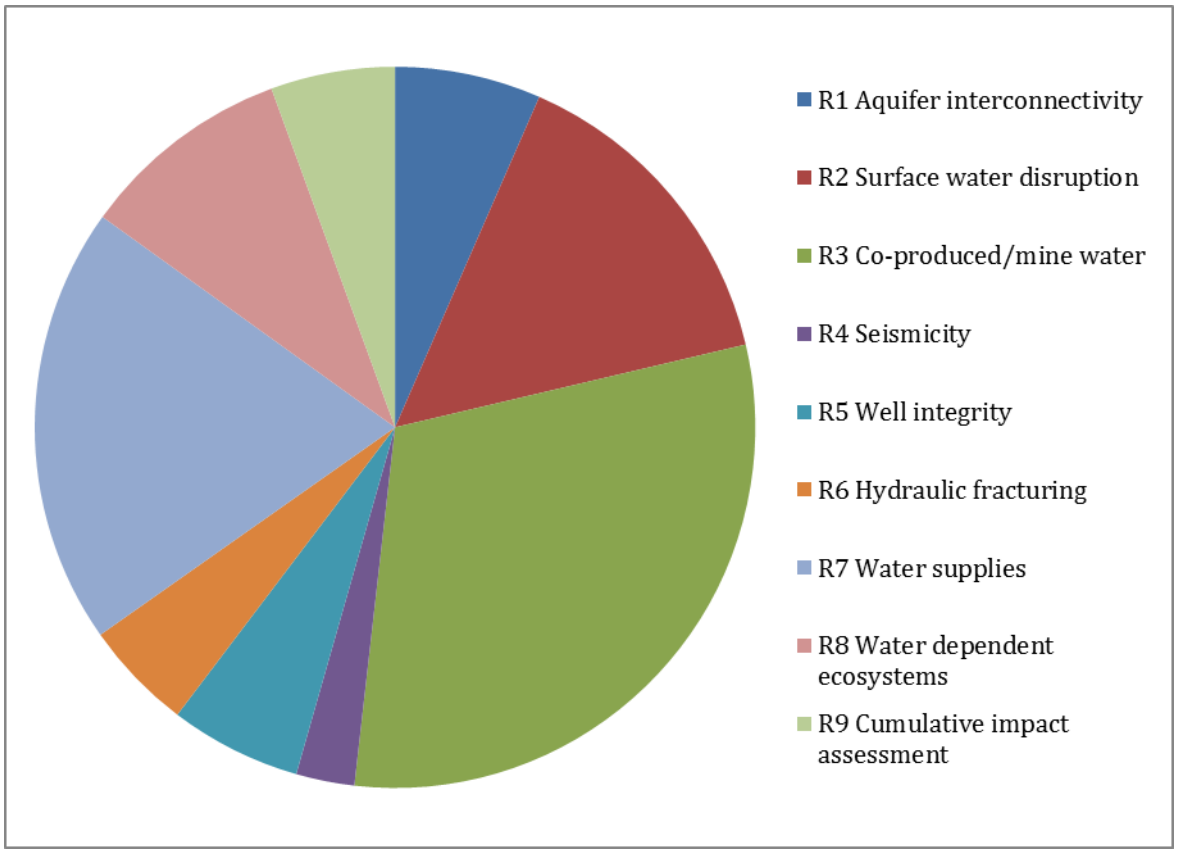

Figure 3.1 Distribution of research themes

3.2 Summaries by country

Research into the water impacts of coal seam gas and coal mining is connected to (and often largely driven by) the production of coal seam gas and coal mining in each country. According to Flores (2014), the only countries producing significant amounts of coal seam gas are China, Australia, India, US and Russia.

The relative distribution of the 210 research projects by country and research theme is displayed in Figure 3.2. More research projects were identified from Australia than from any of the other countries. Many research projects were also identified from China and the US, while very few relevant ones were found from Russia or Canada.

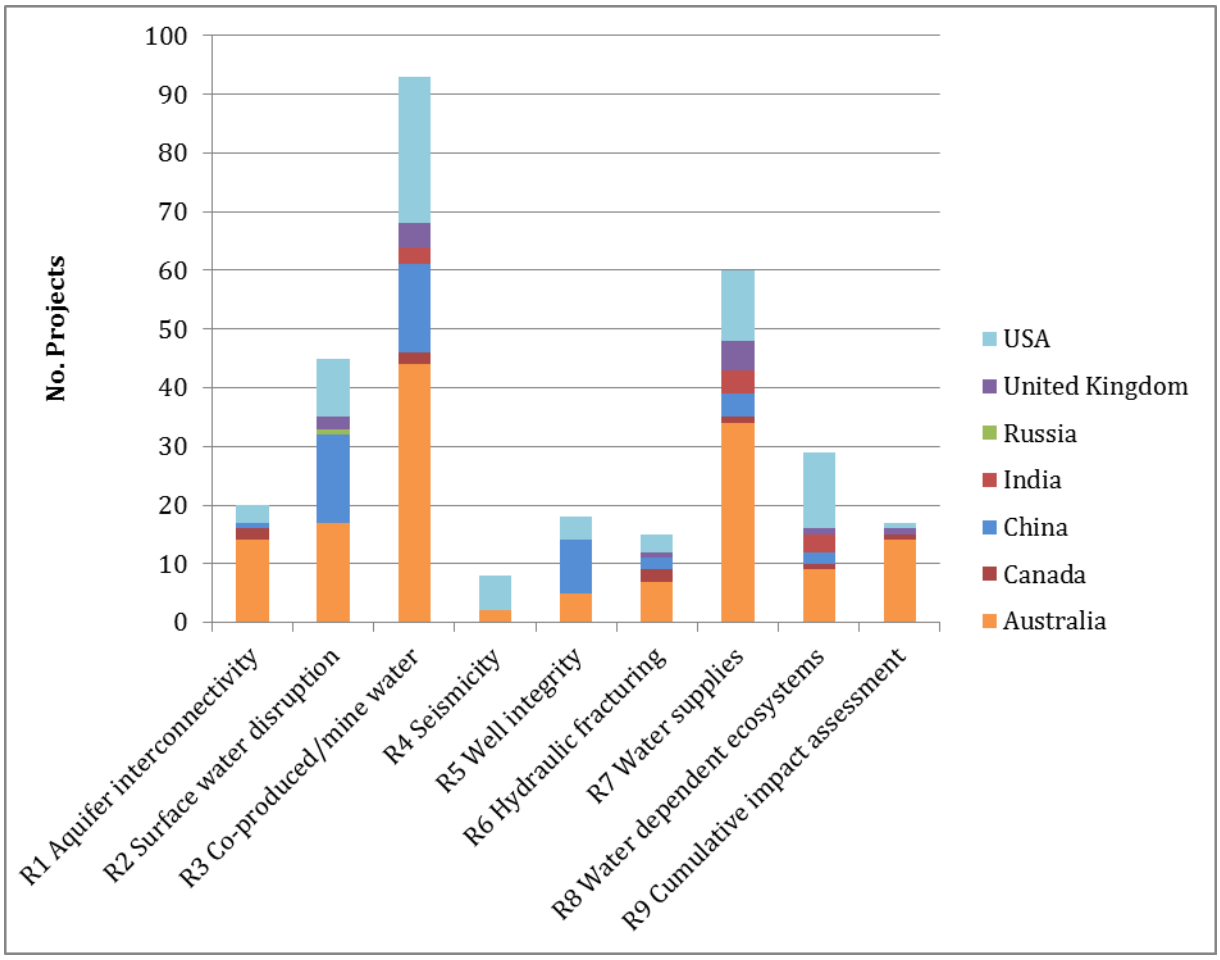

Figure 3.2 Relative proportion of projects by country and research theme

3.2.1 Australia

Australia is second only to the US and Canada in the production of coal seam gas (Flores 2014). While Australia contains more than 30 coal-bearing basins, the Surat and Bowen Basins in Queensland are the most gas-rich in the country.

The majority of the projects reviewed were from Australian sources. Of the 210 projects identified, 99 originated from Australia. The distribution of research themes represented in these projects is displayed in Figure 3.3. As with the overall distribution of research themes amongst the research projects, the theme of co-produced/mine water dominated the

research into water impacts of coal mining and coal seam gas in Australia, followed closely by water supplies.

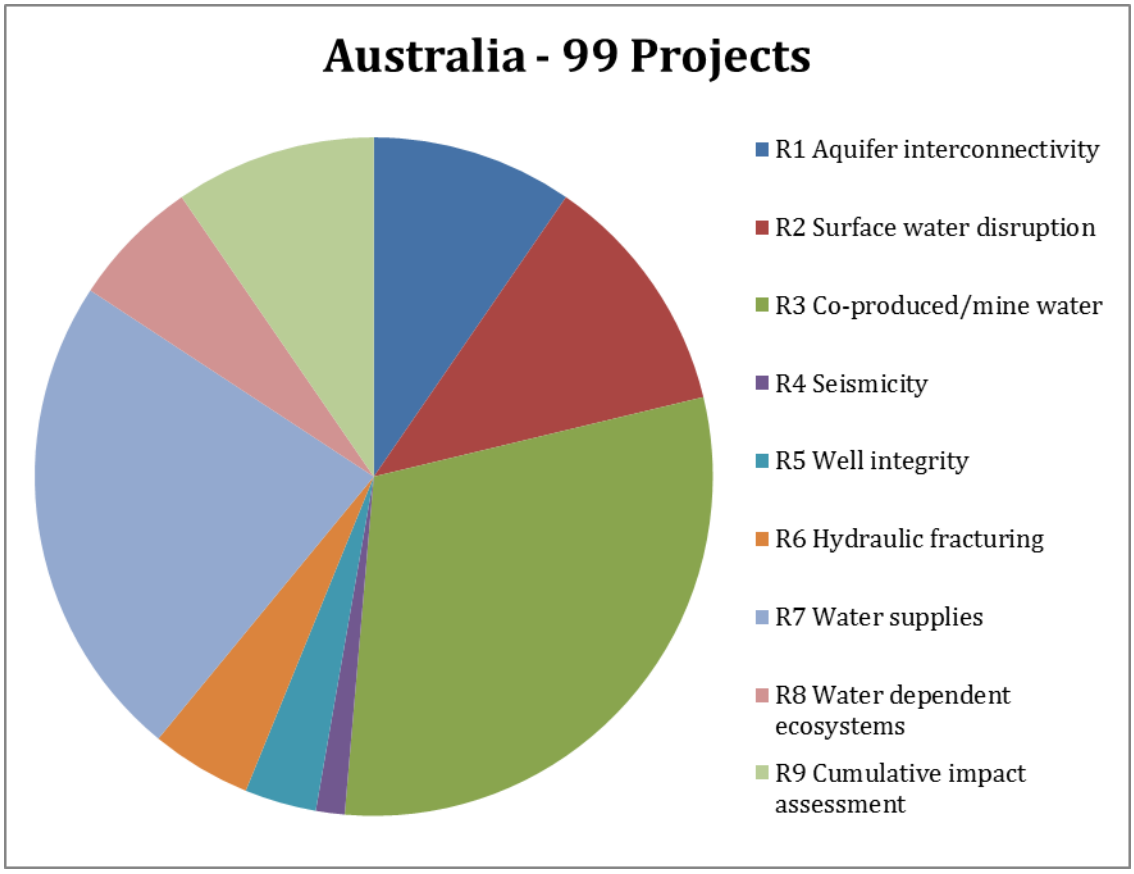

Figure 3.3 Distribution of research themes in projects from Australia

3.2.2 Canada

There are 15 coal basins extending throughout Canada, some of which are shared with the US. The majority of the coal bed gas reserves in Canada are in the Western Canada Sedimentary Basin (Flores 2014). Production of coal seam gas commenced in 2000, with more than 6000 wells producing gas by 2008 (Flores 2014).

The majority of literature available on Canadian coal bed methane was completed prior to 2012 and was therefore, outside the scope of this report. Since 2012, Canadian research has focused on the water-related impacts of wellbore integrity and hydraulic fracturing in shale and tight gas reservoirs (for examples see The Canadian Water Network website <http://www.cwn-rce.ca/project-library/#category=hydraulic-fracturing>).

Of the 210 projects identified, only five originated from Canada. These were distributed amongst most of the research themes (excluding R2 (surface water disruption), R4 (seismicity) and R5 (well integrity)). The distribution of research themes represented in these projects is displayed in Figure 3.4.

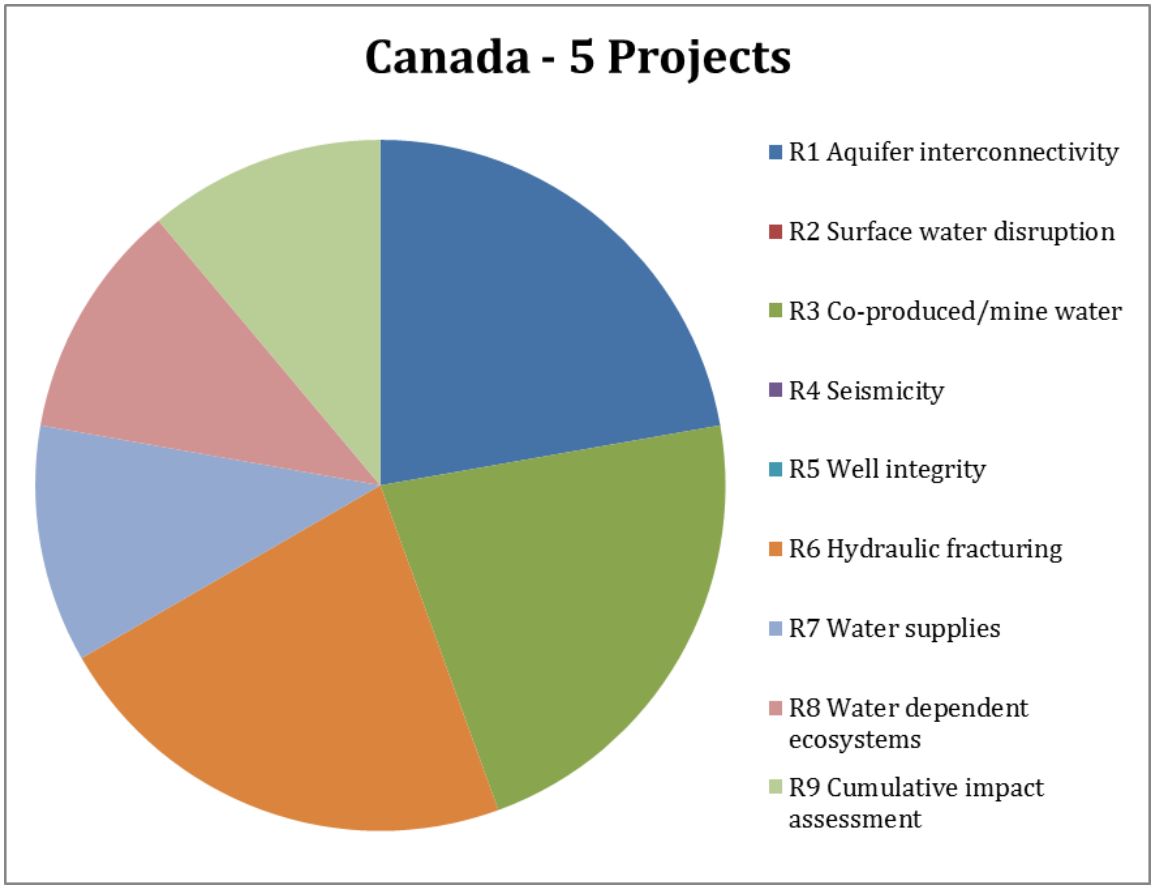

Figure 3.4 Distribution of research themes in projects from Canada

3.2.3 China

China is actively exploring coal seam gas resources and has commenced production. IEA (2012) in Flores (2014) predicts that China will greatly increase its dependency on coal by 2017. China produced twice as much coal as Australia and the US combined in 2011. Much of the coal gas currently produced is coal mine methane (CMM), which is recovered from active mines. However, coal seam gas production has been rapidly increasing since 2003, with the Qinshui and Ordos Basins found to be most commercially productive (Flores 2014).

The Embassy of the People's Republic of China provided two main contacts for acquiring research project information. Of these two bodies, only the Ministry for Environmental Protection had responded at the time of finalising this report. The Ministry of Environmental Protection is not directing any research into water impacts of coal mining or coal seam gas (Y Zou 2014, pers. comm., 24 March).

Of the 210 projects identified, 43 were from researchers in China. The distribution of research themes represented in these projects is displayed in Figure 3.5. As with the overall distribution of research themes amongst the research projects, the theme of co-produced/mine water dominated the research into water-related impacts of coal mining and coal seam gas in China. Compared to the research reviewed in report 2 of this series (covering a 12 year period, January 2000 to June 2012), there has been a substantial increase in research pertaining to surface water pathways disruption and well integrity.

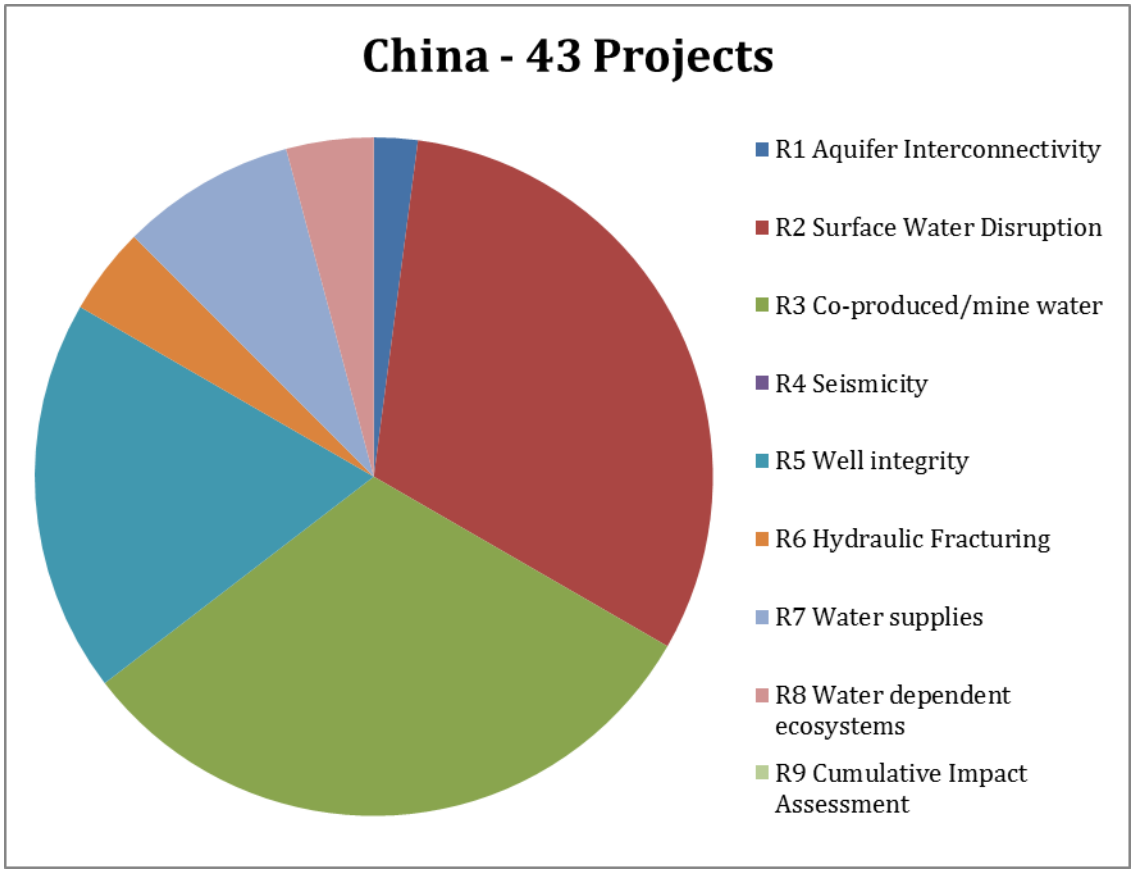

Figure 3.5 Distribution of research themes in Chinese research projects

3.2.4 India

Although there is currently no commercial production of coal seam gas (coal bed methane) in India, there is large coal bed methane (CBM) potential and one successful pilot project at Raniganj (Shah and Komal 2014).

Only four relevant projects were identified during this review from India. These related to the coal mining research themes of R3 (mine water), R7 (water supplies) and R8 (water dependent ecosystems).

3.2.5 Russia

Russia has the second largest coal reserves in the world (Flores 2014). While Russia is also thought to have one of the largest reserves of coal bed gas in the world, it also has abundant conventional natural gas reserves and thus, less incentive to exploit coal seam gas. Russia commenced production of coal seam gas after 2010 (Flores 2014). IEA (2012) in Flores (2014) predicted that Russia will greatly increase its dependency on coal by 2017.

Only one research paper was found related to the water impacts of coal mining and coal seam gas in Russia. However, accessing Russian literature and research organisations was greatly limited by language barriers. The primary theme of this paper was surface water disruption (research theme R2).

The Embassy of the Russian Federation in Australia were unable to find any research institutions involved in this kind of research in Russia and hypothesised that private oil and

gas companies may be the main source of research pertaining to the water impacts of coal mining and coal seam gas in Russia. The major commercial company Gazprom was approached, but could not provide any information.

3.2.6 United Kingdom

Coal mining in the United Kingdom has decreased since 1990 and subsequently, the recovery of coal mine gas has increased (Flores 2014). However, there are no commercially active sites of coal seam gas extraction in the United Kingdom. In the United Kingdom, the term 'unconventional gas' is used to encompass shale gas, coal bed methane and underground coal gasification. Most of the literature in the United Kingdom relates to shale gas, due to the presence of large shale beds. According to the Scottish Environmental Protection Agency, exploration of unconventional gas fields is in its infancy in the United Kingdom (SEPA 2014).

Of the 210 projects identified, eight were from the United Kingdom. The distribution of research themes represented in these projects is displayed in Figure 3.6.

Compared to the research reviewed in report 2 of this series (covering a 12 year period, January 2000 to June 2012), the relative proportion of research into the water-related impacts of coal mining and coal seam gas has increased in the UK.

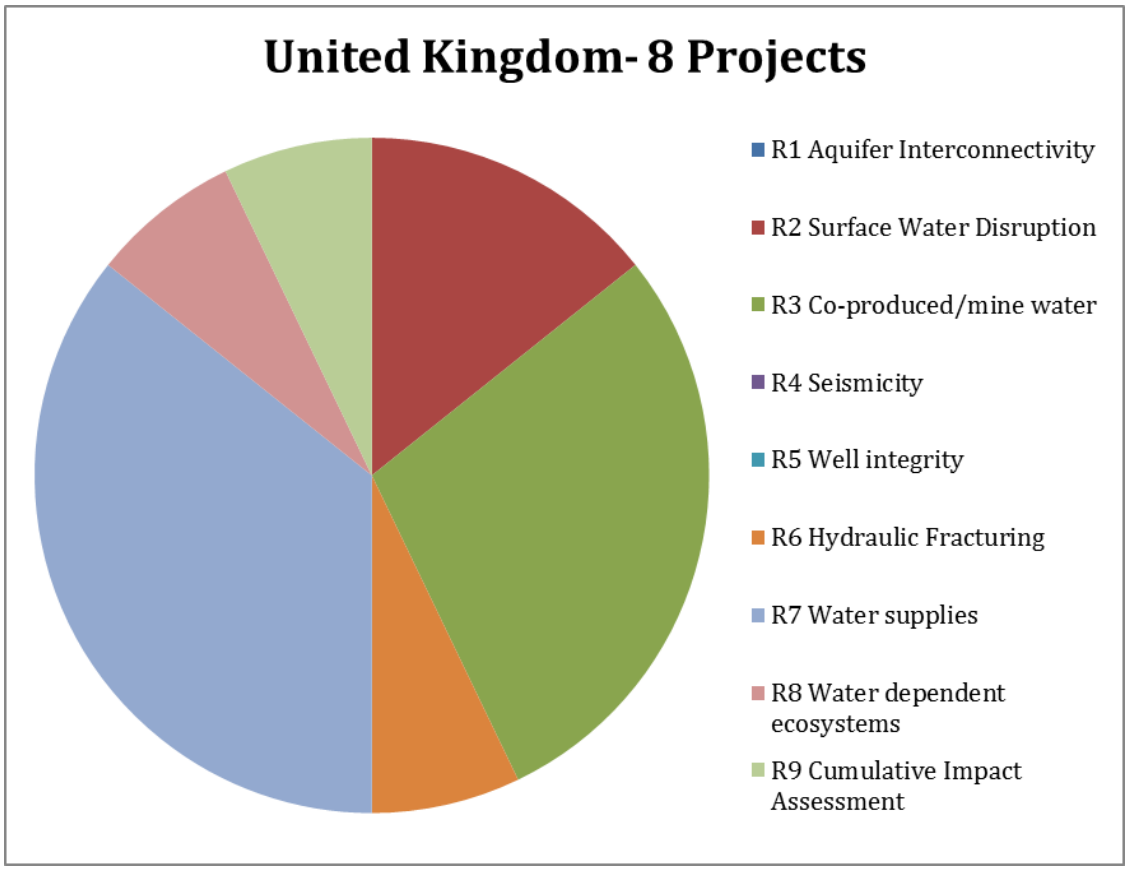

Figure 3.6 Distribution of research themes in projects from the United Kingdom

3.2.7 United States

The US is the biggest producer of coal seam gas and has been producing coal bed gas from coal mines since the 1950s. The highest gas producing basins are Powder River (Wyoming and Montana), San Juan (Colorado and New Mexico) and Black Warrior (Alabama); however, there are 12 coal basins across the country. Much of the literature regarding the water impacts of coal seam gas are focused on the Powder River Basin.

Of the 210 projects identified, 50 were from the US. The distribution of research themes represented in these projects is displayed in Figure 3.7. As with the overall distribution of research themes amongst the research projects, the theme of R3 (co-produced/mine water) dominated the research into water-related impacts of coal mining and coal seam gas in the US, followed by R8 (water dependent ecosystems) and R7 (water supplies). Projects were present from all of the research themes.

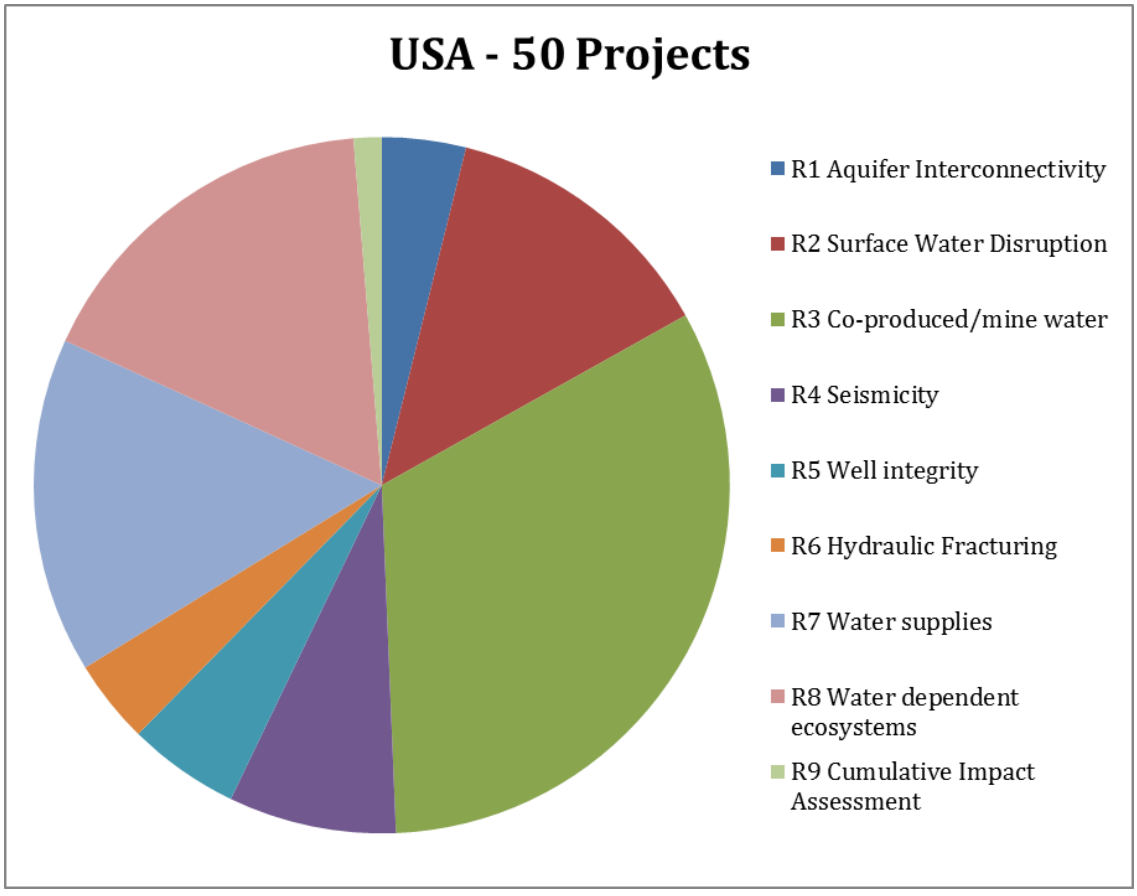

Figure 3.7 Distribution of research themes in projects from the US

3.3 Centres of research

The 210 projects collated were completed by 120 research organisations and companies. The number of projects completed by each research organisation is shown in Table 3.1.

In Australia, the universities heavily involved in research projects were found in Queensland:

- Queensland University of Technology, Brisbane

- University of Queensland, Brisbane
- University of Southern Queensland, Toowoomba

Origin Energy (commercial company) and the CSIRO (Australian Government) were also involved in research projects.

A total of 25 research organisations were found to be involved with research in China. The universities leading research in China were:

- China University of Geosciences, Beijing
- China University of Mining and Technology, Beijing
- China University of Mining and Technology, Xuzhou
- Anhui University of Science and Technology, Huainan
- China University of Petroleum, Beijing.

In India, the Central Institute of Mining and Fuel Research, Dhanbad was the most prolific of the research organisations and also completed one research project during the review period.

In the United Kingdom, the University of Newcastle, Newcastle upon Tyne, the Coal Authority and the University of Edinburgh were each involved with two research projects each during the review period. The US Geological Survey completed more research projects than any of the other 32 research groups involved in research into the water impacts of coal seam gas and coal mining during the review period, followed by the University of Wyoming.

Table 3.1 Distribution of projects by research centres

Country and research organisation	**Number of projects**
Australia	
Alluvium Consulting	1
APLNG, Arrow Energy	1
Arup	1
Aurecon	1
Australian National University	1
Coffey Geotechnics	3
Cooperative Research Centre for Spatial Information	1
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	9
Department of Natural Resources and Mines, State of Queensland	3
Department of Science, Information Technology, Innovation and the Arts (Queensland Government)	1
Eco Logical Australia	1
General Purpose Standing Committee No. 5 Inquiry into Coal seam gas	1
Golder Associates, Australia	1
Hyder Consulting, North Sydney	1

Country and research organisation	Number of projects
John Williams Scientific Services Pty Ltd	1
Kellogg, Brown and Root	2
Klohn Crippen Berger	4
Macquarie University	1
Mine Subsidence Engineering Consultants	1
Monash University	1
MWH Australia	1
Namoi Catchment Management Authority	1
New South Wales Chief Scientist and Engineer (New South Wales Government)	1
Office of Groundwater Impact Assessment (Queensland Government)	2
Origin Energy	9
Parsons Brinckerhoff, Sydney, Australia	1
Pells Consulting	1
QGC	3
Queensland Department of Environment and Heritage Protection, Australia	1
Queensland University of Technology, Brisbane	7
RPS	2
Santos, APLNG	1
Schlumberger Water Services	2
SMEC	2
Standing Council on Energy and Resources	1
Strata Control Technology	1
Sydney Catchment Authority	1
Tree Crop Technologies	1
University of Adelaide	1
University of Melbourne	1
University of New South Wales	4
University of Newcastle	1
University of Queensland, Brisbane	9
University of Southern Queensland	5
URS Australia Pty Ltd, Melbourne	1
Worley Parsons	3
Canada	
Curtin University, Canada	1

Country and research organisation	Number of projects
Geofirma Engineering Ltd.	1
Simon Fraser University	1
China	
Yangtze University, Jingzhou, Hubei, China	1
Anhui Polytechnic University, Wuhu	1
Anhui University of Science and Technology, Huainan	3
China Coal Research Institute, Beijing	2
China Coal Research Institute, Tangshan, China	1
China United Coaled Methane Corporation Ltd, China	1
China University of Geoscience, Wuhan	1
China University of Geosciences, Beijing	3
China University of Mining & Technology (Beijing), Beijing	5
China University of Mining and Technology, Xuzhou, China	3
China University of Petroleum, Beijing	4
China University of Petroleum, Qingdao	1
Chinese Academy of Geological Sciences Shijiazhuang	1
Chongqing University Science & Technology, Chongqing	1
China National Petroleum Corporation Drilling Research Institute, Beijing	1
Graduate University of Chinese Academy of Sciences	1
Hangzhou Research Institute, China Coal Technology and Engineering Group Corp., Hangzhou	2
Henan Polytechnic. University, Jiaozuo	2
Inner Mongolia Agricultural University, Hohhot	1
Luneng Heze Coal & Power Development Co., Ltd., Yuncheng	1
Nanjing University, Nanjing, 210023, China	1
Northeast Forestry University, Harbin, China	1
Northeast Petroleum University, Daqing	2
Shijiazhuang University of Economics, China	1
Southeast University, Nanjing, 210096, China	1
India	
Central Institute of Mining and Fuel Research, Dhanbad	1
Council of Scientific and Industrial Research-National Geophysical Research Institute, Uppal Road, Hyderabad	1
National Institute of Technology, Durgapur	1

Country and research organisation	Number of projects
Russia	
Kotelnikov Institute of Radioengineering and Electronics, RAS, Fryazino 141120, Russia	1
United Kingdom	
Scottish Environment Protection Agency	1
The Coal Authority	2
Durham Energy Institute, Department of Earth Sciences, Durham University, Science Labs, Durham	1
Environment Agency,	1
Newcastle University, Newcastle Upon Tyne, United Kingdom	2
University of Edinburgh, Edinburgh	2
University of Leeds	1
University of Salford, Salford,	1
United States	
Apache Corporation	2
University of Rio Grande, Rio Grande,	1
Boston University	1
Brierley Assoc., Denver	1
Clemson University	1
Colorado School of Mines, Golden	3
Colorado State University	1
Columbia University	1
Duke University, Durham, North Carolina	3
First Energy, Greensburg, PA,	1
Gannett Fleming, Inc., Audubon, PA,	1
Halliburton, United States	1
Illinois Department of Natural Resources, Office of Mines and Minerals, Land Reclamation Division, Benton	1
Montana State University	1
National Institute for Occupational Safety and Health, Office of Mine Safety and Health Research	1
National Renewable Energy Laboratory	1
New Mexico Institute of Mining and Technology	1
Pennsylvania State University, DuBois	1
Perkins Trotter	1
Shell	1

Country and research organisation	Number of projects
Southern Illinois University, Carbondale	1
The State University of New York Institute of Technology, Utica	1
U. S. Geological Survey, Reston	5
University of Kansas, Lawrence	1
University of Oklahoma	1
University of Tennessee, Knoxville	2
University of Texas at Arlington	1
University of Utah, Salt Lake City	1
University of Wyoming	4
US Department of Agriculture, National Resources Conservation Services, Point Pleasant	1
UT Southwestern Medical Center	1
West Virginia University, Morgantown	3
Youngstown State University	1

4 Research project profiles

This section profiles the 210 recently commissioned or completed research and knowledge acquisition projects found during this review. The projects are organised by:

- research theme, then
- country, and finally
- research organisations.

Where a project is relevant to several of the identified themes, it has been categorised by its primary theme and its relevance to secondary themes also noted.

The data source of each project profile is specified at the bottom of each project table. Where the information was received directly from the project survey, it has been formatted for consistency. Where the data source is directly from literature, Endnote fields have been adapted to fit the required information, where possible. Project summaries have been copied directly from abstracts rather than interpreting the project findings.

It should be noted that the year of literature publication has been used for the project duration and to categorise each project into one of the four reports in this reference list series. It may be that this does not accurately reflect the timeframe of the project, which may have finished long before the publication or may be ongoing.

Of the 210 projects identified, eight were sourced from project surveys, two from the ACARP website, 28 from the UQ CCSG Online Portal and 173 from literature. A complete listing of these projects is summarised in Table D1 at Appendix D, in the order they appear in this report.

4.1 Aquifer interconnectivity

The R1 aquifer interconnectivity research theme examines the water impacts of coal seam gas and coal mining due to the connections between aquifers. Topics under this category included: the collection of water quality and quantity baseline data; field based and modelling approaches for assessing connectivity; and groundwater flow and solute transport dynamics.

A total of 16 projects were identified with the primary theme of aquifer interconnectivity, from Australia (13), Canada (2) and the US (1).

4.1.1 Australia

Table 4.1 Project 1: Groundwater monitoring report for April - May 2012, Angus Place and Springvale groundwater monitoring program

Project characteristics	Details
Project title	**Groundwater monitoring report for April - May 2012, Angus Place and Springvale groundwater monitoring program**
Project location	Australia
Principal investigator	Aurecon
Lead institution	Aurecon
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	As part of the environmental management plans for the Angus Place and Springvale Collieries, an intensive monitoring program has been implemented on the Newnes Plateau to detect any impacts from underground mining on the groundwater regime, and in particular the Newnes Plateau Shrub Swamps.
Outputs	Aurecon. (2012). Groundwater monitoring report for April - May 2012: Angus Place and Springvale groundwater monitoring program. Prepared by Aurecon for Centennial Coal, Report Ref: 208362/208354.
Key personnel	Aurecon
Research themes	Aquifer interconnectivity
Project information source	Literature

Table 4.2 Project 2: Conceptualisation of the Walloon Coal Measures beneath the Condamine Alluvium

Project characteristics	Details
Project title	**Conceptualisation of the Walloon Coal Measures beneath the Condamine Alluvium**
Project location	Queensland, Australia
Principal investigator	Klohn Crippen Berger
Lead institution	Queensland Government Department of Environment and Resource Management
Project budget	This project was one component (Activity 1.1) of the $5 million Healthy HeadWaters Coal Seam Gas Water Feasibility Study
Source of funding	Australian Government Water for the Future initiative
Project duration	Project completed July 2011
Current status	Completed
Project summary	This activity undertook a comprehensive review of all existing data regarding the hydrogeology of the Condamine Alluvium and the underlying and flanking sections of the Walloon Coal Measures. It developed a new interpretation of these formations and assembled a three-dimensional block model. The findings of this activity provide an improved understanding of the structure of the Walloon Coal Measures and their relationship with the Condamine Alluvium, and also highlight priorities for future research. Outputs of this activity have been used by the Office of Groundwater Impact Assessment in the development of a groundwater flow model to assess impacts of CSG water extraction in the cumulative management areas.
Outputs	Healthy HeadWaters Coal Seam Gas Water Feasibility Study <http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-1> Project final report < http://www.dnrm.qld.gov.au/__data/assets/pdf_file/0014/106133/walloons-condamine-conceptualisation.pdf>
Research themes	Aquifer connectivity
Project information source	UQ CCSG Online Portal, Queensland Government website

Table 4.3 Project 3: Using hydrogeochemistry to understand inter-aquifer mixing in the on-shore part of the Gippsland Basin, southeast Australia

Project characteristics	Details
Project title	**Using hydrogeochemistry to understand inter-aquifer mixing in the on-shore part of the Gippsland Basin, southeast Australia**
Project location	Australia
Principal investigator	Hofmann, H.; Cartwright, I.
Lead institution	Monash University, School of Geoscience
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Groundwater in the Latrobe Valley in the Gippsland Basin of southeast Australia is important for domestic, agricultural and industrial uses. This sedimentary basin contains a number of aquifers that are used for water supply, dewatered for open pit coal mining, and which are potentially influenced by off-shore oil and gas production. Major ion chemistry together with stable and Sr isotope data imply that the main hydrogeochemical processes are evapotranspiration with minor silicate and carbonate weathering; methanogenesis and SO4 reduction in reduced groundwater associated with coal deposits have also occurred. Groundwater has estimated C-14 ages of up to 36 ka and is largely H-3 free. Carbon-14 ages are irregularly distributed and poorly correlated with depth and distance from the basin margins. The observations that the geochemistry of groundwater in aquifers with different mineralogies are similar and the distribution of C-14 ages is irregular implies that the aquifers are hydraulically connected and horizontal as well as vertical inter-aquifer mixing occurs. The connection of shallow and deeper aquifers poses a risk for the groundwater resources in Gippsland as contaminants can migrate across aquifers and dewatering of shallow units may impact deeper parts of the groundwater system. © 2013 Elsevier Ltd. All rights reserved.
Outputs	Hofmann and Cartwright. (2013). Using hydrogeochemistry to understand inter-aquifer mixing in the on-shore part of the Gippsland Basin, southeast Australia. *Applied Geochemistry.*
Key personnel	Hofmann, H.; Cartwright, I. Hofmann, H Monash Univ, Sch Geosci, Wellington Rd, Clayton, Vic 3800, Australia Flinders Univ S Australia, Natl Ctr Groundwater Res
Research themes	Aquifer interconnectivity
Project information source	Literature

Table 4.4 Project 4: 2013 Annual Report: Surat underground water impact report

Project characteristics	Details
Project title	**2013 Annual Report: Surat underground water impact report**
Project location	Australia
Principal investigator	Unknown
Lead institution	Office of Groundwater Impact Assessment (Queensland Government)
Project budget	Unknown
Source of funding	Queensland Government
Project duration	2013
Current status	Active (ongoing)
Project summary	The Surat Underground Water Impact Report (UWIR) was approved in December 2012. The 2013 Annual Report describes changes that have occurred since the UWIR was prepared, as well as OGIA activities being carried out in preparation for the revision of the UWIR in December 2015.
Outputs	http://www.dnrm.qld.gov.au/ogia/surat-underground-water-impact-report http://www.dnrm.qld.gov.au/ogia/2013-annual-report-summary
Research themes	Aquifer connectivity, water dependant ecosystems
Project information source	UQ CCSG Online Portal

Table 4.5 Project 5: Integrated water model

Project characteristics	Details
Project title	**Integrated water model**
Project location	Australia
Principal investigator	Unknown
Lead institution	Origin Energy
Project budget	Unknown
Source of funding	Origin Energy
Project duration	2012
Current status	Unknown
Project summary	To develop an integrated water model to provide deterministic and probabilistic mass balance modelling of hydrological impacts of APLNG CSG water management solutions.
Outputs	Unknown
Research themes	Aquifer connectivity
Project information source	UQ CCSG Online Portal

Table 4.6 Project 6: Vertical hydraulic connectivity studies

Project characteristics	Details
Project title	**Vertical hydraulic connectivity studies**
Project location	Australia
Principal investigator	Unknown
Lead institution	Origin Energy
Project budget	Unknown
Source of funding	Origin Energy
Project duration	2012
Current status	Unknown
Project summary	Suite of interconnectivity studies including centrifuge permeameter analysis at UNSW/NCGRT to determine vertical permeabilities and Quarts Helium diffusion studies at CSIRO to determine insitu vertical hydraulic flow velocity.
Outputs	Unknown
Research themes	Aquifer connectivity
Project information source	UQ CCSG Online Portal

Table 4.7 Project 7: New insights into the hydrodynamics of the Surat Basin

Project characteristics	Details
Project title	**New insights into the hydrodynamics of the Surat Basin**
Project location	Australia
Principal investigator	Moser, Andrew; Morris, Ryan
Lead institution	Origin Energy Resources, Brisbane, Queensland, Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The development of major coal seam gas (CSG) projects in Queensland has resulted in a significant increase in the amount of scientific data being collected from the Great Artesian Basin (GAB). Australia Pacific LNG, one of the four major CSG-LNG proponents in south east Queensland, is in the process of installing a network of over 100 dedicated monitoring bores into aquifers and aquitards of the GAB sequence of Surat Basin. The majority of these bores are in nested sites, where between two and six individual units are monitored. This is augmented by groundwater data collected during the baseline survey of all existing groundwater bores on project areas. In many areas, the new monitoring bore installations are the first to target specific individual hydrostratigraphic units. Historically, the hydrodynamic relationship between hydrostatic units has been inferred from geographically distant sites and spot tests under taken decades apart. The new data from nested sites provides insights into vertical hydraulic gradients which is changing the current understanding of hydrodynamic relationships in the basin. The data can be used to draw inferences regarding the degree of connection between those aquifers that have been extensively utilised for water supply over the past century and those that have not. Hydraulic testing results have been used to corroborate aquifer pressures to update conceptual hydrogeological models. This presentation will discuss in detail the data collected by Australia Pacific LNG to date and insights it provides into the implied hydrodynamics of the Surat Basin.
Outputs	Moser and Morris. (2012). New insights into the hydrodynamics of the Surat Basin. International Geological Congress, Abstracts = Congres Geologique International, Resumes. [International Geological Congress], [location varies], International.
Key personnel	Moser, Andrew; Morris, Ryan Origin Energy Resources, Brisbane, Queensl., Australia
Research themes	Aquifer interconnectivity
Project information source	Literature

Table 4.8 Project 8: Connectivity between MNES Springs and Walloon Coal Measures (QGC, Santos, Australia Pacific LNG)

Project characteristics	Details
Project title	**Connectivity between MNES Springs and Walloon Coal Measures (QGC, Santos, Australia Pacific LNG)**
Project location	Australia
Principal investigator	Unknown
Lead institution	QGC, Santos, APLNG
Project budget	Unknown
Source of funding	QGC
Project duration	2013
Current status	Unknown
Project summary	The three major CSG operators in the southern Bowen and Surat Basins (QGC, Santos and APLNG) are working collaboratively to develop a monitoring scheme to address the risk of groundwater drawdown propagating from CSG production and potentially affecting MNES springs.
Outputs	Unknown
Research themes	Aquifer connectivity
Project information source	UQ CCSG Online Portal

Table 4.9 Project 9: Groundwater Visualisation System (GVS): A software framework for integrated display and interrogation of conceptual hydrogeological models, data and time-series animation

Project characteristics	Details
Project title	**Groundwater Visualisation System (GVS): A software framework for integrated display and interrogation of conceptual hydrogeological models, data and time-series animation**
Project location	Australia
Principal investigator	Cox, Malcolm E.; James, Allan; Hawke, Amy; Raiber, Matthias
Lead institution	Queensland Univ Technol, Sch Earth Environm & Biol Sci, Brisbane, Qld
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Management of groundwater systems requires realistic conceptual hydrogeological models as a framework for numerical simulation modelling, but also for system understanding and communicating this to stakeholders and the broader community. To help overcome these challenges we developed GVS (Groundwater Visualisation System), a stand-alone desktop software package that uses interactive 3D visualisation and animation techniques. The goal was a user-friendly groundwater management tool that could support a range of existing real-world and pre-processed data, both surface and subsurface, including geology and various types of temporal hydrological information. GVS allows these data to be integrated into a single conceptual hydrogeological model. In addition, 3D geological models produced externally using other software packages, can readily be imported into GVS models, as can outputs of simulations (e.g. piezometric surfaces) produced by software such as MODFLOW or FEFLOW. Boreholes can be integrated, showing any down-hole data and properties, including screen information, intersected geology, water level data and water chemistry. Animation is used to display spatial and temporal changes, with time-series data such as rainfall, standing water levels and electrical conductivity, displaying dynamic processes. Time and space variations can be presented using a range of contouring and colour mapping techniques, in addition to interactive plots of time-series parameters. Other types of data, for example, demographics and cultural information, can also be readily incorporated. The GVS software can execute on a standard Windows or Linux-based PC with a minimum of 2 GB RAM, and the model output is easy and inexpensive to distribute, by download or via USB/DVD/CD. Example models are described here for three groundwater systems in Queensland, northeastern Australia: two unconfined alluvial groundwater systems with intensive irrigation, the Lockyer Valley and the upper Condamine Valley, and the Surat Basin, a large sedimentary basin of confined artesian aquifers. This latter example required more detail in the hydrostratigraphy, correlation of formations with drillholes and visualisation of simulation piezometric surfaces. Both alluvial system GVS models were developed during drought conditions to support government strategies to implement groundwater management. The Surat Basin model was industry sponsored research, for coal seam gas groundwater management and community information and consultation. The “virtual” groundwater systems in these 3D GVS models can be interactively

Project characteristics	Details
	interrogated by standard functions, plus production of 2D cross-sections, data selection from the 3D scene, rear end database and plot displays. A unique feature is that GVS allows investigation of time-series data across different display modes, both 2D and 3D. GVS has been used successfully as a tool to enhance community/stakeholder understanding and knowledge of groundwater systems and is of value for training and educational purposes. Projects completed confirm that GVS provides a powerful support to management and decision making, and as a tool for interpretation of groundwater system hydrological processes. A highly effective visualisation output is the production of short videos (e.g. 2–5 min) based on sequences of camera 'fly-throughs' and screen images. Further work involves developing support for multi-screen displays and touch-screen technologies, distributed rendering, gestural interaction systems. To highlight the visualisation and animation capability of the GVS software, links to related multimedia hosted online sites are included in the references.
Outputs	Cox et al. (2013). Ground water visualisation system (GVS); a software framework for integrated display and interrogation of conceptual hydrogeological models, data and time series animation. *Journal of Hydrology.* Elsevier, Amsterdam, Netherlands.
Key personnel	Cox, Malcolm E.; James, Allan; Hawke, Amy; Raiber, Matthias Cox, ME Queensland Univ Technol, Sch Earth Environm & Biol Sci, Brisbane, Qld 4001, Australia
Research themes	Aquifer interconnectivity
Project information source	Literature

Table 4.10 Project 10: Linking 3D geological modelling and multivariate statistical analysis to define groundwater chemistry baseline and inter-aquifer connectivity, Clarence-Moreton Basin, southeast Queensland, Australia

Project characteristics	Details
Project title	**Linking 3D geological modelling and multivariate statistical analysis to define groundwater chemistry baseline and inter-aquifer connectivity, Clarence-Moreton Basin, southeast Queensland, Australia**
Project location	Australia
Principal investigator	Raiber, Matthias; Cox, M. E.
Lead institution	Queensland University of Technology
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The Clarence-Moreton Basin (CMB) covers approximately 26 000 km (super 2) in Queensland and New South Wales and is the only Great Artesian Basin sub-basin with both a predominant south-westerly groundwater flow and a substantial eastward flow. In certain sections of this sub-basin, notably catchments of the Bremer, Logan and upper Condamine Rivers, the Jurassic Walloon Coal Measures are under exploration for coal seam gas (CSG). To assess spatial variations in groundwater flow and hydrochemistry at a basin-wide scale, a 3D hydrogeological model of the Queensland section of the CMB has been developed using GoCAD. Prior to any large-scale CSG extraction, it is essential to understand the existing hydrochemical character of different aquifers and to establish any potential linkages. To effectively use the large amount of groundwater chemistry contained in the DERM database (several thousand samples for the CMB) and data collected during our new studies, multivariate statistical techniques were employed. Following extensive data quality checks, the assessment used (a) Hierarchical Cluster Analysis to identify hydrochemical groups that are characteristic of distinct evolutionary pathways and mark a common hydrologic history of groundwaters, and (b) Principal Component Analysis to facilitate identification of processes of groundwater evolution and the primary determinants of the hydrochemical groups. The multivariate analysis confirms that there is considerable hydrochemical variation within groundwater of the different geological units that can be attributed to a range of factors, including recharge processes, aquifer redox environments, spatial differences of lithology and interaction (mixing) between aquifers. These factors are also associated with groundwater of different ages.
Outputs	Raiber and Cox. (2012). Linking 3D geological modelling and multivariate statistical analysis to define groundwater chemistry baseline and inter-aquifer connectivity, Clarence-Moreton Basin, southeast Queensland, Australia. *International Geological Congress, Abstracts = Congres Geologique International, Resumes.* [International Geological Congress], [location varies], International.
Key personnel	Raiber, Matthias; Cox, M. E. Queensland University of Technology, School of Earth, Environmental and Biological Sciences, Brisbane, Queensl., Australia

Project characteristics	Details
Research themes	Aquifer interconnectivity, water supplies
Project information source	Literature

Table 4.11 Project 11: Observations of ground movements within the overburden strata above longwall panels and implications for groundwater impacts

Project characteristics	Details
Project title	**Observations of ground movements within the overburden strata above longwall panels and implications for groundwater impacts**
Project location	Australia
Principal investigator	Mills, K W
Lead institution	Strata Control Technology
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Longwall mining is recognised to cause disturbance to the overburden strata as the overburden strata moves downward into the void created by mining. These ground movements have been observed as surface subsidence over many decades and by numerous researchers through numerous surface and sub-surface monitoring programs, in a wide variety of different geological settings, using a wide variety of monitoring techniques. This monitoring provides an excellent database of experience from which to characterise the nature and extent of disturbance within the overburden strata above longwall panels. This characterisation is intended to provide a basis for better understanding the effects of longwall mining on the surrounding strata and, particularly in the context of groundwater interactions, the formulation of hydrogeological models used to predict groundwater impacts about longwall panels. The extent and nature of zones within the overburden are characterised in this paper on the basis of the level of disturbance and the nature of this disturbance. Zones characterised by tensile changes or stretching behaviour are found to be located directly above each panel with the level of disturbance above the mining horizon graduated as a function of panel width from the mining horizon through to about three times panel width above each individual longwall panel. These stretching zones and their influence on the hydraulic conductivity of the overburden strata contrast with zones of increased compression located directly above the chain pillars that separate individual longwall panels.
Outputs	Mills. (2012). Observations of ground movements within the overburden strata above longwall panels and implications for groundwater impacts. *Proceedings of the 38th symposium on the advances in the study of the Sydney basin.* Hunter Valley:.
Key personnel	Mills, K W
Research themes	Surface water, water supplies, water dependent ecosystems
Project information source	Literature

Table 4.12 Project 12: Geotechnical centrifuge permeater for characterizing the hydraulic integrity of partially saturated confining strata for CSG operations

Project characteristics	Details
Project title	**Geotechnical centrifuge permeater for characterizing the hydraulic integrity of partially saturated confining strata for CSG operations**
Project location	Australia
Principal investigator	Bouzalakos, S; Timms, W; Rahman, P; McGeeney, D; Whelan, M
Lead institution	University of New South Wales
Project budget	Unknown
Source of funding	Australian Research Council and National Water Commission, as part of National Centre for Groundwater Research and Training Program 1B.
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Vertical hydraulic conductivity of aquitards is enabled under accelerated gravity in a Broadbent G-18 geotechnical centrigure (2 m diamter). Expedited determination of Kv under saturated steady state flow required very high G-levels (up to 250 G) to forece flow, providing evidence that intact shale core from deep sedimentary formations are very low permeability. New centrigufe instrumentation developments are proposed for experimentation under partially saturated conditions and transient flow to determine the extent to which vertical seepage is influenced. This may be a ctricial dynamic process that reduces potential impacts of depressuration or dewatering fom CSG extraction.
Outputs	Bouzalakos et al. (2013). Geotechnical centrifuge permeater for characterizing the hydraulic integrity of partially saturated confining strata for CSG operations. *International Mine Water Congress.* Colorado: Colorado School of Mines.
Key personnel	Bouzalakos, S; Timms, W; Rahman, P; McGeeney, D; Whelan, M
Research themes	Aquifer interconnectivity
Project information source	Literature

Table 4.13 Project 13: Leading practices for assessing the integrity of confining strata - Application to mining and coal-seam gas extraction

Project characteristics	Details
Project title	**Leading practices for assessing the integrity of confining strata - Application to mining and coal-seam gas extraction**
Project location	Australia
Principal investigator	Timms, Wendy; Acworth, R.I.; Hartland, Adam; Laurence, David
Lead institution	UNSW
Project budget	Unknown
Source of funding	Australian Research Council and National Water Commission, as part of National Centre for Groundwater Research and Training, Program 1B
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Confining strata, or aquitards that act as low permeability seepage barriers, can limit potential impacts of depressurization or dewatering and migration of contaminants associated with mining and coal seam gas (CSG) development. Innovative geophysical and hydrochemical methods are recommended in a staged approach to best practice aquitard assessment including coupled numerical modelling. For example, tests of drill core in the new NCGRT geotechnical centrifuge have enabled relatively rapid measurement of permeability or vertical hydraulic conductivity (Kv) of clayey sediments and shale (Kv 10-9 to <10-12 m/s). Stratigraphic and structural data and 3D modelling are also required to assess lateral continuity, and the likelihood of preferential leakage paths.
Outputs	Timms et al. (2012). Leading practices for assessing the integrity of confining strata: Application to mining and coal-seam gas extraction. *International Mine Water Association Conference.* Bunbury.
Key personnel	Timms, Wendy; Acworth, R.I.; Hartland, Adam; Laurence, David
Research themes	Aquifer interconnectivity, surface water
Project information source	Literature

Table 4.14 Project 14: Impacts of longwall mining and coal seam gas extraction on groundwater regimes in the Sydney Basin

Project characteristics	Details
Project title	**Impacts of longwall mining and coal seam gas extraction on groundwater regimes in the Sydney Basin**
Project location	Australia
Principal investigator	Pells, S E; Pells, P.J.N.
Lead institution	UNSW, Pells Consulting
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Part 1 of this paper presented simple equations for transient and steady state downwards flow, in saturated and unsaturated ground, that are considered to be useful in understanding flow and pressure regimes above extensive areas of longwall mining and coal seam gas extraction. This Part 2 paper presents field data from longwall mines in the Sydney Basin and relates the data to findings from Part 1. This Part 2 also analyses how different views have been expressed in relation to impacts of longwall mining on groundwater regimes, and proposes that these differences have largely arisen out of poor differentiation between seepage flows and pressures. The field data presented in this part support a finding of Part 1, namely that the question that should be asked in respect to groundwater impacts from longwall mining, and CSG extraction, is not “if” impacts will occur, but “how long” will they take to occur.
Outputs	Pells and Pells. (2012). Impacts Of Longwall Mining And Coal Seam Gas Extraction On Groundwater Regimes In The Sydney Basin Part 1 – Theory. *Australian Geomechanics Journal*. http://www.pellsconsulting.com.au/downloads/impactsOfLongwallMiningAndCoalSeamGasExtractionOnGroundwaterRegimesInTheSydneyBasinPart2PracticalApplications.pdf
Key personnel	Pells, S.E.; Pells, P.J.N.
Research themes	Aquifer interconnectivity, water supplies
Project information source	Literature

4.1.2 United States

Table 4.15 Project 15: Surface water and groundwater interactions in an extensively mined watershed, upper Schuylkill River, Pennsylvania, USA

Project characteristics	Details
Project title	**Surface water and groundwater interactions in an extensively mined watershed, upper Schuylkill River, Pennsylvania, USA**
Project location	US
Principal investigator	Cravotta, Charles A.; Goode, Daniel J.; Bartles, Michael D.; Risser, Dennis W.; Galeone, Daniel G.
Lead institution	USGS
Project budget	Unknown
Source of funding	Pennsylvania Department of Environmental Protection (PaDEP), the US Army Corps of Engineers (USACE), the Schuylkill Conservation District (SCD), the Schuylkill Headwaters Association, Inc. (SHA) and the US Environmental Protection Agency (USEPA)
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Streams crossing underground coal mines may lose flow, whereas abandoned mine drainage (AMD) restores flow downstream. During 2005–2012, discharge from the Pine Knot Mine Tunnel, the largest AMD source in the upper Schuylkill River Basin, had near-neutral pH and elevated concentrations of iron, manganese and sulphate. Discharge from the tunnel responded rapidly to recharge but exhibited a prolonged recession compared with nearby streams, consistent with rapid infiltration of surface water and slow release of groundwater from the mine complex. Dissolved iron was attenuated downstream by oxidation and precipitation, whereas dissolved CO2 degassed and pH increased. During high flow conditions, the AMD and downstream waters exhibited decreased pH, iron and sulphate with increased acidity that were modelled by mixing net-alkaline AMD with recharge or run-off having low ionic strength and low pH. Attenuation of dissolved iron within the river was least effective during high flow conditions because of decreased transport time coupled with inhibitory effects of low pH on oxidation kinetics. A numerical model of groundwater flow was calibrated by using groundwater levels in the Pine Knot Mine and discharge data for the Pine Knot Mine Tunnel and West Branch Schuylkill River during a snowmelt event in January 2012. Although the calibrated model indicated substantial recharge to the mine complex took place away from streams, simulation of rapid changes in mine pool level and tunnel discharge during a high flow event in May 2012 required a source of direct recharge to the Pine Knot Mine. Such recharge produced small changes in mine pool level and rapid changes in tunnel flow rate because of extensive unsaturated storage capacity and high transmissivity within the mine complex. Thus, elimination of stream leakage could have a small effect on the annual discharge from the tunnel, but a large effect on peak discharge and associated water quality downstream.
Outputs	Cravotta et al. (2013). Surface water and groundwater interactions in an extensively mined watershed, upper Schuylkill River, Pennsylvania, USA. *Hydrological Processes*. http://dx.doi.org/10.1002/hyp.9885

Project characteristics	Details
Key personnel	Cravotta, Charles A.; Goode, Daniel J.; Bartles, Michael D.; Risser, Dennis W.; Galeone, Daniel G.
Research themes	Co-produced/mine water, water supplies
Project information source	Literature

4.2 Disruption of surface water flow pathways

This research theme encompasses research that describes how surface water flows may be disturbed due to coal seam gas and coal mining. This may be through mining-induced subsidence, the mine cone of depression due to dewatering, stream diversions or the physical placement of infrastructure causing disruption of surface water flows. Thirty-seven projects were identified with the primary theme of disruption of surface water flow pathways.

4.2.1 Australia

Table 4.16 Project 16: Criteria for functioning river landscape units in mining and post mining landscapes

Project characteristics	Details
Project title	**Criteria for functioning river landscape units in mining and post mining landscapes**
Project location	Australia
Principal investigator	Karen White, Darcy Moar, Ross Hardie, Dom Blackham, Rohan Lucas
Lead institution	Alluvium Consulting
Project budget	$250 000
Source of funding	Australian Coal Association Research Program
Project duration	2011-2014
Current status	Completed
Project summary	ACARP commissioned Alluvium to analyse the performance of 60 watercourse diversions and adjoining reaches in the Bowen Basin to provide regional insight into the current condition of diversions. This information has been used to identify if there is a difference in the condition of diversions constructed since 2002 using the existing ACARP diversion criteria. The results of these analyses have underpinned the refinement of criteria for mine closure and the development of additional ACARP diversion design criteria. The Alluvium team has also carried out a review of Australian and global best practice diversion design and conducted interviews with mine staff and the regulator to refine the criteria.
Objectives	Establish the criteria for functioning river landscape units in mining and post mining landscapes
Outputs	http://www.acarp.com.au/abstracts.aspx?repId=C20017
Key personnel	Rohan Lucas http://alluvium.com.au/People.aspx
Research themes	Surface water
Project information source	Survey, ACARP website

Table 4.17 Project 17: Subsidence: an overview of causes, risks and future developments for coal seam gas production

Project characteristics	Details
Project title	**Subsidence: an overview of causes, risks and future developments for coal seam gas production**
Project location	Australia
Principal investigator	Pineda, Jubert A.; Sheng, Daichao
Lead institution	ARC Centre of Excellence for Geotechnical Science and Engineering (University of Newcastle)
Project budget	Unknown
Source of funding	New South Wales Government
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The paper discusses the main causes of subsidence with particular emphasis on the effects associated with CSG extraction. Coal is a multi-phase porous media in which hydraulic and mechanical processes interact and may cause the compaction of the coal seam during CSG extraction and to some degree affect the entire geological profile. Subsidence does not necessarily represent a prohibitive drawback for CSG production if those processes are properly understood and controlled.
Outputs	Pineda and Sheng. (2013). Subsidence: an overview of causes, risks and future developments for coal seam gas production. ARC Centre of Excellence for Geotechnical Science and Engineering (University of Newcastle). http://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0017/31274/Subsidence_Cause_OCSE_Final_Aug2013.pdf
Key personnel	Pineda, Jubert A.; Sheng, Daichao
Research themes	Surface water
Project information source	Literature

Table 4.18 Project 18: Subsidence monitoring - technical background paper for NSW Chief Scientist and Engineer

Project characteristics	Details
Project title	**Subsidence monitoring - technical background paper for NSW Chief Scientist and Engineer**
Project location	Australia
Principal investigator	McClusky, Simon; Tregoning, Paul
Lead institution	Australian National University
Project budget	Unknown
Source of funding	New South Wales Government
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The purpose of this background paper is to describe the measurement techniques that are available which might be used to monitor regions where CSG activities are either taking place already or are identified for future activities. The question, at its simplest level, amounts to defining the accuracy with which ground deformation can be measured and at what temporal and spatial scales.
Outputs	McClusky and Tregoning. (2013). Subsidence monitoring - technical background paper for NSW Chief Scientist and Engineer. Australian National University. http://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0016/33028/Subsidence-Monitoring_McClusky-Tregoning_ANU.pdf
Key personnel	McClusky, Simon; Tregoning, Paul
Research themes	Surface water
Project information source	Literature

Table 4.19 Project 19: Some interesting abandoned mine stabilization projects in Australia

Project characteristics	Details
Project title	**Some interesting abandoned mine stabilization projects in Australia**
Project location	Australia
Principal investigator	Knott, David L.
Lead institution	Coffey Geotechnics Pty. Ltd., Warabrook, NSW, Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Three examples of Australian practice dealing with development over abandoned coal mines are presented. Coal mining started in Newcastle, north of Sydney in about 1800 using convict miners. In portions of New South Wales, approval for development over mined areas is regulated by the Mine Subsidence Board (MSB), a government agency that is responsible for repairing structures damaged by subsidence. The MSB is funded by a levy on coal and it regulates investigation and development standards to limit its exposure to claims, a process that provides uniform guidelines for development. Sites above abandoned mine workings were able to be developed by stabilizing the underlying workings by injecting a flowable cement fly ash grout through grout holes drilled from the surface and / or over-excavation. Shafts must also be mitigated. Copyright 2013 ARMA, American Rock Mechanics Association.
Outputs	Knott. (2013). Some interesting abandoned mine stabilization projects in Australia. *47th US Rock Mechanics / Geomechanics Symposium 2013, June 23, 2013 - June 26, 2013.* San Francisco, CA, United states: American Rock Mechanics Association (ARMA).
Key personnel	Knott, David L. Coffey Geotechnics Pty. Ltd., Warabrook, NSW, Australia
Research themes	Surface water
Project information source	Literature

Table 4.20 Project 20: Assessment of mine subsidence in an area with a major pillar crushing event - Newcastle, Australia

Project characteristics	Details
Project title	**Assessment of mine subsidence in an area with a major pillar crushing event - Newcastle, Australia**
Project location	Australia
Principal investigator	Knott, David L.; Baker, Simon; Ditton, Steven; Love, Arthur
Lead institution	Coffey Geotechnics Pty. Ltd., Warabrook, NSW, Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	This paper demonstrates the use of historical and 'new' information to develop a model for pillar strength and subsidence analyses using empirical and numerical methods. The subsidence assessment was for a 4ha (10 ac) multi-storey redevelopment site along Newcastle Harbour. The 6m (20.3ft) thick Borehole Coal Seam was mined using the room and pillar method in the 1880's and 1890's, approximately 70m (230ft) beneath the harbour. The mined height was approximately 5m (16ft) and the pillars were approximately 5.5m (18ft) wide; thus, resulting in marginally stable pillars. Soon after mining was completed in one area in 1896, pillar failure occurred. It probably failed due to the fall of the 1.2m (4ft) thick roof coal layer, which had been left inplace, further increasing the height of the pillars. An approximately 25ha (60 ac) crushed area with up to 1.2m (4ft) of trough subsidence resulted. The workings were not flooded and the colliery closed in 1905 and allowed to flood. The investigation targeted pillars with boreholes to assess their condition and coal thickness. A downhole geophysical survey was also performed to confirm the coal thickness. The amount of crushing was determined by comparing the coal thickness in a borehole in a pillar with the thickness of coal in a borehole in an unmined location. The site is within a Mine Subsidence Board (MSB) district and the MSB is the referral authority for any improvement. In order to gain approval for development, it is necessary to; &bull Demonstrate the risk of subsidence in the future is acceptable; and / or should subsidence occur, the resulting damage is acceptable and safe, serviceable and repairable; or &bull Reduce the risk of subsidence by stabilization. The stability of pillars was assessed using numerical modelling with LaModel. The model was calibrated and predicted that when the unmined roof coal falls, the pillars fail, fitting the historical records. Subsidence was estimated with the Surface Deformation Prediction System (SDPS) program. The subsidence associated with the crush was modelled and a model was developed assuming future crushing in areas with uncrushed or partially crushed pillars. Potential future subsidence was determined by subtracting the subsidence associated with the crush from the worst case crushing. To mitigate potential subsidence impacts, grouting is planned to strengthen the pillars by providing confinement and reducing their effective height. Copyright 2012 ARMA, American Rock Mechanics Association.
Outputs	Knott et al. (2012). Assessment of mine subsidence in an area with a major pillar crushing event - Newcastle, Australia. *46th US Rock Mechanics / Geomechanics Symposium 2012, June 24, 2012 - June 27, 2012.* Chicago,

Project characteristics	Details
	IL, United states: American Rock Mechanics Association (ARMA).
Key personnel	Knott, David L.; Baker, Simon; Ditton, Steven; Love, Arthur Coffey Geotechnics Pty. Ltd., Warabrook, NSW, Australia
Research themes	Surface water
Project information source	Literature

Table 4.21 Project 21: Seismic imaging of stressed pillars in abandoned coal mines - Case studies from Australia

Project characteristics	Details
Project title	**Seismic imaging of stressed pillars in abandoned coal mines - Case studies from Australia**
Project location	Australia
Principal investigator	Whiteley, Robert J.
Lead institution	Coffey Geotechnics, Sydney, Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Systematic underground coal mining began in eastern Australia in 1802. Coal is now Australia's largest commodity export. With continuing expansion of this industry and population growth over the last 209 years many abandoned mines now lie within the precincts of large Australian cities, towns or high priority growth areas and are now adversely impacting surface developments due to fear of mine subsidence. Many of these old mines were operated with the room-and-pillar mining method and represent a major subsidence risk where standing and/or partially collapsed workings lie within 100m of the ground surface. Among the key issues hampering urban and infrastructure development are the lack of reliable data on the location and likely stability of these old workings and the costs of traditional investigative geotechnical technologies, principally drilling, that attempt to provide this information. It is widely accepted that P-wave borehole seismic imaging can greatly increase the cost-effectiveness of drilling by expanding the effective radius of investigation of a borehole and can locate regions of lower seismic velocity associated with collapsed workings and voids. However, it is less well recognised that regions of increased stress within the roof-pillar system, indicative of high risk standing workings, can also be seismically imaged as regions of higher seismic velocity. Demonstrations of this approach are provided by two case studies from Australian coalfields. The first study applies direct underground seismic imaging of a coal pillar in the Eastern Coalfields before and after it was split. This shows that approximately doubling the stress on the load-bearing regions of the split pillar increases P-wave seismic velocities by about forty percent. The second study, near the margins of old workings in the Western Coalfields, uses crosshole and surface-to-borehole seismic imaging to identify unexpected mine voids that were not intersected in the boreholes and observes the high velocity signature typical of a high risk, standing pillar. It is concluded that using P-wave borehole seismic imaging technologies with increased focus on the regions of increased stress can greatly improve the assessment of high risk mine subsidence areas. © 2012 Taylor Francis Group, London.
Outputs	Whiteley. (2012). Seismic imaging of stressed pillars in abandoned coal mines: Case studies from Australia. *12th International Congress on Rock Mechanics of the International Society for Rock Mechanics, ISRM 2011, October 18, 2011 - October 21, 2011.* Beijing, China: Taylor and Francis Inc.
Key personnel	Whiteley, Robert J.

Project characteristics	Details
	Coffey Geotechnics, Sydney, Australia
Research themes	Surface water
Project information source	Literature

Table 4.22 Project 22: Subsidence monitoring - technical background paper for NSW Chief Scientist and Engineer

Project characteristics	Details
Project title	**Subsidence monitoring - technical background paper for NSW Chief Scientist and Engineer**
Project location	Australia
Principal investigator	Lemon, R., Tickle, P., Spies, B., Dawson, J., Rosin, S.
Lead institution	Cooperative Research Centre for Spatial Information
Project budget	Unknown
Source of funding	New South Wales Government
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	This report describes observing techniques that are capable of quantifying subsidence over a range of spatial and temporal scales. We explain how the observing techniques work, how they are applied to monitoring subsidence and the strengths and weaknesses of each technique.
Outputs	Lemon, R., Tickle, P., Spies, B., Dawson, J., Rosin, S. (2013), *Subsidence Monitoring in Relation to Coal Seam Gas Production. Independent Review of Coal Seam Gas Activities in NSW*. Office of the NSW Chief Scientist and Engineer. NSW Government. http://www.chiefscientist.nsw.gov.au/coal-seam-gas-review/csg-background-papers http://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0007/35998/Subsidence-Monitoring_CRCSI.pdf
Key personnel	Tickle, Phil
Research themes	Surface water
Project information source	Literature

Table 4.23 Project 23: Building new bridges on the hunter expressway over abandoned coal mines

Project characteristics	Details
Project title	**Building new bridges on the hunter expressway over abandoned coal mines**
Project location	Australia
Principal investigator	Pokharel, Hari; Hespe, Iain; Mills, Ken
Lead institution	Hyder Consulting, 141 Walker Street, North Sydney NSW 2060, Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The industrial development of our societies over the past century used coal as the main source of energy which was mined from deep underground seams leaving voids below the ground surface. New urban development and transportation networks planned to meet the demand of future generations require roads and bridges to be built over these historical mining areas. Substantial mine related ground movement has been observed at the surface level above mining areas where standing pillars have become destabilised as a result of rising water levels within the mine, earthquakes, adjacent mining activity and the effect of sustained load in its supports. Building new bridges in such areas is a challenge for engineers. This paper discusses the details of three prestressed concrete segmental balanced cantilever bridges having a combined total length of 850m with internal span lengths of 75m and pier heights varying up to 30m above the ground. Up to 500mm vertical and 450mm horizontal ground movements are predicted in the event of pillar instability in bord and pillar workings in the seams ranging from 65m to 170m below the surface. Ground treatment works have been undertaken to reduce the predicted vertical movements to 25mm while horizontal movements of 450mm remain to be considered in the design. The bridges have been articulated to accommodate the predicted ground movements due to mining subsidence. Various types of foundation have been adopted.
Outputs	Pokharel et al. (2012). Building new bridges on the hunter expressway over abandoned coal mines. *Australasian Structural Engineering Conference (2012 : Perth, W.A.).* Barton, A.C.T. Engineers Australia. http://search.informit.com.au/documentSummary;dn=003561453525192;res=IELENG
Key personnel	Pokharel, Hari; Hespe, Iain; Mills, Ken Hyder Consulting
Research themes	Surface water
Project information source	Literature

Table 4.24 Project 24: Managing mine subsidence along railways and highway pavements in the southern coalfield

Project characteristics	Details
Project title	**Managing mine subsidence along railways and highway pavements in the southern coalfield**
Project location	Australia
Principal investigator	Kay, Daryl
Lead institution	Mine Subsidence Engineering Consultants
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	There is a long history of underground coal mining in the Illawarra, dating back to the mid-1800s. In recent times, coal mines have worked closely with the owners and operators of both private and public infrastructure to mine directly beneath infrastructure whilst maintaining their safe operation. An overview is presented of recent methods that have been used to successfully manage potential mine subsidence impacts on railway and highway infrastructure, whose presence in the past necessitated sterilisation of coal resources. Some of these methods represent "world first" technology and have applications beyond the field of mine subsidence management.
Outputs	Kay. (2012). Managing mine subsidence along railways and highway pavements in the southern coalfield. *Australian Geomechanics Journal.* PO Box 588, (2 Ernest Place), Crows Nest, NSW 1585, Australia: Engineers Media.
Key personnel	Kay, Daryl Mine Subsidence Engineering Consultants, Australia
Research themes	Surface water
Project information source	Literature

Table 4.25 Project 25: Continuous monitoring of mining induced strain in a road pavement using fiber Bragg grating sensors

Project characteristics	Details
Project title	**Continuous monitoring of mining induced strain in a road pavement using fiber Bragg grating sensors**
Project location	Australia
Principal investigator	Nosenzo, Giorgio; Whelan, B. E.; Brunton, M.; Kay, Daryl; Buys, Henk
Lead institution	Monitor Optics Systems Limited, Dublin, Ireland
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	This paper describes the application of fiber Bragg grating (FBG) based sensors for monitoring road pavement strains caused by mining induced ground subsidence as a result of underground longwall coal mining beneath a major highway in New South Wales, Australia. After a lengthy planning period, the risks to the highway pavement were successfully managed by the highway authority and the mining company through a technical committee. The technical committee comprised representatives of the mining company, the highway authority and specialists in the fields of pavement engineering, geotechnical engineering and subsidence. An important component of the management strategy is the installation of a total of 840 strain and temperature sensors in the highway pavement using FBG arrays encapsulated in glass-fiber composite cables. The sensors and associated demodulation equipment provide continuous strain measurements along the pavement, enabling on-going monitoring of the effects of mining subsidence on the pavement and timely implementation of planned mitigation and response measures to ensure the safety and serviceability of the highway throughout the mining period. © 2012 The Author(s).
Outputs	Nosenzo et al. (2013). Continuous monitoring of mining induced strain in a road pavement using fiber Bragg grating sensors. *Photonic Sensors.* Tiergartenstrasse 17, Heidelberg, D-69121, Germany: Springer Verlag.
Key personnel	Nosenzo, Giorgio; Whelan, B. E.; Brunton, M.; Kay, Daryl; Buys, Henk Monitor Optics Systems Limited, Dublin, Ireland
Research themes	Surface water
Project information source	Literature

Table 4.26 Project 26: Hunter Expressway, Australia: Dealing with poor ground and subsidence

Project characteristics	Details
Project title	**Hunter Expressway, Australia: Dealing with poor ground and subsidence**
Project location	Australia
Principal investigator	Aryal, Sudar; Kingsland, Robert; Rees, Peter; Russell, Geoff; Stahlhut, Olaf; Wheatley, David
Lead institution	Parsons Brinckerhoff, Sydney, Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The Hunter Expressway project near Newcastle, Australia, is an impressive 40 km motorway traversing a floodplain and rugged terrain by means of a series of bridges, viaducts and massive earthworks. Former underground coal mining activities and poor ground conditions presented exceptional engineering and construction challenges. Subsidence movements associated with the sudden collapse of standing pillars could leave some of project's structures unserviceable, while earthworks feature a proportionally large amount of poor quality materials derived from cutting construction. The designers incorporated expansive and carbonaceous materials, which would otherwise be spoiled because of their poor engineering properties. This paper chronicles the unique design and construction challenges associated with earthworks and mine subsidence for the eastern section of the project.
Outputs	Aryal *et al.* (2013). Hunter Expressway, Australia: Dealing with poor ground and subsidence. *Proceedings of the Institution of Civil Engineers: Civil Engineering.* 1 Heron Quay, London, E14 4JD, United Kingdom: ICE Publishing.
Key personnel	Aryal, Sudar; Kingsland, Robert; Rees, Peter; Russell, Geoff; Stahlhut, Olaf; Wheatley, David Parsons Brinckerhoff, Sydney, Australia
Research themes	Surface water
Project information source	Literature

Table 4.27 Project 27: Rail corridor mine remediation - from investigation to verification

Project characteristics	Details
Project title	**Rail corridor mine remediation - from investigation to verification**
Project location	Australia
Principal investigator	Thompson, Ian; Land, Barry; Holz, Bill
Lead institution	SMEC Australia SMEC Australia Keller Mine Fill
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The Goodna Colliery is one of Queensland's oldest underground coal mining operations and was operated from the mid 1860's through to the 1920's. An open cut mine was also in operation in the same area in the 1960's and 1970's. No original plans of the Goodna mine have ever been sourced and most information that was available was based on either estimates, anecdotal recollections or a combination of both. During the investigation and remediation of the Goodna Mine for the Dinmore to Goodna section of the adjacent Ipswich Motorway it became apparent that the Goodna coal mine extended beneath the current Queensland Rail Corridor, at shallow depth. This paper presents a case study of the work undertaken to remediate the mine workings and provide protection to the railway infrastructure from future mine induced subsidence. It covers the important geotechnical aspects of the work including historical information of the mine, local and regional geology, investigation methodologies (including video and sonar imagery) and results, risk assessment, remediation design, construction specifications and supervision and finally verification of the final product. Detailed geotechnical investigations were undertaken during a complete rail shutdown to determine the extent of the motorway corridor affected by previous mining activities. The investigations used a variety of techniques, such as conventional percussion and core drilling and sonar and video imaging to investigate the locations, dimensions and conditions of the abandoned mine. In all 65 holes were drilled and mapped in the 2 day investigation. The required measures to remediate the affected area was to completely fill the mine workings beneath the rail corridor with a low strength grout. This involved the construction of a barrier wall at the down-dip edge of filling boundary and then filling in an up-dip direction behind the barrier wall. During the filling operation a groundwater monitoring regime was undertaken to monitor groundwater levels and filling rates. To ensure the regional groundwater regime remained unaffected during the filling operation mine water was extracted from flooded workings at or below the rate of grout injection. The collected mine water was treated at a purpose built Reverse Osmosis treatment plant. Following the filling operation a series of verification works were undertaken to validate the completed works.
Outputs	Thompson *et al.* (2012). Rail corridor mine remediation - from investigation to verification. *CORE (2012 : Brisbane, Qld.).* Barton, A.C.T.: Engineers Australia.
Key personnel	Thompson, Ian; Land, Barry; Holz, Bill SMEC Australia SMEC Australia Keller Mine Fill

Project characteristics	Details
Research themes	Surface water
Project information source	Literature

Table 4.28 Project 28: Numerical modelling of mining subsidence in the Southern Coalfield of New South Wales, Australia

Project characteristics	Details
Project title	**Numerical modelling of mining subsidence in the Southern Coalfield of New South Wales, Australia**
Project location	Australia
Principal investigator	Zhang, C; Mitra, R; Hebblewhite, B; Tarrant, G
Lead institution	The University of New South Wales
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Mining subsidence associated with longwall extractions beneath significant natural features such as rivers and streams in the Southern Coalfield of New South Wales has posed risks to the natural environment. In this paper, a case study is presented showing the methodology in two-dimensional UDEC (Itasca 2006) modeling for mining induced subsidence around river valley, taking advantage of the discretization based on Voronoi diagram. The potential three-dimensional modeling method for subsidence is also introduced in this paper.
Outputs	http://www.itascacg.com/documents/numerical-modeling-of-mining-subsidence-in-the-southern-coalfield-of-new-south-wales https://research.unsw.edu.au/people/dr-rudrajit-mitra/publications
Key personnel	Zhang, C; Mitra, R; Hebblewhite, B; Tarrant, G School of Mining Engineering, The University of New South Wales, Australia
Research themes	Surface water
Project information source	Literature

4.2.2 China

Table 4.29 Project 29: Study on regulations of coal mining under highway

Project characteristics	Details
Project title	**Study on regulations of coal mining under highway**
Project location	China
Principal investigator	Deng, Wei Nan; Zhang, Hua Xing
Lead institution	Coal Mining and Designing Branch, China Coal Research Institute, Beijing, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	For guiding coal mining under highway scientifically and systematically, Regulations of coal mining under highway is necessary to be compiled in a few years in China.Base on the study of laws about highway and coal mining and existent regulations about coal mining under other constructions, this paper proposed the principal parts of the regulations according to the deformation and failure characteristics of highway caused by the effect of coal mining.The study provided the supports with theories and mining technologies for extracting unexploited coal under highway, increasing the coal production, optimizing mining design, prolonging the coal mine life and put forward some constructive suggestions for completing the regulations in the coal mining area in China. © (2013) Trans Tech Publications, Switzerland.
Outputs	Deng and Zhan. (2013). Study on regulations of coal mining under highway. *2013 2nd International Conference on Energy and Environmental Protection, ICEEP 2013, April 19, 2013 - April 21, 2013.* Guilin, China: Trans Tech Publications Ltd.
Key personnel	Deng, Wei Nan; Zhan, Hua Xing Coal Mining and Designing Branch, China Coal Research Institute, Beijing, China
Research themes	Surface water
Project information source	Literature

Table 4.30 Project 30: Present situation of research on coal mining subsidence under highway in China

Project characteristics	Details
Project title	**Present situation of research on coal mining subsidence under highway in China**
Project location	China
Principal investigator	Deng, Wei Nan; Zhang, Hua Xing
Lead institution	Coal Mining and Designing Branch, China Coal Research Institute, Beijing, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Research on coal mining subsidence under highway can be divided into two fields: research on the problems caused by coal mining under highway and research on the problems caused by highway construction above mined-out area of coal mine.The issues about safety, design and engineering are the key points restricting the safety and the construction of highway in coal mining areas. The paper completely summarized and analysed the present situation of research on coal mining subsidence under highway and the special characteristics comparing with the general building and the railway. In order to ensure the safety of existing highways and highways in planning in coal mining areas, according to the deficiency of current research, this paper put forward the future research directions of coal mining subsidence under highway. © (2013) Trans Tech Publications, Switzerland.
Outputs	Deng and Zhang. (2013). Present situation of research on coal mining subsidence under highway in China. *2012 International Conference on Environmental and Materials Engineering, EME 2012, December 9, 2012 - December 10, 2012.* Seoul, Korea, Republic of: Trans Tech Publications.
Key personnel	Deng, Weinan; Zhang, Huaxing Coal Mining and Designing Branch, China Coal Research Institute, Beijing, China
Research themes	Surface water
Project information source	Literature

Table 4.31 Project 31: Effects of coal mining subsidence on the changes of soil nutrient in Shenfu-Dongsheng coal field

Project characteristics	Details
Project title	**Effects of coal mining subsidence on the changes of soil nutrient in Shenfu-Dongsheng coal field**
Project location	China
Principal investigator	Yang, Ting Ting; Gao, Yong; Yao, Guo Zheng; Li, Peng
Lead institution	College of Ecology and Environmental Science, Inner Mongolia Agricultural University, Hohhot, 010019, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Ground surface subsidence will cause enormous impact to ecological environment in Coal Gob. But the study concerning the effect of the surface subsidence on soil nutrients is little. Taking Bulianta (Sandstorm--subsidence Area) and Yujialiang (Loess-subsidence Area) coal mine in Shenfu-Dongsheng coal field as study object, the characteristics of soil nutients in non-collapse area and the effect of collapse on soil nutrients are studied systematically by field sampling and laboratory analysis.The results showed that with the increasing of soil depth, total soil nutrient content gradually reduced in both study areas, while in Sandstorm-subsidence Area, total nitrogen and total phosphorus increased with soil depth. The total nitrogen and total phosphorus in Sandstorm-subsidence Area is lower than those in Loess-subsidence Area, but the total K is higher than that in Loess-subsidence Area. In a word, the effect of coal mining subsidence on total soil nutrients in both Areas is on the small side. © (2013) Trans Tech Publications, Switzerland.
Outputs	Yang *et al.* (2013). Effects of coal mining subsidence on the changes of soil nutrient in Shenfu-Dongsheng coal field. *2013 2nd International Conference on Energy and Environmental Protection, ICEEP 2013, April 19, 2013 - April 21, 2013.* Guilin, China: Trans Tech Publications Ltd.
Key personnel	Yang, Ting Ting; Gao, Yong; Yao, Guo Zheng; Li, Peng College of Ecology and Environmental Science, Inner Mongolia Agricultural University, Hohhot, 010019, China
Research themes	Surface water
Project information source	Literature

Table 4.32 Project 32: Changes of precipitation infiltration recharge in the circumstances of coal mining subsidence in the Shen-dong coal field, China

Project characteristics	Details
Project title	**Changes of precipitation infiltration recharge in the circumstances of coal mining subsidence in the Shen-dong coal field, China**
Project location	China
Principal investigator	Zhang, Fawang; Song, Yaxin; Zhao, Hongmei; Han, Zhantao; Wang, Dong
Lead institution	Institute of Hydrogeology and Environmental Geology, CAGS, Shijiazhuang 050061, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Coal mining subsidence is a universal environmental-geological problem in mining areas. By selecting the Shen-Dong coal mining subsidence area as the research field, this paper studies the changes in precipitation infiltration recharge in the circumstances of coal mining subsidence by means of field geological investigation and laboratory simulation experiments, which is expected to provide a scientific basis for eco-environmental restoration in the mining area. The results indicate that at the unstable stage of subsidence, three types of subsidence in the Shen-Dong mining area have positive effects on the precipitation infiltration recharge, and the type of full-thickness bedrock subsidence has the greatest influence. In the stable stage of subsidence, the precipitation infiltration process after long-term drought and the moisture migration in the aeration zone undergo three different stages: evaporation-infiltration before precipitation, infiltration-upward infiltration-infiltration during precipitation and evaporation-infiltration after precipitation. During a heavy rainfall infiltration process, the wetting front movement in fine sand, coarse sand and dualistic structure of fine-coarse sand consists of two stages: the stage of wetting front movement during precipitation, in which the wetting front movement distance has linear relationship with the depth, and the stage of wetting front movement after precipitation, in which the wetting front movement distance has the power function relationship with the depth. The wetting front movement velocity is influenced by the rainfall amount and the lithology in the aeration zone. However, as the depth increases, the movement velocity will decay exponentially.
Outputs	Zhang et al. (2012). Changes of precipitation infiltration recharge in the circumstances of coal mining subsidence in the shen-dong coal field, China. *Acta Geologica Sinica.* 155 Cremorne, St Richmond VIC, 3121, Australia: Wiley-Blackwell Publishing Asia.
Key personnel	Zhang, Fawang; Song, Yaxin; Zhao, Hongmei; Han, Zhantao; Wang, Dong
Contact	Institute of Hydrogeology and Environmental Geology, CAGS, Shijiazhuang 050061, China
Research themes	Surface water
Project information source	Literature

Table 4.33 Project 33: Dynamic monitoring of land subsidence in mining area from multi-source remote-sensing data - a case study at Yanzhou, China

Project characteristics	Details
Project title	**Dynamic monitoring of land subsidence in mining area from multi-source remote-sensing data - a case study at Yanzhou, China**
Project location	China
Principal investigator	Hu, Zhenqi; Xu, Xianlei; Zhao, Yanling
Lead institution	Institute of Land Reclamation and Ecological Reconstruction, China University of Mining and Technology (Beijing), Beijing, 100083, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Energy consumption in China is currently based on coal, but the exploitation of coal resources is accompanied by serious threats to the environment. In order to balance mine exploitation, land resource protection and land reclamation, there is an opportunity for monitoring land subsidence in mining area. This article examines a case study of Yanzhou mining area (YZMA) and proposes a new method for dynamic monitoring of land subsidence, which is a hybrid approach using a combination of multi-scale edge detection, relational model establishment and digital elevation model (DEM) difference analysis. A wavelet transform is used to extract the edges of water and marsh, which are buffered with the model to achieve the acquisition of the subsidence edge. DEM difference analysis is finally used to modify the results. The results indicate that this hybrid method improves subsidence monitoring performance by 0.02 km2 of the area accuracy. This method can be viewed as an effective approach to monitor a wide range of land subsidence in plain mining areas of China. © 2012 Copyright Taylor and Francis Group, LLC.
Outputs	Hu et al. (2012). Dynamic monitoring of land subsidence in mining area from multi-source remote-sensing data - a case study at Yanzhou, China. *International Journal of Remote Sensing.* 4 Park Square, Milton Park, Abingdon, Oxfordshire, OX14 4RN, United Kingdom: Taylor and Francis Ltd.
Key personnel	Hu, Zhenqi; Xu, Xianlei; Zhao, Yanling Institute of Land Reclamation and Ecological Reconstruction, China University of Mining and Technology (Beijing), Beijing, 100083, China
Research themes	Surface water
Project information source	Literature

Table 4.34 Project 34: Analysis on distribution characteristics of soil carbon pool in mining subsidence wetlands

Project characteristics	Details
Project title	**Analysis on distribution characteristics of soil carbon pool in mining subsidence wetlands**
Project location	China
Principal investigator	Qu, Junfeng; Zhang, Shaoliang; Xu, Zhanjun; Zhang, Ying
Lead institution	Jiangsu Key Lab. of Resources Environ. Inf. Eng., Xuzhou, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	There are short cycle, intensity disturbance and other characteristics about formation of subsided wetlands in mining coal area with higher groundwater table, there are also differences to general wetlands about conversion of "carbon sources, carbon sinks" and succession law, it has been a focus of attention about coal mining area of ecological restoration. The article aims to reveal the spatial and temporal changes characteristics, control elements of "carbon pool" in subsided wetlands, to reveal succession rules of "carbon sinks" in subsided coal mining wetlands with higher groundwater table. To present based target of ecological restoration with carbon of "adding sinks, source reduction" in mining coal subsided wetlands with higher groundwater table.
Outputs	Qu et al. (2012). Analysis on distribution characteristics of soil carbon pool in mining subsidence wetlands. *2013 Fifth International Conference on Measuring Technology and Mechatronics Automation (ICMTMA 2013), 16-17 Jan. 2013.* Los Alamitos, CA, USA: IEEE Computer Society.
Key personnel	Qu, Junfeng; Zhang, Shaoliang; Xu, Zhanjun; Zhang, Ying Jiangsu Key Lab. of Resources Environ. Inf. Eng., Xuzhou, China
Research themes	Surface water
Project information source	Literature

Table 4.35 Project 35: The monitoring of ecological reclamation evolution and landscape ecology remodeling technology in mining subsidence area

Project characteristics	Details
Project title	**The monitoring of ecological reclamation evolution and landscape ecology remodeling technology in mining subsidence area**
Project location	China
Principal investigator	Li, Xingli; Li, Shuzhi; Gao, Junhai
Lead institution	Mine Surveying Research Institute, Tangshan Branch, China Coal Research Institute, Tangshan, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	This paper discusses some key issues in the ecological reclamation. First, terrain, water system, the soil physical and chemical properties, and biological changes in the mining subsidence area were monitored; the ecological environment and soil ecological destruction mechanism and farmland ecological system elements space-time evolution rules in mining subsidence area were revealed. Second, the landscape pattern changes before and after reclamation were examined with RS and GIS technology. Finally, the mining subsidence area landscape ecology remodeling technologies were carried out. © 2012 IEEE.
Outputs	Li et al. (2012). The monitoring of ecological reclamation evolution and landscape ecology remodeling technology in mining subsidence area. *2nd International Workshop on Earth Observation and Remote Sensing Applications, EORSA 2012, June 8, 2012 - June 11, 2012.* Shanghai, China: IEEE Computer Society.
Key personnel	Li, Xingli; Li, Shuzhi; Gao, Junhai
Contact	Mine Surveying Research Institute, Tangshan Branch, China Coal Research Institute, Tangshan, China
Research themes	Surface water
Project information source	Literature

Table 4.36 Project 36: Water quality variation of mining-subsidence lake during the initial stage: cases study of Zhangji and Guqiao Mines

Project characteristics	Details
Project title	**Water quality variation of mining-subsidence lake during the initial stage: cases study of Zhangji and Guqiao Mines**
Project location	China
Principal investigator	Fan, Ting-yu; Yan, Jia-ping; Wang, Shun; Zhang, Bing; Ruan, Shu-xian; Zhang, Mei-li; Li, Shou-qin; Chen, Yong-chun; Liu, Jin
Lead institution	Sch. of Earth Environ., Anhui Univ. of Sci. Technol., Huainan, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Four quarters' water collecting and monitoring samples were done in the mining subsidence lakes of different water storing periods (2 to 7 years), considering the water storing time and pollution sources state of the subsidence lakes. The following indexes were discussed such as organic indexes (TOC, CODMn, BOD, COD), nutrient salts (TN, + NH4+, NO3-, NO2-, Kjeldahl Nitrogen, TP, PO43-), etc. It is shown that water quality of the mining subsidence lake during the initial stage (2 years to 7 years) can stay relatively stable with a fluctuation during different quarters in a year, which can reach class III or IV of the Surface Water Environmental Quality Standard.
Outputs	Fan et al. (2012). Water quality variation of mining-subsidence lake during the initial stage: cases study of Zhangji and Guqiao Mines. *Journal of Coal Science and Engineering (China).* China: Springer Asia Ltd.
Key personnel	Fan, Ting-yu; Yan, Jia-ping; Wang, Shun; Zhang, Bing; Ruan, Shu-xian; Zhang, Mei-li; Li, Shou-qin; Chen, Yong-chun; Liu, Jin
Contact	Sch. of Earth Environ., Anhui Univ. of Sci. Technol., Huainan, China
Research themes	Surface water
Project information source	Literature

Table 4.37 Project 37: Study on the deformation and stability of building foundations in mining subsidence areas

Project characteristics	Details
Project title	**Study on the deformation and stability of building foundations in mining subsidence areas**
Project Location	China
Principal Investigator	Huabin, Chai
Lead Institution	Sch. of Surveying Land Inf. Eng., Henan Polytech. Univ., Jiaozuo, China
Project Budget	Unknown
Source of Funding	Unavailable
Project Duration	Unknown- literature output 2012
Current Status	Unknown- literature output 2012
Project Summary	To enhance the effective of the land in mining subsidence areas, realize the development of new rural construction and urbanization. According to the geological and mining conditions, the scale, shape and regularity of the potential crack areas in the coal goafs, separated overburden strata, and the influencing factors which affect the deformation foundation of architecture and stability are studied. Probability integral method is used to establish the further deformations formula of the building foundations in mining subsidence areas. The monitoring data from the ground observation stations are used to invert the further deformation predicting parameters, the surface further deformations of each coal goafs, and the whole surface's further deformations are calculated by the superposition method. The foundation further deformations, geological structures, etc, are comprehensively taken into consideration. The stability of the building foundations in mining subsidence area are analyzed and evaluated. Research results are very valuable to process, design, and plan the foundations of the buildings in coal mining subsidence areas.
Outputs	Huabin. (2012). Study on the deformation and stability of building foundations in mining subsidence areas. *Applied Mechanics and Materials.* Switzerland: Trans Tech Publications Ltd.
Key Personnel	Huabin, Chai
Contact	Sch. of Surveying Land Inf. Eng., Henan Polytech. Univ., Jiaozuo, China
Research Themes	Surface water
Project Information Source	Literature

Table 4.38 Project 38: Surface subsidence prediction for the WUTONG mine using a 3-D finite difference method

Project characteristics	Details
Project title	**Surface subsidence prediction for the WUTONG mine using a 3-D finite difference method**
Project location	China
Principal investigator	Xu, Nengxiong; Kulatilake, Pinnaduwa H. S. W.; Tian, Hong;Wu, Xiong; Nan, Yinhua; Wei, Tian
Lead institution	School of Engineering and Technology, China University of Geosciences, Beijing 100083, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	WUTONG coal mine is adjacent to an auxiliary dam of the Yuecheng Reservoir. In this paper, mining-induced surface subsidence prediction is conducted by means of the finite difference method (FDM) to judge whether the extraction of the coal seam will have a negative impact on the dam. First, the initial values of the rock mass mechanical parameters are estimated using the available literature that relates intact rock and discontinuity properties to rock mass parameters. Then, based on available surface subsidence monitoring data on WUTONG's mined areas, the main mechanical parameters of coal and rock masses are determined by a back analysis procedure that combines an experimental design technique with numerical simulations. Finally, the surface subsidence results in the mining area are numerically predicted for four different mining scenarios (S1 through S4). Scenario S3 emerged as the best choice of these four scenarios. The predictions are: (1) the maximum surface subsidence within the mining area is 2.14. m, with the maximum settlement point located in the mid-west area of the coalfield, and (2) the nearest distance from the boundary of the surface movement area to the edge of the dam foundation is 35. m. Therefore, mining the coal seam will not cause damage to the dam. © 2012 Elsevier Ltd.
Outputs	Xu et al. (2013). Surface subsidence prediction for the WUTONG mine using a 3-D finite difference method. *Computers and Geotechnics.* Langford Lane, Kidlington, Oxford, OX5 1GB, United Kingdom: Elsevier Ltd.
Key personnel	Xu, Nengxiong; Kulatilake, Pinnaduwa H. S. W.; Tian, Hong; Wu, Xiong; Nan, Yinhua; Wei, Tian
Contact	School of Engineering and Technology, China University of Geosciences, Beijing 100083, China
Research themes	Surface water
Project information source	Literature

Table 4.39 Project 39: Huge thick conglomerate movement induced by full thick longwall mining huge thick coal seam

Project characteristics	Details
Project title	**Huge thick conglomerate movement induced by full thick longwall mining huge thick coal seam**
Project location	China
Principal investigator	Ma, Liqiang; Qiu, Xiaoxiang; Dong, Tao; Zhang, Jixiong; Huang, Yanli
Lead institution	School of Mines, China University of Mining and Technology, Xuzhou 221116, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	A discrete elemental method was used to study the thickness of conglomerate layer in a full thick seam mining activities under the influence of the law, pointing out the thickness of the conglomerate at different seam mining, and during the destruction and instability of existing state of laws. At 21141 thick seam mining, the face toward the direction of separation between the thick layer of conglomerate rock and the next bit after reaching its maximum capacity due to pull from the bottom of the plastic zone, formed a stratified and hierarchical down collapse. The shape of caving area is a "triangular block", the length of the plastic zone and face advancement from the linear fit between the height of the plastic zone and the advancing face is a quadratic function of distance, while the top layer of thick gravel layer is the overall bending subsidence trend. Tilting the direction of the face, a thick gob of collapsed conglomerate layer is formed in the coal gob entity on both sides of the thick conglomerate at the top of the overall fracture morphology performance, thus forming a mutual extrusion of articulated block structure. The instability, separation and balance of the thick conglomerate layer in the hinged block stope stress leads to abnormal occurrence of rock burst induced by face as the major factor in the accident. This research reveals the form of stress distribution in the destroyed layer of the thick conglomerate rock, analyzes the stope law of coupling for the pressure burst behavior law for the mining work face, and the choice of preventive measures to provide a theoretical basis and implementation.
Outputs	Ma et al. (2012). Huge thick conglomerate movement induced by full thick longwall mining huge thick coal seam. *International Journal of Mining Science and Technology.* Xuzhou Jiangsu, 221008, China: China University of Mining and Technology.
Key personnel	Ma, Liqiang; Qiu, Xiaoxiang; Dong, Tao; Zhang, Jixiong; Huang, Yanli
Contact	School of Mines, China University of Mining and Technology, Xuzhou 221116, China
Research themes	Surface water
Project information source	Literature

Table 4.40 Project 40: Management of water quality information in mining subsidence waterlogged area

Project characteristics	Details
Project title	**Management of water quality information in mining subsidence waterlogged area**
Project location	China
Principal investigator	Hui, Guo
Lead institution	School of Surveying, Anhui University of Science and Technology, No.168, Shungeng Road, Huainan 232001, Anhui, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Based of the technology of CAD VBA and Access database, the management program of water quality monitoring information in mining subsidence area is developed; it mainly includes functions of attribute query, attribute edition, visualization of water monitoring point. The table structure in monitoring point attribute database is designed, and problem of dynamic linkage between drawing data and attribute data is solved. The key code about them is given in the paper. The program can provide some decision support for reasonable use of water resources and environment protection in the mine area, and will promote the more scientific and sustainable development of mine area. © (2013) Trans Tech Publications, Switzerland
Outputs	Hui. (2013). Management of water quality information in mining subsidence waterlogged area. *2013 2nd International Conference on Energy and Environmental Protection, ICEEP 2013, April 19, 2013 - April 21, 2013.* Guilin, China: Trans Tech Publications Ltd.
Key personnel	Hui, Guo
Contact	School of Surveying, Anhui University of Science and Technology, No.168, Shungeng Road, Huainan 232001, Anhui, China
Research themes	Surface water
Project information source	Literature

Table 4.41 Project 41: Quantitative prediction of mining subsidence and its impact on the environment

Project characteristics	Details
Project title	**Quantitative prediction of mining subsidence and its impact on the environment**
Project location	China
Principal investigator	Song, Jianjun; Han, Chunjian; Li, Ping; Zhang, Junwei; Liu, Deyuan; Jiang, Minde; Zheng, Lin; Zhang, Jingkai; Song, Jianying
Lead institution	State Key Laboratory of Coal Resources and Safety Mining, School of Geosciences and Surveying Engineering, China University of Mining and Technology, Beijing 100083, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	This study is focused on the prediction of mining subsidence and its impact on the environment in the Hongqi mining area. The study was carried out by means of a probability integral model based, in first instance based on field surveys and the analysis of data collected from this area. Isolines of mining subsidence were then drawn and the impact caused by mining subsidence on the environment was analyzed quantitatively by spatial analysis with Geographic Information System (GIS). The results indicate that the subsidence area of the first working-mine can be as large as 2.54 km^2, the maximum subsidence is 3440 mm which will cause 1524 houses to be relocated. The entire subsidence area of the mine can reach 8.09 km2, with a maximum subsidence of 3590 mm. Under these circumstances the value of the loss of ecosystem services will reach 5.371 million Yuan and the cost of relocating buildings will increase to 6.858 million Yuan. © 2012 Published by Elsevier B.V. on behalf of China University of Mining Technology.
Outputs	Song et al. (2012). Quantitative prediction of mining subsidence and its impact on the environment. *International Journal of Mining Science and Technology.* Xuzhou Jiangsu, 221008, China: China University of Mining and Technology.
Key personnel	Song, Jianjun; Han, Chunjian; Li, Ping; Zhang, Junwei; Liu, Deyuan; Jiang, Minde; Zheng, Lin; Zhang, Jingkai; Song, Jianying
Contact	State Key Laboratory of Coal Resources and Safety Mining, School of Geosciences and Surveying Engineering, China University of Mining and Technology, Beijing 100083, China
Research themes	Surface water
Project information source	Literature

Table 4.42 Project 42: Highway construction across heavily mined ground and steep topography in southern China

Project characteristics	Details
Project title	**Highway construction across heavily mined ground and steep topography in southern China**
Project location	China
Principal investigator	Tong, Liyuan; Liu, Lian; Yu, Qiu
Lead institution	Transportation College, Southeast University, Nanjing, 210096, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Due to rapid expansion of the highway network in southern China in recent years, abandoned mine areas have been increasingly considered for highway construction. It is particularly challenging to carry out the assessment and remediation of mining subsidence effects on highway infrastructures, including high-filling embankments, deep-cutting slopes, and bridges. This article describes the subsidence mechanisms of abandoned mines with longwall workings and room-and-pillar systems, and also the potential geohazards and risks associated with abandoned mines. A hazard zonation criterion adopted for highway design and construction in China is introduced, as well as the possible remedial measures that can be carried out for various highway infrastructures. In the case study, grouting was used to fill cavities and stabilize the voids, and a two-layered geogrid was incorporated in the sub-base and embankment to avoid subsidence or sudden collapse of the ground. The remedial measures applied to deep-cutting slopes involved grouting, an anchor, or grid beam, employed either alone or in combination. In addition, a reinforced soil-piled embankment was utilized to reduce differential settlement at the transition zone between a bridge abutment and embankment. Based on the experiences gained, recommendations for future projects are given. © 2013 Springer-Verlag Berlin Heidelberg
Outputs	Tong et al. (2013). Highway construction across heavily mined ground and steep topography in southern China.
Key personnel	Tong, Liyuan; Liu, Lian; Yu, Qiu
Contact	Transportation College, Southeast University, Nanjing, 210096, China
Research themes	Surface water
Project information source	Literature

4.2.3 Russia

Table 4.43 Project 43: Earth surface subsidence in the Kuznetsk coal basin caused by manmade and natural seismic activity according to ALOS PALSAR interferometry

Project characteristics	Details
Project title	**Earth surface subsidence in the Kuznetsk coal basin caused by manmade and natural seismic activity according to ALOS PALSAR interferometry**
Project location	Russia
Principal investigator	Zakharov, Alexander I.; Epov, Michael I.; Mironov, Valery L.; Chymitdorzhiev, Tumen N.; Seleznev, Victor S.; Emanov, Alexander F.; Bykov, Michael E.; Cherepenin, Vladimir A.
Lead institution	Kotelnikov Institute of Radioengineering and Electronics, RAS, Fryazino 141120, Russia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	This paper presents results of a spaceborne radar interferometry technique application for land subsidence observations in a coal mining area in Kuzbass, Russia. Joint analysis of radar interferometry measurements with simultaneous seismic observations shows that the land subsidence is triggered by seismic events, both natural and caused by human underground activity. Surface displacements are linked typically to the boundaries of block structures and correlate with the location of clusters of seismic events. © 2013 IEEE.
Outputs	Zakharov et al. (2013). Earth surface subsidence in the kuznetsk coal basin caused by manmade and natural seismic activity according to ALOS PALSAR interferometry. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing.* 445 Hoes Lane, PO Box 1331, Piscataway, 08855 - 1331, United States: Institute of Electrical and Electronic Engineers.
Key personnel	Zakharov, Alexander I.; Epov, Michael I.; Mironov, Valery L.; Chymitdorzhiev, Tumen N.; Seleznev, Victor S.; Emanov, Alexander F.; Bykov, Michael E.; Cherepenin, Vladimir A.
Contact	Kotelnikov Institute of Radioengineering and Electronics, RAS, Fryazino 141120, Russia
Research themes	Surface water
Project information source	Literature

4.2.4 United Kingdom

Table 4.44 Project 44: Relationship between joint movement and mining subsidence

Project characteristics	Details
Project title	**Relationship between joint movement and mining subsidence**
Project location	United Kingdom
Principal investigator	Swift, G.
Lead institution	Civil Engineering Research Centre, University of Salford, Newton Building, Peel Park, The Crescent, Salford, M5 4WT, United Kingdom
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The hazards associated with the possible collapse of old mine workings underlying an active landfill site in north-east England have been identified as a significant concern to both the regulatory authorities and to the landfill operator. A quantitative assessment of the hazards and their perceived risks to the integrity of the composite lining system in place beneath the landfill has been undertaken using a combination of field observation, established mine subsidence prediction tools and numerical modelling techniques. Field observations have identified the presence of extensive fissuring within the limestone underlying the site, however, it is difficult to assess the extent to which mining has contributed to the development of these features. In light of this, an influence function technique has been used to attempt to predict the degree of fracturing that could have been experienced at the surface due solely to mining, with the intention of illustrating whether the scale of movements on pre-existing joints could be attributed to mining subsidence. The results of this analysis have subsequently been used within a finite-difference numerical model to assess the effect that a fracture of the scale predicted would have on the composite lining system. © 2013 Springer-Verlag Berlin Heidelberg
Outputs	Swift. (2013). Relationship between joint movement and mining subsidence.
Key personnel	Swift, G.
Contact	Civil Engineering Research Centre, University of Salford, Newton Building, Peel Park, The Crescent, Salford, M5 4WT, United Kingdom
Research themes	Surface water
Project information source	Literature

Table 4.45 Project 45: Numerical modelling of shallow abandoned mine working subsidence affecting transport infrastructure

Project characteristics	Details
Project title	**Numerical modelling of shallow abandoned mine working subsidence affecting transport infrastructure**
Project location	United Kingdom
Principal investigator	Helm, P. R.; Davie, C. T.; Glendinning, S.
Lead institution	School of Civil Engineering and Geosciences, Newcastle University, Newcastle Upon Tyne, United Kingdom
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	This work presents details of a shallow mining subsidence event that occurred in the summer of 2001 causing the formation of crown-holes at the surface which affected the East Coast Main Railway line in the UK. This subsidence event caused significant disruption and the remediation effort required the construction of a 1.8. km long diversion built on a piled, reinforced concrete raft. Details of the ground investigation are summarised along with a large parametric numerical modelling study undertaken in FLAC 3D into the potential causes of the instability, including the role of variations of the level of the groundwater table, the influence of the structure of the rock mass and also the potential geometry of the abandoned workings. Ultimately the modelling allowed constraints to be placed on the likely excavation width of the workings at the site along with bedding spacing and strength of the overlying rock mass. The modelling also suggests that the increase in the ground water table may also have been a factor in the occurrence of instability on the site. © 2012 Elsevier B.V.
Outputs	Helm *et al.* (2013). Numerical modelling of shallow abandoned mine working subsidence affecting transport infrastructure. *Engineering Geology.* P.O. Box 211, Amsterdam, 1000 AE, Netherlands: Elsevier.
Key personnel	Helm, P. R.; Davie, C. T.; Glendinning, S.
Contact	School of Civil Engineering and Geosciences, Newcastle University, Newcastle Upon Tyne, United Kingdom
Research themes	Surface water
Project information source	Literature

4.2.5 United States

Table 4.46 Project 46: Exploring the legacy effects of surface coal mining on stream chemistry

Project characteristics	Details
Project title	**Exploring the legacy effects of surface coal mining on stream chemistry**
Project location	US
Principal investigator	Hopkins Ii, Robert L.; Altier, Bradley M.; Haselman, Derek; Merry, Andrea D.; White, Jacob J.
Lead institution	Biology Department, University of Rio Grande, Rio Grande, OH, United States
Project budget	Unknown
Source of funding	Provost Academic Excellence Initiative Grant from the University of Rio Grande
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Surface coal mining results in dramatic alterations of the landscape in central Appalachia, leading to a myriad of environmental problems. In this study, we explore the long-term effects of surface coal mining on stream chemistry and endeavor to gain a better understanding of the efficacy of reclamation. We examined 30 sites in the Raccoon Creek watershed in southeastern Ohio, where the majority of surface mine sites are in various stages of reclamation. Our results show that conductivity (r = 0.862; P = 0.000), sulfate (r = 0.619; P = 0.000), and aluminum (r = 0.469; P = 0.009) levels increase linearly as a function of the areal extent of reclaimed mines in each subwatershed, suggesting limited success of reclamation to restore natural stream chemistry. In contrast, pH was not significantly linearly correlated with the areal extent of surface mines. This suggests that local acid mine drainage remediation projects are able to regulate acidity levels in the watershed but not conductivity and certain heavy metal concentrations. Many sites had conductivity levels high enough to impair aquatic biota via ionic and osmoregulatory stress. In sum, surface coal mining appears to have a strong legacy effect on stream chemistry in the Raccoon Creek watershed. © 2013 Springer Science+Business Media Dordrecht
Outputs	Hopkins Ii et al. (2013). Exploring the legacy effects of surface coal mining on stream chemistry. *Hydrobiologia.* Van Godewijckstraat 30, Dordrecht, 3311 GZ, Netherlands: Springer Netherlands.
Key personnel	Hopkins Ii, Robert L.; Altier, Bradley M.; Haselman, Derek; Merry, Andrea D.; White, Jacob J.
Contact	Biology Department, University of Rio Grande, Rio Grande, OH, United States
Research themes	Surface water
Project information source	Literature

Table 4.47 Project 47: Templeton gap floodway levees, investigation and mitigation of mine subsidence

Project characteristics	Details
Project title	**Templeton gap floodway levees, investigation and mitigation of mine subsidence**
Project location	US
Principal investigator	Soule, N.; Parekh, M. L.; Kuehr, S.; Amundson, A.; Hanna, K.; Bare, D.; Pauley, C.
Lead institution	Brierley Assoc., Denver, CO, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	As part of FEMA's Digital Flood Insurance Rate Map (DFIRM) conversion project for El Paso County, Colorado, the Templeton Gap Levee (TGL) System required certification. The purpose of levee certification is to provide FEMA with documentation that areas behind the levees are protected from the 1% annual chance of exceedance flood event and may be accredited as such by FEMA on the DFIRM. Without certification, property owners behind the TGL could be required to purchase flood insurance, potentially costing the community millions of dollars annually in insurance premiums. During preliminary exploration and literature review, the engineering team found evidence of historic coal mining, predominantly room and pillar type mines with approximately 9 to 30 meters (30 to 100 feet) of cover over the coal seams under and around the TGL. Subsequent targeted drilling, geophysical surveys using DC resistivity and reverse vertical seismic profiling, and subsurface sonar and video void imaging confirmed that open mine voids exist under the levee, placing the structure at risk for future subsidence that could threaten the integrity of the TGL. The geophysical investigation: 1) provided detailed information on the subsurface characteristics beneath the TGL; 2) mapped possible mine workings beneath and adjacent to the levee; and 3) provided information for assessing risk for potential subsidence or sinkhole development associated with abandoned mines. Mitigation measures consisted of grouting the areas considered at high risk of subsidence, using staged sanded cement grout injection into open mine voids. The Colorado Division of Reclamation, Mining and Safety finalized the mitigation plan and performed the work under the Inactive Mine Program. This paper describes the geotechnical and geophysical investigation and subsidence mitigation, as well as the agency partnership which developed to facilitate completion of this work.
Outputs	Soule et al. (2013). Templeton gap floodway levees, investigation and mitigation of mine subsidence. *Geochallenges - Rising to the Geotechnical Challenges of Colorado.* Reston, VA, USA: American Society of Civil Engineers.
Key personnel	Soule, N.; Parekh, M. L.; Kuehr, S.; Amundson, A.; Hanna, K.; Bare, D.; Pauley, C.
Contact	Brierley Assoc., Denver, CO, United States
Research themes	Surface water

Project characteristics	Details
Project information source	Literature

Table 4.48 Project 48: Enhanced subsurface subsidence prediction model that considers overburden stratification

Project characteristics	Details
Project title	**Enhanced subsurface subsidence prediction model that considers overburden stratification**
Project location	US
Principal investigator	Luo, Yi; Qiu, Biao
Lead institution	Department of Mining Engineering, West Virginia University, Morgantown, WV, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Subsurface strata movements and deformations caused by longwall mining operations in underground coal mines could affect many important coal mining activities, such as gob well degasification, ground water protection and multiple seam mining. The stratifications in the overburden have significant influence on the subsurface and surface movements and deformations in the ground subsidence process. An enhanced subsurface subsidence prediction model considering overburden stratifications has been introduced in this paper. In this method, the entire overburden strata are equally divided into a finite number of layers and the percent of the hard rocks in each layer is an additional input. The proven influence function method is applied to predict the subsidence on each of the predefined layers progressively upward using the predicted subsidence on the previous layer as the subsidence cause for the current layer. A computer program is developed to facilitate the calculations. A case demonstration is used to show the applicability of the proposed subsurface subsidence prediction model.
Outputs	Luo and Qiu. (2012). Enhanced subsurface subsidence prediction model that considers overburden stratification. *Mining Engineering.* 12999 E. Adam Aircraft Circle, Englewood,Colorado, 80112, United States: Society for Mining, Metallurgy, and Exploration, Inc. (SME).
Key personnel	Luo, Yi; Qiu, Biao
Contact	Department of Mining Engineering, West Virginia University, Morgantown, WV, United States
Research themes	Surface water
Project information source	Literature

Table 4.49 Project 49: Applications of DInSAR for measuring mine-induced subsidence and constraining ground deformation model

Project characteristics	Details
Project title	**Applications of DInSAR for measuring mine-induced subsidence and constraining ground deformation model**
Project location	US
Principal investigator	Ismaya, F.; Donovan, J.
Lead institution	Dept. of Min. Eng., Univ. of Utah, Salt Lake City, UT, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Differential Interferometric Synthetic Aperture Radar (DInSAR) was used to measure subsidence above an underground longwall mine in Book Cliffs coal field Utah. DInSAR is a remote sensing technique capable of producing high-density displacement maps with sub-centimeter accuracy. In this study several SAR images covering an area of the West Ridge mine were used to produce displacement maps of the three-dimensional subsidence troughs developed above the active longwall panels. The results were validated using traditional field methods and subsequently used for constraining a ground deformation model. DInSAR identified the maximum amount of subsidence as 1.1 meters, nearly identical to the 1.2 meters measured using survey-controlled photogrammetry. Time-lapsed DInSAR subsidence profiles were fit to the active longwall mining sequence and were able to properly identify the dynamic progress of subsidence trough development above the extracted panels. Finally, DInSAR results were used to constrain a subsidence model and the result indicates that DInSAR is not only capable of providing high accuracy data for subsidence measurement but can also be used for model validation and improvement.
Outputs	Ismaya and Donovan. (2012). Applications of DInSAR for Measuring Mine-Induced Subsidence and Constraining Ground Deformation Model. *GeoCongress 2012 State of the Art and Practice in Geotechnical Engineering, 25-29 March 2012.* Reston, VA, USA: American Society of Civil Engineers.
Key personnel	Ismaya, F.; Donovan, J.
Contact	Dept. of Min. Eng., Univ. of Utah, Salt Lake City, UT, United States
Research themes	Surface water
Project information source	Literature

Table 4.50 Project 50: Mitigation and monitoring of structural distress in the Whitely Electrical Substation due to mine subsidence

Project characteristics	Details
Project title	**Mitigation and monitoring of structural distress in the Whitely Electrical Substation due to mine subsidence**
Project location	US
Principal investigator	Horn, M.; Cass, P.; Bazan-Zurita, E.
Lead institution	First Energy, Greensburg, PA, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Mine subsidence mitigation for an energized electrical substation. Underground coal mining is a common activity in the North East United States which often impacts surface facilities including electric transmission/substation systems. In longwall mining, coal seams are excavated over large areas that cause near immediate, vertical and horizontal displacements of the ground surface above the mined seam. Structures located on these affected areas are subjected to varying permanent and temporary foundation displacements and rotations that may induce strains and stresses beyond the capacity of the structure. Cumberland Coal informed West Penn Power that long-wall mining would occur underneath the West Penn Power, 138kV, Whiteley Substation in early 2010. Their estimates indicated the ground would settle a total of approximately 4.5 feet. It was also necessary for West Penn Power to maintain service, from the substation during this subsidence event for its customers including the mining equipment. This paper discusses how the structural integrity of the substation components was maintained during the subsidence event by devising, implementing and monitoring various mitigation actions that reduced horizontal and vertical strains, compensated for the induced deformations in the structures, and reinforced components to tolerate anticipated deformations. Depending on the materials, geometry, and foundation layout of each structure, the impact of subsidence can be significantly alleviated by either stiffening of the panels and foundations to promote rigid body movements, and/or by softening the connections in order to facilitate limited mechanism types of movements. Whiteley substation functioned as needed during the subsidence event, as the result of these mitigation actions.
Outputs	Horn et al. (2012). Mitigation and monitoring of structural distress in the whitely electrical substation due to mine subsidence. *2012 Electrical Transmission and Substation Structures Conference, 4-8 Nov. 2012.* Reston, VA, USA: American Society of Civil Engineers.
Key personnel	Horn, M.; Cass, P.; Bazan-Zurita, E.
Contact	First Energy, Greensburg, PA, United States
Research themes	Surface water
Project information source	Literature

Table 4.51 Project 51: Geotechnical aspects of a 16 m high steep embankment in Eastern Pennsylvania

Project characteristics	Details
Project title	**Geotechnical aspects of a 16 m high steep embankment in Eastern Pennsylvania**
Project location	US
Principal investigator	McCullough, M. L.; Lei, Gu; Bohr, R.; Mouradian, A. G.
Lead institution	Gannett Fleming, Inc., Audubon, PA, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	This paper presents the geotechnical investigations, analyses of data, design requirements and proposed construction methods for a steep embankment in eastern Pennsylvania. As part of the improvements to the I-81 Exit 178Avoca/Airport Interchange project, a new 1.4 km road is proposed between the interchange and a nearby industrial park. The new road will be constructed mostly on embankment fill. At one point, the road is required to pass between two existing airport runway light towers. Due to an existing valley in this vicinity and the geometric constraints of the light towers, the proposed embankment fill in this area reaches a maximum of approximately 16 m in height with slopes as steep as 0.6 horizontal to 1 vertical (0.6H:1V). The project site is located within the Northern Anthracite coal fields. Historical mine data indicate that the anthracite coal is characterized by extensive abandoned surface and underground mine workings. The critical nature of existing towers, along with difficult subsurface conditions at the project site, results in several geotechnical challenges in design of the steep embankment for the new road. This paper focuses on the proposed steep slopes at the runway tower site and presents investigations and analyses performed by Gannett Fleming including mine void identification, potential settlement estimates due to mine subsidence and stability issues of the steep embankment. Additional considerations presented include grout stabilization of mine voids and settlement monitoring.
Outputs	McCullough et al. (2013). Geotechnical Aspects of a 16 m High Steep Embankment in Eastern Pennsylvania. *GeoCongress 2013: Stablility and Performance of Slopes and Embankments III, 3-7 March 2013.* Reston, VA, USA: American Society of Civil Engineers.
Key personnel	McCullough, M.L.; Lei, Gu; Bohr, R.; Mouradian, A.G.
Contact	Gannett Fleming, Inc., Audubon, PA, United States
Research themes	Surface water
Project information source	Literature

Table 4.52 Project 52: Applications of surface and subsurface subsidence theories to solve ground control problems

Project characteristics	Details
Project title	**Applications of surface and subsurface subsidence theories to solve ground control problems**
Project location	US
Principal investigator	Qiu, Biao
Lead institution	West Virginia University
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The stability of the underground mine openings largely depends on the surrounding ground conditions, such as stress concentrations, geological conditions and support intensities etc. In particular, the ground control stability associated with large movements and deformations of the strata is much more complicated and could induce much more severe safety problems. A ground control failure could endanger the coal miner's safety not only directly by roof, pillar, floor and/or rib failure, but also by ground cracks induced methane and water inundations indirectly. This study is aimed to develop comprehensive models to simulate the ground response to mining and solve the ground control problems associated with it. During the last four decades, many research works have been conducted on the ground control study, and numerous models, including analytical, empirical, numerical and hybrid models, were developed to facilitate ground control and support design. If a model is to be used as a common mine design tool, the simplicity of the model itself and the consistency between actual in-mine and modeled ground response to mining are essential. For the study of the ground control stability associated with large movements and deformations, the key is to know the movements and deformations of the subsurface strata. The subsidence prediction models can determine the movements and deformations very accurately as proven by plenty of surface subsidence survey data. In this study, the subsidence prediction models are employed to analyze the stability of some subsidence related ground control problems based on the subsurface strata movements and deformations. In this dissertation, an innovative approach, employing the influence function method while considering the hard rock layers, is applied in the development of an enhanced subsurface subsidence prediction model. This improved model is then applied in analyzing three specific subsidence related ground control problems. An analytical model, employing dynamic subsurface subsidence theory and considering the roof support interaction, is developed to analyze the stability of pre-driven longwall recovery room. The mechanism of the ground control stability problems as well as the potential safety problems associated with multi-seam mining interactions is discussed. Multi-seam mining subsidence prediction methods are re-examined based on the multi-seam mining interaction analysis. The redistribution of the stresses and strains in overburden is also able to affect the surface and subsurface water bodies in various degrees. Mathematical models are developed to link longwall induced overburden strata permeability change and subsurface deformations. A ground water flow model is used to assess the longwall mining impacts on

Project characteristics	Details
	surface and subsurface hydrological systems. This study provides a greater understanding of the mechanism of the subsidence-related ground control problems. Innovative methods are developed to derive stress, strain and permeability change, and quantify the subsidence effects on mine structure stability and the hydrological system sustainability. The developed models are coded and incorporated into a software suite to provide an easy-to-use tool for the mine planning and designing of all subsidence related issues.
Key personnel	Qiu. (2013). Applications of surface and subsurface subsidence theories to solve ground control problems. Ann Arbor: West Virginia University.Qiu, Biao
Contact	West Virginia University, Morgantown, WV, United States
Research themes	Surface water
Project information source	Literature

Table 4.53 Project 53: Identifying root causes for subsidence over abandoned coal mine - A case study

Project characteristics	Details
Project title	**Identifying root causes for subsidence over abandoned coal mine - A case study**
Project location	US
Principal investigator	Luo, Y.; Qiu, B.
Lead institution	West Virginia University, Morgantown, WV, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Correctly identifying root cause for subsidence events in areas over abandoned coal mines is often a difficult task. It is important to collect available data about the reported subsidence event including historical events, observed and measured ground and structural deformations, geological and mining conditions, etc. Comprehensive analysis of the collected information should be performed to characterize the reported event. A detailed comparison between the identified characteristics and those of mine subsidence events often could lead to delineation whether the event is caused by abandoned mine. For the events possibly not caused by mining, identifying the root cause could be even more difficult. This paper presents the investigation of a complicated subsidence case over an abandoned coal mine. The collected data, analysis and findings are detailed. The root cause other than the abandoned mine has been identified. © 2013 ARMA, American Rock Mechanics Association
Outputs	Luo and Qiu. (2013). Identifying root causes for subsidence over abandoned coal mine - A case study. *47th US Rock Mechanics / Geomechanics Symposium 2013, June 23, 2013 - June 26, 2013.* San Francisco, CA, United states: American Rock Mechanics Association (ARMA).
Key personnel	Luo, Y.; Qiu, B.
Contact	West Virginia University, Morgantown, WV, United States
Research themes	Surface water
Project information source	Literature

4.3 Co-produced water and salt management (CSG) and mine water and salt management (coal mines)

Projects in this category are focussed on the water impacts of water produced during coal seam gas and mining operations and consequently the need for salt management. This encompasses technologies for water disposal such as aquifer injection or water treatment, and the effects of this water on land, water resources and water dependent ecosystems due to the selected management method.

Sixty-six projects were identified with the primary theme of co-produced/mine water and salt management.

4.3.1 Australia

Table 4.54 Project 54: Assessment of options for using coal seam gas water in the Central Condamine Alluvium - Business case

Project characteristics	Details
Project title	**Assessment of options for using coal seam gas water in the Central Condamine Alluvium - Business case**
Project location	Queensland, Australia
Principal investigator	Arup
Lead institution	Queensland Government Department of Environment and Resource Management
Project budget	This project was one component (Activity 8.3B) of the $5 million Healthy HeadWaters Coal Seam Gas Water Feasibility Study
Source of funding	Australian Government Water for the Future initiative
Project duration	Project completed April 2013
Current status	Completed
Project summary	This activity examined suitable governance arrangements for implementing and operating a substitution/injection scheme in the Central Condamine Alluvium. The report also reports on additional work on modelling the response of the aquifer to such a scheme.
Outputs	Healthy HeadWaters Coal Seam Gas Water Feasibility Study <http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-8> Business Case report < http://www.dnrm.qld.gov.au/__data/assets/pdf_file/0015/106017/act-8-3-cca-recharge-business-case.pdf>
Research themes	Co-produced/mine water
Project information source	UQ CCSG Online Portal, Queensland Government website

Table 4.55 Project 55: Coal seam gas, coal and agriculture - water implications

Project characteristics	Details
Project title	**Coal seam gas, coal and agriculture - water implications**
Project location	Australia
Principal investigator	Lauren Kaye
Lead institution	Centre for Water in the Minerals Industry, Sustainable Minerals Institute, The University of Queensland
Project budget	Unknown
Source of funding	ACARP
Project duration	?-Oct 2012
Current status	Completed
Project summary	This document was commissioned by ACARP to improve the understanding of conflict for water resources between the established coal mining and agricultural sectors and the rapidly expanding Coal Seam Gas (CSG) industry.
Outputs	http://www.acarp.com.au/abstracts.aspx?repId=C21006
Research themes	Co-produced water, water impacts
Project information source	ACARP website

Table 4.56 Project 56: Chemicals associated with coal seam gas exploration: towards understanding their ecological risks

Project characteristics	Details
Project title	**Chemicals associated with coal seam gas exploration: towards understanding their ecological risks**
Project location	Australia
Principal investigator	Kookana, Rai; Batley, Graeme; Apte, Simon
Lead institution	Commonwealth Scientific and Industrial Research Organisation
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	To reduce dependence on fossil fuels and as a clean energy source, there is unprecedented interest worldwide in exploring the reserves of natural gas (e.g. coal seam gas and shale gas). In Australia, major expansions in natural gas exploration are currently occurring, for example in the Bowen and Surat Basins of Queensland. Technological advances now allow the industry to source gas reservoirs economically and efficiently through techniques such as horizontal drilling and hydraulic fracturing, commonly referred to as 'fracking'. The fracking technique requires high pressure pumping of specially engineered fluids containing chemical additives and proppants into the exploration well. There is growing community concern about the potential environmental impact of such exploration activities, in particular the impacts of fracking chemicals on surface and groundwater resources. This presentation will present data from a review of the available published literature on fracking chemicals and attempt a screening level risk assessment of their potential ecological impacts on aquatic ecosystems, especially surface water receiving environments. There is a dearth of reliable data on what fracking chemicals are being used in Australia, as well as on their ecotoxicity, fate and environmental concentrations. For chemicals already listed as being used in Australia and internationally, those that are likely to pose the greatest environmental concerns have been identified. The presentation will highlight the current knowledge gaps that must be addressed to allow a sound understanding of the ecological risks of fracking chemicals in Australian environment. less
Outputs	Kookana et al. (2012). Chemicals associated with coal seam gas exploration: towards understanding their ecological risks. *SETAC Australasia 2012.* Brisbane, QLD, Australia: SETAC Australasia.
Key personnel	Kookana, Rai; Batley, Graeme; Apte, Simon
Research themes	Co-produced/mine water, hydraulic fracturing, water supplies, water dependent ecosystems
Project information source	Literature

Table 4.57 Project 57: CSIRO's Water for a Healthy Country Flagship

Project characteristics	Details
Project title	**CSIRO's Water for a Healthy Country Flagship**
Project location	Australia
Principal investigator	Batley, Graeme E.; Kookana, Rai S.
Lead institution	Commonwealth Scientific and Industrial Research Organisation
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Coal seam gas reserves are likely to make a major contribution to future energy needs. However, the new technology for exploiting these reserves, termed hydraulic fracturing, raises several environmental issues.
Outputs	Batley and Kookana. (2012). Environmental issues associated with coal seam gas recovery: Managing the fracking boom. *Environmental Chemistry.* P.O. Box 1139, Collingwood, VIC 3066, Australia: CSIRO.
Key personnel	Batley, Graeme E.; Kookana, Rai S.
Contact	Centre for Environmental Contaminants Research, CSIRO Land and Water, Locked Bag 2007, Kirrawee NSW 2232, Australia
Research themes	Co-produced/mine water, hydraulic fracturing, water supplies
Project information source	Literature

Table 4.58 Project 58: Optimal reinjection strategies for the management of coal seam gas production water

Project characteristics	Details
Project title	**Optimal reinjection strategies for the management of coal seam gas production water**
Project location	Australia
Principal investigator	Janardhanan, Sreekanth; Moore, Catherine; Wolf, Leif
Lead institution	Commonwealth Scientific and Industrial Research Organisation
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Environmental context Coal seam gas reserves are likely to make a major contribution to future energy needs. However, the new technology for exploiting these reserves, termed hydraulic fracturing, raises several environmental issues. We discuss the research required to assess the ecological risks from gas recovery. Abstract Coal seam gas reserves represent a major contribution to energy needs, however, gas recovery by hydraulic fracturing (fracking or fraccing), requires management to minimise any environmental effects. Although the industry is adapting where possible to more benign fracking chemicals, there is still a lack of information on exposure to natural and added chemicals, and their fate and ecotoxicity in both the discharged produced and flow-back waters. Geogenic contaminants mobilised from the coal seams during fracking may add to the mixture of chemicals with the potential to affect both ground and surface water quality. The research needs to better assess the ecological risks from gas recovery are discussed. © CSIRO 2012
Outputs	Janardhanan et al. (2012). Optimal reinjection strategies for the management of coal seam gas production water. *39th IAH Congress.* Niagara Falls, Canada: International Association of Hydrogeologists.
Key personnel	Janardhanan, Sreekanth; Moore, Catherine; Wolf, Leif
Research themes	Co-produced/mine water, water dependent ecosystems
Project information source	Literature

Table 4.59 Project 59: Healthy HeadWaters coal seam gas water feasibility study

Project characteristics	Details
Project title	**Healthy HeadWaters coal seam gas water feasibility study**
Project location	Australia
Principal investigator	Various scientists and consultants
Lead institution	Department of Natural Resources and Mines (Queensland Government)
Project budget	$5 million
Source of funding	Australian Government Water for the Future initiative
Project duration	Completed April 2013
Current status	Completed
Project summary	The coal seam gas water feasibility study examined the opportunities and risks of using coal seam gas (CSG) water in the Queensland Murray-Darling Basin (QMDB). The study undertook a series of activities. Activities 1 to 7 investigated the risks of extracting and using CSG water, as well as analysing likely supply and demand. Activities 8 and 9 assessed specific opportunities for using CSG water in the QMDB. The activities were: • coal seam gas feasibility study • activity 1: chemistry, origins and hydrogeology of coal • activity 2: modelling and forecasting of coal seam gas water production • activity 3: assessment of the salinity impacts of coals seam gas water • activity 4: stream ecosystem health response to coal seam gas water release • activity 5: vulnerability of aquifers to coal seam gas water extraction • activity 6: aquifer injection feasibility • activity 7: South West Queensland water demand analysis • activity 8: proposals for using coal seam gas water in the Central Condamine Alluvium • activity 9: proposals for coals seam gas water use in the QMDB.
Outputs	<http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study>
Research themes	Co-produced/mine water
Project information source	UQ CCSG Online Portal, Queensland Government website

Table 4.60 Project 60: Assessment of salinity impacts of CSG water on landscapes and surface streams

Project characteristics	Details
Project title	**Assessment of salinity impacts of CSG water on landscapes and surface streams**
Project location	Queensland, Australia
Principal investigator	Biggs, Andrew; Witheyman, Sandra; Williams, Kristie; Cupples, N.; de Voil, Catherine; Power, Ed; Stone, B.J.
Lead institution	Department of Natural Resources and Mines (Queensland Government)
Project budget	This project was one component (Activity 3) of the $5 million Healthy HeadWaters Coal Seam Gas Water Feasibility Study
Source of funding	Australian Government Water for the Future initiative
Project duration	Unknown- literature output 2013
Current status	Completed
Project summary	This activity has produced a salinity risk assessment framework for irrigation proposals using CSG water.
Outputs	Biggs et al. (2013). Assessment of salinity impacts of CSG water on landscapes and surface streams. Department of Natural Resources and Mines (Queensland Government). http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-3
Key personnel	Biggs, Andrew; Witheyman, Sandra; Williams, Kristie; Cupples, N.; de Voil, Catherine; Power, Ed; Stone, B. J.
Research themes	Co-produced/mine water
Project information source	Literature, Queensland Government website

Table 4.61 Project 61: Coal seam gas (CSG): What becomes of produced water? Regulation and strategies

Project characteristics	Details
Project title	**Coal seam gas (CSG): What becomes of produced water? Regulation and strategies**
Project location	Australia
Principal investigator	Hatley, Ray
Lead institution	Golder Associates, Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Introduction: Strong LNG demand, both here in Australia and overseas, fuelled by worldwide transition to a low carbon economies is driving unprecedented growth in coal seam gas (CSG) exploration and development of east coast resources, not to mention the other conventional gas resources around Australia. With this accelerated growth in demand for gas, particularly with the onshore CSG production, comes the matter of the associated environmental affects and the need for socially responsible environmental management and mitigation of impacts. Why do I single out the CSG industry in this regard - after all the oil and gas industry has been the subject of considerable environmental regulation during the many decades of production in this country, and has a very proud record in doing the right thing. This paper relates specifically to one unique attribute associated with the production of CSG, namely the need to extract groundwater from the gas production wells in order that they be depressurised as a precursor to gas release. Pumping groundwater from of the coal seam 'aquifers' targeted for the resource reduces the hydraulic pressure to the point that the adsorption bonds holding the methane to the surfaces of the coal cleats (or microfractures) are reversed and the gas moves into the gaseous phase, and is hence available to flow to the well under the prevailing hydraulic gradients. Typically, a CSG well is pumped for its groundwater, producing its peak flows early in the life of the well, with flows of water tapering off with time, as gas flows increase and peak some years into its life. (Figure Presented) The consequence is, for a typical wellfield arrangement (of approximately 800 m by 800 m grid penetrations), considerable quantities of water are produced. We'll get to quantify this shortly. Copyright 2012, SPE/APPEA International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production.
Outputs	Hatley. (2012). Coal seam gas (CSG): What becomes of produced water? Regulation and strategies. *SPE/APPEA International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production 2012: Protecting People and the Environment - Evolving Challenges, September 11, 2012 - September 13, 2012.* Perth, WA, Australia: Society of Petroleum Engineers.
Key personnel	Hatley, Ray
Contact	Golder Associates, Australia
Research themes	Co-produced/mine water

Project characteristics	Details
Project information source	Literature

Table 4.62 Project 62: Infrastructure options for delivering coal seam gas water to the Central Condamine Alluvium

Project characteristics	Details
Project title	**Infrastructure options for delivering coal seam gas water to the Central Condamine Alluvium**
Project location	Queensland, Australia
Principal investigator	Kellogg, Brown and Root
Lead institution	Queensland Government Department of Environment and Resource Management
Project budget	This project was one component (Activity 8.1) of the $5 million Healthy HeadWaters Coal Seam Gas Water Feasibility Study
Source of funding	Australian Government Water for the Future initiative
Project duration	Unknown – literature output June 2012
Current status	Completed
Project summary	This activity evaluated the feasibility of infrastructure options for delivering treated CSG water to the CCA. It has outlined the infrastructure, associated costs, water delivery volumes and issues associated with eight potential pipeline options.
Outputs	http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-8 http://www.dnrm.qld.gov.au/__data/assets/pdf_file/0016/106090/condamine-infrastructure-options-report.pdf
Research themes	Co-produced/mine water, water supplies
Project information source	UQ CCSG Online Portal, Queensland Government website

Table 4.63 Project 63: CSG water use in the Central Condamine Alluvium: Substitution issues

Project characteristics	Details
Project title	**CSG water use in the Central Condamine Alluvium: Substitution issues**
Project location	Queensland, Australia
Principal investigator	Kellogg, Brown and Root
Lead institution	Queensland Government Department of Environment and Resource Management
Project budget	This project was one component (Activity 8.3A) of the $5 million Healthy HeadWaters Coal Seam Gas Water Feasibility Study
Source of funding	Australian Government Water for the Future initiative
Project duration	2013
Current status	Completed
Project summary	This activity provide a detailed assessment of the use of CSG water for groundwater substitution purposes for all pipeline options identified in the Central Condamine Alluvium.
Outputs	http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-8
Key personnel	Unknown
Contact	Unknown
Research themes	Co-produced/mine water
Project information source	UQ CCSG Online Portal, Queensland Government website

Table 4.64 Project 64: Hydrochemical compatibility assessments of aquifer injection of treated coal seam gas water into Surat Basin aquifers

Project characteristics	Details
Project title	**Hydrochemical compatibility assessments of aquifer injection of treated coal seam gas water into Surat Basin aquifers**
Project location	Australia
Principal investigator	Harris, David; Landers, Matthew; Morris, Ryan; Usher, Brent; Moser, Andrew
Lead institution	Klohn Crippen Berger
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Management of coal seam gas (CSG) water is one of the greatest challenges facing the rapidly developing CSG industry in Queensland, Australia. The demand from regulatory bodies for beneficial use of CSG water, and regulatory disapproval of the traditional method of disposal through evaporation, has increased the need for cost effective, sustainable management options. The feasibility of aquifer injection of treated CSG water into the Great Artesian Basin (GAB) is being investigated as a sustainable management option by the Australia Pacific LNG Project under strict Government guidelines. This paper outlines the process of hydrochemical compatibility assessments under taken as part of these feasibility studies. Sites were identified as trial injection targets based on infrastructure location, presence of suitable aquifers and aquifer usage. Monitoring bores installed in the target aquifers have provided core and groundwater samples from which, key hydrogeochemical data has been collected. The assessments comprised PHREEQC modelling of water qualities of various injectate/aquifer blends and simplified 1-D reactive-transport modelling. To date, investigations have only been under taken at one site. Preliminary findings indicate that the target aquifer is a suitable target for injection trials and the injection of treated CSG water is unlikely to have adverse water quality effects on the target aquifer, if managed according to the injection plan.
Outputs	Harris et al. (2012). Hydrochemical compatibility assessments of aquifer injection of treated coal seam gas water into Surat Basin aquifers. *International Geological Congress, Abstracts = Congres Geologique International, Resumes.* [International Geological Congress], [location varies], International.
Key personnel	Harris, David; Landers, Matthew; Morris, Ryan; Usher, Brent; Moser, Andrew
Contact	Klohn Crippen Berger, Brisbane, Queensland, Australia
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.65 Project 65: Injection of coal seam gas water into the Central Condamine Alluvium: Site prioritisation

Project characteristics	Details
Project title	**Injection of coal seam gas water into the Central Condamine Alluvium: Site prioritisation**
Project location	Queensland, Australia
Principal investigator	Klohn Crippen Berger
Lead institution	Queensland Government Department of Environment and Resource Management
Project budget	This project was one component (Activity 8.2) of the $5 million Healthy HeadWaters Coal Seam Gas Water Feasibility Study
Source of funding	Australian Government Water for the Future initiative
Project duration	Unknown – literature output 2013
Current status	Completed
Project summary	This project was Phase 1 of Activity 8.2 (Field program design for injection trials). This activity prioritised deep and shallow injection sites in the Central Condamine Alluvium and has developed a conceptual work program to guide the design of injection trials.
Outputs	http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-8
Research themes	Co-produced/mine water
Project information source	UQ CCSG Online Portal, Queensland Government website

Table 4.66 Project 66: Feasibility of injecting coal seam gas water into the Central Condamine Alluvium

Project characteristics	Details
Project title	**Feasibility of injecting coal seam gas water into the Central Condamine Alluvium**
Project location	Queensland, Australia
Principal investigator	Klohn Crippen Berger
Lead institution	Queensland Government Department of Environment and Resource Management
Project budget	This project was one component (Activity 6) of the $5 million Healthy HeadWaters Coal Seam Gas Water Feasibility Study
Source of funding	Australian Government Water for the Future initiative
Project duration	Literature output July 2011
Current status	Completed
Project summary	Based on physical and hydro-chemical analyses of the alluvium, a total of 22 'target areas' were identified, which will are being investigated as potential sites for future injection trials. The activity found that matching the water quality of the injected water with that of the receiving aquifer is critical to the success of an injection project.
Outputs	http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-6
Research themes	Co-produced/mine water ,water dependant ecosystems
Project information source	UQ CCSG Online Portal, Queensland Government website

Table 4.67 Project 67: Produced Water - technical background paper for NSW Chief Scientist and Engineer

Project characteristics	Details
Project title	**Produced water - technical background paper for NSW Chief Scientist and Engineer**
Project location	Australia
Principal investigator	Gore, Damian; Davies, Peter
Lead institution	Macquarie University
Project budget	Unknown
Source of funding	New South Wales Government
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The purpose of this report is to review the issues, management practices, impacts and risks related to produced water and solids generated by the coal seam gas (CSG) industry. The report has been commissioned by the NSW Office of the Chief Scientist and Engineer as one of a number of independent studies to inform the NSW Government about the potential impacts of CSG exploration, extraction and related activities on human health and the environment. The content and recommendations of this report are based largely on publicly available, independent peer-reviewed literature and reports by and for government agencies.
Outputs	Gore and Davies. (2013). Produced Water - technical background paper for NSW Chief Scientist and Engineer. Macquarie University. http://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0003/34779/Produced-water-_Gore_Davies_MQU.pdf
Key personnel	Gore, Damian; Davies, Peter
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.68 Project 68: Coal seam gas associated water treatment and management; opportunities and limitations

Project characteristics	Details
Project title	**Coal seam gas associated water treatment and management; opportunities and limitations**
Project location	Australia
Principal investigator	Jia, H.; Poinapen, J.
Lead institution	MWH Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Coal seam gas (CSG) is a new major export for Australia. The production of CSG releases a significant amount of brackish water to the surface, known as associated water. This presents a major challenge to the CSG industry in water and its by-product (brine) management. CSG water quality varies across regions, but is typically high in total dissolved solids, bicarbonate, hardness, and silica. Consequently, CSG water without treatment is unsuitable for beneficial uses. To date, reverse osmosis (RO) desalination processes with suitable pre-treatment steps have been employed to remove elevated salts and other compounds. RO brine, a highly saline stream, requires a managed response to ensure a socially, environmentally and financially sound outcome. Conventional evaporation in brine ponds is not considered favourably under existing regulations. This peer-reviewed paper concludes that a thermal process in conjunction with a high-recovery RO membrane plant, configured as a hybrid membrane/thermal configuration, is probably a suitable solution to meet policy direction by improving system recovery as a precursor to advance associated water treatment and brine management.
Outputs	Jia and Poinapen. (2013). Coal seam gas associated water treatment and management; opportunities and limitations. *APPEA Journal.* Australian Petroleum Production and Exploration Association, Canberra, A.C.T., Australia. http://www.mwhglobal.com/mwh-projects/australia-pacific-LNG-water-treatment-facility
Key personnel	Jia, H.; Poinapen, J.
Contact	MWH Australia, Brisbane, Queensland, Australia
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.69 Project 69: Coal seam gas and associated water: A review paper

Project characteristics	Details
Project title	**Coal seam gas and associated water: A review paper**
Project location	Australia
Principal investigator	Hamawand, Ihsan; Yusaf, Talal; Hamawand, Sara G.
Lead institution	National Centre of Engineering in Agriculture (NCEA) at the University of Southern Queensland (USQ)
Project budget	Unknown
Source of funding	National Centre of Engineering in Agriculture (NCEA) at the University of Southern Queensland (USQ)
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Coalbed methane (CBM) or coal seam gas (CSG) as it is known in Australia is becoming an increasingly important source of energy around the world. Many countries such as United States, Canada, Australia and China are investing in the CSG industry. A rise in the cost of conventional natural gas and many other energy resources, along with a decline in these conventional resources and issues such as climate change have encouraged a global interest in alternative sources of energy like CSG. The estimated quantity of CSG worldwide is around 1.4×1014 m^3, it is clear that coal seam gas is a significant source of energy. The first section of this paper will discuss the production size of CSG worldwide and the future of the industry. The usage of the coal bed seam for the sequestration of CO^2 is also an added benefit. The reduction of CO^2 released to the environment may help in the future mitigation of global warming. In addition, the re-injecting of the co-produced CO^2 enhances the commercial recovery and production of CSG wells. In the second section, the impact of the CSG industry's by-products on the environment, the freshwater ecosystem and human health are analysed. The second section includes issues associated with the large volume of co-produced water with undesirable composition in the CSG industry. The management of this enormous amount of water requires cost effective technologies and methods. Many methods for dealing with water problems are discussed and analysed in this paper
Outputs	Hamawand et al. (2013). Coal seam gas and associated water: A review paper. *Renewable and Sustainable Energy Reviews*.
Key personnel	Hamawand, Ihsan; Yusaf, Talal; Hamawand, Sara G.
Research themes	Co-produced/mine water, water supplies
Project information source	Literature

Table 4.70 Project 70: Initial report on the Independent Review of Coal Seam Gas Activities in NSW

Project characteristics	Details
Project title	**Initial report on the Independent Review of Coal Seam Gas Activities in NSW**
Project location	Australia
Principal investigator	O'Kane, Mary
Lead institution	New South Wales Chief Scientist and Engineer (New South Wales Government)
Project budget	Unknown
Source of funding	New South Wales Government
Project duration	2013
Current status	Unknown
Project summary	Professor O'Kane's initial report acknowledges CSG extraction, like all forms of energy production, poses human health and environmental challenges. But it's found many of those concerns can be offset by ensuring engineering best practice; superb monitoring by industry; diligent and transparent compliance checks by regulators; and a rapid and effective response, then remediation, should an incident occur. As the review continues, the team will be undertaking further work in relation to landholders' legal rights; examining appropriate levels of industry insurance; conducting a full industry compliance study; reviewing government best practice in the management of CSG extraction; and analysing in-depth the methods for CSG risk and assessment.
Outputs	http://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0016/31246/130730_1046_CSE-CSG-July-report.pdf
Research themes	Co-produced/mine water, water supplies
Project information source	UQ CCSG Online Portal

Table 4.71 Project 71: Modelling of drainage and salinity

Project characteristics	Details
Project title	**Modelling of drainage and salinity**
Project location	Australia
Principal investigator	Unknown
Lead institution	Origin Energy
Project budget	Unknown
Source of funding	Origin Energy
Project duration	Unknown
Current status	Unknown
Project summary	Modelling of drainage from irrigation in surface and unsaturated layers to determine impacts of irrigation
Outputs	Unknown
Research themes	Co-produced/mine water, water supplies
Project information source	UQ CCSG Online Portal

Table 4.72 Project 72: Selective salt recovery trials

Project characteristics	Details
Project title	**Selective salt recovery trials**
Project location	Australia
Principal investigator	Unknown
Lead institution	Origin Energy
Project budget	Unknown
Source of funding	Origin Energy
Project duration	2013
Current status	Unknown
Project summary	To identify and confirm the technical and economic viability of potential solutions to convert brine into commercial grade products through a Pilot Project program.
Outputs	Unknown
Research themes	Co-produced/mine water
Project information source	UQ CCSG Online Portal

Table 4.73 Project 73: Brine injection

Project characteristics	Details
Project title	**Brine injection**
Project location	Australia
Principal investigator	Unknown
Lead institution	Origin Energy
Project budget	Unknown
Source of funding	Origin Energy
Project duration	2013
Current status	Unknown
Project summary	Technical and economic feasibility assessment of injection of brine into fractured basement geological formations.
Outputs	Unknown
Research themes	Co-produced/mine water
Project information source	UQ CCSG Online Portal

Table 4.74 Project 74: Selective salt recovery - brine management (QGC, Australia Pacific LNG, Arrow Energy)

Project characteristics	Details
Project title	**Selective salt recovery - brine management**
Project location	Australia
Principal investigator	Unknown
Lead institution	QGC, APLNG, Arrow Energy
Project budget	Unknown
Source of funding	QGC, APLNG, Arrow Energy
Project duration	2013
Current status	Unknown
Project summary	QGC, APLNG and Arrow Energy have formed an alliance to trial four separate pilot plant technologies to separate the various salts to industrial grade purity salts to enable commercialisation. The objective of the pilots is to demonstrate the technical and commercial feasibility.
Outputs	Unknown
Research themes	Co-produced/mine water, water supplies
Project information source	UQ CCSG Online Portal

Table 4.75 Project 75: Treatment methods for CSG production waters

Project characteristics	Details
Project title	**Treatment methods for CSG production waters**
Project location	Australia
Principal investigator	Unknown
Lead institution	Queensland University of Technology
Project budget	Unknown
Source of funding	Unavailable
Project duration	2013
Current status	Unknown
Project summary	Advanced water treatment.
Outputs	Unknown
Research themes	Co-produced/mine water
Project information source	UQ CCSG Online Portal

Table 4.76 Project 76: Testing application of CSG production waters

Project characteristics	Details
Project title	**Testing application of CSG production waters**
Project location	Australia
Principal investigator	Unknown
Lead institution	Queensland University of Technology
Project budget	Unknown
Source of funding	Unavailable
Project duration	2012
Current status	Unknown
Project summary	End use application and assimilation of CSG Water
Outputs	Unknown
Research themes	Co-produced/mine water
Project information source	UQ CCSG Online Portal

Table 4.77 Project 77: Design of beneficial use schemes for disposal of treated CSG production water

Project characteristics	Details
Project title	**Design of beneficial use schemes for disposal of treated CSG production water**
Project location	Australia
Principal investigator	Dr David Freebairn
Lead institution	RPS
Project budget	$400 000
Source of funding	Various Energy Companies
Project duration	2011-2014
Current status	Completed
Project summary	CSG production water, when treated to a high standard, has to be either used on site or released to the environment in a manner that does not negatively influence environmental values. A combination of analysis tools - GoldSim, IQQM and Howleaky were used to explore system configurations to optimise beneficial uses.
Objectives	To determine optimum designs for maximum beneficial use and minimum release to the environment
Achievements	A set of designs that were acceptable to the regulator and energy company clients
Outputs	http://www.aplng.com.au/pdf/condabri/Integrated_Condabri_Talinga_CSG_Water_Management_Plan_Rev4.pdf www.howleaky.net
Key personnel	David Freebairn
Research themes	• Co-produced water and salt management (CSG) and mine water & salt management (coal mines) − effect on land and water resources (including irrigation) • Quality and reliability of water supplies including environmental health − long term impacts, including, timescales for water levels to return to pre-development levels (quality/quantity) • Cumulative impact assessments
Project information source	Survey

Table 4.78 Project 78: Injection of coal seam gas water into the Central Condamine Alluvium: Field program design

Project characteristics	Details
Project title	**Injection of coal seam gas water into the Central Condamine Alluvium: Field program design**
Project location	Queensland, Australia
Principal investigator	Schlumberger Water Services
Lead institution	Queensland Government Department of Environment and Resource Management
Project budget	This project was one component (Activity 8.2) of the $5 million Healthy HeadWaters Coal Seam Gas Water Feasibility Study
Source of funding	Australian Government Water for the Future initiative
Project duration	Unknown – literature output January 2013
Current status	Complete
Project summary	This project was Phase 2 of Activity 8.2 (Field program design for injection trials). This activity designed an injection trial field program in the Central Condamine Alluvium and an accompanying program of works to implement the field program.
Outputs	http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-8
Research themes	Co-produced/mine water
Project information source	UQ CCSG Online Portal, Queensland Government website

Table 4.79 Project 79: Field trial to measure and model water use of range of forage crops to be irrigated by CSG water 2: Glasshouse trial to ascertain the root zone salinity tolerance of range of forage crops

Project characteristics	Details
Project title	**Field trial to measure and model water use of range of forage crops to be irrigated by CSG water 2: Glasshouse trial to ascertain the root zone salinity tolerance of range of forage crops**
Project location	Australia
Principal investigator	Shelton, Max
Lead institution	School of Agriculture and Food Sciences (University of Queensland)
Project budget	Unknown
Source of funding	Santos
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	No summary available.
Outputs	Shelton. (2013). 1: Field trial to measure and model water use of range of forage crops to be irrigated by CSG water 2: Glasshouse trial to ascertain the root zone salinity tolerance of range of forage crops. School of Agriculture and Food Sciences (University of Queensland). http://researchers.uq.edu.au/research-project/20331
Key personnel	Shelton, Max
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.80 Project 80: Compatibility of injected concentrated brines with formation waters and their tendency for scaling

Project characteristics	Details
Project title	**Compatibility of injected concentrated brines with formation waters and their tendency for scaling**
Project location	Australia
Principal investigator	Rudolph, Victor
Lead institution	School of Chemical Engineering (University of Queensland)
Project budget	Unknown
Source of funding	Australian National Low Emissions Coal Research and Development
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	No summary available
Outputs	Rudolph. (2012). Compatibility of injected concentrated brines with formation waters and their tendency for scaling. School of Chemical Engineering (University of Queensland).
Key personnel	Rudolph, Victor
Research themes	Co-produced/mine water, water supplies
Project information source	Literature

Table 4.81 Project 81: Algal growth and community structure in a mixed-culture system using coal seam gas water as the water source

Project characteristics	Details
Project title	**Algal growth and community structure in a mixed-culture system using coal seam gas water as the water source**
Project location	Australia
Principal investigator	Buchanan, Jessica J.; Slater, Frances R.; Bai, Xue; Pratt, Steven
Lead institution	School of Chemical Engineering, University of Queensland, Brisbane, Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Coal seam gas (CSG) is being touted as a transition fuel as the world moves towards low-carbon economies. However, the development of CSG reserves will generate enormous volumes of saline water. In this work, we investigate the potential of using this saline water to support mass algae production. Water and brine from a CSG water treatment facility (1.6 and 11.6 g total dissolved solids per litre (TDS L-1) respectively) were inoculated with algal biomass from freshwater and seawater environments and supplemented with nutrients in open, fed-batch reactors. Significant algal growth was recorded, with maximum specific growth rates in CSG water and CSG brine of 0.200.05 d-1 and 0.260.04 d-1 respectively. These maximum specific growth rates were equal to or greater than specific growth rates in deionized water and seawater diluted to the same salinity. However, algal growth lag time in CSG brine was between 7 and 9 times longer than in other waters. Microscopy and terminal-restriction fragment length polymorphism (T-RFLP) were used to monitor community structure in the reactors. The same few algal species dominated all of the reactors, except for the CSG brine reactor at day 15. This result indicates that conditions in CSG brine select for different species of algae compared to seawater of the same salinity and other waters tested. The findings suggest that mass algae production in CSG water is feasible but algae community composition may be a function of CSG water chemistry. This has implications for the downstream use of algae. © 2013 Taylor and Francis Group, LLC
Outputs	Buchanan et al. (2013). Algal growth and community structure in a mixed-culture system using coal seam gas water as the water source. *Environmental Technology (United Kingdom).* 4 Park Square, Milton Park, Abingdon, Oxfordshire, OX14 4RN, United Kingdom: Taylor and Francis Ltd.
Key personnel	Buchanan, Jessica J.; Slater, Frances R.; Bai, Xue; Pratt, Steven
Contact	School of Chemical Engineering, University of Queensland, Brisbane, Australia
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.82 Project 82: Assessment of alternative use options for coal seam gas water proposed for Central Condamine Alluvium recharge schemes

Project characteristics	Details
Project title	**Assessment of alternative use options for coal seam gas water proposed for Central Condamine Alluvium recharge schemes**
Project location	Australia
Principal investigator	Tree Crop Technologies
Lead institution	Queensland Government Department of Environment and Resource Management
Project budget	This project was one component (Activity 8.3B) of the $5 million Healthy HeadWaters Coal Seam Gas Water Feasibility Study
Source of funding	Australian Government Water for the Future initiative
Project duration	Literature output March 2013
Current status	Completed
Project summary	This activity compare the CSG water use schemes proposed the Central Condamine Alluvium with alternative uses for the same CSG water in order to identify the relative benefits, costs and feasibility issues.
Outputs	http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-8
Research themes	Co-produced/mine water
Project information source	UQ CCSG Online Portal

Table 4.83 Project 83: Fracture delineation and monitoring of geothermal and coal seam gas areas using magnetotellurics

Project characteristics	Details
Project title	**Fracture delineation and monitoring of geothermal and coal seam gas areas using magnetotellurics**
Project location	Australia
Principal investigator	Thiel, Stephan; Peacock, Jared; Heinson, Graham; Hatch, Michael; Reid, Peter
Lead institution	University of Adelaide, Adelaide, South Aust., Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	New ways of energy production through the use of coal seam gas plays and geothermal hot dry rock and hot sedimentary aquifer systems pose challenges in identifying and monitoring fluid in the subsurface. We propose the use of the magnetotelluric (MT) method to image static and dynamic fluid distributions in the subsurface exhausting the contrast in electrical conductivity between resistive host rock and conductive fluid-filled, porous rock. Base line MT measurements provide reference transfer functions and inverse models to characterise the electrical conductivity distribute on which is linked with bore hole and other geophysical data to obtain knowledge about fluid distribution at depth. The reference models are used to accurately forward model fluid injection or extraction temporally and spatially. This work shows results from fluid injections at a hot dry rock system at Paralana, South Australia, and its applicability to other geothermal and coal seam gas systems.
Outputs	Thiel et al. (2012). Fracture delineation and monitoring of geothermal and coal seam gas areas using magnetotellurics. *ASEG Extended Abstracts.* CSIRO Publishing for the Australian Society of Exploration Geophysicists, Collingwood, Victoria, Australia.
Key personnel	Thiel, Stephan; Peacock, Jared; Heinson, Graham; Hatch, Michael; Reid, Peter
Contact	University of Adelaide, Adelaide, South Aust., Australia
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.84 Project 84: Evaluating the effect of bicarbonate in coal seam gas water on soil threshold electrolyte concentration relationships

Project characteristics	Details
Project title	**Evaluating the effect of bicarbonate in coal seam gas water on soil threshold electrolyte concentration relationships**
Project location	Australia
Principal investigator	Unknown
Lead institution	University of Southern Queensland
Project budget	Unknown
Source of funding	Unavailable
Project duration	2012
Current status	Unknown
Project summary	No summary available
Outputs	Unknown
Research themes	Co-produced/mine water, water supplies
Project information source	UQ CCSG Online Portal

Table 4.85 Project 85: Assessing impacts of CSG amended water application: soil chemistry equilibrium as influenced by solution volume and time

Project characteristics	Details
Project title	**Assessing impacts of CSG amended water application: soil chemistry equilibrium as influenced by solution volume and time**
Project location	Australia
Principal investigator	Unknown
Lead institution	University of Southern Queensland
Project budget	Unknown
Source of funding	Unavailable
Project duration	2012
Current status	Unknown
Project summary	Student project investigating the volume and time required for soil equilibration with percolating solutions on the basis of solution concentration and pore volume.
Outputs	Unknown
Research themes	Co-produced/mine water, water supplies
Project information source	UQ CCSG Online Portal

Table 4.86 Project 86: Coal seam gas water as a medium to grow Dunalliella Tertiolecta for lipid extraction

Project characteristics	Details
Project title	**Coal seam gas water as a medium to grow Dunalliella Tertiolecta for lipid extraction**
Project location	Australia
Principal investigator	Aravinthan, Vasantha; Harrington, Daniel
Lead institution	University of Southern Queensland
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The objective of this bench-scale investigation is to assess the potential of using bicarbonate-rich CSG water as a medium for growing Dunalliella tertiolecta for biofuel production. The rates of microalgal growth and carbon sequestration were found to be 49.7 mg SS/L/d and 29 mg C/L/d respectively, with an average total lipid content of 22% in CSG medium enriched with nutrients and amended for a salinity concentration of 10 gNaCl/ L and 200 mg carbon/L in non-aerated batch reactor. In summary, the brine resulting from reverse osmosis treated CSG water could be trialled as an ideal medium to grow the microalgae Dunalliella tertiolecta
Outputs	Aravinthan and Harrington. (2013). Coal seam gas water as a medium to grow *Dunalliella Tertiolecta* for lipid extraction. University of Southern Queensland. http://eprints.usq.edu.au/24107/
Key personnel	Aravinthan, Vasantha; Harrington, Daniel
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.87 Project 87: CSG water as a medium to grow microalgae for biofuel production

Project characteristics	Details
Project title	**CSG water as a medium to grow microalgae for biofuel production**
Project location	Australia
Principal investigator	Unknown
Lead institution	University of Southern Queensland
Project budget	Unknown
Source of funding	Unavailable
Project duration	2011
Current status	Unknown
Project summary	Preliminary investigation to assess the potential of using bicarbonate rich CSG water as a medium for growing salinity tolerant microalgae for biofuel production. Rates of microalgal growth, carbon sequestration, nutrient removal potential and lipid contents were evaluated in a batch reactor.
Outputs	Unknown
Research themes	Co-produced/mine water ,water dependant ecosystems
Project information source	UQ CCSG Online Portal

Table 4.88 Project 88: Renewed demands for mine water management

Project characteristics	Details
Project title	**Renewed demands for mine water management**
Project location	Australia
Principal investigator	Hancock, S.; Wolkersdorfer, C.
Lead institution	URS Australia Pty Ltd, Melbourne, Vic 3006, Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The intensity and diversity of resource development projects has increased by orders of magnitude over the past two decades. At the same time, there has been an emphasis on environmental issues, decontamination of former industrial sites, a recognition of global warming issues, and a focus on the ability of project developers to initiate, operate, and close transient projects without compromising the land and water resource values that underpin existing and future land uses. This concurrence of issues is creating a massive demand for hydrogeologists and groundwater engineers throughout the world. Neither academic institutions nor their funding bodies have foreseen this demand. As a consequence, Australia is seeking to fill its demands by either temporary or permanent importation of skills but, since the same issues afflict other countries, or may come to do so in the near future, the Australian approach will probably be only marginally successful. Another issue confronting all countries active in groundwater management is that the range of skills now required for competent groundwater management around resource development projects have increased. These cannot be readily met by simply increasing the training load on new industry entrants. Rather, delegation of expertise will be necessary and management teams will need to include diverse professions in teams in order to cover the range of responsibilities that must be applied if sustainable decisions are to be made. The authors believe that there is an urgent need for groundwater managers to take up the learning opportunities and expand their skills by working even more internationally. This process should ensure cross fertilization of experience to the benefit of all the countries where groundwater issues are taken seriously.
Outputs	Hancock and Wolkersdorfer. (2012). Renewed Demands for Mine Water Management. *Mine Water and the Environment.*
Key personnel	Hancock, S.; Wolkersdorfer, C.
Contact	[Hancock, Stephen] URS Australia Pty Ltd, Melbourne, Vic 3006, Australia. [Wolkersdorfer, Christian] Cape Breton Univ, Sydney, NS B1P 6L2, Canada. Hancock, S (reprint author), URS Australia Pty Ltd, Melbourne, Vic 3006, Australia.
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.89 Project 89: Spatial analysis of coal seam water chemistry

Project characteristics	Details
Project title	**Spatial analysis of coal seam water chemistry**
Project location	Australia
Principal investigator	WorleyParsons
Lead institution	Queensland Government Department of Environment and Resource Management
Project budget	This project was one component (Activity 1.2) of the $5 million Healthy HeadWaters Coal Seam Gas Water Feasibility Study
Source of funding	Australian Government Water for the Future initiative
Project duration	Unknown – literature output February 2012
Current status	Complete
Project summary	The analysis consolidates existing knowledge about the mineralogical, hydrogeological and geochemical properties of these formations and provides new information about their distinguishing chemical features. The findings provide an enriched understanding of baseline conditions in these formations, and will be invaluable in the design and interpretation of future groundwater monitoring activities. A new database, which integrates all publicly available groundwater quality data for Queensland (as at March 2011) was constructed as part of this activity.
Outputs	http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-1
Research themes	Co-produced/mine water, water supplies
Project information source	UQ CCSG Online Portal, Queensland Government website

Table 4.90 Project 90: CSG water; desalination and the challenge for the CSG industry; developing a holistic CSG brine management solution

Project characteristics	Details
Project title	**CSG water; desalination and the challenge for the CSG industry; developing a holistic CSG brine management solution**
Project location	Australia
Principal investigator	Ly, L.; Fergus, I.; Page, S.
Lead institution	WorleyParsons
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Unknown
Outputs	Ly et al. (2013). CSG water; desalination and the challenge for the CSG industry; developing a holistic CSG brine management solution. *APPEA Journal.* Australian Petroleum Production and Exploration Association, Canberra, A.C.T., Australia.
Key personnel	Ly, L.; Fergus, I.; Page, S.
Contact	WorleyParsons, Brisbane, Queensl., Australia
Research themes	Co-produced/mine water
Project information source	Literature

4.3.2 China

Table 4.91 Project 91: A treatment process for coal-bed-methane-extraction water

Project characteristics	Details
Project title	**A treatment process for coal-bed-methane-extraction water**
Project location	China
Principal investigator	Ondrey, Gerald
Lead institution	Unknown
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The first pilot-scale demonstration in China for treating and recycling coal-bed methane extraction water has been conducted by a team from the Graduate University of the Chinese Academy of Sciences, led by professor Zhang Hongxun. The team focused on coal-bed-methane co-produced water in Liulin County of Luliang City, Shanxi Province, and developed a system with sand filtration, ultrafiltration and RU to treat that water. In the process (flowsheet), the raw water is first aerated to increase the amount of dissolved oxygen.
Outputs	Ondrey. (2012). A treatment process for coal-bed-methane-extraction water. *Chemical Engineering.* New York: Access Intelligence LLC.
Key personnel	Ondrey, Gerald
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.92 Project 92: A treatment study of acid mine wastewater and the performance of electricity generation by coupling system using sludge anaerobic fermentation-sulfate reducing bacteria

Project characteristics	Details
Project title	**A treatment process for coal-bed-methane-extraction water A treatment study of acid mine wastewater and the performance of electricity generation by coupling system using sludge anaerobic fermentation-sulfate reducing bacteria**
Project location	China
Principal investigator	Cai, Chang-Feng; Luo, Ya-Nan; Zhang, Ya-Fei; Huang, Zhi
Lead institution	College of Biological and Chemical Engineering, Anhui Polytechnic University, Wuhu 241000, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	In order to treat in-situ acid mine water from high sulphur coal mining area, a coupling system using microbial fuel cell sludge anaerobic fermentation and sulfate reducing bacteria was proposed to investigate the effects of sulfate treatment and the performance of electricity generation under the conditions of different types of electrode, anode area, pole spacing, and ion concentration. The results from a single factor experiment show that the optimal performance of electricity generation is achieved with anode of carbon cloth and moderate inter-electrode distance(3 cm), and the power density increases with the increase in NaCl concentration and the decrease in anode area. However, the optimal conditions for sulfate removal rate are as follows: carbon cloth is anode, inter-electrode distance is 5 cm. The larger anode area achieves a higher sulfate removal rate with a moderate ion concentration. For the constructed single room without membrane carbon piece as the anode coupling system with the optimal sulfate removal, the maximum power density of 2.093 3 mW/m2, the sludge COD removal of 43% after 10 days, the average sulfate removal rate of 194.4 mg/(L&middotd) were attained respectively. The highest sulfate removal rate is 64.3%, which increase 24% comparing with the open circuit. The coupled electro-genesis system using sludge anaerobic fermentation-sulfate can achieve synchronous degradation residual sludge and treat SO42- wastewater.
Outputs	Cai et al. (2013). A treatment study of acid mine wastewater and the performance of electricity generation by coupling system using sludge anaerobic fermentation-sulfate reducing bacteria. *Meitan Xuebao/Journal of the China Coal Society.* Hepingli, Beijing, 100013, China: China Coal Society.
Key personnel	Cai, Chang-Feng; Luo, Ya-Nan; Zhang, Ya-Fei; Huang, Zhi
Contact	College of Biological and Chemical Engineering, Anhui Polytechnic University, Wuhu 241000, China
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.93 Project 93: A harmless treatment for coal bed methane produced water and its reuse

Project characteristics	Details
Project title	**A harmless treatment for coal bed methane produced water and its reuse**
Project location	China
Principal investigator	Hu, Youlin
Lead institution	College of Petroleum Engineering, Yangtze University, Jingzhou, Hubei, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Produced water treatment has become one of the problems of coal bed methane (CBM) exploitation, according to th-e characteristics of the CBM produced water in Qinshui basin, the produced water was treated by coagulation- fenton oxidation.
Outputs	Hu. (2013). A harmless treatment for coal bed methane produced water and its reuse. *International Journal of Earth Sciences and Engineering.* CAFET INNOVA Technical Society.
Key personnel	Hu, Youlin
Contact	College of Petroleum Engineering, Yangtze University, Jingzhou, Hubei, China
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.94 Project 94: A pilot-scale demonstration of reverse osmosis unit for treatment of coal-bed methane co-produced water and its modelling

Project characteristics	Details
Project title	**A pilot-scale demonstration of reverse osmosis unit for treatment of coal-bed methane co-produced water and its modelling**
Project location	China
Principal investigator	Qian, Zhi; Liu, Xinchun; Yu, Zhisheng; Zhang, Hongxun; Ju, Yiwen
Lead institution	Graduate University of Chinese Academy of Sciences
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	This study presents the first demonstration project in China for treatment of coal-bed methane (CBM) co-produced water and recycling. The work aims to provide a research and innovation base for solving the pollution problem of CBM extraction water. The reverse osmosis (RO) unit is applied to the treatment of CBM co-produced water. The results indicate that system operation is stable, the removal efficiency of the total dissolved solids (TDS) is as high as 97.98, and Fe, Mn, and F- are almost completely removed. There is no suspended solids (SS) detected in the treated water. Furthermore, a model for the RO membrane separation process is developed to describe the quantitative relationship between key physical quantities - membrane length, flow velocity, salt concentration, driving pressure and water recovery rate, and the water recovery restriction equation based on mass balance is developed. This model provides a theoretical support for the RO system design and optimization. The TDS in the CBM co-produced water are removed to meet the "drinking water standards" and "groundwater quality standards" of China and can be used as drinking water, irrigation water, and livestock watering. In addition, the cost for treatment of CBM co-produced water is assessed, and the RO technology is an efficient and cost-effective treatment method to remove pollutants. © 2012 Chemical Industry and Engineering Society of China (CIESC) and Chemical Industry Press (CIP)
Outputs	Qian et al. (2012). A pilot-scale demonstration of reverse osmosis unit for treatment of coal-bed methane co-produced water and its modeling. *Chinese Journal of Chemical Engineering.* No. 3 Huixinli, Chaoyangqu, Beijing, 100029, China: Chemical Industry Press.
Key personnel	Qian, Zhi; Liu, Xinchun; Yu, Zhisheng; Zhang, Hongxun; Ju, Yiwen
Contact	College of Resources and Environment, Graduate University of Chinese Academy of Sciences, Beijing 100049, China
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.95 Project 95: Design of water purification plant of micro-polluted source water in Shendong mine area

Project characteristics	Details
Project title	**Design of water purification plant of micro-polluted source water in Shendong mine area**
Project location	China
Principal investigator	Zhang, J.; Zhou, R.L.; Guo, Z.Q.; Cui, D.F.
Lead institution	Hangzhou Research Institute, China Coal Technology and Engineering Group Corp., Hangzhou 311201, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	According to the characteristics of micro-polluted surface water source in Shendong mine area, combined with technology research and engineering practice of micro-polluted source water treatment in recent years, the integrated treatment technologies including potassium permanganate double salt/powdered activated carbon pretreatment, enhanced conventional treatment and ozone/activated carbon advanced treatment could effectively remove organic matters from the polluted water body. The finished water quality was superior to the Standards for Drinking Water Quality (GB 5749 - 2006), with turbidity < 1 NTU, color < 10 and COD sub(Mn) < 1 mg/L. The operation practice showed that the process had the characteristics of stable operation effect, high degree of automation, and low running cost. Meanwhile, the process selection, process flow, design parameters of main structures were introduced for reference.
Outputs	Zhang et al. (2013). Design of Water Purification Plant of Micro-polluted Source Water in Shendong Mine Area. *China Water & Wastewater.* China International Book Trading Corporation.
Key personnel	Zhang, J.; Zhou, R. L.; Guo, Z. Q.; Cui, D. F.
Contact	Hangzhou Research Institute, China Coal Technology and Engineering Group Corp., Hangzhou 311201, China
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.96 Project 96: Underground direct treatment and recycle of coal mine water

Project characteristics	Details
Project title	**Underground direct treatment and recycle of coal mine water**
Project location	China
Principal investigator	Zhou, Ru-Lu; Gao, Liang; Guo, Zhong-Quan; Cui, Dong-Feng; Yang, Jian-Chao
Lead institution	Hangzhou Research Institute, China Coal Technology and Engineering Group, Hangzhou 311201, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	To save energy, reduce emission and protect environment of mining areas, goaf formed after mining, aeration oxidation tank and pressurized air-water backwashing filter were used to treat and recycle coal mine water underground directly as dustproof water and cooling water for devices. Most suspended solids in coal mine water were removed through sedimentation, filtration and adsorption by minerals filled within the huge space of goaf. In addition, the remaining suspended solids, colloidal substances, iron and manganese were further removed by aeration and contact oxidation filtration. The operating practice showed that the process system did not need any chemicals, could be suited for the underground environment of coal mines, and had the advantages of short flow, few treatment facilities, low treatment cost, high automation and stable running.
Outputs	Zhou et al. (2013). Underground direct treatment and recycle of coal mine water. *China Water and Wastewater.* 52, Xinxing Lu, 21/F, Dushi Huayuan Dasha,, Tianjin, 300070, China: China Water and Wastewater Journal Editorial Office.
Key personnel	Zhou, Ru-Lu; Gao, Liang; Guo, Zhong-Quan; Cui, Dong-Feng; Yang, Jian-Chao
Contact	Hangzhou Research Institute, China Coal Technology and Engineering Group, Hangzhou 311201, China
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.97 Project 97: National Science and Technology Major Project (No. 2011ZX05060-005)

Project characteristics	Details
Project title	**National Science and Technology Major Project (No. 2011ZX05060-005)**
Project location	China
Principal investigator	Li, Xiangdong; Wang, Jing; Feng, Qiyan; Sun, Yue
Lead institution	Jiangsu Key Laboratory of Resources and Environmental Information Engineering, China University of Mining and Technology, Xuzhou, China
Project budget	Unknown
Source of funding	National Science and Technology Major Project (No. 2011ZX05060-005)
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The objective of this study was to examine the chemical properties of CBM product water at discharge sites and in associated impoundments across the Qinshui Basin. Results show that TDS, pH and Total Alkalinity of product water for three areas increased in impoundments compared with discharge sites. The CBM product water exhibited relatively less change in ion and element concentrations in Zhengzhuang impoundments, however, the dissolved F concentration increased in Shizhuang impoundments. Due to cation exchange and precipitation, concentrations of HCO3 -, Ca2+ and Mg2+ of product water increased considerably but concentration of K++Na+ and CO3 2- of product water decreased considerably in impoundment waters of Shizhuang and Guxian areas, concentration of Cl-, SO4 2-, NH4 +and dissolved Fe, Zn and Mn of product water showed less change in impoundment water of three areas. Dissolved As, Cu, Pb and Cd concentrations were non-detectable in both CBM discharge site and associated pond waters of the three areas.
Outputs	Xiangdong Li et al. (2013). Chemical properties of coal bed methane product water in Qinshui. Basin in China. *Journal of Chemical and Pharmaceutical Research*.
Key personnel	Li, Xiangdong; Wang, Jing; Feng, Qiyan; Sun, Yue
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.98 Project 98: Mine water treatment technology analysis

Project characteristics	Details
Project title	**Mine water treatment technology analysis**
Project location	China
Principal investigator	Zhang, H.F.; Zhang, Y.; Wu, B.X.; Wang, W.J.; Fan, R.
Lead institution	Luneng Heze Coal & Power Development Co., Ltd., Yuncheng 274700, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Introduces the characteristics of the mine water, Guotun analysis of the mine water quality, according to the purposes of mine water, put forward water treatment technological process and the technological characteristics.
Outputs	Zhang et al. (2012). Mine Water Treatment Technology Analysis. *Meitan Jishu/Coal Technology.* Harbin Coal Mine Machinery Research Institute.
Key personnel	Zhang, H.F.; Zhang, Y.; Wu, B.X.; Wang, W.J.; Fan, R.
Contact	Luneng Heze Coal & Power Development Co., Ltd., Yuncheng 274700, China
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.99 Project 99: Mechanism and experimental research on treatment of coal chemical wastewater by external circular anaerobic reactor

Project characteristics	Details
Project title	**Mechanism and experimental research on treatment of coal chemical wastewater by external circular anaerobic reactor**
Project location	China
Principal investigator	Bao, Hong-Fu; Li, Yi-Wei; Zhao, Yu-Sen; Zhang, Li-Yan; Pan, Yong-Zhi
Lead institution	Northeast Forestry University, Harbin, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	In view of the defects of existing much "dead area" and decreased effective volume causing by distributing water device of UASB reactor, a new-style of external circular(EC) reactor was developed in this research. In this paper, through laboratory scale and pilot scale study on the external circular anaerobic reactor to treat coal chemical wastewater, we conducted profoundly theoretic and testing analysis on external cyclone-flow distribution water device, the results reveal that the new-style anaerobic reactor can largely advance the mixture of granular sludge with wastewater, enhance the availability of reactor's cubage, heighten mass-transfer efficiency between substrate and microbes, and avoid effectively the losing of granular sludge, further reduce the cost of disposing coal chemical wastewater, which had very important theoretical indication function and practical application value in the development of coal chemical wastewater treatment by anaerobic technology. © (2013) Trans Tech Publications, Switzerland
Outputs	Bao et al. (2013). Mechanism and experimental research on treatment of coal chemical wastewater by external circular anaerobic reactor. *2nd International Conference on Energy, Environment and Sustainable Development, EESD 2012, October 12, 2012 - October 14, 2012.* Jilin, China: Trans Tech Publications.
Key personnel	Bao, Hong-Fu; Li, Yi-Wei; Zhao, Yu-Sen; Zhang, Li-Yan; Pan, Yong-Zhi
Contact	Northeast Forestry University, Harbin, China
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.100 Project 100: Small experiment of high - efficiency intelligent coal mine water recycling equipment

Project characteristics	Details
Project title	**Small experiment of high - efficiency intelligent coal mine water recycling equipment**
Project location	China
Principal investigator	Li, H.; Guo, Y.; Zhang, C.; Wang, C.; Luo, M.; Wu, J.
Lead institution	School of Chemical & Environmental Engineering, China University of Mining & Technology (Beijing), Beijing 100083, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	In order to solve the problem of coal mine water pretreatment, a high - efficiency and intelligent coal water recycling equipment was developed. Based on the separation equipment, conditions, which demonstrates the minimum energy consumption and best suspension removal efficiency, is screen cloth 0.4 mm, rotation speed 28 r/min, inflow velocity 1 m super(3)/h. The highest turbidity removal rate is up to 82%. This equipment saves a lot of water resources and the coal resources, producing huge economic and social interest and has very good prospects for promotion.
Outputs	Li et al. (2012). Small Experiment of High - efficiency Intelligent Coal Mine Water Recycling Equipment. *Environmental Science and Management.* China Journal.
Key personnel	Li, H.; Guo, Y.; Zhang, C.; Wang, C.; Luo, M.; Wu, J.
Contact	School of Chemical & Environmental Engineering, China University of Mining & Technology (Beijing), Beijing 100083, China
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.101 Project 101: Treatment of coal mine drainage with high turbidity, high iron and manganese in the use of coagulation and sedimentation process

Project characteristics	Details
Project title	**Treatment of coal mine drainage with high turbidity, high iron and manganese in the use of coagulation and sedimentation process**
Project location	China
Principal investigator	Wang, Jian-Bing; Li, Ya-Nan; Jiang, Wen-Ting; Gao, Zhen-Feng; He, Xu-Wen; Xu, Cui-Hua
Lead institution	School of Chemical and Environmental Engineering, China University of Mining and Technology, Beijing 100083, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	For the treatment of coal mine drainage with high turbidity, high iron and manganese in the use of coagulation and sedimentation process, the study carried out the coagulation-flocculation jar tests and dynamic experiments with G value gradually decreasing. Through the measurement of effluent quality with nephelometer/spectrophotometer and the analysis of flocs change with microscope, the effect of coagulant, pH and hydraulic condition on the treatment was studied and the optimal G value was investigated. The use of FeCl3 coagulant enhanced turbidity removal while PAC improved the ion removal of iron and manganese. The increase of pH value was beneficial for the ion removal of iron and manganese. As G value increased the removal of turbidity, and iron ion first increased and then decreased. When disposing coal mine drainage with the turbidity of 159-168 NTU, iron ion concentration of 29.6-32.1 mg/L and manganese ion concentration of 2.2-2.4 mg/L, the best result was obtained with the PAC dosage of 60 mg/L, PAM dosage of 0.2 mg/L, G value of 39.8 s-1 for rapid mixing and 5.4 s-1 for slow mixing. G value decreasing step by step accelerated the destabilization of colloids, and prevented flocs from being broken. When the G value were 39.8, 9.9 and 5.5 s-1 respectively, the turbidity, iron and manganese ion concentrations of the effluent from dynamic experiments were 20.4-23.8 NTU, 0.67-1.08 mg/L and 0.96-1.04 mg/L. The removal of turbidity, iron and manganese ion was excellent in coal mine drainage treatment by coagulation and sedimentation process.
Outputs	Wang et al. (2013). Treatment of coal mine drainage with high turbidity, high iron and manganese in the use of coagulation and sedimentation process. *Zhongguo Kuangye Daxue Xuebao/Journal of China University of Mining and Technology.* Xuzhou Jiangsu, 221008, China: China University of Mining and Technology.
Key personnel	Wang, Jian-Bing; Li, Ya-Nan; Jiang, Wen-Ting; Gao, Zhen-Feng; He, Xu-Wen; Xu, Cui-Hua
Contact	School of Chemical and Environmental Engineering, China University of Mining and Technology, Beijing 100083, China
Research themes	Co-produced/mine water

Project characteristics	Details
Project information source	Literature

Table 4.102 Project 102: A nitrogen foam fluid with low formation damage for CBM fracturing treatment

Project characteristics	Details
Project title	**A nitrogen foam fluid with low formation damage for CBM fracturing treatment**
Project location	China
Principal investigator	Li, Zhao-Min; Lu, Qi-Chao; Li, Song-Yan; Li, Bin-Fei; Sun, Qian
Lead institution	School of Petroleum Engineering in China University of Petroleum, Qingdao
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Fracturing treatment is essential for the development of coalbed methane (CBM) fields. In the fracturing of coal seams, high filtration loss, serious formation damage, low flow-back and poor efficiency were the main problems when using conventional water-based fracturing fluids. A nitrogen foam fracturing fluid system with low formation damage was developed based on the geological features of CBM reservoirs. The formula of the foam fluid mainly includes a bactericidal agent, foaming surfactants and clay stabilizers. Filtration loss, dispersion, and microscopic foaming experiments were conducted for testing the capacities of the fluid system as a foaming and fracturing fluid. Experimental results show that the fracturing fluid has a good foaming ability and foam stability, excellent shearing bearing ability, strong sand carrying capacity. The plugging effect of foam can significantly reduce the filtration loss, and nitrogen can improve the flow back ability of the fracturing fluid. The surfactants in the fracturing fluid can also reduce the interfacial tension between coal and water, thus improving the dispersion of coal powders in the fluid. In comparison with conventional fracturing fluids, the nitrogen foam fracturing fluid can cause much less formation damage to the CBM reservoir.
Outputs	Li et al. (2013). A nitrogen foam fluid with low formation damage for CBM fracturing treatment. *Zhongguo Shiyou Daxue Xuebao (Ziran Kexue Ban)/Journal of China University of Petroleum (Edition of Natural Science).* Shandong, Dongying 257061, 257062, China: University of Petroleum, China.
Key personnel	Li, Zhao-Min; Lu, Qi-Chao; Li, Song-Yan; Li, Bin-Fei; Sun, Qian
Contact	School of Petroleum Engineering in China University of Petroleum, Qingdao 266580, China
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.103 Project 103: New technologies of purification and utilization on mine water

Project characteristics	Details
Project title	**New technologies of purification and utilization on mine water**
Project location	China
Principal investigator	Shao, Aijun; Li, Zhiguang
Lead institution	Shijiazhuang University of Economics, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	China is a big country of coal production, in the coal mining process, the great massive mine drainage has caused not only the waste of groundwater resource, but also environmental pollution. On the other hand, mining production and life supply water is very scarce. According to the mine water features, the majority of mine drainage water belonging to the mine water containing suspended, the mine water needs to do the necessary purification then can be used. That purification mainly eliminates is the suspended. In this paper, the method of purification and the technological process about mine water are discussed. The main methods of handling are coagulation, sedimentation, filtration and disinfection. According to different characteristics of water quality, different ways of handling and technological processes have to be chosen. Finally, the purification and utilization of mine water are shown through practical examples, Pingdingshan Coal Group Company, Wannian Coal Mine of Fengfeng Group Limited Company and Tangshan Coal Mine of Kailuan Group Company, to have obvious social, economic and environmental benefits. (2012) Trans Tech Publications, Switzerland.
Outputs	Shao and Li. (2012). New technologies of purification and utilization on mine water. *2nd International Conference on Civil Engineering, Architecture and Building Materials, CEABM 2012, May 25, 2012 - May 27, 2012.* Yantai, China: Trans Tech Publications.
Key personnel	Shao, Aijun; Li, Zhiguang
Contact	Shijiazhuang University of Economics, China
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.104 Project 104: Comment on "identifying well contamination through the use of 3-D fluorescence spectroscopy to classify coalbed methane produced water"

Project characteristics	Details
Project title	**Comment on "identifying well contamination through the use of 3-D fluorescence spectroscopy to classify coalbed methane produced water"**
Project location	China
Principal investigator	Li, Wen-Tao; Xu, Zi-Xiao; Li, Ai-Min
Lead institution	State Key Laboratory of Pollution Control and Resources Reuse, School of the Environment, Nanjing University, Nanjing, 210023, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	
Outputs	Li et al. (2013). Comment on "identifying well contamination through the use of 3-D fluorescence spectroscopy to classify coalbed methane produced water". *Environmental Science and Technology.* 2540 Olentangy River Road, P.O. Box 3337, Columbus, OH 43210-3337, United States: American Chemical Society.
Key personnel	Li, Wen-Tao; Xu, Zi-Xiao; Li, Ai-Min
Contact	State Key Laboratory of Pollution Control and Resources Reuse, School of the Environment, Nanjing University, Nanjing, 210023, China
Research themes	Co-produced/mine water
Project information source	Literature

4.3.3 United Kingdom

Table 4.105 Project 105: Hydraulic performance assessment of passive coal mine water treatment systems in the UK

Project characteristics	Details
Project title	**Hydraulic performance assessment of passive coal mine water treatment systems in the UK**
Project location	United Kingdom
Principal investigator	Kusin, F. M.; Jarvis, A. P.; Gandy, C. J.
Lead institution	Hydrogeochemical Engineering Research and Outreach Group, School of Civil Engineering and Geosciences, Newcastle University, NE1 7RU, United Kingdom
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Hydraulic performance assessment of passive treatment systems has been conducted for UK's Coal Authority mine water treatment systems. The study aims to improve the understanding of the hydraulic factors that govern contaminant behaviour, such that future design of treatment systems is able to optimise treatment efficiency and make performance more predictable, and improve performance over the long-term. Assessment of the hydraulic behaviour (i.e. residence time and flow pattern) of the treatment systems was accomplished by means of tracer tests. The tracer tests were undertaken at eight UK Coal Authority mine water treatment systems (lagoons and wetlands) within Northern England (main study areas) and part of southern Scotland. A modelling approach using a tanks-in-series (TIS) model was adopted to precisely analyse and characterise the residence time distributions (RTDs), in an effort to account for the different flow patterns across the treatment systems. Generally, lagoon RTDs are characterised by a greater flow dispersion compared to wetlands (i.e. higher dispersion number, D and lower number of TIS, n). Consequently, the hydraulic efficiency, e for lagoons is much lower than wetlands (mean of 0.20 for lagoons compared to 0.66 for wetlands). Implications for design and maintenance of mine water treatment systems are discussed. © 2012 Elsevier B.V.
Outputs	Kusin et al. (2012). Hydraulic performance assessment of passive coal mine water treatment systems in the UK. *Ecological Engineering.* P.O. Box 211, Amsterdam, 1000 AE, Netherlands: Elsevier.
Key personnel	Kusin, F. M.; Jarvis, A. P.; Gandy, C. J.
Contact	Hydrogeochemical Engineering Research and Outreach Group, School of Civil Engineering and Geosciences, Newcastle University, NE1 7RU, United Kingdom
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.106 Project 106: Mine water management post-closure

Project characteristics	Details
Project title	**Mine water management post-closure**
Project location	United Kingdom
Principal investigator	Lee Wyatt, The Coal Authority
Lead institution	The Coal Authority, United Kingdom
Project budget	N/A – internally funded
Source of funding	Department of Energy & Climate Change, United Kingdom
Project duration	2011-2013
Current status	Completed
Project summary	Part of the historical mining legacy in the UK is the significant problems and potential risks with regard to managing coalfield post-closure. This study comprised a review of key factors and methods in understanding, developing and managing mine water pollution post-closure and other mining-associated risks.
Objectives	Assessment of mine water monitoring coverage over time, including an assessment of the parameters requiring monitoring.
Achievements	Improve understanding of how mine water recovers and impacts on the mining block
Outputs	Identify, through the use of case studies, effective management strategies to prevent aquifer pollution, manage rising mine waters, treat mine water and adapt to changes in environmental regulations over time.
Key personnel	Lee Wyatt
Research themes	water supplies, co-produced/mine water
Project information source	Survey

4.3.4 United States

Table 4.107 Project 107: Potential for beneficial use of coal-bed methane produced water in western Alabama to augment water supplies during intense drought

Project characteristics	Details
Project title	**Potential for beneficial use of coal-bed methane produced water in western Alabama to augment water supplies during intense drought**
Project location	US
Principal investigator	Beebe, D. Alex; Alley, Bethany; Castle, James W.; Rodgers, John H.
Lead institution	Clemson University
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Recent extreme and exceptional dry weather periods in the southeast have lead to increasing concern over water availability during times of intense drought, resulting in a two decade legal battle between Alabama, Florida, and Georgia over surface water consumption. In order to sustain potable water resources and mitigate the effects of drought, additional emphasis could be placed on the use of reclaimed waters for non-potable uses. Currently, around 80 million barrels (3.2 billion gallons) of coal-bed methane produced water are generated annually from the Black Warrior Basin in western Alabama. This study investigates the potential for beneficial use of Black Warrior Basin produced water as a means to augment water supplies for local agricultural and industrial use. Chemical characterization was performed using available literature and analysis of produced water samples. Chemical constituent concentrations were compared with published beneficial use criteria (crop irrigation and cooling water) to determine the percentage of samples that may be suitable for use. Common constituents that limit reuse were also identified for future evaluation of treatment technologies. Of 126 produced water samples identified from literature and 7 analyzed in the laboratory, 46.6% met irrigation criteria for salt tolerant crops such as cotton. 45.1% of the samples did not meet the criteria due to excessive conductivity. 77.2% of the samples met the criteria for use as cooling water; however, 15.7% of the samples did not meet the criteria due to excessive iron. Other constituents in excess of beneficial use criteria for either irrigation or cooling water in some samples were sulfate, cadmium, and manganese. Based on the samples characterized, some Black Warrior Basin coal-bed methane produced water has the potential to be used in place of potable water for irrigation of cotton and as cooling water thus preserving or enhancing potable water resources.
Outputs	Beebe et al. (2012). Potential for beneficial use of coal-bed methane produced water in western Alabama to augment water supplies during intense drought. *Abstracts with Programs - Geological Society of America.* Geological Society of America (GSA), Boulder, CO, United States.
Key personnel	Beebe, D. Alex; Alley, Bethany; Castle, James W.; Rodgers, John H.
Contact	Clemson University, Department of Environmental Engineering and Earth Sciences, Clemson, SC, United States

Project characteristics	Details
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.108 Project 108: Forward osmosis treatment of drilling mud and fracturing wastewater from oil and gas operations

Project characteristics	Details
Project title	**Forward osmosis treatment of drilling mud and fracturing wastewater from oil and gas operations**
Project location	US
Principal investigator	Hickenbottom, K. L.; Hancock, N. T.; Hutchings, N. R.; Appleton, E. W.; Beaudry, E. G.; Xu, P.; Cath, T. Y.
Lead institution	Colorado School of Mines, Golden
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	To produce large volumes of newly discovered unconventional gas, hydraulic fracturing of wells is commonly practiced in basins where shale gas and coal bed methane are extracted. Hydraulic fracturing of wells during oil and gas (O&G) exploration consumes large volumes of fresh water and generates larger volumes of contaminated wastewater. In this study, a novel application of forward osmosis (FO) was tested for treatment and reclamation of water from drilling waste to facilitate beneficial water reuse. By using FO, two major benefits were achieved: both the volume of the waste stream and the need for a fresh water source were greatly reduced. Results indicate that FO can achieve high rejection of organic and inorganic contaminants, membrane fouling was reversible, and that the process was able to effectively recover more than 80% of the water from the drilling waste. Osmotic backwashing was demonstrated to be an effective membrane cleaning technique; successfully removing fouling and restoring water flux. (C) 2012 Elsevier B.V. All rights reserved.
Outputs	Hickenbottom et al. (2013). Forward osmosis treatment of drilling mud and fracturing wastewater from oil and gas operations. *Desalination.*
Key personnel	Hickenbottom, K. L.; Hancock, N. T.; Hutchings, N. R.; Appleton, E. W.; Beaudry, E. G.; Xu, P.; Cath, T. Y.
Contact	Cath, TY Colorado Sch Mines, Golden, CO 80401 USA Colorado Sch Mines, Golden, CO 80401 USA Bear Creek Serv, Shreveport, LA USA Hydrat Technol Innovat, Albany, OR USA
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.109 Project 109: Photo-induced graft polymerization of N-isopropyl acrylamide on thin film composite membrane: Produced water treatment and antifouling properties

Project characteristics	Details
Project title	**Photo-induced graft polymerization of N-isopropyl acrylamide on thin film composite membrane: Produced water treatment and antifouling properties**
Project location	US
Principal investigator	Mondal, S.; Wickramasinghe, S. R.
Lead institution	Colorado State University
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Thin film composite (TFC) nanofiltration membranes are widely used for waste water treatments. However, membrane fouling constitutes a major obstacle for the applications of TFC technology for the treatment of waste water. Fouling is caused by undesired interactions between colloids (e.g. oil droplets in water) with the membrane active surface. The consequence is a sharp decline in permeate flux and changing permeate quality with operation time, which has detrimental effects on the efficiency and economics of the membrane process. Membrane fouling could be controlled by altering the surface chemistry of membrane. Changing the membrane surface chemistry by surface modification of temperature responsive polymer is an attractive approach to reduce membrane fouling. In this study, we made an approach to modify the membrane surface with temperature responsive polymer such as poly(N-isopropyl acrylamide) poly(NIPAM) by photo-induced graft polymerization method. Membrane surfaces were characterized by field emission scanning electron microscopy (FESEM), atomic force microscopy and attenuated total reflection-Fourier transform infrared analysis. Changes in surface chemistry and morphology confirmed the grafting of poly(NIPAM). Hydrophilicity of the grafted membrane has been improved significantly which was determined by contact angle measurements. Furthermore, grafted membranes shows temperature responsive property which was characterized by lower critical solution temperature of poly(NIPAM) at temperature 30C. Grafted membrane was used for the treatment of waste water obtained from coal bed methane gas exploration which is known as produced or co-produced water. Permeate flux through the grafted membrane has been decreased due the blockage of surface/pores. However, grafted membrane gave better results in terms of separation such as salt rejection. Initial salt rejection of grafted membrane is 48.04% as compared to the 7.2% for un-grafted membrane. FESEM revealed used grafted membranes are capable to release the foulants after lukewarm (40C) water wash. © 2012 Elsevier B.V. All rights reserved.
Outputs	Mondal and Wickramasinghe. (2012). Photo-induced graft polymerization of N-isopropyl acrylamide on thin film composite membrane: Produced water treatment and antifouling properties. *Separation and Purification Technology.* P.O. Box 211, Amsterdam, 1000 AE, Netherlands: Elsevier.
Key personnel	Mondal, S.; Wickramasinghe, S. R.

Project characteristics	Details
Contact	Department of Chemical and Biological Engineering, Colorado State University, Fort Collins, CO 80523-1370, United States
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.110 Project 110: Performance and microbial community dynamics of a sulfate-reducing bioreactor treating coal generated acid mine drainage

Project characteristics	Details
Project title	**Performance and microbial community dynamics of a sulfate-reducing bioreactor treating coal generated acid mine drainage**
Project location	US
Principal investigator	Burns, A.S.; Pugh, C.W.; Segid, Y.T.; Behum, P.T.; Lefticariu, L.; Bender, K.S.
Lead institution	Department of Microbiology, Southern Illinois University, 1125 Lincoln Drive, Mail Code 6508, Carbondale, IL 62901, US
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The effectiveness of a passive flow sulfate-reducing bioreactor processing acid mine drainage (AMD) generated from an abandoned coal mine in Southern Illinois was evaluated using geochemical and microbial community analysis 10 months post bioreactor construction. The results indicated that the treatment system was successful in both raising the pH of the AMD from 3.09 to 6.56 and in lowering the total iron level by 95.9%. While sulfate levels did decrease by 67.4%, the level post treatment (1153 mg/l) remained above recommended drinking water levels. Stimulation of biological sulfate reduction was indicated by a +2.60 per mil increase in delta ^{34}S content of the remaining sulfate in the water post-treatment. Bacterial community analysis targeting 16S rRNA and dsrAB genes indicated that the pre-treated samples were dominated by bacteria related to iron-oxidizing Betaproteobacteria, while the post-treated water directly from the reactor outflow was dominated by sequences related to sulfur-oxidizing Epsilonproteobacteria and complex carbon degrading Bacteroidetes and Firmicutes phylums. Analysis of the post-treated water, prior to environmental release, revealed that the community shifted back to predominantly iron-oxidizing Betaproteobacteria. DsrA analysis implied limited diversity in the sulfate-reducing population present in both the bioreactor outflow and oxidation pond samples. These results support the use of passive flow bioreactors to lower the acidity, metal, and sulfate levels present in the AMD at the Tab-Simco mine, but suggest modifications of the system are necessary to both stimulate sulfate-reducing bacteria and inhibit sulfur-oxidizing bacteria.
Outputs	Burns et al. (2012). Performance and microbial community dynamics of a sulfate-reducing bioreactor treating coal generated acid mine drainage. *Biodegradation*.
Key personnel	Burns, A.S.; Pugh, C.W.; Segid, Y.T.; Behum, P.T.; Lefticariu, L.; Bender, K.S.
Contact	Department of Microbiology, Southern Illinois University, 1125 Lincoln Drive, Mail Code 6508, Carbondale, IL 62901, US
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.111 Project 111: Radium and barium removal through blending hydraulic fracturing fluids with acid mine drainage

Project characteristics	Details
Project title	**Radium and barium removal through blending hydraulic fracturing fluids with acid mine drainage**
Project location	US
Principal investigator	Kondash, Andrew J.; Warner, Nathaniel R.; Lahav, Ori; Vengosh, Avner
Lead institution	Division of Earth and Ocean Sciences, Nicholas School of the Environment, Duke University, Durham, North Carolina
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Wastewaters generated during hydraulic fracturing of the Marcellus Shale typically contain high concentrations of salts, naturally occurring radioactive material (NORM), and metals, such as barium, that pose environmental and public health risks upon inadequate treatment and disposal. In addition, fresh water scarcity in dry regions or during periods of drought could limit shale gas development. This paper explores the possibility of using alternative water sources and their impact on NORM levels through blending acid mine drainage (AMD) effluent with recycled hydraulic fracturing flowback fluids (HFFFs). We conducted a series of laboratory experiments in which the chemistry and NORM of different mix proportions of AMD and HFFF were examined after reacting for 48 h. The experimental data combined with geochemical modeling and X-ray diffraction analysis suggest that several ions, including sulfate, iron, barium, strontium, and a large portion of radium (60–100%), precipitated into newly formed solids composed mainly of Sr barite within the first 10 h of mixing. The results imply that blending AMD and HFFF could be an effective management practice for both remediation of the high NORM in the Marcellus HFFF wastewater and beneficial utilization of AMD that is currently contaminating waterways in northeastern U.S.A.
Outputs	Kondash et al. (2013). Radium and Barium Removal through Blending Hydraulic Fracturing Fluids with Acid Mine Drainage. *Environmental Science & Technology.* American Chemical Society.
Key personnel	Kondash, Andrew J.; Warner, Nathaniel R.; Lahav, Ori; Vengosh, Avner
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.112 Project 112: The role of ownership in environmental performance: Evidence from coalbed methane development

Project characteristics	Details
Project title	**The role of ownership in environmental performance: Evidence from coalbed methane development**
Project location	US
Principal investigator	Fitzgerald, Timothy
Lead institution	Montana State University
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	One way coalbed methane production differs from traditional oil and gas extraction is in the large quantities of produced water. This water must be disposed of for production to occur. Surface discharge has proven to be a low-cost alternative; regulations are in place to protect surface water quality. This paper investigates the effects of alternative ownership regimes on regulatory compliance. A unique dataset linking coalbed methane wells in Wyoming to water disposal permit violations is used to explore differences in environmental performance across severed and unified minerals. Empirical analysis of these data suggest that ownership does impact environmental compliance behavior. Most violations occur on split estate. Federal split estate wells have more severe violations, though not necessarily more of them. Federal unified wells performed best, with fewer and less serious violations. Wells on private land have more, though not necessarily more severe, violations. These results suggest some room for policy proposals accounting for alternative ownership regimes. © 2013 Springer Science+Business Media New York
Outputs	Fitzgerald. (2013). The role of ownership in environmental performance: Evidence from coalbed methane development. *Environmental Management.* 233 Spring Street, New York, NY 10013-1578, United States: Springer New York.
Key personnel	Fitzgerald, Timothy
Contact	Department of Agricultural Economics and Economics, Montana State University, Box 172920, Bozeman, MT 59717-2920, United States
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.113 Project 113: An estimate of the near-term electricity generation potential of co-produced water from active oil and gas wells

Project characteristics	Details
Project title	**An estimate of the near-term electricity generation potential of co-produced water from active oil and gas wells**
Project location	US
Principal investigator	Augustine, Chad; Falkenstern, David
Lead institution	National Renewable Energy Laboratory, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Co-produced water is water produced as a by-product during oil and gas production. Previous studies have estimated that 15-25 billion barrels of water are co-produced during oil and gas operations annually in the United States. Some well fields produce enough water at high enough temperatures that they could be used to produce electricity. Further, some have speculated that the total electricity generation potential of co-produced water resources in the United States could be tens of gigawatts. This study estimates the near-term market electricity generation potential of water produced as a by-product from active oil and gas operations. The study focuses on the near-term market potential of the co-produced resource and only considers co-production from existing oil and gas operations. A database consisting of oil and gas well data from across the United States was created by aggregating information from state oil and gas well databases. In all, oil and gas databases from 24 states determined to have significant oil and gas activity were aggregated, resulting in a co-production database containing records from 2.5 million wells, half a million of which were identified as active, producing wells. Then, a Geographic Information System (GIS) was developed to combine oil and gas well location, depth, and water production information with geothermal resource maps to estimate the co-produced water temperature. Co-produced water temperatures were estimated based on maps created from a separate database containing the bottom-hole temperature of 27,000 wells and from temperature-at-depth maps developed by the Southern Methodist University Geothermal Laboratory. Models were developed to calculate the power generation potential of the co-production resource based on the co-produced water volume and temperature estimates. A cut-off temperature for electricity production of 176F (80C) was assumed. Several scenarios were explored to determine the sensitivity of the resource potential estimate to assumptions and results from the study. Over 60% of active wells in the database were found to have estimated temperatures of less than 176F (80C). Nearly 20% of the active wells lack sufficient data (primarily well depth) to make a temperature estimate. Although the study indicates that there are a significant number of oil and gas operations with sufficient temperatures and co-produced water volumes that could potentially be utilized for electricity generation, it was concluded that the near-term market potential for the co-production resource as a whole is roughly 300 MW e. This estimate does not take into account practical operational factors such as a minimum power plant size, availability of cooling water or transmission, project economics, etc., that could further limit the number of sites that could be developed. The majority of the co-production resource

Project characteristics	Details
	potential is in Texas, which accounts for roughly two-thirds of the near-term electricity generation potential. Given the size of the Texas co-produced resource potential relative to the rest of the United States and that co-produced water data for Texas was based on reported re-injected water volumes, a more thorough study based on actual well data is recommended.
Objectives	Augustine and Falkenstern. (2012). An estimate of the near-term electricity generation potential of co-produced water from active oil and gas wells. *Geothermal Resources Council Annual Meeting 2012 - Geothermal: Reliable, Renewable, Global, GRC 2012, September 30, 2012 - October 3, 2012.* Reno, NV, United states: Geothermal Resources Council.
Key personnel	Augustine, Chad; Falkenstern, David
Contact	National Renewable Energy Laboratory, United States
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.114 Project 114: Disclosure of hydraulic fracturing fluid chemical additives: analysis of regulations

Project characteristics	Details
Project title	**Disclosure of hydraulic fracturing fluid chemical additives: analysis of regulations**
Project location	US
Principal investigator	Maule, Alexis L.; Makey, Colleen M.; Benson, Eugene B.; Burrows, Isaac J.; Scammell, Madeline K.
Lead institution	School of Public Health (Boston University)
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	We explore hydraulic fracturing exemptions from federal regulations, as well as current and future efforts to mandate chemical disclosure at the federal and state level.
Outputs	Maule et al. (2013). Disclosure of Hydraulic Fracturing Fluid Chemical Additives: Analysis of Regulations. School of Public Health (Boston University). http://baywood.metapress.com/link.asp?id=wq212w3419542284
Key personnel	Maule, Alexis L.; Makey, Colleen M.; Benson, Eugene B.; Burrows, Isaac J.; Scammell, Madeline K.
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.115 Project 115: Geochemical and microbial community dynamics of a remediation system treating coal-derived acid mine drainage

Project characteristics	Details
Project title	**Geochemical and microbial community dynamics of a remediation system treating coal-derived acid mine drainage**
Project location	US
Principal investigator	Walters, Evan R.; Pugh, Charles W.; Bender, Kelly S.; Lefticariu, Liliana
Lead institution	Southern Illinois University, Department of Geology, Carbondale, IL, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Mobility of toxic elements and the overall treatment efficiency of coal-generated acid mine drainage (AMD) depends on the dynamic evolution of biogeochemical processes taking place in the system. Tab Simco is an abandoned coal mine near Carbondale, Illinois that produces AMD with pH approximately 2.4 and average concentration (ppm) of dissolves ions: 600 Fe, 150 Al, 40 Mn and 3500 SO (sub 4). To abate this problem, a passive treatment system comprised of open limestone drains, a SO (sub 4) -reducing bioreactor, and an oxidation pond was built in 2007. Over the past five years, within the bioreactor, a horizontally stratified Al-and Fe-rich layer with a thickness of approximately 0.7 m has precipitated above the compost layer. This layer consists of finely laminated, optically distinguishable microcrystalline sub-layers. Structural order within this layer suggests stratified zones of redox conditions control organization of precipitates. To model the fate of toxic elements in the system, we followed the chemical, mineralogical and biological evolution through a multi-analytical approach (XRD, SEM, ICP-MS, 16S rRNA gene analysis) applied to surface precipitates and associated waters. The precipitates evolve through a temporal transition from amorphous Fe and Al phases, to schwertmannite and halotrichite, and finally to goethite and clay minerals. Results indicate that Fe(III) oxide nanoparticles play a paramount role in remediation due to high sorption capacities for metal and anionic contaminants. Still, experiments mimicking a static system show that alkalinity produced from fresh limestone is inhibited by the formation of Fe-oxides that coat the surface. Molecular analysis of the bacterial 16S rRNA gene sequences present in the effluent indicated that bacterial oxidation of Fe(II) is primarily mediated by Betaproteobacteria, with 49% of the identified sequences classified in this group. While most of these phylotypes shared the highest DNA similarity to uncharacterized environmental clones, the most closely related isolate in pure culture is Sideroxydans lithotrophicus. To further quantify the biogeochemical interplay, additional data must be collected at lab and field scale. Connecting the response of the system to changes that propagate through time is critical in the design of an effective remediation strategy for Tab Simco.
Outputs	Walters et al. (2012). Geochemical and microbial community dynamics of a remediation system treating coal-derived acid mine drainage. *Abstracts with Programs - Geological Society of America.* Geological Society of America (GSA), Boulder, CO, United States.

Project characteristics	Details
Key personnel	Walters, Evan R.; Pugh, Charles W.; Bender, Kelly S.; Lefticariu, Liliana
Contact	Southern Illinois University, Department of Geology, Carbondale, IL, United States
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.116 Project 116: Minerals and mine drainage

Project characteristics	Details
Project title	**Minerals and mine drainage**
Project location	US
Principal investigator	Wei, X. C.; Wolfe, F. A.
Lead institution	The State University of New York Institute of Technology, Utica, NY 13502, US
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	A review of the literature published in 2012 on topics relating to acid mine drainage (AMD) or acid rock drainage (ARD) due to the presence of sulfide bearing minerals in active and abandoned coal/hard rock mining sites or waste spoil piles is presented. This review is divided into the following sections: (1) Characterization and Assessment, (2) Protection, Prevention and Restoration, (3) Toxicity Assessment, (4) Fate and Transport, (5) Biological Characterization, and (6) Treatment Technologies. Due to the complexity of the minerals and mine drainage, many papers presented in this review address more than one important topic, indicating that they can be categorized into more than one section. Therefore, the different sections presented in this review should not be regarded as being mutually-exclusive or all-inclusive.
Outputs	Wei and Wolfe. (2013). Minerals and mine drainage. *Water Environment Research*.
Key personnel	Wei, X. C.; Wolfe, F. A.
Contact	The State University of New York Institute of Technology, Utica, NY 13502, US
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.117 Project 117: Deep subsurface drip irrigation using coal-bed sodic water: Part I. Water and solute movement

Project characteristics	Details
Project title	**Deep subsurface drip irrigation using coal-bed sodic water: Part I. Water and solute movement**
Project location	US
Principal investigator	Bern, Carleton R.; Breit, George N.; Healy, Richard W.; Zupancic, John W.; Hammack, Richard
Lead institution	US Geological Survey
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Water co-produced with coal-bed methane (CBM) in the semi-arid Powder River Basin of Wyoming and Montana commonly has relatively low salinity and high sodium adsorption ratios that can degrade soil permeability where used for irrigation. Nevertheless, a desire to derive beneficial use from the water and a need to dispose of large volumes of it have motivated the design of a deep subsurface drip irrigation (SDI) system capable of utilizing that water. Drip tubing is buried 92 cm deep and irrigates at a relatively constant rate year-round, while evapotranspiration by the alfalfa and grass crops grown is seasonal. We use field data from two sites and computer simulations of unsaturated flow to understand water and solute movements in the SDI fields. Combined irrigation and precipitation exceed potential evapotranspiration by 300-480 mm annually. Initially, excess water contributes to increased storage in the unsaturated zone, and then drainage causes cyclical rises in the water table beneath the fields. Native chloride and nitrate below 200 cm depth are leached by the drainage. Some CBM water moves upward from the drip tubing, drawn by drier conditions above. Chloride from CBM water accumulates there as root uptake removes the water. Year over year accumulations indicated by computer simulations illustrate that infiltration of precipitation water from the surface only partially leaches such accumulations away. Field data show that 7% and 27% of added chloride has accumulated above the drip tubing in an alfalfa and grass field, respectively, following 6 years of irrigation. Maximum chloride concentrations in the alfalfa field are around 45 cm depth but reach the surface in parts of the grass field, illustrating differences driven by crop physiology. Deep SDI offers a means of utilizing marginal quality irrigation waters and managing the accumulation of their associated solutes in the crop rooting zone.
Outputs	Bern et al. (2013). Deep subsurface drip irrigation using coal-bed sodic water: Part I. Water and solute movement. *Agricultural Water Management.* P.O. Box 211, Amsterdam, 1000 AE, Netherlands: Elsevier.
Key personnel	Bern, Carleton R.; Breit, George N.; Healy, Richard W.; Zupancic, John W.; Hammack, Richard
Contact	Crustal Geophysics and Geochemistry Science Center, U.S. Geological Survey, Denver Federal Center, Denver, CO 80225, United States
Research themes	Co-produced/mine water

Project characteristics	Details
Project information source	Literature

Table 4.118 Project 118: The effect of coal-bed methane water on spearmint and peppermint

Project characteristics	Details
Project title	**The effect of coal-bed methane water on spearmint and peppermint**
Project location	US
Principal investigator	Zheljazkov, Valtcho D.; Cantrell, Charles L.; Astatkie, Tess; Schlegel, Vicki; Jeliazkova, Ekaterina; Lowe, Derek
Lead institution	Univ. of Wyoming
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Coal bed methane is extracted from underground coal seams that are flooded with water. To reduce the pressure and to release the methane, the water needs to be pumped out. The resulting waste water is known as coal bed methane water (CBMW). Major concerns with the use of CBMW are its high concentrations of S, Na, dissolved Ca2+, Mg2+, SO4 2-, and bicarbonate (HCO3-). Irrigation water is a scarce resource in most of the western states. The objective of this study was to evaluate the effect of various amounts of CBMW on the growth, essential oil content, composition, and antioxidant activity of spearmint (Mentha spicata L.) and peppermint (Mentha piperita L.) crops that were irrigated with the water. These two crops are grown in some western states and are potential specialty crops to Wyoming farmers. The irrigation treatments were 0% CBMW (tap water only), 25% CBMW (25% CBMW plus 75% tap water), 50% CBMW (50% CBMW and 50% tap water), 75% CBMW (75% CBMW plus 25% tap water), and 100% CBMW. Analyses of the data revealed that the CBMW treatments did not affect the antioxidant capacity of spearmint or peppermint oil (242 and 377 mmol L-1 Trolox g-1, respectively) or their major oil constituents (carvone or menthol). Coal bed methane water at 100% increased total phenols and total flavonoids in spearmint but not in peppermint. Coal bed methane water also affected oil content in peppermint but not in spearmint. Spearmint and peppermint could be watered with CBMW at 50% without suppression of fresh herbage yields. However, CBMW at 75 and 100% reduced fresh herbage yields of both crops and oil yields of peppermint relative to the control. © American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.
Outputs	Zheljazkov et al. (2013). The effect of coal-bed methane water on spearmint and peppermint. *Journal of Environmental Quality.* 677 South Segoe Road, Madison, WI 53711, United States: ASA/CSSA/SSSA.
Key personnel	Zheljazkov, Valtcho D.; Cantrell, Charles L.; Astatkie, Tess; Schlegel, Vicki; Jeliazkova, Ekaterina; Lowe, Derek
Contact	Univ. of Wyoming, Sheridan Research and Extension Center, 663 Wyarno Road, Sheridan, WY 82801, United States
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.119 Project 119: Analysis of reserve pit sludge from unconventional natural gas hydraulic fracturing and drilling operations for the presence of technologically enhanced naturally occurring radioactive material (TENORM)

Project characteristics	Details
Project title	**Analysis of reserve pit sludge from unconventional natural gas hydraulic fracturing and drilling operations for the presence of technologically enhanced naturally occurring radioactive material (TENORM)**
Project location	US
Principal investigator	Rich, Alisa L.; Crosby, Ernest C.
Lead institution	University of Texas at Arlington, School of Public Health (University of North Texas Health Science Center)
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The potential for impact of TENORM to the environment, occupational workers, and the general public is presented with potential health effects of individual radionuclides. Current oversight, exemption of TENORM in federal and state regulations, and complexity in reporting are discussed.
Outputs	Rich and Crosby. (2013). Analysis of Reserve pit sludge from unconventional natural gas hydraulic fracturing and drilling operations for the presence of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM). University of Texas at Arlington, School of Public Health (University of North Texas Health Science Center). http://baywood.metapress.com/link.asp?id=k621376330557386
Key personnel	Rich, Alisa L.; Crosby, Ernest C.
Research themes	Co-produced/mine water
Project information source	Literature

Table 4.120 Project 120: Shallow groundwater and soil chemistry response to 3 years of subsurface drip irrigation using coalbed-methane-produced water

Project characteristics	Details
Project title	**Shallow groundwater and soil chemistry response to 3 years of subsurface drip irrigation using coalbed-methane-produced water**
Project location	US
Principal investigator	Bern, C.R.; Boehlke, A.R.; Engle, M.A.; Geboy, N.J.; Schroeder, K.T.; Zupancic, J.W.
Lead institution	US Geological Survey
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Disposal of produced waters, pumped to the surface as part of coalbed methane (CBM) development, is a significant environmental issue in the Wyoming portion of the Powder River Basin, US. High sodium adsorption ratios (SAR) of the waters could degrade agricultural land, especially if directly applied to the soil surface. One method of disposing of CBM water, while deriving beneficial use, is subsurface drip irrigation (SDI), where acidified CBM waters are applied to alfalfa fields year-round via tubing buried 0.92 m deep. Effects of the method were studied on an alluvial terrace with a relatively shallow depth to water table (3 m). Excess irrigation water caused the water table to rise, even temporarily reaching the depth of drip tubing. The rise corresponded to increased salinity in some monitoring wells. Three factors appeared to drive increased groundwater salinity: (1) CBM solutes, concentrated by evapotranspiration; (2) gypsum dissolution, apparently enhanced by cation exchange; and (3) dissolution of native Na-Mg-SO4 salts more soluble than gypsum. Irrigation with high SAR (24) water has increased soil saturated paste SAR up to 15 near the drip tubing. Importantly though, little change in SAR has occurred at the surface. © 2013 Springer-Verlag Berlin Heidelberg (outside the US)
Outputs	**Bern** et al. (2013). Shallow groundwater and soil chemistry response to 3 years of subsurface drip irrigation using coalbed-methane-produced water. *Hydrogeology Journal.* Tiergartenstrasse 17, Heidelberg, D-69121, Germany: Springer Verlag.
Key personnel	Bern, C.R.; Boehlke, A.R.; Engle, M.A.; Geboy, N.J.; Schroeder, K.T.; Zupancic, J.W.
Contact	US Geological Survey, Denver, CO, United States
Research themes	Co-produced/mine water
Project information source	Literature

4.4 Seismicity

Projects in this category investigate the impacts of seismic events caused by coal seam gas and coal mining operations on water resources and water dependent ecosystems. Eight projects were identified with the primary theme of the water impacts of seismicity caused by coal seam gas or coal mining developments.

4.4.1 Australia

Table 4.121 Project 121: Seismicity - technical background paper for NSW Chief Scientist and Engineer

Project characteristics	Details
Project title	**Seismicity - technical background paper for NSW Chief Scientist and Engineer**
Project location	Australia
Principal investigator	Drummond, Barry
Lead institution	Unknown
Project budget	Unknown
Source of funding	New South Wales Government
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	General review of seismicity in the US and in NSW, and the potential for induced seismicity as a result of CSG activities.
Outputs	Drummond. (2013). Seismicity - technical background paper for NSW Chief Scientist and Engineer. www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0019/32761/Background-Paper-on-Seismicity_Dr-Barry-Drummond.pdf
Key personnel	Drummond, Barry
Research themes	Seismicity
Project information source	Literature

Table 4.122 Project 122: Seismicity and induced earthquakes (background paper to NSW Chief Scientist and Engineer)

Project characteristics	Details
Project title	**Seismicity and induced earthquakes (background paper to NSW Chief Scientist and Engineer)**
Project location	Australia
Principal investigator	Gibson, Gary; Sandiford, Mike
Lead institution	Melbourne Energy Institute (University of Melbourne)
Project budget	Unknown
Source of funding	New South Wales Government
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	This report aims to describe the characteristics of triggered earthquakes, and to develop a path towards quantification of the earthquake hazards and induced seismicity effects associated with coal seam gas (CSG) production.
Outputs	Gibson and Sandiford. (2013). Seismicity and induced earthquakes (background paper to NSW Chief Scientist and Engineer). Melbourne Energy Institute (University of Melbourne). http://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0017/31616/Seismicity-and-induced-earthquakes_Gibson-and-Sandiford.pdf
Key personnel	Gibson, Gary; Sandiford, Mike
Research themes	Seismicity
Project information source	Literature

4.4.2 United States

Table 4.123 Project 123: Introduction to this special section: Passive seismic and microseismic—Part 2

Project characteristics	Details
Project title	**Introduction to this special section: Passive seismic and microseismic—Part 2**
Project location	US
Principal investigator	Shemeta, Julie; Goodway, Bill; Willis, Mark; Heigl, Werner
Lead institution	Apache Corporation
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Welcome to the second half of TLE's two-part special section on passive seismic and microseismic. This month, we focus again on monitoring hydraulic fracturing with microseismic with five articles, but also expand beyond “micro” seismicity, to include unintended “induced” seismicity that may occur during injection. Five articles in this special section focus on induced-seismicity topics. In this introduction, we will highlight various issues related to undesired induced seismicity which may be caused by hydraulic fracturing and deep, underground salt water disposal.
Outputs	Shemeta et al. (2012). Introduction to this special section: Passive seismic and microseismic—Part 2. *The Leading Edge*. http://tle.geoscienceworld.org/content/31/12/1428.abstract
Key personnel	Shemeta, Julie; Goodway, Bill; Willis, Mark; Heigl, Werner
Research themes	Seismicity
Project information source	Literature

Table 4.124 Project 124: Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 Mw 5.7 earthquake sequence

Project characteristics	Details
Project title	**Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 Mw 5.7 earthquake sequence**
Project location	US
Principal investigator	Keranen, Katie M.; Savage, Heather M.; Abers, Geoffrey A.; Cochran, Elizabeth S.
Lead institution	ConocoPhillips School of Geology and Geophysics, University of Oklahoma
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Significant earthquakes are increasingly occurring within the continental interior of the United States, including five of moment magnitude (Mw) 5.0 in 2011 alone. Concurrently, the volume of fluid injected into the subsurface related to the production of unconventional resources continues to rise. Here we identify the largest earthquake potentially related to injection, an Mw 5.7 earthquake in November 2011 in Oklahoma. The earthquake was felt in at least 17 states and caused damage in the epicentral region. It occurred in a sequence, with 2 earthquakes of Mw 5.0 and a prolific sequence of aftershocks. We use the aftershocks to illuminate the faults that ruptured in the sequence, and show that the tip of the initial rupture plane is within ?200 m of active injection wells and within 1 km of the surface; 30% of early aftershocks occur within the sedimentary section. Subsurface data indicate that fluid was injected into effectively sealed compartments, and we interpret that a net fluid volume increase after 18 yr of injection lowered effective stress on reservoir-bounding faults. Significantly, this case indicates that decades-long lags between the commencement of fluid injection and the onset of induced earthquakes are possible, and modifies our common criteria for fluid-induced events. The progressive rupture of three fault planes in this sequence suggests that stress changes from the initial rupture triggered the successive earthquakes, including one larger than the first.
Outputs	Keranen et al. (2013). Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 Mw 5.7 earthquake sequence. *Geology*. http://geology.gsapubs.org/content/early/2013/03/26/G34045.1.abstract
Key personnel	Keranen, Katie M.; Savage, Heather M.; Abers, Geoffrey A.; Cochran, Elizabeth S.
Research themes	Seismicity
Project information source	Literature

Table 4.125 Project 125: Earthquake catalogues for New Mexico and bordering areas: 2005-2009

Project characteristics	Details
Project title	**Earthquake catalogues for New Mexico and bordering areas: 2005-2009**
Project location	US
Principal investigator	Pursley, Jana; Bilek, Susan L.; Ruhl, Christine J.
Lead institution	Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The earliest documented records of large earthquakes in New Mexico go back to the early 1900s, and seismicity has been monitored instrumentally since the early 1960s. This catalog is a continuation of previous catalogs spanning 1962 through 2004 and includes 165 earthquakes Md 2.0. In addition it also includes all located events with Md 0 in New Mexico. Similar to the 1999-2004 catalog, we found that a large number of earthquakes Md 2.0 were located in two distinct regions. One of these regions is in southeastern New Mexico near the Dagger Draw oil field (32% of all events with Md 2.0), and the other is in northeastern New Mexico within and surrounding the coalbed methane fields near Raton (44% of all events with Md 2.0). Only 5% of the larger earthquakes occurred in the Socorro Seismic Anomaly region. The remaining events were scattered throughout New Mexico, southeastern Colorado, eastern Arizona, northern Mexico, and western Texas.
Outputs	Pursley et al. (2013). Earthquake catalogs for New Mexico and bordering areas: 2005-2009. *New Mexico Geology.* 801 Leroy Place, Socorro, NM 87801-4750, United States: New Mexico Bureau of Mines and Mineral Resources.
Key personnel	Pursley, Jana;Bilek, Susan L.;Ruhl, Christine J.
Contact	Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM 87801, United States
Research themes	Seismicity
Project information source	Literature

Table 4.126 Project 126: Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons

Project characteristics	Details
Project title	**Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons**
Project location	US
Principal investigator	Davies, Richard; Foulger, Gillian; Bindley, Annette; Styles, Peter
Lead institution	Durham Energy Institute, Department of Earth Sciences, Durham University, Science Labs, Durham
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	We compile published examples of induced earthquakes that have occurred since 1929 that have magnitudes equal to or greater than 1.0. Of the 198 possible examples, magnitudes range up to 7.9. The potential causes and magnitudes are (a) mining (M 1.6e5.6); (b) oil and gas field depletion (M 1.0e7.3); (c) water injection for secondary oil recovery (M 1.9e5.1); (d) reservoir impoundment (M 2.0e7.9); (e) waste disposal (M 2.0e5.3); (f) academic research boreholes investigating induced seismicity and stress (M 2.8e3.1); (g) solution mining (M 1.0e5.2); (h) geothermal operations (M 1.0e4.6) and (i) hydraulic fracturing for recovery of gas and oil from low-permeability sedimentary rocks (M 1.0e3.8). Reactivation of faults and resultant seismicity occurs due to a reduction in effective stress on fault planes. Hydraulic fracturing operations can trigger seismicity because it can cause an increase in the fluid pressure in a fault zone. Based upon the research compiled here we propose that this could occur by three mechanisms. Firstly, fracturing fluid or displaced pore fluid could enter the fault. Secondly, there may be direct connection with the hydraulic fractures and a fluid pressure pulse could be transmitted to the fault. Lastly, due to poroelastic properties of rock, deformation or 'inflation' due to hydraulic frac- turing could increase fluid pressure in the fault or in fractures connected to the fault. The following pathways for fluid or a fluid pressure pulse are proposed: (a) directly from the wellbore; (b) through new, stimulated hydraulic fractures; (c) through pre-existing fractures and minor faults; or (d) through the pore network of permeable beds or along bedding planes. The reactivated fault could be intersected by the wellbore or it could be 10s to 100s of metres from it. We propose these mechanisms have been responsible for the three known examples of felt seismicity that are probably induced by hydraulic fracturing. These are in the USA, Canada and the UK. The largest such earthquake was M 3.8 and was in the Horn River Basin, Canada. To date, hydraulic fracturing has been a relatively benign mechanism compared to other anthropogenic triggers, probably because of the low volumes of fluid and short pumping times used in hydraulic fracturing operations. These data and analysis should help provide useful context and inform the current debate surrounding hydraulic fracturing technology.
Outputs	Davies et al. (2013). Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons. *Marine and Petroleum Geology*.

Project characteristics	Details
Key personnel	Davies, Richard; Foulger, Gillian; Bindley, Annette; Styles, Peter
Research themes	Seismicity
Project information source	Literature

Table 4.127 Project 127: Enhanced remote earthquake triggering at fluid-injection sites in the Midwestern United States

Project characteristics	Details
Project title	**Enhanced remote earthquake triggering at fluid-injection sites in the Midwestern United States**
Project location	US
Principal investigator	van der Elst, Nicholas J.; Savage, Heather M.; Keranen, Katie M.; Abers, Geoffrey A.
Lead institution	Lamont-Doherty Earth Observatory of Columbia University
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	A recent dramatic increase in seismicity in the midwestern United States may be related to increases in deep wastewater injection. Here, we demonstrate that areas with suspected anthropogenic earthquakes are also more susceptible to earthquake-triggering from natural transient stresses generated by the seismic waves of large remote earthquakes. Enhanced triggering susceptibility suggests the presence of critically loaded faults and potentially high fluid pressures. Sensitivity to remote triggering is most clearly seen in sites with a long delay between the start of injection and the onset of seismicity and in regions that went on to host moderate magnitude earthquakes within 6 to 20 months. Triggering in induced seismic zones could therefore be an indicator that fluid injection has brought the fault system to a critical state.
Outputs	van der Elst et al. (2013). Enhanced remote earthquake triggering at fluid-injection sites in the midwestern United States. *Science*. http://www.sciencemag.org/content/341/6142/164.abstract
Key personnel	van der Elst, Nicholas J.; Savage, Heather M.; Keranen, Katie M.; Abers, Geoffrey A.
Research themes	Seismicity
Project information source	Literature

Table 4.128 Project 128: Injection-induced earthquakes

Project characteristics	Details
Project title	**Injection-induced earthquakes**
Project location	US
Principal investigator	Ellsworth, William L.
Lead institution	US Geological Survey
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Earthquakes in unusual locations have become an important topic of discussion in both North America and Europe, owing to the concern that industrial activity could cause damaging earthquakes. It has long been understood that earthquakes can be induced by impoundment of reservoirs, surface and underground mining, withdrawal of fluids and gas from the subsurface, and injection of fluids into underground formations. Injection-induced earthquakes have, in particular, become a focus of discussion as the application of hydraulic fracturing to tight shale formations is enabling the production of oil and gas from previously unproductive formations. Earthquakes can be induced as part of the process to stimulate the production from tight shale formations, or by disposal of wastewater associated with stimulation and production. Here, I review recent seismic activity that may be associated with industrial activity, with a focus on the disposal of wastewater by injection in deep wells; assess the scientific understanding of induced earthquakes; and discuss the key scientific challenges to be met for assessing this hazard.
Outputs	Ellsworth. (2013). Injection-induced earthquakes. *Science.* http://www.sciencemag.org/content/341/6142/1225942.abstract
Key personnel	Ellsworth, William L.
Research themes	Seismicity
Project information source	Literature

4.5 Integrity of wells - installation, operation, decommissioning

The integrity of wells during all coal seam gas phases of installation, operation and decommissioning may impact on water resources and water dependent ecosystems. Seventeen projects were identified with the primary theme of integrity of wells and their impacts on water.

4.5.1 Australia

Table 4.129 Project 129: Life cycle of coal seam gas projects: technologies and potential impacts (Report for the New South Wales Office of the Chief Scientist and Engineer)

Project characteristics	Details
Project title	**Life cycle of coal seam gas projects: technologies and potential impacts (Report for the New South Wales Office of the Chief Scientist and Engineer)**
Project location	Australia
Principal investigator	Cook, Peter J.
Lead institution	Unknown
Project budget	Unknown
Source of funding	New South Wales Government
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Addresses: 1) the CSG project lifecycle; 2) Factors contributing to site selection for CSG activities; 3) how geological conditions affect the different stages of CSG development; 4) how changes in technology have affected the economics and dynamics of CS
Outputs	Cook. (2013). Life cycle of coal seam gas projects: technologies and potential impacts (Report for the New South Wales Office of the Chief Scientist and Engineer). http://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0010/31321/Life-Cycle-of-Coal-Seam-Gas-Report_FINAL_PJC.pdf
Key personnel	Cook, Peter J.
Research themes	Well integrity hydraulic fracturing
Project information source	Literature

Table 4.130 Project 130: Low cycle cement fatigue experimental study and the effect on HPHT well integrity

Project characteristics	Details
Project title	**Low cycle cement fatigue experimental study and the effect on HPHT well integrity**
Project location	Australia
Principal investigator	Yuan, Zhaoguang; Teodoriu, Catalin; Schubert, Jerome
Lead institution	Department of Petroleum Engineering, TU Clausthal, Germany
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Cement sheath is very important to maintain wellbore integrity in high pressure high temperature (HPHT) wells and steam injection wells. Due to the HPHT cycles experienced in the process of hydraulic fracturing, production and steam injection, the failure probability of low cycle cement fatigue is high in these wells and is likely to cause the failure of the zonal isolation and increase the casing failure probability. The experiment was set up to simulate conditions under which cement low cycle fatigue failure can occur. In the test, the casing was applied with zero based cyclic pressure to study the cement failure characteristics. The cement mechanical properties were measured at 14 days curing time under three different conditions: (1) room condition; (2) 167. F, 14.7. psi; (3) 212. F, 2610. psi; and used as the input data for finite element method analysis. The cement elastic strain and plastic strain developed in the experimental test was calculated by finite element method and thereby the cement cycles to failure can be predicted based on the strain-cycle relationship. As the confining pressure increase, the cement shows more plasticity and can hold more pressure cycles. At the temperature below 300. F, the stress developed by thermal expansion has minor effect on the cement low cycle fatigue. The cement with higher Poisson's ratio and lower Young's modulus shows better low cycle fatigue behavior. The results of strain-cycle relationship were applied in HPHT gas wells in south Texas to predict the cement fatigue failure under different operations. This paper proposes the low cycle fatigue failure envelope that can help reduce the cement failure and improve the cement design in HPHT wells and steam injection wells. © 2013 Elsevier B.V.
Outputs	Yuan et al. (2013). Low cycle cement fatigue experimental study and the effect on HPHT well integrity. *Journal of Petroleum Science and Engineering.* P.O. Box 211, Amsterdam, 1000 AE, Netherlands: Elsevier. http://dx.doi.org/10.1016/j.petrol.2013.03.006
Key personnel	Yuan, Zhaoguang; Teodoriu, Catalin; Schubert, Jerome
Contact	Department of Petroleum Engineering, TU Clausthal, Germany
Research themes	Well integrity
Project information source	Literature

Table 4.131 Project 131: Anisotropic damage mechanics as a novel approach to improve pre- and post-failure borehole stability analysis

Project characteristics	Details
Project title	**Anisotropic damage mechanics as a novel approach to improve pre- and post-failure borehole stability analysis**
Project location	Australia
Principal investigator	Gaede, O.; Karrech, A.; Regenauer-Lieb, K.
Lead institution	Queensland Univ Technol, Sch Earth Environm & Biol Sci, Brisbane
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Anisotropic damage distribution and evolution have a profound effect on borehole stress concentrations. Damage evolution is an irreversible process that is not adequately described within classical equilibrium thermodynamics Therefore, we propose a constitutive model, based on non-equilibrium thermodynamics, that accounts for anisotropic damage distribution, anisotropic damage threshold and anisotropic damage evolution. We implemented this constitutive model numerically, using the finite element method, to calculate stress strain curves and borehole stresses. The resulting stress strain curves are distinctively different from linear elastic-brittle and linear elastic-ideal plastic constitutive models and realistically model experimental responses of brittle rocks. We show that the onset of damage evolution leads to an inhomogeneous redistribution of material properties and stresses along the borehole wall. The classical linear elastic-brittle approach to borehole stability analysis systematically overestimates the stress concentrations on the borehole wall, because dissipative strain-softening is underestimated. The proposed damage mechanics approach explicitly models dissipative behaviour and leads to non-conservative mud window estimations. Furthermore, anisotropic rocks with preferential planes of failure, like shales, can be addressed with our model.
Outputs	Gaede et al. (2013). Anisotropic damage mechanics as a novel approach to improve pre- and post-failure borehole stability analysis. *Geophysical Journal International.*
Key personnel	Gaede, O.; Karrech, A.; Regenauer-Lieb, K.
Contact	[Gaede, O.] Queensland Univ Technol, Sch Earth Environm & Biol Sci, Brisbane, Qld 4001, Australia. Univ Western Australia, Sch Earth & Environm, Crawley, WA 6009, Australia.
Research themes	Well integrity
Project information source	Literature

4.5.2 China

Table 4.132 Project 132: The "U-type" wells history of fuzzy ball drilling fluids for CBM drilling in China

Project characteristics	Details
Project title	**The "U-type" wells history of fuzzy ball drilling fluids for CBM drilling in China**
Project location	China
Principal investigator	Guo, Ben Guang; Zheng, Li Hui; Meng, Shang Zhi; Zhang, Zhi Heng
Lead institution	China United Coaled Methane Corporation Ltd, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The fuzzy ball drilling fluids have been developed on the basis of the circulation foam and Aphron to control lost circulation effectively. There are some difficulties in drilling "U-type" well, such as well-bore stability, cutting carrying problem, large torque and friction at the horizontal section, and formation damage to coal-bed. The objective of this paper was to show some applications of fuzzy ball drilling fluids on U-type wells of the Ordos Basin and prove the superiority of fuzzy ball drilling fluid in CBM drilling. To the three mentioned cases, the density of fuzzy ball drilling fluid was 0.90~1.18g/cm^3, the funnel viscosity was 45~72s, the dynamic shear force was 12~19 Pa, the PV was 13~19mPa&middots and the pH was ranged from 7 to 9. To use the fuzzy ball drilling fluids, the average ROP increased above 10% with no borehole complexity, such as stuck pipe, hole enlargement causing poor cleaning and etc. These cases reflected excellent properties of the fuzzy ball drilling fluids including effectively sealing, good carrying and suspension ability, formation damage control and compatible weighted by inert materials. Furthermore, the fuzzy ball drilling fluids will not affect BHA tools like motors and MWD in CBM drilling. © (2013) Trans Tech Publications, Switzerland
Outputs	Guo et al. (2013). The "U-type" wells history of fuzzy ball drilling fluids for CBM drilling in china. *2013 4th International Conference on Material and Manufacturing Technology, ICMMT 2013, May 11, 2013 - May 12, 2013.* Seoul, Korea, Republic of: Trans Tech Publications Ltd. http://dx.doi.org/10.4028/www.scientific.net/AMR.748.1273
Key personnel	Guo, Ben Guang; Zheng, Li Hui; Meng, Shang Zhi; Zhang, Zhi Heng
Contact	China United Coaled Methane Corporation Ltd, China
Research themes	Well integrity
Project information source	Literature

Table 4.133 Project 133: A Mechanical model of borehole stability for weak plane formation under porous flow

Project characteristics	Details
Project title	**A Mechanical model of borehole stability for weak plane formation under porous flow**
Project location	China
Principal investigator	Lu, Y.H.; Chen, M.; Jin, Y.; Zhang, G.Q.
Lead institution	China Univ Petr, Coll Petr Engn, State Key Lab Petr Resources & Prospecting, Beijing
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Based on influence of porous flow on weak plane model, the authors established a mechanical model of borehole stability for weak plane formation under porous flow and analyzed effect of weak plane on borehole stability under porous flow. The results indicated that porous flow decreased strength of weak plane, enlarged the affecting domains of weak plane for rock mass strength, and worsened borehole instability in weak plane formations. With porous flow increasing, water content of weak plane increases. For the weak plane with DIP < 10 degrees, the borehole is stable; for 10 degrees < DIP < 30 degrees, the borehole is likely unstable when azimuth is close to the direction of maximum stress, and the larger the dip, the worse the borehole stability; for DIP > 30 degrees, it is opposite to the situation of 10 degrees < DIP < 30 degrees. While weak plane formation is next to be saturated, the minimum drilling fluid density for borehole stability does not change with weak plane azimuth and borehole stability is the worst. The mechanical model of borehole stability for weak plane formation under porous flow is applied to a well in Tarim Basin piedmont.
Outputs	Lu et al. (2012). A Mechanical Model of Borehole Stability for Weak Plane Formation Under Porous Flow. *Petroleum Science and Technology.*
Key personnel	Lu, Y.H.; Chen, M.; Jin, Y.; Zhang, G.Q.
Contact	[Lu, Y. H.] China Univ Petr, Coll Petr Engn, State Key Lab Petr Resources & Prospecting, Beijing 102249, Peoples R China.
Research themes	Well integrity
Project information source	Literature

Table 4.134 Project 134: Study on borehole stability of unconsolidated sandstone in depleted reservoir

Project characteristics	Details
Project title	**Study on borehole stability of unconsolidated sandstone in depleted reservoir**
Project location	China
Principal investigator	Tan, Q.; Deng, J.G.; Yu, B.H.
Lead institution	China Univ Petr, State Key Lab Petr Resource & Prospecting, Beijing
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Reservoir pressure will decline generally along with production in the oil and gas development process. There are some problems such as borehole collapse or reduced diameter and lost circulation in drilling of initial production stage in unconsolidated sandstone. As the formation pressure declines the stress around borehole changes, and then collapse pressure and fracture pressure are affected. Especially in directional wells, variation of wellbore stability is more complex with different borehole deviation and azimuth. The calculation models of collapse and fracture pressure in depleted reservoirs were established, and relevant data in unconsolidated sand reservoir of an oilfield in Bohai Sea was used to calculate collapse pressure and fracture pressure of directional wells in the condition of pressure depletion before and after. The results showed that collapse and fracture pressure decreased as formation pressure depletion, and safe drilling fluid density window was wider when drilled to the direction of minimum horizontal principle stress. The calculation results can be reference to drilling design of adjustment wells in unconsolidated sandstones.
Outputs	Tan et al. (2013). Study on borehole stability of unconsolidated sandstone in depleted reservior. *Sustainable Development of Natural Resources, Pts 1-3.* Stafa-Zurich: Trans Tech Publications Ltd.
Key personnel	Tan, Q.; Deng, J.G.; Yu, B.H.
Contact	[Tan, Qiang; Deng, Jingen; Yu, Baohua] China Univ Petr, State Key Lab Petr Resource & Prospecting, Beijing, Peoples R China.
Research themes	Well integrity
Project information source	Literature

Table 4.135 Project 135: Borehole stability analysis and its application in Xujiahe Formation of ZJ Block

Project characteristics	Details
Project title	**Borehole stability analysis and its application in Xujiahe Formation of ZJ Block**
Project location	China
Principal investigator	Su, K.H.; Liu, H.; Wang, J.
Lead institution	Chongqing Univ Sci & Technol, Chongqing
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The mainly borehole problems are sticking (collapse) and circulation loss in Xujiahe formation of ZJ block, so the drilling rate is very low. In order to improve the penetration of rate of ZJ block, the rock mechanical test method, ground stress test method, well history statistics method, and logging data analysis method were adopted. The borehole stability mechanism of xujiahe formation was analyzed. Combined with the drilling fluid experimental evaluation, the measures of improve wellbore stability of xujiahe formation was Proposed. Field application tests show that, the borehole problems and its processing time are greatly reduced using those proposed measures. The penetration of rate in the Xujiahe formation of test well increased 20-30%, and the application effect is obvious.
Outputs	Su et al. (2012). Borehole stability analysis and its application in Xujiahe Formation of ZJ Block. *Natural Resources and Sustainable Development Ii, Pts 1-4.* Stafa-Zurich: Trans Tech Publications Ltd.
Key personnel	Su, K.H.; Liu, H.; Wang, J.
Contact	[Su, Kanhua; Liu, Hong; Wang, Jun] Chongqing Univ Sci & Technol, Chongqing, Peoples R China.
Research themes	Well integrity
Project information source	Literature

Table 4.136 Project 136: Wellbore stability analysis of coal seam based on Hoek-Brown Criterion

Project characteristics	Details
Project title	**Wellbore stability analysis of coal seam based on Hoek-Brown Criterion**
Project location	China
Principal investigator	Yang, H.L.; Tian, Z.L.; Zhang, L.S.; Yan, X.Z.
Lead institution	CNPC Drilling Res Inst, Coal Bed Methane & Storage Cavern Engn Dept, Beijing
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Stable evaluation of coal strength is needed in coal well-bore stability analysis. The regular analysis method of wellbore stability adopts Mohr-Coulomb strength criteria to judge the collapse pressure. Coal is dual porosity structure and contains joint fissures richly. Hoek-Brown criterion is much more reasonable to estimate the strength of jointed and fractured rock. So Hoek-Brown criterion is used to analyze the stability of multi-lateral horizontal coal bed methane well. Considering the GSI (geological strength index), structural and surface conditions of coal, the coal and rock mass strength parameters are converted into the underground coal mechanical parameters based on the triaxial test of intact coal. According to the stress state of multi-lateral horizontal well, the borehole collapse formulas are established based on Hoek-Brown Criterion. The effects on the wellbore stability, due to the joint fissures of coal, borehole size, drilling disturbance, are also discussed in this paper.
Outputs	Yang et al. (2012). Wellbore stability analysis of coal seam based on Hoek-Brown criterion. *Manufacturing Science and Technology, Pts 1-8.* Stafa-Zurich: Trans Tech Publications Ltd. http://www.scientific.net/AMR.383-390.3882.pdf
Key personnel	Yang, H.L.; Tian, Z.L.; Zhang, L.S.; Yan, X.Z.
Contact	[Yang, Heng-lin; Tian, Zhong-lan] CNPC Drilling Res Inst, Coal Bed Methane & Storage Cavern Engn Dept, Beijing 100195, Peoples R China.
Research themes	Well integrity, hydraulic fracturing
Project information source	Literature

Table 4.137 Project 137: Discrete element model for coal wellbore stability

Project characteristics	Details
Project title	**Discrete element model for coal wellbore stability**
Project location	China
Principal investigator	Zhao, Haifeng; Chen, Mian; Li, Yawei; Zhang, Wei
Lead institution	Department of Petroleum Engineering, China University of Petroleum, Beijing 102249, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Coal-bed methane (CBM) is a significant component of unconventional natural gas production. As the world's natural gas demand grows substantially over the next two decades, CBM exploration and development will become increasingly important for ensuring adequate natural gas supplies. To maximize the production of CBM in some complicated geological settings, it is becoming a common practice to drill directional and horizontal wells in coal-beds; because of the special mechanical properties of the often fractured coal, the wells are prone to wellbore instability problems induced by drilling, completion and production operations [1], [2], [3] and [4]. Coal-bed is characterized by its natural cleat network, anisotropy with regard to permeability, brittle and mechanically weak property. The mechanism of wellbore instability in coal-bed is very different from that in conventional sandstone formations; traditional wellbore stability models do not account for the special mechanical properties of fractured coal-bed, and thus they often produce erroneous predictions [5], [6] and [7]. In this study, a new wellbore stability model for highly-cleated coalbed is proposed. In this model, a coalbed is divided into discrete elements by the network of face and butt cleats, stress analysis is done on the elements prone to collapse and an element analysis model for collapse pressure is established through equilibrium condition of stresses. With this model, the relation between borehole pressure and wellbore stability is discussed, mud weight window to ensure safe drilling is determined. This model also considers the size effect of wellbores on wellbore stability.
Outputs	Zhao et al. (2012). Discrete element model for coal wellbore stability. *International Journal of Rock Mechanics and Mining Sciences (1997).* Elsevier, Oxford-New York.
Key personnel	Zhao, Haifeng; Chen, Mian; Li, Yawei; Zhang, Wei
Research themes	Well integrity
Project information source	Literature

Table 4.138 Project 138: Analysis of failure criterions on wellbore stability prediction

Project characteristics	Details
Project title	**Analysis of failure criterions on wellbore stability prediction**
Project location	China
Principal investigator	Feng, Y.; Deng, J.; Li, X.; Wei, B.
Lead institution	MOE Key Laboratory of Petroleum Engineering, China University of Petroleum, Beijing 102249, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Wellbore collapse is mostly caused by the shear failure of the rock around borehole. One of the key considerations on wellbore stability prediction is the choice of shear failure criterion. The commonly used Mohr-Coulomb and Drucker-Prager failure criterions have obvious shortcomings, which leads to the unrealistic predicting results. Therefore, a new failure criterion, Mogi-Coulomb criterion, is introduced in this paper. The advantage of this criterion is that it properly evaluates the effect of intermediate principal stress on rock strength, thus it has more accurate prediction result. In order to present its advantage, the prediction results of rock strength predicted by the three criterions above are compared based on true triaxial test data. The results indicate that, under true triaxial stress state, it is more precise to predicate rock strength using the Mogi-Coulomb criterion rather than using the Mogi-Coulomb and Drucker-Prager failure criterions. In view of the advantages of the Mogi-Coulomb criterion, such as simple expression, easy to use and high prediction accuracy, it is highly recommended to use the shear failure criterion in the analysis of future wellbore stability.
Outputs	Feng et al. (2012). Analysis of failure criterions on wellbore stability prediction. *Duankuai Youqitian (Fault-Block Oil & Gas Field).* Duankuai Youqitian Qikanshe.
Key personnel	Feng, Y.; Deng, J.; Li, X.; Wei, B.
Contact	MOE Key Laboratory of Petroleum Engineering, China University of Petroleum, Beijing 102249, China
Research themes	Well integrity
Project information source	Literature

Table 4.139 Project 139: Study on borehole stability in Haita Basin

Project characteristics	Details
Project title	**Study on borehole stability in Haita Basin**
Project location	China
Principal investigator	Sun, Y.X.; Xie, J.B.; Zhao, J.Y.
Lead institution	NE Petr Univ, Dept Petr Engn, Daqing
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The geological structure is very complex in Haita Basin, due to the difficult drilling, sidewall instability phenomena happened frequently during drilling process. And it has restricted the drilling speed and the development and exploration process seriously. According to the borehole collapse problems, physical and chemical properties experiment of mud shale had been operated, then we analyzed and predicted borehole stability of Haita Basin by experimental data, discussed the collapse mechanism in this area, and established corresponding countermeasures to prevent the collapse which has laid a good foundation for further research on key drilling technology and improving drilling rate in Haita Basin.
Outputs	Sun et al. (2012). Study on borehole stability in Haita Basin. *Materials and Computational Mechanics, Pts 1-3.* Stafa-Zurich: Trans Tech Publications Ltd.
Key personnel	Sun, Y.X.; Xie, J.B.; Zhao, J.Y.
Contact	[Sun, Yuxue; Xie, Jianbo; Zhao, Jingyuan] NE Petr Univ, Dept Petr Engn, Daqing, Peoples R China.
Research themes	Well integrity
Project information source	Literature

Table 4.140 Project 140: Effect of pore pressure variation on borehole stability of drilling in sandstone reservoir

Project characteristics	Details
Project title	**Effect of pore pressure variation on borehole stability of drilling in sandstone reservoir**
Project location	China
Principal investigator	Li, Y.W.; Liu, J.; Hu, C.Y.; Li, S.; Liu, Y.
Lead institution	Northeast Petr Univ, Educ Minist, Key Lab Enhanced Oil & Gas Recovery, Daqing
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Considering pore pressure variation of sidewall rock, which is caused by drilling fluid filtering, the porosity variation model of sidewall rock in sandstone reservoir and effective stress factor variation model are established, and according to relationship between pore pressure and total volume strain of sandstone, the calculation model of safe window of drilling fluid density on sandstone reservoir, with which considered variation of porosity and effective stress factor are finally established. Applying the calculation of this model shows that: with increased function of drilling fluid filtering, which is as increased as pore pressure of sidewall rock, caving pressure that ensures well hole stability is increased, fracturing pressure is decreased, safe window of drilling fluid is narrowing, and that is against of safety drilling.
Outputs	Li et al. (2012). Effect of pore pressure variation on borehole stability of drilling in sandstone reservoir. *Energy Material, Chemical Engineering and Mining Engineering.* Stafa-Zurich: Trans Tech Publications Ltd.
Key personnel	Li, Y.W.; Liu, J.; Hu, C.Y.; Li, S.; Liu, Y.
Contact	[Li, Yuwei; Hu, Chaoyang; Li, Shuang; Liu, Yu] Northeast Petr Univ, Educ Minist, Key Lab Enhanced Oil & Gas Recovery, Daqing 163318, Peoples R China.
Research themes	Well integrity
Project information source	Literature

4.5.3 United States

Table 4.141 Project 141: Environmental risk arising from well construction failure: Difference between barrier and well failure, and estimates of failure frequency across common well types, locations and well age

Project characteristics	Details
Project title	**Environmental risk arising from well construction failure: Difference between barrier and well failure, and estimates of failure frequency across common well types, locations and well age**
Project location	US
Principal investigator	King, George E.; King, Daniel E.
Lead institution	Apache Corporation
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Do oil and gas wells leak to the environment? The great majority of wells do not pollute. The purpose of this paper is to explain basic concepts of well construction and illustrate differences between single barrier failure in multiple barrier well design and outright well integrity failure that could lead to pollution, using published investigations and reviews from data sets of over 600 000 wells worldwide. For US wells, while individual barrier failures (containment maintained and no pollution indicated) in a specific well group may range from very low to several percent (depending on geographical area, operator, era, well type and maintenance quality), actual well integrity failures are very rare. Well integrity failure is where all barriers fail and a leak is possible. True well integrity failure rates are two to three orders of magnitude lower than single barrier failure rates. When a series of barriers fail and a leak path is formed, gas is the most common fluid lost. Common leak points are failed gaskets or valves at the surface and are easily and quickly repaired. If the failure is subsurface, an outward leak is uncommon due to lower pressure gradient in the well than in outside formations. Subsurface leaks in oil wells are rare and are routinely exterior formation salt water leaking into the well towards the lower pressure in the well. Failure frequency numbers are estimated for wells in several specific sets of environmental conditions (location, geologic strata, produced fluid composition, soils, etc.). Accuracy of these numbers depends on a sufficient database of wells with documented failures, divided into: 1) barrier failures in a multiple barrier system that do not create pollution, and 2) well integrity failures that create a leak path, whether or not pollution is created. Estimated failure frequency is only for a specific set of wells operating under the same conditions with similar design and construction quality. Well age and era of construction are variables. There is absolutely no one-size-fits-all well failure frequency. © 2013. Society of Petroleum Engineers.
Outputs	King and King. (2013). Environmental risk arising from well construction failure: Difference between barrier and well failure, and estimates of failure frequency across common well types, locations and well age. *SPE Annual Technical Conference and Exhibition, ATCE 2013, September 30, 2013 - October 2,*

Project characteristics	Details
	2013. New Orleans, LA, United states: Society of Petroleum Engineers (SPE).
Key personnel	King, George E.; King, Daniel E.
Contact	Apache Corporation, United States
Research themes	Well integrity
Project information source	Literature

Table 4.142 Project 142: Identifying well contamination through the use of 3-D fluorescence spectroscopy to classify coalbed methane produced water

Project characteristics	Details
Project title	**Identifying well contamination through the use of 3-D fluorescence spectroscopy to classify coalbed methane produced water**
Project location	US
Principal investigator	Dahm, K.G.; Van Straaten, C.M.; Munakata-Marr, J.; Drewes, J.E.
Lead institution	Department of Civil and Environmental Engineering, Colorado School of Mines, Golden
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Production of unconventional gas resources commonly requires the use of hydraulic fracturing and chemical production well additives. Concern exists for the use of chemical compounds in gas wells due to the risk of groundwater contamination. This study focuses on a proposed method of identifying groundwater contamination from gas production. The method focuses on the classification of naturally occurring organic signatures of coalbed methane (CBM) produced water compared to anthropogenic organic compounds. The 3-D fluorescence excitation-emission matrix (EEM) spectra of coalbed methane produced water samples revealed four peaks characteristic of coalbed methane produced water: Peak P (aromatic proteins region), Peak M(1) (microbial byproducts region), Peak M(2) (microbial byproducts region), and Peak H (humic acid-like region). Peak H is characteristic of the coal-water equilibria present in all basins, while peaks P and M(2) correlate with microbial activity in basins with biogenic methane generation pathways. Anthropogenic well additives produce EEM signatures with notable flooding of peaks P, M(1), M(2), and H, relatively higher overall fluorescence intensity, and slightly higher DOC concentrations. Fluorescence spectroscopy has the potential to be used in conjunction with groundwater contamination studies to determine if detected organic compounds originate from naturally occurring sources or well production additives.
Outputs	Dahm et al. (2013). Identifying well contamination through the use of 3-D fluorescence spectroscopy to classify coalbed methane produced water. *Environ Sci Technol*. http://www.ncbi.nlm.nih.gov/pubmed/23198677
Key personnel	Dahm, K.G.; Van Straaten, C.M.; Munakata-Marr, J.; Drewes, J.E.
Contact	Department of Civil and Environmental Engineering, Colorado School of Mines, Golden, Colorado 80401-1887, United States
Research themes	Hydraulic fracturing, water dependent ecosystems
Project information source	Literature

Table 4.143 Project 143: Modeling reveals hidden conditions that can impair wellbore stability and integrity

Project characteristics	Details
Project title	**Modeling reveals hidden conditions that can impair wellbore stability and integrity**
Project location	US
Principal investigator	Sweatman, Robert; Young, Ronald
Lead institution	Halliburton, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	This paper describes thermal modeling and its combination with drilling fluid analysis to reveal concealed changes in well conditions during various drilling and completion operations. These hidden conditions represent significant changes in the well's drilling and completion fluid temperature, pressure, and density (FTPD) that may help explain wellbore stability and integrity issues. For example, the model results may allow operators to look for FTPD-related wellbore stability issues where the hole is not circulated and is static for many hours. Deeper wells and those with greater differences between induced and natural temperature and pressure conditions may have dangerous conversions of pressure over-balances into under-balances that can cause pore fluid influx, cross-flow, collapse, and other severe wellbore failures. Long, deep holes that are being circulated may also be modeled to look for FTPD-related issues not revealed by other means. Conditions such as over-balanced pressure and stable rock conditions may actually change to under-balanced pressure and unstable rock conditions with consequences including kicks, solids beds from formation breakouts, flow after cementing, stuck pipe by hole collapse, salt creep acceleration, etc. A case history is discussed where the prototype model correctly predicted that no formation gas influx would occur during a long static period. A nearby well with similar open-hole conditions experienced a blowout during the same static time period. A comparison of the well's annular pressure measurements to the model's predictions indicated that the pressure changes were thermally induced and were not from a formation pore-pressure source. When the annular pressures subsided as predicted, no gas was found in the annulus. Studies will continue to test the FTPD model in different types of wells, well conditions, and applications for drilling and completion operations, and the prototype model may be modified accordingly. © 2013, SPE/IADC Drilling Conference and Exhibition.
Outputs	Sweatman and Young. (2013). Modeling reveals hidden conditions that can impair wellbore stability and integrity. *SPE/IADC Drilling Conference and Exhibition 2013, March 5, 2013 - March 7, 2013.* Amsterdam, Netherlands: Society of Petroleum Engineers (SPE).
Key personnel	Sweatman, Robert; Young, Ronald
Contact	Halliburton, United States
Research themes	Well integrity

Project characteristics	Details
Project information source	Literature

Table 4.144 Project 144: What are we going to do with all these wells then?

Project characteristics	Details
Project title	**What are we going to do with all these wells then?**
Project location	US
Principal investigator	Cramer, Ron
Lead institution	Shell
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Advances in drilling technology (e.g. fracing, horizontal wells) has led to successful development of onshore shale gas, tight gas, coal bed methane, shale oil and burgeoning well numbers. Some Majors have indicated that they will drill up to 20 000 new wells by the end of the decade. To achieve well numbers and cope with the work load and manpower shortages, drilling automation technologies are being introduced that will allow multiple rigs to be operated remotely and downmanned. It is premised that well production operations will also have to be automated to cope with increasing work load as resource will not be available to operate these wells in the traditional, manual way. Associated production processes that will have to be automated include, well surveillance/optimization, well testing, sampling, chemical injection and hydrocarbon accounting. It is desirable to bring the wells onstream as soon as possible after drilling and to maintain production rates at as high a level as possible and to simultaneously account for production of oil, gas and water. It also is imperative to ensure the highest level of safety and environmental factors. Hence, the purpose of this paper is to describe well automation business requirements/benefits and potential system solutions to optimize production over the life cycle for the ever increasing number of onshore wells that will be drilled in the near future. © 2013, Society of Petroleum Engineers.
Outputs	Cramer. (2013). What are we going to do with all these wells then? *SPE Digital Energy Conference and Exhibition 2013, March 5, 2013 - March 7, 2013.* The Woodlands, TX, United states: Society of Petroleum Engineers.
Key personnel	Cramer, Ron
Contact	Shell, United States
Research themes	Hydraulic fracturing, water supplies
Project information source	Literature

Table 4.145 Project 145: Historical analysis of oil and gas well plugging in New York: Is the regulatory system working?

Project characteristics	Details
Project title	**Historical analysis of oil and gas well plugging in New York: Is the regulatory system working?**
Project location	US
Principal investigator	Bishop, Ronald E.
Lead institution	Youngstown State University
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The aim of this work is to evaluate New York State's regulatory program for plugging inactive oil and gas wells.
Outputs	Bishop. (2013). Historical Analysis of Oil and Gas Well Plugging in New York: Is the Regulatory System Working? : Youngstown State University. http://baywood.metapress.com/link.asp?id=b047j34r87552325
Key personnel	Bishop, Ronald E.
Research themes	Well integrity, water supplies
Project information source	Literature

4.6 Hydraulic fracturing

Hydraulic fracturing during coal seam gas operations may impact water resources and water dependent ecosystems. Research in this area includes the effects of fracking chemicals on surface and groundwater quality, and the physical impacts of fracking such as aquitard disruption and borehole collapse.

Though many projects were identified relating to hydraulic fracturing, only five projects were identified with the primary theme of the water impacts of hydraulic fracturing from coal seam gas. Projects regarding hydraulic fracturing for shale gas developments were considered to be out of the scope of this project; however, it is acknowledged that much of the research regarding shale gas may be relevant.

4.6.1 Australia

Table 4.146 Project 146: Environmental regulation of hydraulic fracturing in Queensland

Project characteristics	Details
Project title	**Environmental regulation of hydraulic fracturing in Queensland**
Project location	Australia
Principal investigator	Campin, David
Lead institution	Queensland Department of Environment and Heritage Protection, Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Since the late 1990s, coalbed methane (CBM) has grown to be a significant part of the Queensland economy, building alongside the world-scale coal export operations. Environmental regulation in Queensland, over the same period, has become highly integrated with petroleum activities following a unified mineral rights/land tenure and environmental permitting process. Development of environmental regulation of CBM evolved with the sector as industry-specific issues became evident. Following the announcement around 2008 of a number of multi-billion dollar LNG export projects with upwards of 40 000 wells, attention by interest groups and the public at large, gave rise to increased scrutiny by regulators of the scope of prevailing rules. Environmental regulation in Australia is largely state-based with nationally agreed guidelines adopted for various media (air quality, receiving water, drinking water, etc). In respect to the environmental aspects of CBM development, a National Framework has been recently agreed to, identifying performance principles including hydraulic fracturing, however the details will be developed and regulated by the states. This paper presents information supporting the chain evidence leading to a revision of the Queensland regulations that is expected to be completed and approved in the middle of 2014 following industry and public consultation and peer review. © 2013, Society of Petroleum Engineers.
Outputs	Campin. (2013). Environmental regulation of hydraulic fracturing in Queensland. *SPE Annual Technical Conference and Exhibition, ATCE 2013,*

Project characteristics	Details
	September 30, 2013 - October 2, 2013. New Orleans, LA, United states: Society of Petroleum Engineers (SPE).
Key personnel	Campin, David
Contact	Queensland Department of Environment and Heritage Protection, Australia
Research themes	Hydraulic fracturing
Project information source	Literature

4.6.2 Canada

Table 4.147 Project 147: Link between rocks, hydraulic fracturing, economics, environment, and the global gas portfolio

Project characteristics	Details
Project title	**Link between rocks, hydraulic fracturing, economics, environment, and the global gas portfolio**
Project location	Canada
Principal investigator	Aguilera, Roberto F.; Ripple, Ronald D.; Aguilera, Roberto
Lead institution	Centre for Research in Energy and Mineral Economics (CREME), Curtin University, Canada
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	This paper presents a methodology for connecting geology, hydraulic fracturing, economics, environment and the global natural gas endowment in conventional, tight, shale and coalbed methane (CBM) reservoirs. The volumetric estimates are generated by a variable shape distribution model (VSD). The VSD has been shown in the past to be useful for the evaluation of conventional and tight gas reservoirs. However, this is the first paper in which the method is used to also include shale gas and CBM formations. Results indicate a total gas endowment of 70 000 tcf, split between 15 000 tcf in conventional reservoirs, 15 000 tcf in tight gas, 30 000 tcf in shale gas and 10 000 tcf in CBM reservoirs. Thus, natural gas formations have potential to provide a significant contribution to global energy demand estimated at approximately 790 quads by 2035. A common thread between unconventional formations is that nearly all of them must be hydraulically fractured to attain commercial production. A significant volume of data indicates that the probabilities of hydraulic fracturing (fracking) fluids and/or methane contaminating ground water through the hydraulically-created fractures are very low. Since fracking has also raised questions about the economic viability of producing unconventional gas in some parts of the world, supply cost curves are estimated in this paper for the global gas portfolio. The curves show that, in some cases, the costs of producing gas from unconventional reservoirs are comparable to those of conventional gas. The conclusion is that there is enough natural gas to supply the energy market for nearly 400 years at current rates of consumption and 110 years with a growth rate in production of 2% per year. With appropriate regulation, this may be done safely, commercially, and in a manner that is more benign to the environment as compared with other fossil fuels. © 2012, Society of Petroleum Engineers.
Outputs	Aguilera et al. (2012). Link between rocks, hydraulic fracturing, economics, environment, and the global gas portfolio. *SPE Canadian Unconventional Resources Conference 2012, CURC 2012, October 30, 2012 - November 1, 2012.* Calgary, AB, Canada: Society of Petroleum Engineers.
Key personnel	Aguilera, Roberto F.; Ripple, Ronald D.; Aguilera, Roberto

Project characteristics	Details
Contact	Centre for Research in Energy and Mineral Economics (CREME), Curtin University, Canada
Research themes	Hydraulic fracturing
Project information source	Literature

4.6.3 China

Table 4.148 Project 148: Effect of interface defects on shear strength and fluid channeling at cement-interlayer interface

Project characteristics	Details
Project title	**Effect of interface defects on shear strength and fluid channeling at cement-interlayer interface**
Project location	China
Principal investigator	Gu, J.; Zhong, P.; Shao, C.; Bai, S.H.; Zhang, H.; Li, K.
Lead institution	China University of Geoscience, Faculty of Earth Resources, Wuhan
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The fluid channeling during hydraulic fracturing has been seriously restricting the efficient development of low permeability oilfield and CBM Field. The occurrence of fluid channeling after hydraulic fracturing is hinged on shear strength at cement-interlayer interface (CII) and hydraulic fracturing pressure. Interface defects are key factors that influence the shear strength at CII. In view of this, the influence of interface defects on shear strength at CII and fluid channeling is discussed in this paper. The formation reasons of interface defects are analyzed firstly. Based on analysis of the essence of shear strength at CII, it is concluded that all interface defects amount to the missing amount of mud cake ring. Then a mathematical model between missing amount of mud cake ring and shear strength at CII is developed. In order to verify the accuracy of the model, a simulated experimental system is built. Based on the model and fluid channeling coefficient equation, a modified version of the fluid channeling coefficient is derived and the influence of interface defects on interlayer fluid channeling during hydraulic fracturing is evaluated quantitatively. The results revealed that the shear strength at CII decreases linearly with the increase of interface defects, and verification results show that the relative errors between calculated values by the model and experimental values are less than 10%. From the modified equation of the fluid channeling coefficient, this paper established a typical exponential relationship between missing amount of mud cake ring and fluid channeling coefficient, which indicates that interface defects drastically affect fluid channeling at CII. © 2012 Elsevier B.V. All rights reserved.
Outputs	Gu et al. (2012). Effect of interface defects on shear strength and fluid channeling at cement-interlayer interface. *Journal of Petroleum Science and Engineering*.
Key personnel	Gu, J.; Zhong, P.; Shao, C.; Bai, S.H.; Zhang, H.; Li, K.
Contact	[Gu, Jun; Zhong, Pei; Shao, Chun; Bai, Shaohui; Zhang, Hui; Li, Ke] China Univ Geosci, Fac Earth Resources, Wuhan 430074, Hubei, Peoples R China.
Research themes	Hydraulic fracturing

Project characteristics	Details
Project information source	Literature

4.6.4 United States

Table 4.149 Project 149: Community-based risk assessment of water contamination from high-volume horizontal hydraulic fracturing

Project characteristics	Details
Project title	**Community-based risk assessment of water contamination from high-volume horizontal hydraulic fracturing**
Project location	US
Principal investigator	Penningroth, Stephen M.; Yarrow, Matthew M.; Figueroa, Abner X.; Bowen, Rebecca J.; Delgado, Soraya
Lead institution	Community Science Institute, Great Wilderness, Department of Neurology (UT Southwestern Medical Center)
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The nonprofit Community Science Institute (CSI) partners with community volunteers who perform regular sampling of more than 50 streams in the Marcellus and Utica Shale regions of upstate New York; samples are analysed for parameters associated with HVHHF. Similar baseline data on regional groundwater comes from CSI's testing of private drinking water wells. Analytic results for groundwater (with permission) and surface water are made publicly available in an interactive, searchable database.
Outputs	Penningroth et al. (2013). *Community-based risk assessment of water contamination from high-volume horizontal hydraulic fracturing.* Community Science Institute, Great Wilderness, Department of Neurology (UT Southwestern Medical Center). http://baywood.metapress.com/link.asp?id=d78247089265226j
Key personnel	Penningroth, Stephen M.; Yarrow, Matthew M.; Figueroa, Abner X.; Bowen, Rebecca J.; Delgado, Soraya
Research themes	Co-produced/mine water, water supplies, water dependent ecosystems
Project information source	Literature

Table 4.150: Project 150: History and development of effective regulation of hydraulic fracturing; the genesis of Colorado Rule 205A

Project characteristics	Details
Project title	**History and development of effective regulation of hydraulic fracturing; the genesis of Colorado Rule 205A**
Project location	US
Principal investigator	Peiserich, John F.
Lead institution	Perkins Trotter
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Hydraulic fracturing (HF) was first conducted in the late 1940's--the first experimental well in the Hugoton gas field in Grant County, KS (1947) and the first two commercial fracturing treatments--one in Stephens County, OK and the other in Archer County, TX both on March 17, 1949. Since that time it is estimated that more than 1 000 000 HF treatments have been performed. It has been estimated that HF has increased US recoverable reserves of oil by at least 30% and of gas by 90%. The Safe Drinking Water Act (SDWA) (1974) and its amendments (1986 and 1996) never addressed HF. In between, the Legal Environmental Assistance Foundation (LEAF) petitioned EPA to withdraw approval of the Alabama UIC program. The EPA declined to do so stating that EPA does not and never has regulated HF. In 1997 the 11 (super th) Circuit Court of Appeals requires EPA to regulate HF (re: coalbed methane (CBM)) based on LEAF petition. In 2001, the Court approved the Alabama UIC program as complying with SDWA and, thus, allowed HF to continue. The court activity resulted in legislation--the Inhofe-Sessions Bill and the 2003 Energy Bill--neither of which passed. In 2004 EPA conducted an extensive study of HF. Based on the study, EPA concluded that the injection of HF fluids into CBM wells poses little threat to United States Drinking Water. Finally, the Energy Policy Act of 2005 amended the SDWA changing the definition of underground injection to exclude HF as long as diesel fuel isn't used as the carrier fluid. Since 2005, regulation of HF has been left to the states. The state regulation of HF began with the development of resource plays. Since that time several states including Arkansas-January 2011, Wyoming-September 2010, and Colorado-December 2011 have developed regulations related to HF. The Colorado rule, the latest, is comprehensive and effectively provides information to the agency and the public while limiting the burden on industry and should serve a model for future regulation in other states. Colorado Rule 205A requires all operators to utilize a disclosure registry to disclose information about the well and well treatments performed including the chemicals used. The rule provides for trade secret protection with provisions for disclosure to health professionals. Other rules require notice to the landowner (Rule 305.E.(1) A) and to the Commission (Rule 316C).
Outputs	Peiserich. (2012). History and development of effective regulation of hydraulic fracturing; the genesis of Colorado Rule 205A. *Abstracts with Programs - Geological Society of America.* Geological Society of America (GSA), Boulder, CO, United States.

Project characteristics	Details
Key personnel	Peiserich, John F.
Contact	Perkins Trotter, Little Rock, AR, United States
Research themes	Hydraulic fracturing
Project information source	Literature

4.7 Quality and reliability of water supplies including environmental health

Coal seam gas and coal mining may impact the quality and reliability of water supplies both during operation and long after decommissioning. Research projects into this area include mine site and gas field remediation, the long term impacts of mines and coal seam gas operations, contamination due to chemical use and salt and heavy metal management.

Twenty-eight projects were collated with the primary theme of quality and reliability of water supplies; however, it is recognised that there is significant overlap with Section 4.2 (disruption of surface water flow pathways) and Section 4.3 (co-produced/mine water).

4.7.1 Australia

Table 4.151 Project 151: Opportunities and challenges to coal bed methane production in Australia

Project characteristics	Details
Project title	**Opportunities and challenges to coal bed methane production in Australia**
Project location	Australia
Principal investigator	Freij-Ayoub, Reem
Lead institution	Unknown
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	This paper highlights the factors controlling CBM production and focus on the opportunity and the challenges facing CBM production in Australia. In addition to a favourable government policy and gas market and the advancement in directional drilling technology, the paper analyses factors that impact CBM investment decisions.
Outputs	Freij-Ayoub. (2012). Opportunities and challenges to coal bed methane production in Australia. https://publications.csiro.au/rpr/pub?list=BRO&pid=csiro:EP122343&sb=RECENT&n=2&rpp=25&page=67&tr=188568&dr=all
Key personnel	Freij-Ayoub, Reem
Research themes	Water supplies
Project information source	Literature

Table 4.152 Project 152: Toxicity and eco-toxicity testing for stimulation chemicals and flowback waters

Project characteristics	Details
Project title	**Toxicity and eco-toxicity testing for stimulation chemicals and flowback waters**
Project location	Australia
Principal investigator	Unknown
Lead institution	QGC
Project budget	Unknown
Source of funding	QGC
Project duration	2013
Current status	Unknown
Project summary	QGC is collaborating with other proponents on an industry-level total effluent toxicity test program to assess the comparative hazard of pre-stimulation coal seam groundwater and flowback waters. QGC is also doing extensive work on the toxicity and ecotoxicity of individual fracturing agents.
Outputs	Unknown
Research themes	Hydraulic fracturing, water supplies
Project information source	UQ CCSG Online Portal

Table 4.153 Project 153: Ecological assessment of areas requiring remediation and stabilisation within East Wolgan and Narrow Swamps at Angus Place and Springvale Coal Mines, Newnes Plateau

Project characteristics	Details
Project title	**Ecological assessment of areas requiring remediation and stabilisation within East Wolgan and Narrow Swamps at Angus Place and Springvale Coal Mines, Newnes Plateau**
Project location	Australia
Principal investigator	RPS
Lead institution	RPS
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Unknown
Outputs	RPS. (2012). Ecological Assessment of Areas Requiring Remediation and Stabilisation within East Wolgan and Narrow Swamps at Angus Place and Springvale Coal Mines, Newnes Plateau. Prepared by RPS Australia East Pty Ltd for Centennial Springvale Pty Ltd. PR108767-1.
Key personnel	RPS
Research themes	Surface water, water supplies
Project information source	Literature

Table 4.154 Project 154: The potential impacts of coal seam gas on biodiversity

Project characteristics	Details
Project title	**The potential impacts of coal seam gas on biodiversity**
Project location	Australia
Principal investigator	Adams-Hosking, Christine; Erskine, Peter; McAlpine, Clive; Schoettker, Birte; Seabrook, Leonie; Williams, Elizabeth
Lead institution	School of Geography, Planning and Environmental Management (University of Queensland)
Project budget	Unknown
Source of funding	University of Queensland, Santos, QGC, Arrow Energy
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	This scoping study investigated the potential impacts of CSG infrastructure and operations on terrestrial biodiversity through: 1) a review of scientific and industry literature, 2) eliciting expert opinion, and 3) by analysis of remote sensing data through a case study. Our assessment of these sources revealed knowledge gaps and suggested priorities for research.
Outputs	Adams-Hosking et al. (2013). The potential impacts of coal seam gas on biodiversity. School of Geography, Planning and Environmental Management (University of Queensland).
Key personnel	Adams-Hosking, Christine; Erskine, Peter; McAlpine, Clive; Schoettker, Birte; Seabrook, Leonie; Williams, Elizabeth
Research themes	Water supplies
Project information source	Literature

Table 4.155 Project 155: The National Harmonised Regulatory Framework for natural gas from coal seams

Project characteristics	Details
Project title	**The National Harmonised Regulatory Framework for natural gas from coal seams**
Project location	Australia
Principal investigator	SCER
Lead institution	Standing Council on Energy and Resources
Project budget	Unknown
Source of funding	Standing Council on Energy and Resources
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The Standing Council on Energy and Resources (SCER) has endorsed a National Harmonised Regulatory Framework for Natural Gas from Coal Seams (the Framework). The Framework delivers on a commitment by Australian governments to put in place a suite of leading practice principles, providing guidance to regulators in the management of natural gas from coals seams and ensuring regulatory regimes are robust, consistent and transparent across all Australian jurisdictions. The Framework focuses on four key areas of operations which cover the lifecycle of development: well integrity, water management and monitoring, hydraulic fracturing and chemical use. Through this focus, the Framework provides assurance for communities and farmers that concerns in relation to protecting and managing both underground and surface water resources in particular are taken seriously by government and are being effectively regulated. The Framework does acknowledge that natural gas from coals seams is, and will continue to be into the future, an important component of eastern Australia's domestic gas supply. It also acknowledges that as the Queensland Liquefied Natural Gas (LNG) projects commence production from 2014-15; the industry will contribute substantial export income to Australia's economy and is already creating jobs and business opportunities in the rural and regional areas where development occurs. However, the Framework provides guidance in developing the regulatory tools required to ensure that this development is managed sustainably.
Outputs	SCER. (2013). The national harmonised regulatory framework for natural gas from coal seams. Standing Council on Energy and Resources,. http://www.scer.gov.au/workstreams/land-access/coal-seam-gas/
Key personnel	SCER
Research themes	Co-produced/mine water, well integrity, hydraulic fracturing, water supplies
Project information source	Literature

Table 4.156 Project 156: Literature review: coal seam gas impacts on water resources

Project characteristics	Details
Project title	**Literature review: coal seam gas impacts on water resources**
Project location	Australia
Principal investigator	Sydney Catchment Authority
Lead institution	Sydney Catchment Authority
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	This literature review has been prepared to provide the Sydney Catchment Authority (SCA) with a comprehensive summary of the Coal Seam Gas (CSG) fundamentals (occurrence, exploration, fracture stimulation, produced water quantity and quality), highlight major differences between existing CSG projects in different geological environments of the Great Artesian Basin in Queensland (Surat Basin) and the Sydney Basin (Camden) and assess potential impacts of CSG exploration in the SCA Special Areas.
Outputs	Sydney Catchment Authority. (2012). Literature review: coal seam gas impacts on water resources. http://www.water.nsw.gov.au/Water-management/Groundwater/Water-and-coal-seam-gas/Water-and-coal-seam-gas
Key personnel	Authority, Sydney Catchment
Contact	info@sca.nsw.gov.au
Research themes	Co-produced/mine water, water supplies
Project information source	Literature

Table 4.157 Project 157: Vulnerability of aquifers to coal seam gas water extraction

Project characteristics	Details
Project title	**Vulnerability of aquifers to coal seam gas water extraction**
Project location	Queensland, Australia
Principal investigator	WorleyParsons
Lead institution	Queensland Government Department of Environment and Resource Management
Project budget	This project was Activity 5 of the Healthy HeadWaters Coal Seam Gas Water Feasibility Study, which had a budget of $5 million from the Australian Government and in-kind support from the Queensland Government
Source of funding	Australian Government Water for the Future initiative
Project duration	Unknown – literature output March 2013
Current status	Complete
Project summary	This activity assessed the vulnerability of the aquifers of the Surat and southern Bowen basins to CSG industry development in the Walloon, Bandana and Baralaba coal measures. Its aim was to provide a better understanding of which aquifers are most vulnerable to, and at greatest risk of impacts from, CSG water extraction. Outputs of this activity are of value to the Office of Groundwater Impact Assessment in the review of its groundwater flow model to assess impacts of CSG water extraction in the cumulative management areas.
Outputs	http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-5
Research themes	Water supplies
Project information source	UQ CCSG Online Portal, Queensland Government website

4.7.2 China

Table 4.158 Project 158: Stable isotope and water quality analysis of coal bed methane produced water in the southern Qinshui Basin, China

Project characteristics	Details
Project title	**Stable isotope and water quality analysis of coal bed methane produced water in the southern Qinshui Basin, China**
Project location	China
Principal investigator	Pan, Jienan; Zhang, Xiaomin; Ju, Yiwen; Zhao, Yanqing; Bai, Heling
Lead institution	Henan Polytechnic University
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	China is one of the countries with the highest reserves of coal bed methane (CBM) in the world. Likewise, the CBM industry is significantly growing in China. However, activities related to CBM development have led to more environmental problems, which include serious environmental damage and pollution caused by CBM-produced water. In this paper, the detailed characteristics of CBM-produced water in the southern Qinshui Basin were investigated and analyzed and compared with local surface water and coal mine drainage. Most of CBM-produced water samples are contaminated by higher concentration of total dissolved solids (TDS), K (Potassium), Na (Sodium) and NH4. The alkalinity of the water from coalmines and CBM production was higher than that of the local surface water. The concentrations of some trace elements such as P (Phosphorus), Ti (Titanium), V (Vanadium), Cr (Chromium), Ni (Nickel), Zn (Zinc), Ge (Germanium), As (Arsenic), Rb (Rubidium), and Pd (Palladium) in water from the coalmines and CBM production are higher than the acceptable standard limits. The D and 18O values of the CBM-produced water are lower than those of the surface water. Similarly, the D values of the CBM-produced water decreased with increasing drainage time. © 2013 Techno-Press, Ltd.
Outputs	Pan et al. (2013). Stable isotope and water quality analysis of coal bed methane produced water in the southern Qinshui Basin, China. *Membrane Water Treatment.* P.O. Box 33 Yusong, Taejon, 305-600, Korea, Republic of: Techno Press. http://dx.doi.org/10.12989/mwt.2013.4.4.265
Key personnel	Pan, Jienan; Zhang, Xiaomin; Ju, Yiwen; Zhao, Yanqing; Bai, Heling
Contact	School of Resources And Environment, Henan Polytechnic University, Jiaozuo 454000, China
Research themes	Co-produced/mine water, water supplies
Project information source	Literature

Table 4.159 Project 159: Ecological restoration of abandoned mine land in China

Project characteristics	Details
Project title	**Ecological restoration of abandoned mine land in China**
Project location	China
Principal investigator	Hu, Zhenqi; Wang, Peijun; Li, Jing
Lead institution	Institute of Land Reclamation and Ecological Restoration, China University of Mining and Technology (Beijing), Beijing 100083, China
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Unknown
Outputs	Hu et al. (2012). Ecological restoration of abandoned mine land in China. *Journal of Resources and Ecology*.
Key personnel	Hu, Zhenqi; Wang, Peijun; Li, Jing
Research themes	Surface water, water supplies, water dependent ecosystems
Project information source	Literature

Table 4.160 Project 160: Variational characteristics of water quality of produced formation water in coalbed methane production area

Project characteristics	Details
Project title	**Variational characteristics of water quality of produced formation water in coalbed methane production area**
Project location	China
Principal investigator	Liu, Hui Hu; Sang, Shu Xun; Xu, Hong Jie; Liu, Shi Qi
Lead institution	School of Earth and Environment, Anhui University of Science and Technology
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The produced formation water samples and the stored water samples of the tanks in coalbed methane production area were sampled, and their pH, the ion concentration were tested, the variational characteristics of pH, the distribution and the variation with time of the ion concentration, the variational characteristics of the salinity and the conductivity from the produced formation water and the water of the tanks were discussed in order to investigate the variational characteristics of water quality of the proudced formation water in coalbed methane production area. The results show that the produced formation water are alkalescent, the pH of the produced formation water and the stored water in the tanks are near to or beyond the maximum of Chinese irrigation water quality standards. The anions of the produced formation water are mainly HCO3-and Cl-, the ion concentration haven't dearease effectively during the discharge of the produced formation water, the concentration of Cl- in the produced formation water and the stored water of the tanks from the partial coalbed methane wells is beyond the limit of the national standards. The salinity of the produced formation water and the stored water of the tanks are between 1500 mg/L and 2000 mg/L, and they are between the maximum of the non-saline areas and the maximum of the saline area according to Chinese irrigation water quality standards. The total hardness and the conductivity of the produced formation water and the stored water of the tanks in coalbed methane production area are relatively low, and they can meet the national discharged standard of sewage. © (2013) Trans Tech Publications, Switzerland.
Outputs	Liu et al. (2013). Variational characteristics of water quality of produced formation water in coalbed methane production area. *2013 2nd International Conference on Energy and Environmental Protection, ICEEP 2013, April 19, 2013 - April 21, 2013.* Guilin, China: Trans Tech Publications Ltd.
Key personnel	Liu, Hui Hu; Sang, Shu Xun; Xu, Hong Jie; Liu, Shi Qi
Contact	School of Earth and Environment, Anhui University of Science and Technology, Huainan, Anhui 232001, China
Research themes	Water supplies
Project information source	Literature

Table 4.161 Project 161: Hydrogeochemical evolution of Ordovician limestone groundwater in Yanzhou, North China

Project characteristics	Details
Project title	**Hydrogeochemical evolution of Ordovician limestone groundwater in Yanzhou, North China**
Project location	China
Principal investigator	Han, Yong; Wang, Guangcai; Cravotta, Charles A.; Hu, Weiyue; Bian, Yueyue; Zhang, Zongwen; Liu, Yuanyuan
Lead institution	School of Water Resources and Environment, China University of Geosciences
Project budget	Unknown
Source of funding	Fundamental Research Funds for the Central Universities of China (No. 53200959016), the National Basic Research Program of China (973 Program) (No. 2006CB202205) and NSFC (No. 40930637)
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Major-ion compositions of groundwater are employed in this study of the water–rock interactions and hydrogeochemical evolution within a carbonate aquifer system. The groundwater samples were collected from boreholes or underground tunnels in the Ordovician limestone of Yanzhou Coalfield where catastrophic groundwater inflows can be hazardous to mining and impact use of the groundwater as a water supply. The concentration of total dissolved solid (TDS) ranged from 961 to 3555?mg/l and indicates moderately to highly mineralized water. The main water-type of the middle Ordovician limestone groundwater is Ca-Mg-SO4, with SO42- ranging from 537 to 2297?mg/l, and average values of Ca2+ and Mg2+ of 455.7 and 116.6?mg/l, respectively. The water samples were supersaturated with respect to calcite and dolomite and undersaturated or saturated with respect to gypsum. Along the general flow direction, deduced from increases of TDS and Cl-, the main water–rock interactions that caused hydrogeochemical evolution of the groundwater within the aquifer were the dissolution of gypsum, the precipitation of calcite, the dissolution or precipitation of dolomite, and ion exchange. Ion exchange is the major cause for the lower mole concentration of Ca2+ than that of SO42-. The groundwater level of Ordovician aquifer is much higher than that of C-P coal-bearing aquifers, so the potential flow direction is upward, and the pyrite in coal is not a possible source of sulfate; additional data on the stable sulfur and oxygen isotopic composition of the sulfate may be helpful to identify its origin. Although ion exchange probably accounts for the higher mole concentration of Na+ than that of Cl-, the dissolution of aluminosilicate cannot be ruled out. The data evaluation methods and results of this study could be useful in other areas to understand flow paths in aquifers and to provide information needed to identify the origin of groundwater. © © 2012 John Wiley & Sons, Ltd.
Outputs	Han et al. (2013). Hydrogeochemical evolution of Ordovician limestone groundwater in Yanzhou, North China. *Hydrological Processes*. http://dx.doi.org/10.1002/hyp.9297
Key personnel	Han, Yong; Wang, Guangcai; Cravotta, Charles A.; Hu, Weiyue; Bian, Yueyue; Zhang, Zongwen; Liu, Yuanyuan
Research themes	Aquifer interconnectivity, water supplies

Project characteristics	Details
Project information source	Literature

4.7.3 India

Table 4.162 Project 162: Assessment of water quality around surface coal mine in India

Project characteristics	Details
Project title	**Assessment of water quality around surface coal mine in India**
Project location	India
Principal investigator	Shinde, V.; Nandgude, S.B.; Singh, M.
Lead institution	Unknown
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The present study highlights techniques to identify suitability of water for different purposes such as domestic, irrigation and industrial uses. Water samples from Olidih watershed in Jharia coalfield were collected in premonsoon (PRM) and post-monsoon (POM) seasons and analysed for different physico-chemical properties. Water Quality Index (WQI), Sodium Adsorption Ratio (SAR), percent sodium (%Na) and total hardness (TH) weredetermined on the basis of various physico-chemical parameters in order to ascertain the suitability of water for domestic, irrigation and industrial uses. The WQI for the study area found to vary from 23.86 to 166.72 in PRM season and from 22.14 to 146.44 in POM season. In 16.3% and 11.4% of watershed area, water is found unfit for drinking during PRM and POM seasons respectively. The calculated values of SAR and %Na indicate 'excellent to permissible use' of water for irrigation uses during both the seasons. High salinity, %Na and Mg-hazard values at some sites limit use for irrigation purposes. Box plots were plotted to represent seasonal concentration of the major ions which shows increasing trend of Ca, Na, NO sub(3) and SO sub(4) during POM.
Outputs	Shinde et al. (2013). Assessment of water quality around surface coal mine in India. *Nature, Environment and Pollution Technology.* Technoscience Publications.
Key personnel	Shinde, V.; Nandgude, S.B.; Singh, M.
Research themes	Co-produced/mine water, water supplies, water dependent ecosystems
Project information source	Literature

Table 4.163 Project 163: Environmental geochemistry and quality assessment of mine water of Jharia coalfield, India

Project characteristics	Details
Project title	**Environmental geochemistry and quality assessment of mine water of Jharia coalfield, India**
Project location	India
Principal investigator	Singh, A.K.; Mahato, M.K.; Neogi, B.; Tewary, B.K.; Sinha, A.
Lead institution	Central Institute of Mining and Fuel Research, Dhanbad 826015, Jharkhand, India
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	A long mining history and unscientific exploitation of Jharia coalfield caused many environmental problems including water resource depletion and contamination. A geochemical study of mine water in the Jharia coalfield has been undertaken to assess its quality and suitability for domestic, industrial and irrigation uses. For this purpose, 92 mine water samples collected from different mining areas of Jharia coalfield were analysed for pH, electrical conductivity (EC), major cations (Ca2+, Mg2+, Na+, K+), anions (F-, Cl-, HCO3-, SO42-, NO3-), dissolved silica (H4SiO4) and trace metals. The pH of the analysed mine water samples varied from 6.2 to 8.6, indicating mildly acidic to alkaline nature. Concentration of TDS varied from 437 to 1,593 mg L-1 and spatial differences in TDS values reflect the variation in lithology, surface activities and hydrological regime prevailing in the region. SO42- and HCO3- are dominant in the anion and Mg2+ and Ca2+ in the cation chemistry of mine water. High concentrations of SO42- in the mine water of the area zare attributed to the oxidative weathering of pyrites. Ca-Mg-SO4 and Ca-Mg-HCO3 are the dominant hydrochemical facies. The drinking water quality assessment indicates that number of mine water samples have high TDS, total hardness and SO42- concentrations and needs treatment before its utilization. Concentrations of some trace metals (Fe, Mn, Ni, Pb) were also found to be above the desirable levels recommended for drinking water. The mine water is good to permissible quality and suitable for irrigation in most cases. However, higher salinity, residual sodium carbonate and Mg-ratio restrict its suitability for irrigation at some sites.
Outputs	Singh et al. (2012). Environmental geochemistry and quality assessment of mine water of Jharia coalfield, India. *Environmental Earth Sciences.*
Key personnel	Singh, A.K.; Mahato, M.K.; Neogi, B.; Tewary, B.K.; Sinha, A.
Contact	[Singh, Abhay Kumar; Mahato, M. K.; Neogi, B.; Tewary, B. K.; Sinha, A.] CSIR, Cent Inst Min & Fuel Res, Dhanbad 826015, Jharkhand, India
Research themes	Water supplies, water dependent ecosystems
Project information source	Literature

Table 4.164 Project 164: Multivariate statistical analysis for assessment of groundwater quality in Talcher Coalfield area, Odisha

Project characteristics	Details
Project title	**Multivariate statistical analysis for assessment of groundwater quality in Talcher Coalfield area, Odisha**
Project location	India
Principal investigator	Dhakate, Ratnakar; Mahesh, J.; Sankaran, S.; Gurunadha Rao, V. V.S.
Lead institution	CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad 500 007, India
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	In order to assess the impact of coal mining on groundwater quality in Talcher Coalfield area, seventeen groundwater samples for pre and post monsoon seasons were collected from borewells/dugwells and analysed for major ions and trace elements. Water quality analysis of major ions and trace elements shows elevated concentration in few groundwater samples. The water quality data was analysed using multivariate statistical techniques viz., factor analysis and cluster analysis. The result clearly shows that the variation in the season is due to recharge of rain water during monsoon. The factor and cluster analysis brought out impact of intensity by mining activity on groundwater regime. Discharge of mining seepage effluents and its interaction with the groundwater contaminate the surrounding groundwater regime. Multivariate statistical techniques are potential tools and provide greater precision for identifying contaminant parameters linkages with mining environment. © 2013 Geological Society of India.
Outputs	Dhakate et al. (2013). Multivariate statistical analysis for assessment of groundwater quality in Talcher Coalfield area, Odisha. *Journal of the Geological Society of India.* P.O. Box 1922, Gavipuran, Bangalore, 560 019, India: Geological Society of India. http://dx.doi.org/10.1007/s12594-013-0167-7
Key personnel	Dhakate, Ratnakar; Mahesh, J.; Sankaran, S.; Gurunadha Rao, V. V.S.
Contact	CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad 500 007, India
Research themes	Co-produced/mine water, water supplies, water dependent ecosystems
Project information source	Literature

Table 4.165 Project 165: Effect of mining on geochemistry of groundwater in Permo-carboniferous Gondwana coalfields: Raniganj Basin, India

Project characteristics	Details
Project title	**Effect of mining on geochemistry of groundwater in Permo-carboniferous Gondwana coalfields: Raniganj Basin, India**
Project location	India
Principal investigator	Adhikari, K.; Sadhu, K.; Chakroborty, B.; Gangopadhyay, A.
Lead institution	Department of Geology, National Institute of Technology, Durgapur 713 209, India
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Lack of proper reclamation strategy and indiscriminate mining of various economic resources, particularly coal from Permo-carboniferous Gondwana coalfields affects the groundwater quality of the concerned regions. Leaching from mine-tailings along with seasonal fluctuation of water table caused a significant change in groundwater geochemistry of Raniganj coalfield area. Gondwana sequences, developed in intracratonic rift basin, are characterized by numerous longitudinal and cross faults. This results in the formation of many small aquifer systems which may be interconnected laterally as well as vertically providing the conduit for homogenization of aquifers. Although the predominance of major cations (CaNaMgK) and anions (HCO 3ClSO4NO3) remain same irrespective of season, the dominance of Na and SO4 have significantly increased in post-monsoon season. The types of groundwater in pre-monsoon and postmonsoon seasons are CaMgCl and CaHCO3 respectively. Leaching of SO 4 from surface sources (mine tailings) has increased TDS in post-monsoon. Base exchange (direct and reverse) reactions have taken place between aquifer materials and groundwater. © 2013 Geological Society of India.
Outputs	Adhikari et al. (2013). Effect of mining on geochemistry of groundwater in Permo-carboniferous Gondwana coalfields: Raniganj Basin, India. *Journal of the Geological Society of India.* P.O. Box 1922, Gavipuran, Bangalore, 560 019, India: Geological Society of India. http://dx.doi.org/10.1007/s12594-013-0166-8
Key personnel	Adhikari, K.; Sadhu, K.; Chakroborty, B.; Gangopadhyay, A.
Contact	Department of Geology, National Institute of Technology, Durgapur 713 209, India
Research themes	Co-produced/mine water, water supplies
Project information source	Literature

4.7.4 United Kingdom

Table 4.166 Project 166: Modified multi-phase stability diagrams: An AMD case study at a site in Northumberland, UK

Project characteristics	Details
Project title	**Modified multi-phase stability diagrams: An AMD case study at a site in Northumberland, UK**
Project location	United Kingdom
Principal investigator	Samborska, Katarzyna; Sitek, Sawomir; Bottrell, Simon H; Sracek, Ondra
Lead institution	Earth Surface Sciences Institute, School of Earth and the Environment, University of Leeds
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The weathering of sulphide minerals within spoil heaps causes the release of sulphate and environmentally hazardous metal ions. Newly-formed species can subsequently precipitate as highly soluble, secondary sulphate minerals, which, in turn, might be flushed by dilute recharge water or eventually transformed into more stable minerals. These processes determine which components are retained in the spoil as immobile solid phases and which (and when) others are released into the wider aquatic environment. To elucidate this sequence of mineral formation and transformation, we studied mineral-fluid equilibria in a major abandoned coal mine spoil heap at the former Shillbottle Colliery, Northumberland, UK. The investigations focussed on stability of iron minerals produced during the acid mine drainage process. The multi-component Phreeplot-calculated pE/pH diagrams reveal that many post-mining secondary minerals may co-exist, in contrast to what is indicated by the more commonly used charts. Being able to visualize the mutual stability of these minerals under specific chemical and physical conditions might aid understanding of formation and transformation mechanisms.
Outputs	Samborska et al. (2013). Modified multi-phase stability diagrams: An AMd case study at a site in Northumberland, UK. *Mine Water and the Environment.* Springer Berlin Heidelberg. http://dx.doi.org/10.1007/s10230-013-0223-y
Key personnel	Samborska, Katarzyna; Sitek, Sawomir; Bottrell, Simon H; Sracek, Ondra
Research themes	Co-produced/mine water, water supplies
Project information source	Literature

Table 4.167 Project 167: Science project SC030136/SR41

Project characteristics	Details
Project title	**Science project SC030136/SR41**
Project location	United Kingdom
Principal investigator	Johnston, Dave; Potter, Hugh; Jones, Ceri; Rolley, Stuart; Watson, Ian; Pritchard, Jim
Lead institution	Environment Agency, the Coal Authority, Scottish Environment Protection Agency
Project budget	Unknown
Source of funding	Environment Agency, Coal Authority, Scottish Environment Protection Agency SC030136/SR41
Project duration	Unknown- literature output 2008
Current status	Unknown- literature output 2008
Project summary	Abandoned mines are one of the most significant pollution threats in Britain. Our legacy of mining for coal, metal ores and other minerals dates back to the Bronze Age. Many thousands of mines have been abandoned and now discharge minewater containing heavy metals and other pollutants into our watercourses. Other more recently closed mines are still filling up with groundwater and will start discharging in the future. Nine percent of rivers in England and Wales, and two percent in Scotland are at risk of failing to meet their Water Framework Directive targets of good chemical and ecological status because of abandoned mines. These rivers carry some of the biggest discharges of metals such as cadmium, iron, copper and zinc to the seas around Britain. Seventy-two per cent of failures to achieve the cadmium quality standard in freshwater are in mined areas. In some areas, important drinking water supply aquifers are polluted or threatened by plumes of sulphate and chloride. The legal position in the UK is such that no-one can be held liable for the pollution from the majority of mines. It is only since 1999 that the operator of a mine has had any obligation to deal with the consequences of abandonment. The Environment Agency, Scottish Environment Protection Agency (SEPA) and Coal Authority are leading efforts to deal with the problem. Between us we have made significant advances, mostly dealing with the problem from coal mines. We have built 54 minewater treatment plants, which prevent 2500 tonnes of iron and other metals from entering our rivers every year, protecting over 200 km of rivers and drinking water aquifers. Most of these plants are owned and operated by the Coal Authority, which works with the environment agencies to prioritise the worst discharges from closed deep coal mines and identify future problems.
Outputs	Johnston et al. (2008). Abandoned mines and the water environment. Bristol: Environment Agency. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/291482/LIT_8879_df7d5c.pdf
Key personnel	Johnston, Dave; Potter, Hugh; Jones, Ceri; Rolley, Stuart; Watson, Ian; Pritchard, Jim
Contact	enquiries@environment-agency.gov.uk
Research themes	Water supplies
Project information source	Literature

Table 4.168 Project 168: Flow dependent water quality impacts of historic coal and oil shale mining in the Almond River catchment, Scotland

Project characteristics	Details
Project title	**Flow dependent water quality impacts of historic coal and oil shale mining in the Almond River catchment, Scotland**
Project location	United Kingdom
Principal investigator	Haunch, Simon; MacDonald, Alan M.; Brown, Neil; McDermott, Christopher I.
Lead institution	University of Edinburgh
Project budget	Unknown
Source of funding	The work was funded by ECOSSE and carried out jointly between the University of Edinburgh and the British Geological Survey.
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The Almond River catchment in Central Scotland has experienced extensive coal mining during the last 300 years and also provides an example of enduring pollution associated with historic unconventional hydrocarbon exploitation from oil shale. Detailed spatial analysis of the catchment has identified over 300 abandoned mine and mine waste sites, comprising a significant potential source of mine related contamination. River water quality data, collected over a 15 year period from 1994 to 2008, indicates that both the coal and oil shale mining areas detrimentally impact surface water quality long after mine abandonment, due to the continued release of Fe and View the MathML source associated with pyrite oxidation at abandoned mine sites. Once in the surface water environment Fe and View the MathML source display significant concentration-flow dependence: Fe increases at high flows due to the re-suspension of river bed Fe precipitates (Fe(OH)3); View the MathML source concentrations decrease with higher flow as a result of dilution. Further examination of Fe and SO4 loading at low flows indicates a close correlation of Fe and View the MathML source with mined areas; cumulative low flow load calculations indicate that coal and oil shale mining regions contribute 0.21 and 0.31 g/s of Fe, respectively, to the main Almond tributary. Decreases in Fe loading along some river sections demonstrate the deposition and storage of Fe within the river channel. This river bed Fe is re-suspended with increased flow resulting in significant transport of Fe downstream with load values of up to 50 g/s Fe. Interpretation of major ion chemistry data for 2005–2006 indicates significant increases in Ca2+, Mg2+ and View the MathML source in coal mined areas probably as a result of the buffering of proton acidity in mine waters; in the oil shale areas Na and Cl become increasing dominant possibly associated with increased urbanisation and saline pore water discharge from unprocessed oil shale waste. The study demonstrates the importance of considering the cumulative impact of point and diffuse contamination sourced from numerous small coal and oil shale mine sites on surface water quality.
Outputs	Haunch et al. (2013). Flow dependent water quality impacts of historic coal and oil shale mining in the Almond River catchment, Scotland. *Applied Geochemistry.* http://www.sciencedirect.com/science/article/pii/S0883292713001492
Key personnel	Haunch, Simon; MacDonald, Alan M.; Brown, Neil; McDermott, Christopher I.

Project characteristics	Details
Research themes	Water supplies, cumulative impact assessment
Project information source	Literature

Table 4.169 Project 169: Geochemical tracing of methane from unconventional gas production

Project characteristics	Details
Project title	**Geochemical tracing of methane from unconventional gas production**
Project location	United Kingdom
Principal investigator	Gilfillan, Stuart M. V.; Haszeldine, R. Stuart; Stuart, Finlay M.; Waldron, Susan
Lead institution	University of Edinburgh, School of Geosciences, Edinburgh
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	There is significant public concern surrounding the exploitation of unconventional gas resources. Many of these concerns relate to potential methane contamination of potable water supplies in shallow aquifers. Public apprehension is predominantly linked to experiences of unconventional gas extraction in the USA where there is strong and growing public dispute around the "fracking" process. Evidence of groundwater contamination by produced gas is equivocal. Some studies have found no direct causality between fracturing and groundwater contamination. However, there is a developing group of work in the USA by individual researchers and by the Environmental Protection Agency, which suggests that a degree of contamination of groundwater has occurred. In such a commercially active sector, a strong suite of evidence is needed to unequivocally detect contamination and allow successful remediation litigation. Simple documentation of elevated methane content in groundwater is not sufficient to enable a legally secure diagnosis. Rival claims can be made that the methane present in the groundwater is from drilling operations which predate shale gas exploration, or that observations of hydrocarbon content, including methane gas, in shallow aquifers are due to natural processes unconnected with unconventional gas exploration. For these reasons, an extremely robust identification of methane source, or multiple methane sources, is needed. In this study we focus on providing the means to make that identification. Using existing data, we will show how C and H isotopes, radiocarbon ((super 14) C) and noble gases (He Ne Ar Kr Xe) can be used to geochemically "fingerprint" produced gas from coal bed methane and shale gas deposits. This clear "fingerprint" can be used to distinguish any produced gas from from other gas sources and provide a robust means for identifying produced methane contamination of shallow groundwaters.
Outputs	Gilfillan et al. (2013). Geochemical tracing of methane from unconventional gas production. *Mineralogical Magazine.* Mineralogical Society, London, United Kingdom. http://dx.doi.org/10.1180/minmag.2013.077.5.7
Key personnel 1	Gilfillan, Stuart M. V.; Haszeldine, R. Stuart; Stuart, Finlay M.; Waldron, Susan
Contact 1	University of Edinburgh, School of Geosciences, Edinburgh, United Kingdom
Research themes	Co-produced/mine water, hydraulic fracturing, water supplies, water dependent ecosystems
Project information source	Literature

4.7.5 United States

Table 4.170 Project 170: Advanced characterization of coalbed methane produced water quality in the Rocky Mountain region, USA for consideration as a potential water resource

Project characteristics	Details
Project title	**Advanced characterization of coalbed methane produced water quality in the Rocky Mountain region, USA for consideration as a potential water resource**
Project location	US
Principal investigator	Dahm, Katharine G.
Lead institution	Colorado School of Mines
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Coalbed methane (CBM) is an unconventional natural gas resource with large reserves in the United States and worldwide. Production is limited by challenges in the management of large volumes of produced water. Due to the salinity of CBM produced water, it is commonly re-injected into the subsurface for disposal. Utilization of this nontraditional water source is hindered by limited knowledge of water quality. A composite geochemical database was created with 3,255 CBM wellhead entries, covering four basins in the Rocky Mountain region, and resulting in information on 64 parameters and constituents. Water composition is dominated by NaHCO 3 and NaCl type waters with total dissolved solids concentrations (TDS) of 150 to 39 260 mg/L. Constituents commonly exceeding standards for drinking, livestock, and irrigation water applications were TDS, sodium adsorption ratio (SAR), temperature, iron and fluoride. Chemical trends in the basins are linked to the type of coal deposits, the rank of the coal and the proximity of the well to fresh water recharge. Ternary diagrams between Na-Cl-HCO3 and Na-Ca-Mg were created to indicate marine influence in the coal depositional environment and well proximity to recharge, respectively. The natural organic matter (NOM) signature created by CBM produced water in the 3-D fluorescence excitation emission matrix (EEM) spectra was also used to indicate water origin. The EEM spectra were compared to various sources of organic matter to discern fingerprints of NOM that can be used as tracers for indicating tributary wells, methane generation pathway, and anthropogenic contamination of aquifers. These studies represent significant progress towards assessing CBM produced water as an alternative water resource instead of an industry waste product. Treatment options for CBM produced water require consideration of a number of criteria, such as water quality composition, variable water quantities, beneficial use requirements and site restrictions. Membrane pretreatment technologies provided effective solute rejection for particulates and mineral precipitates over a variety of CBM produced water types and compositions. NOM, derived from coal, is also partially rejected due to elevated concentrations of iron in solution acting as a natural coagulant. Porous pretreatment membranes provided sufficient water quality for downstream use in desalination applications.

Project characteristics	Details
Outputs	Dahm. (2012). Advanced characterization of coalbed methane produced water quality in the Rocky Mountain region, USA for consideration as a potential water resource. Ann Arbor: Colorado School of Mines.
Key personnel	Dahm, Katharine G.
Research themes	Co-produced/mine water, water supplies, water dependent ecosystems
Project information source	Literature

Table 4.171 Project 171: Stream reconstruction under SMCRA burning star #4: A case study

Project characteristics	Details
Project title	**Stream reconstruction under SMCRA burning star #4: A case study**
Project location	US
Principal investigator	O'Leary, William G.; Nawrot, Jack R.
Lead institution	Illinois Department of Natural Resources, Office of Mines and Minerals, Land Reclamation Division, Benton, IL, 62959, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Reconstruction of approximately eight miles of stream habitats at the Consolidation Coal Burning Star #4 Mine in Perry County, Illinois was reviewed. Important hydrologic and biologic functions were successfully restored following surface mining for coal through two large streams by reconstruction of the stream systems. Riparian and wetland habitats exceeded that which existed before mining. Stream water sulfate concentration was identified as the biggest difference between the pre-mining and post-mining stream environments with a tenfold increase as a result of mining. Data from these reconstructed streams and from other nearby reclaimed mine sites suggest that elevated sulfates may have little effect on tolerant macroinvertebrate communities but may be detrimental to sensitive macro-invertebrates and may persist for several decades.
Outputs	O'Leary and Nawrot. (2012). Stream reconstruction under SMCRA burning star #4: A case study. *29th Annual National Conference of the American Society of Mining and Reclamation 2012, ASMR 2012, June 8, 2012 - June 15, 2012.* Tupelo, MS, United states: American Society of Mining and Reclamation.
Key personnel	O'Leary, William G.; Nawrot, Jack R.
Contact	Illinois Department of Natural Resources, Office of Mines and Minerals, Land Reclamation Division, Benton, IL, 62959, United States
Research themes	Water supplies, water dependent ecosystems
Project information source	Literature

Table 4.172 Project 172: Assessing different mechanisms of toxicity in mountaintop removal/valley fill coal mining-affected watershed samples using *Caenorhabditis elegans*: e75329

Project characteristics	Details
Project title	**Assessing different mechanisms of toxicity in mountaintop removal/valley fill coal mining-affected watershed samples using *Caenorhabditis elegans*: e75329**
Project location	US
Principal investigator	Turner, Elena A.; Kroeger, Gretchen L.; Arnold, Mariah C.; Thornton, B. Lila; Giulio, Richard TDi; Meyer, Joel N.
Lead institution	Nicholas School of the Environment, Duke University, Durham, North Carolina, United States of America
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Mountaintop removal-valley fill coal mining has been associated with a variety of impacts on ecosystem and human health, in particular reductions in the biodiversity of receiving streams. However, effluents emerging from valley fills contain a complex mixture of chemicals including metals, metalloids, and salts, and it is not clear which of these are the most important drivers of toxicity. We found that streamwater and sediment samples collected from mine-impacted streams of the Upper Mud River in West Virginia inhibited the growth of the nematode Caenorhabditis elegans. Next, we took advantage of genetic and transgenic tools available in this model organism to test the hypotheses that the toxicity could be attributed to metals, selenium, oxidative stress, or osmotic stress. Our results indicate that in general, the toxicity of streamwater to C. elegans was attributable to osmotic stress, while the toxicity of sediments resulted mostly from metals or metalloids.
Outputs	Turner et al. (2013). Assessing different mechanisms of toxicity in mountaintop removal/valley fill coal mining-affected watershed samples using *Caenorhabditis elegans*: e75329. *PLoS ONE.* Public Library of Science, 185 Berry Street San Francisco CA 94107 United States. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3774817/pdf/pone.0075329.pdf
Key personnel	Turner, Elena A.; Kroeger, Gretchen L.; Arnold, Mariah C.; Thornton, B. Lila; Giulio, Richard TDi; Meyer, Joel N.
Research themes	Surface water, water dependent ecosystems
Project information source	Literature

Table 4.173 Project 173: Analyses of geological and hydrodynamic controls on methane emissions experienced in a Lower Kittanning coal mine

Project characteristics	Details
Project title	**Analyses of geological and hydrodynamic controls on methane emissions experienced in a Lower Kittanning coal mine**
Project location	US
Principal investigator	Karacan, C. O.; Goodman, G. V. R.
Lead institution	NIOSH, Office of Mine Safety and Health Research
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	This paper presents a study assessing potential factors and migration paths of methane emissions experienced in a room-and-pillar mine in Lower Kittanning coal, Indiana County, Pennsylvania. Methane emissions were not excessive at idle mining areas, but significant methane was measured during coal mining and loading. Although methane concentrations in the mine did not exceed 1% limit during operation due to the presence of adequate dilution airflow, the source of methane and its migration into the mine was still a concern. In the course of this study, structural and depositional properties of the area were evaluated to assess complexity and sealing capacity of roof rocks. Composition, gas content, and permeability of Lower Kittanning coal, results of flotation tests, and geochemistry of groundwater obtained from observation boreholes were studied to understand the properties of coal and potential effects of old abandoned mines within the same area. These data were combined with the data obtained from exploration boreholes, such as depths, elevations, thicknesses, ash content, and heat value of coal. Univariate statistical and principal component analyses (PCA), as well as geostatistical simulations and co-simulations, were performed on various spatial attributes to reveal interrelationships and to establish area-wide distributions. These studies helped in analyzing groundwater quality and determining gas-in-place (GIP) of the Lower Kittanning seam. Furthermore, groundwater level and head on the Lower Kittanning coal were modeled and flow gradients within the study area were examined. Modeling results were interpreted with the structural geology of the Allegheny Group of formations above the Lower Kittanning coal to understand the potential source of gas and its migration paths. Analyses suggested that the source of methane was likely the overlying seams such as the Middle and Upper Kittanning coals and Freeport seams of the Allegheny Group. Simulated groundwater water elevations, gradients of groundwater flow, and the presence of recharge and discharge locations at very close proximity to the mine indicated that methane likely was carried with groundwater towards the mine entries. Existing fractures within the overlying strata and their orientation due to the geologic conditions of the area, and activation of slickensides between shale and sandstones due to differential compaction during mining, were interpreted as the potential flow paths. Published by Elsevier B.V.
Outputs	Karacan and Goodman. (2012). Analyses of geological and hydrodynamic controls on methane emissions experienced in a Lower Kittanning coal mine. *International Journal of Coal Geology*.

Project characteristics	Details
Key personnel	Karacan, C. O.; Goodman, G. V. R.
Contact	Karacan, CO NIOSH, Off Mine Safety & Hlth Res, Pittsburgh, PA 15236 US
Research themes	Water supplies
Project information source	Literature

Table 4.174 Project 174: Water chemistry in areas with surface mining of coal, West Virginia, USA

Project characteristics	Details
Project title	**Water chemistry in areas with surface mining of coal, West Virginia, USA**
Project location	US
Principal investigator	Orem, William H.; Tatu, Calin; Crosby, Lynn M.; Varonka, Matthew S.; Bates, Anne L.; Engle, Mark; Geboy, Nicholas J.; Hendryx, Michael
Lead institution	U. S. Geological Survey, Reston, VA, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Surface mining, including mountaintop removal mining, has become an increasingly important form of coal production in Appalachia over the past 20 years. Compared to underground mining, surface mining is generally more economical, and safer for miners, but
Outputs	Orem et al. (2012). Water chemistry in areas with surface mining of coal, West Virginia, USA. *Abstracts with Programs - Geological Society of America.* Geological Society of America (GSA), Boulder, CO, United States.
Key personnel	Orem, William H.;Tatu, Calin;Crosby, Lynn M.;Varonka, Matthew S.;Bates, Anne L.;Engle, Mark;Geboy, Nicholas J.;Hendryx, Michael
Contact	U. S. Geological Survey, Reston, VA, United States
Research themes	Co-produced/mine water, water supplies, water dependent ecosystems
Project information source	Literature

Table 4.175 Project 175: Geochemical and stable isotopic analysis of the Tongue River and associated tributaries in the Powder River Basin: An analysis of the cause of annual elevated salinity in spring runoff

Project characteristics	Details
Project title	**Geochemical and stable isotopic analysis of the Tongue River and associated tributaries in the Powder River Basin: An analysis of the cause of annual elevated salinity in spring runoff**
Project location	US
Principal investigator	Scott Quillinan
Lead institution	University of Wyoming
Project budget	Unknown
Source of funding	Wyoming Department of Environmental Quality
Project duration	2010-2012
Current status	Completed
Project summary	The suitability of surface water for agricultural irrigation depends in part on salinity. Salinity reflects soil composition and the underlying geology of the watershed, and varies seasonally with precipitation and snowmelt. In addition, there may be anthropogenic influences on salinity related to land use, including energy development. The purpose of this study is to evaluate whether an observed, annual short-term rise in salinity in the Tongue River of northeastern Wyoming is due to natural or anthropogenic causes. The Tongue River flows north out of Wyoming's Bighorn Mountains and the Powder River geologic basin into Montana. It is a major source of water for agriculture and several residential communities in Wyoming and Montana. The Tongue River and associated tributaries pass through areas of coalbed natural gas (CBNG) production in both states. There are concerns that water discharged during CBNG production in Wyoming is impacting Tongue River water quality. Specifically, a short period of elevated total dissolved solids (TDS) concentrations have been observed in the Tongue River, north of the Wyoming state line, during a short period between late February and early April.
Objectives	The purpose of this study is to use water quality data and isotopic ratios of carbon to characterize the water of the Tongue River and associated tributaries, and to determine whether the source of elevated salinity in the early spring is the result of natural processes or human activities. Surface water sample sites were chosen to include water samples collected upstream, proximal, and downstream of CBNG development. Water collected upstream of CBNG development provides information about the natural system unaffected by CBNG development. If surface waters are chemically and/or isotopically distinct from CBNG produced water, then it is possible to identify if CBNG produced water is influencing the quality of surface water.
Achievements	Results of this study show that CBNG produced water can be distinguished from natural surface waters in the Powder River Basin on the basis of water quality and the carbon isotope ratio of dissolved inorganic carbon. The data suggest that natural spring runoff processes within the basin interior are responsible for elevated TDS measured at the Wyoming/Montana state line during late February and early April. Isotopic and geochemical evidence suggests that CBNG production in the area is likely not the cause of high

Project characteristics	Details
	salinities in the early spring in the Tongue River.
Outputs	Quillinan, S.A. et al. (2012), *Geochemical and stable isotopic analysis of the Tongue River and associated tributaries in the Powder River Basin: An analysis of the cause of annual elevated salinity in spring runoff*, Wyoming State Geological Survey Report of Investigations No. 63-2012 15p. http://www.wsgs.uwyo.edu/public-info/onlinepubs/docs/Tongue%20River_RI.pdf
Key personnel	Scott Quillinan J. Fred McLaughlin
Research themes	• Aquifer interconnectivity: − baseline information (water quality and quantity) − field based and modelling approaches for assessing connectivity • Disruption of surface water flow pathways • Co-produced water and salt management (CSG) and mine water & salt management (coal mines): − effect on Water dependent ecosystems (streams, rivers, floodplains, wetlands, GDEs, peat swamps) • Quality and reliability of water supplies including environmental health: − chemical migration and toxicity
Project information source	Survey

Table 4.176 Project 176: Carbon isotope characterization of Powder River Basin coal bed waters: Key to minimizing unnecessary water production and implications for exploration and production of biogenic gas

Project characteristics	Details
Project title	**Carbon isotope characterization of Powder River Basin coal bed waters: Key to minimizing unnecessary water production and implications for exploration and production of biogenic gas**
Project location	US
Principal investigator	Scott Quillinan
Lead institution	University of Wyoming
Project budget	Unknown
Source of funding	Wyoming State Geological Survey and the Wyoming Water Development Commission
Project duration	2009-2013
Current status	Completed
Project summary	Compared to other natural waters, water associated with biogenic natural gas is enriched in 13-carbon. Shallow coal seams regularly contain abundant resources of biogenic gas; as such water associated with biogenic gas in these coal beds is isotopically distinct from other waters. The production of gas from coal beds requires the removal of large volumes of produced water. Thus a method of discerning coalbed reservoir water from other natural waters (surface and groundwater) is important to both the coalbed natural gas (CBNG) industry and associated environmental and regulatory agencies. Although isotopic tracers have been employed to identify coalbed natural gas produced waters, the isotopic variability within the reservoir has not been documented and explained. In this study, we present the isotopic compositions of dissolved inorganic carbon, oxygen and hydrogen for water produced from 197 CBNG wells in the Powder River Basin of Wyoming and Montana. This extensive database allows us to distinguish variations in isotopic compositions that may occur by multiple processes. These include variations that identify efficient dewatering of coal beds, variations characterizing incomplete hydraulic isolation of coal beds from adjacent strata and the subsequent mixing of groundwaters, variations related to well completion design, and variations associated with geochemical and biogenic processes that occur along groundwater flow paths. These data suggest that little change in 13CDIC occurs within the reservoir as a result of water and gas production; thus, the carbon isotopic composition informs other processes within the reservoir unrelated to coalbed natural gas recovery. The 13CDIC and D of groundwater vary along flow-path across the basin, reflecting different methanogenic pathways that are associated with different isotopic fractionations, and the pathways that dominate in different areas within the basin. In areas where several producing coal seams are present, the 13CDIC and D of produced waters from each seam are distinct. Therefore on a local scale, the isotopic composition of produced water can identify the particular coal seam from which water and gas are withdrawn. The methods and results presented in this case study provide examples that illustrate how water quality and isotopic data can be used to determine the hydraulic connectivity between coal and non-coal strata, identify and quantify water from individual coal horizons, as well as predict and understand the

Project characteristics	Details
	isotopic variability of the reservoir.
Achievements	Our stable isotopic investigation of produced waters associated with coalbed natural gas in the Powder River Basin of Wyoming and Montana has shown that 13CDIC compositions of + 10 to + 25‰ identify produced water that is associated with methanogenesis. This is the range of isotopic compositions of produced water from most PRB CBNG reservoirs. Our analyses of water collected from wells that have been pumping for between 1 and 15 years show no correlation between the amount of water that has been withdrawn from the well and the 13CDIC of the water now being produced. Most importantly, coal bed produced water is isotopically distinct from non-coal bed waters. Regardless of how long the well has been in production, coal bed waters have positive 13CDIC, whereas non-coal bed waters are negative. Although the carbon isotopic compositions of produced waters from individual PRB coal beds vary on a regional scale, they are uniform on a local field scale, and different coal beds have distinct ?13CDIC. Stacked coal beds are easily distinguished from each other: the deeper beds are less enriched with respect to carbon and more enriched with respect to deuterium. This attribute can be used to help identify the source of water in single and multi-production zone environments, and help determine the efficiency of dewatering from different coal beds. 13CDIC isotope compositions of produced water that is lower than + 10‰ should be interpreted to indicate the possibility that coal beds are in communication with waters that have not hosted methanogenesis, usually from another aquifer. Binary mixing models can be used to estimate contributions from other aquifers or from multiple producing zones. Extreme negative values 13CDIC within a CBNG reservoir (<? 15‰) occurs in water from some shallow wells (< 500 ft.) and indicate that SO4 reducing bacteria may have been oxidizing methane. The particular methanogenic pathways operating at different places along flow paths contribute to the variability that is observed regionally. Enriched 13CDIC values decrease and ?D is enriched with increasing residence time in the deeper coal beds where CO2 reduction has been identified as the dominant methanogenic pathway. This report presents the largest 13CDIC and D dataset collected to date from CBNG produced waters in order to characterize multiple coal zones across the basin and describe methanogenic processes at work in different parts of the PRB. The carbon isotope composition is instructive both with respect to the hydrological characteristics and to the biological characteristics within a reservoir. These stable isotopic analyses can provide inexpensive but valuable information during the exploration and the production phases of coal bed natural gas wells. Most importantly, the carbon isotope composition of a reservoir can be used to identify confined reservoirs and to identify efficient dewatering of coal beds in single and multiple zones: information that can help minimize unnecessary water production.
Outputs	Quillinan S.A., and Frost, C.D., (2013) Carbon isotope characterization of Powder River Basin coal bed waters: Key to minimizing unnecessary water production and implications for exploration and production of biogenic gas, in Karacan, C.O., Soeder, D., and Engle, M., Environmental Geology and the Unconventional Gas Revolution, *International Journal of Coal Geology* http://www.sciencedirect.com/science/article/pii/S0166516213002383
Key personnel	Scott Quillinan

Project characteristics	Details
	Carol Frost
Research themes	• Aquifer interconnectivity: − baseline information (water quality and quantity) • Co-produced water and salt management (CSG) and mine water & salt management (coal mines) • Integrity of wells - installation, operation, decommissioning • Water dependent ecosystems
Project information source	Survey

Table 4.177 Project 177: Spatial variability of coalbed natural gas produced water quality, Powder River Basin, Wyoming: Implications for future development

Project characteristics	Details
Project title	**Spatial variability of coalbed natural gas produced water quality, Powder River Basin, Wyoming: Implications for future development**
Project location	US
Principal investigator	Scott Quillinan
Lead institution	University of Wyoming
Project budget	Unknown
Source of funding	Wyoming Geological Survey
Project duration	2009-2012
Current status	Completed
Project summary	Coalbed natural gas (CBNG) production is associated with large volumes of produced water. To date, approximately 12 percent (3.7 TCF) of the CBNG resource in Wyoming's Powder River Basin (PRB) has been produced. Significant gas resources remain but will require the continued production of large volumes of water.
Objectives	In this report, we classify the approximately 30,000 producing, shut-in, permitted, and permanently abandoned CBNG wells by coal zone. Focusing on the five largest CBNG producing coal zones, we calculate water to gas ratios, define "core producing areas," and identify potential areas of future development of these coal zones. In addition, we use water quality data for 337 previously published produced water samples from specific coal zones to map the spatial variability of total dissolved solids and sodium adsorption ratios within these core-producing areas and to identify potential beneficial uses.
Achievements	Classifying wells by coal zone and plotting these locations geospatially, enable definition of "core producing areas" for the five main CBNG-producing coal zones. Furthermore, we are able to predict the water quality for produced water recovered from these coal zones, and identify areas of low water to gas ratios, all of which may indicate favourable conditions for future development. For all coal zones, TDS and SAR generally increase from the southern and eastern margins of the PRB towards the basin axis. Detailed examination of water quality information presented spatially and by coal zone in this study can be used to estimate produced water quality for future development. Although there are some differences that are related to the coal zone from which water is produced, in general, the geographic location of a well is more predictive of TDS and SAR than the coal zone in which it is completed. Common constituents used to determine beneficial use of produced water, particularly for irrigation, are SAR and TDS. These constituents are correlated: water with high SAR may be used for irrigation without impacting soil quality if TDS is also high. Our examination of 337 analyses of produced water from the PRB suggests that most produced water in the PRB water if integrated with careful management practices, could be used to irrigate salt-tolerant plants. We refer the reader to Brinck and Frost (2009) for a more detailed description of the impacts of irrigating with produced water in the PRB and the management practices required to maintain soil health. Primarily completed in the Big George coal bed, the Wyodak Rider coal zone hosts more wells than any other coal zone. This coal zone has produced more

Project characteristics	Details
	gas than any other coal zone and has the lowest water to gas ratios. The Upper and Lower Wyodak coal zones were developed prior to the Wyodak Rider coal zone. They have slightly higher water to gas ratios than the Wyodak Rider. The coal zones that have produced the least amount of gas are the Cook and Wall coal zones, although it is important to note that many of these wells share multi-zone completions with other coal zones, making total gas production estimates from the Cook and Wall coal zones difficult to quantify. Large areas for each coal zone remain to be developed inside and outside of their current core producing area. With the information presented in this study, future development in the PRB could focus on areas where multiple production intervals are present and the water quality can be estimated. This approach would continue the development of the vast CBNG resource, utilize existing infrastructure, minimize surface disturbance, and produce water most suitable for beneficial use
Outputs	Quillinan, S.A., and Frost, C.D., (2012). *Spatial variability of coalbed natural gas produced water quality, Powder River Basin, Wyoming: Implications for future development*, Wyoming State Geological Survey Report of Investigation No. 64-2012 56p.
Key personnel 1	Scott Quillinan Carol Frost
Research themes	• Aquifer interconnectivity − baseline information (water quality and quantity) • Co-produced water and salt management (CSG) and mine water & salt management (coal mines) − effect on land and water resources (including. Irrigation) • Quality and reliability of water supplies including environmental health − long term impacts, including, timescales for water levels to return to pre-development levels (quality/quantity) − chemical migration and toxicity − managing salt and heavy metals
Project information source	Survey

4.8 Water dependent ecosystems

This section outlines projects researching the impact of coal seam gas and coal mining on water dependent ecosystems, such as streams, rivers, floodplains, wetlands, GDEs and peat swamps. This may include response and tolerances of water dependent ecosystems to changes in water regimes (quantity, seasonal patterns, variability, interactions) and water quality; measures for mitigating impacts and monitoring techniques.

Twenty (20) projects were collated with the primary theme of water dependent ecosystems; most of which were from Australia (12) and the US (6).

4.8.1 Australia

Table 4.178 Project 178: Guidelines for establishing ecologically sustainable discharge criteria in seasonally flowing streams

Project characteristics	Details
Project title	**Guidelines for establishing ecologically sustainable discharge criteria in seasonally flowing streams**
Project location	Australia
Principal investigator	Vink, Sue
Lead institution	Centre for Water in the Minerals Industry (University of Queensland)
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	No summary available
Outputs	Vink. (2013). Guidelines for establishing ecologically sustainable discharge criteria in seasonally flowing streams. Centre for Water in the Minerals Industry (University of Queensland).
Key personnel	Vink, Sue
Research themes	Co-produced/mine water, water supplies
Project information source	Literature

Table 4.179 Project 179: Reducing the impact of longwall extraction on groundwater systems

Project characteristics	Details
Project title	**Reducing the impact of longwall extraction on groundwater systems**
Project location	Australia
Principal investigator	Deepak Adhikary
Lead institution	Commonwealth Scientific and Industrial Research Organisation
Project budget	Unknown
Source of funding	ACARP
Project duration	2010-2012
Current status	Completed
Project summary	Longwall mining under or adjacent to surface water, sub-surface aquifers, water reservoirs and flooded workings has been undertaken and is planned at a number of mine sites in Australia. Due to the rock mass deformations associated with longwall mining, unexpected adverse interaction with these water bodies may result if mining is not properly managed. In addition, aquifer interference is the subject of legislative controls and community concern in Australia, particularly in Queensland and New South Wales. Thus the ability to predict and manage mining induced water inflows and aquifer interference can significantly affect mining safety and economics. The project investigated the effects of longwall mining on hydrogeology and water inflow into the mine workings. The project focused on Springvale and Dendrobium Collieries as the project sites due to the availability of extensive hydrogeological data at those sites. Within this project, systematic underground hydrogeological monitoring and measurements were carried out including piezometer, extensometer and water inflow monitoring during mining. On the basis of field monitoring and measurement results site hydrogeological characterisation was undertaken and in situ hydrogeological models were established for both Springvale and Dendrobium Collieries. Groundwater flow mechanisms at the collieries were investigated using a large scale CSIRO coupled mechanical and fluid flow computer code, called COSFLOW. The flow estimates obtained from 3D numerical simulations were compared with the monitoring data. Finally, a series of 2D coupled numerical simulations of the hydrogeological response during mining were conducted, using COSFLOW, to examine the impact of aquitard thickness and distance from the mining seam on mine water inflow into mine workings.
Objectives	The aim of the project was to better understand rock deformation during mining and allow more accurate predictions of the hydrogeological response. Project outcomes are anticipated to assist the coalmines reduce risk and environmental impact, positively influencing mining safety, productivity and coal resource recovery.
Outputs	ACARP Report C18016, Reducing the impact of longwall extraction on groundwater systems. http://www.acarp.com.au/abstracts.aspx?repId=C18016
Key personnel	Deepak Adhikary, CSIRO Andy Wilkins, CSIRO

Project characteristics	Details
Research themes	Aquifer connectivity, cumulative impact assessment
Project information source	Survey

Table 4.180 Project 180: Impact of multi-purpose aquifer utilisation on a variable-density groundwater flow system in the Gippsland Basin, Australia

Project characteristics	Details
Project title	**Impact of multi-purpose aquifer utilisation on a variable-density groundwater flow system in the Gippsland Basin, Australia**
Project location	Australia
Principal investigator	Varma, Sunil; Michael, Karsten
Lead institution	Commonwealth Scientific and Industrial Research Organisation
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The Latrobe aquifer in the Gippsland Basin in southeastern Australia is a prime example for emerging resource conflicts in Australian sedimentary basins. The Latrobe Group forms a major freshwater aquifer in the onshore Gippsland Basin, and is an important reservoir for oil and gas in both onshore and offshore parts of the basin. The Latrobe Group and overlying formations contain substantial coal resources that are being mined in the onshore part of the basin. These may have coal seam gas potential and, in addition, the basin is considered prospective for its geothermal energy and CO2 storage potential. The impacts of large scale groundwater extraction related to open pit coal mine dewatering, public water supply, on the flow of variable density formation water in the Latrobe aquifer has been assessed using equivalent freshwater hydraulic heads and impelling force vectors. The freshwater hydraulic-head distributions suggest that groundwater flows from the northern and western edges towards the central part of the basin. Groundwater discharge occurs offshore along the southern margin and, potentially in the area of the Gippsland Lakes. Freshwater hydraulic gradients in the western part of the basin imply that there is a source of water in the Central Deep where the Latrobe aquifer occurs at depths >2500 m and where the aquifer subcrops beneath the seafloor. However, as shown by the force vector analysis these gradients are largely due to density effects and are probably not solely related to compaction related dewatering of the aquifer as suggested by earlier work. Post-stress hydraulic heads show significant declines near the offshore oil and gas fields, and in the coal mining areas of the Latrobe Valley. A drawdown map constructed using the difference between the pre- and post-stress head distribution shows that the largest drawdowns, of up to 130 m, are in the offshore region near oil and gas fields and onshore in the coal mining areas. A hydrodynamic model of the Latrobe aquifer was used to simulate groundwater recovery in the Latrobe aquifer from different scenarios of cessation of groundwater and other fluid extractions. less
Outputs	Varma and Michael. (2012). Impact of multi-purpose aquifer utilisation on a variable-density groundwater flow system in the Gippsland Basin, Australia. *Hydrogeology Journal*.
Key personnel	Varma, Sunil; Michael, Karsten
Research themes	Surface water, water supplies, water dependent ecosystems
Project information source	Literature

Table 4.181 Project 181: Upscaling hydraulic processes and properties to assess impacts on groundwater from coal seam gas abstractions

Project characteristics	Details
Project title	**Upscaling hydraulic processes and properties to assess impacts on groundwater from coal seam gas abstractions**
Project location	Australia
Principal investigator	Moore, Catherine; Doherty, Catherine
Lead institution	Commonwealth Scientific and Industrial Research Organisation
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Groundwater models that are used to predict the impact of coal seam gas extraction on regional aquifer systems employ coarse grids and grossly upscaled representations of hydraulic properties. The numerical demands of regional simulation also require that representation of two-phase flow near points of gas and water extraction be simplified. By processing the outcomes of detailed two-phase simulation of near-field pressure and saturation distributions, the factors controlling flow of water close to extraction points, and propagation of induced drawdown further afield, can be properly understood. So too can the requirements of an upscaled representation of these processes, if this representation is to have integrity. It is shown that integrity of the upscaling process requires that particular attention be paid to simulation of near-source desaturation, and to meeting the numerical demands arising from high sensitivity of relative water permeability to this desaturation in a grossly upscaled model.
Outputs	Moore and Doherty. (2012). Upscaling hydraulic processes and properties to assess impacts on groundwater from coal seam gas abstractions. *Hydrology and Water Resources Symposium 2012.* Sydney: Engineers Australia.
Key personnel	Moore, Catherine; Doherty, Catherine
Research themes	Water dependent ecosystems
Project information source	Literature

Table 4.182 Project 182: Simulating the impact of coal seam gas water production on aquifers

Project characteristics	Details
Project title	**Simulating the impact of coal seam gas water production on aquifers**
Project location	Australia
Principal investigator	Strand, Julian; Freij-Ayoub, Reem; Ahmed, Shakil
Lead institution	Commonwealth Scientific and Industrial Research Organisation
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Derived from a larger scale project additionally studying geomechanical issues associated with Coal Seam Gas (CSG) production, this paper investigates a hypothetical case study based on the Latrobe Valley, Gippsland Basin, Victoria. The paper focuses on examining aquifer water management associated with CSG production related water extraction. It aims at determining how much water would need to be produced to extract an economic supply of methane from coal resources in the Latrobe Valley. The impact of extraction of this water on the hydraulic head in aquifers underlying the produced seams is quantified. The Latrobe Valley Depression contains coal resources of 129 000 million tonnes and is one of the world's largest, and lowest cost, energy sources. Most of Victoria's electricity is generated utilising coal from the Loy Yang, Hazelwood and Yallourn mines. In addition to these massive operations, significant additional coal resources are available and unallocated at this time. Opportunities exist for the continued utilisation of these resources for electricity production, gasification, liquefaction and other coal conversion processes; as well as solid fuel for industrial, domestic and other uses. A model of the stratigraphy of the Latrobe Valley was derived from the VIC DPI 2003 coal resource model, the existence of which data was the predominant reason for the selection for the case study. Aquifer models were simulated in MODFLOW, based on extraction figures modelled in the CSG simulator COMET3.
Outputs	Strand et al. (2012). Simulating the impact of coal seam gas water production on aquifers. *APPEA Journal and Conference Proceedings*.
Key personnel	Strand, Julian; Freij-Ayoub, Reem; Ahmed, Shakil
Research themes	Water dependent ecosystems
Project information source	Literature

Table 4.183 Project 183: Great Artesian Basin water resource assessment

Project characteristics	Details
Project title	**Great Artesian Basin water resource assessment**
Project location	Australia
Principal investigator	Smerdon, Brian
Lead institution	Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Geoscience Australia (GA)
Project budget	$6.25 million
Source of funding	Australian Government – Department of the Environment and the National Water Commission (NWC)
Project duration	1 July 2010 to March 2013
Current status	Completed. Findings released 27 March 2013
Project summary	The Assessment provided an analytical framework to assist water managers in the GAB, which covers more than 1.7 million square kilometres and underlies parts of Queensland, New South Wales, South Australia and the Northern Territory. The report also provides information regarding modelling the effects of coal seam gas development and groundwater extraction.
Outputs	Smerdon. (2012). Great Artesian Basin Water Resource Assessment. CSIRO (Australian Government). http://www.csiro.au/Organisation-Structure/Flagships/Water-for-a-Healthy-Country-Flagship/Sustainable-Yields-Projects/Great-Artesian-Basin-Assessment.aspx
Key personnel	Brian Smerdon
Research themes	Water dependant ecosystems
Project information source	Literature

Table 4.184 Project 184: Coal seam gas water - river discharge: context matters

Project characteristics	Details
Project title	**Coal seam gas water - river discharge: context matters**
Project location	Australia
Principal investigator	Murray, Janelle
Lead institution	Origin Energy
Project budget	Unknown
Source of funding	Origin Energy
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Coal Seam gas (CSG) is a rapidly growing industry in Queensland, Australia. Water is produced as a by-product of the CSG production process, with the management of this associated water (called CSG water) widely accepted as one of the industry's main challenges. The Australia Pacific Liquefied Natural Gas (LNG) project is a coal seam gas (CSG) to liquefied natural gas (LNG) joint venture between Origin, ConocoPhillips and Sinopec Group. The Australia Pacific LNG project proposes to supply CSG from the Walloons gas fields in south central Queensland to a LNG plant located on Curtis Island, off the coast of Gladstone, on the central Queensland coast. Origin is the upstream operator of the Australia Pacific LNG project (the Project). In the Walloons coal seams, CSG water keeps natural gas adsorbed as a thin film on the surface of the coal. The pressure of the surrounding body of CSG water allows the gas to be retained within the seam by adsorption to the surface of coal particles. Hence to extract gas the water pressure needs to be reduced by transferring the water to the surface. Water from CSG wells extracted to enable gas production is variable in quantity, difficult to predict and influences gas production rates. Variability in water production can be due to the location of the well, communication with other wells, decline in pressure during well life and permeability of the coal seam. The quality of the CSG water can vary from well to well and more noticeably across the project area, but it consistently contains elevated quantities of salts. Appropriate management of CSG water is required to mitigate environmental risks associated with untreated CSG water. Uses for such large and difficult-to-predict quantities of both treated and untreated water in the Walloons gas fields region are limited. As such, it is acknowledged that the treatment, use and disposal of CSG water present a challenge for the Project and the CSG industry in general. This paper will use the Talinga development area, established in 2008 and located southwest of Chinchilla in Queensland as a case study in water management adopted by Australia Pacific LNG. In particular, this paper focuses on the discharge of treated CSG water to surface watercourses (creeks/rivers) - one of a suite of water management options used by the Project. This paper explores the regulatory framework governing this aspect of water management and Origin's approach to ensuring the environmental values of receiving waters are preserved. At time of writing, the gas production from the Talinga field has been operated under an Environmental Authority (EA) with provision for an initial 18-month continuous discharge to the Condamine River of 20 ML/d as the preliminary water management option underpinning a broader management strategy. The broader strategy includes transitioning to a managed discharge flow regime that mimics the natural flows of the River.

Project characteristics	Details
	© 2012, SPE/APPEA International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production.
Outputs	Murray. (2012). Coal seam gas water - River discharge: Context matters. *SPE/APPEA International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production 2012: Protecting People and the Environment - Evolving Challenges, September 11, 2012 - September 13, 2012.* Perth, WA, Australia: Society of Petroleum Engineers.
Key personnel	Murray, Janelle
Contact	Origin Energy, United States
Research themes	Co-produced/mine water, water supplies, water dependent ecosystems
Project information source	Literature

Table 4.185 Project 185: Direct toxicity assessment

Project characteristics	Details
Project title	**Direct toxicity assessment**
Project location	Australia
Principal investigator	Unknown
Lead institution	Origin Energy
Project budget	Unknown
Source of funding	Origin Energy
Project duration	2012
Current status	Unknown
Project summary	Direct toxicity assessment of treated CSG water and boron as it relates to the aquatic ecology of the Condamine River.
Outputs	Unknown
Research themes	Co-produced/mine water, water supplies ,water dependant ecosystems
Project information source	UQ CCSG Online Portal

Table 4.186 Project 186: Condamine River seep investigation

Project characteristics	Details
Project title	**Condamine River seep investigation**
Project Location	Australia
Principal Investigator	Unknown
Lead Institution	Origin Energy
Project Budget	Unknown
Source of Funding	Origin Energy
Project Duration	2012
Current Status	Unknown
Project Summary	Collaboration with government and independent consultants to investigate potential sources and mechanisms for gas observed bubbling within the Condamine River, and set up long term monitoring programmes.
Outputs	Unknown
Research Themes	Water supplies ,water dependant ecosystems
Project Information Source	UQ CCSG Online Portal

Table 4.187 Project 187: Literature and science review of coal seam gas and coal mining impacts on water-related environmental values

Project characteristics	Details
Project title	**Literature and science review of coal seam gas and coal mining impacts on water-related environmental values**
Project location	Australia
Principal investigator	SMEC
Lead institution	Department of the Environment
Project budget	Unavailable
Source of funding	Australian Government
Project duration	2011-2014
Current status	Completed
Project summary	Report one in a series of reports commissioned by the Department of the Environment on the advice of the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC). The series includes summaries of research projects relating to the impacts of coal seam gas and coal mining developments on water resources, currently being undertaken or completed, in Australia, Canada, China, Russia, India, United Kingdom (UK) and United States of America (US) during the period January 2000 to September 2014.
Objectives	The objective of the reference list series is to identify relevant research projects to: • support targeted approaches to future research - that address critical gaps in the scientific understanding of water-related impacts associated with coal seam gas and large coal mining activities • enable the Department of the Environment to effectively support the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) as it provides advice to regulators on the water impacts of coal seam gas and large coal mining.
Achievements	This report profiles 55 research projects relating to the water-related impacts of coal seam gas and coal mining activities.
Outputs	Commonwealth of Australia 2014, *Reference list for water-related coal seam gas and coal mining research, Report 1: Australia, Canada and United States of America, January 2000 to June 2012, p*repared by SMEC for the Department of the Environment, Commonwealth of Australia
Key personnel	SMEC
Research themes	Aquifer interconnectivity, disruption of surface water flow pathways, co-produced water and salt management (CSG) and mine water and salt management (coal mines), seismicity, hydraulic fracturing, quality and reliability of water supplies, including environmental health, water dependent ecosystems, cumulative impact assessments
Project information source	Literature

Table 4.188 Project 188: Condamine River gas seep investigation

Project characteristics	Details
Project title	**Condamine River gas seep investigation**
Project location	Australia
Principal investigator	DNRM
Lead institution	State of Queensland, Department of Natural Resouces and Mines
Project budget	Unknown
Source of funding	Queensland Government
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The LNG Enforcement Unit (LNGEU) was contacted by a landholder on 17 May 2012, regarding the observation and possible causes of bubbling in the Condamine River approximately six kilometres downstream of Chinchilla Weir. Preliminary investigations indicated that the bubbling was unlikely to be caused by coal seam gas (CSG) activities in the region. However, in anticipation of further sites or incidences being discovered, including further information provided by Origin (on behalf of Australia Pacific LNG) indicating that gas bubbling in the Condamine River was occurring at additional sites, the government implemented a two-phase multi-agency investigation. Coordinated by the LNGEU, the government's Condamine River gas seep investigation comprises an immediate focus on ensuring public safety, assessing environmental harm and the extent of gas seeps (Phase 1); and a long-term investigation involving a technical program that will allow government experts to verify the information it receives from Origin (Phase 2). Concurrently, Origin has adopted a three-phase long-term investigative approach. The following report provides a summary of the government's activities regarding its Condamine River gas seep investigation up until 1 October 2012, which incorporates the entirety of Phase 1 and initial activities for Phase 2 of government's investigation.
Outputs	DNRM. (2012). Summary technical report - Part 1: Condamine River gas seep investigation. State of Queensland, Department of Natural Resources and Mines. http://www.dnrm.qld.gov.au/__data/assets/pdf_file/0005/119669/condamine-river-gas-seep.pdf
Key personnel	DNRM
Research themes	Aquifer interconnectivity, water supplies
Project information source	Literature

Table 4.189 Project 189: Stage One Report: Development of ecosystem protection trigger values For sodium sulfate in seasonally flowing streams of the Fitzroy River Basin

Project characteristics	Details
Project title	**Stage One Report: Development of ecosystem protection trigger values For sodium sulfate in seasonally flowing streams of the Fitzroy River Basin**
Project location	Australia
Principal investigator	Rajesh Prasad
Lead institution	The University of Queensland, Department of Environment and Resource Management
Project budget	Unknown
Source of funding	ACARP
Project duration	?-Aug 2012
Current status	Completed
Project summary	Coal mines in the Bowen Basin have reduced freshwater consumption by implementing water re-use in operations. This has resulted in overall increased salinity of water stored on sites. Sulfate is often associated with this water but few studies have elucidated the impacts of sulfate on aquatic organisms making it difficult to set criteria for mine water discharge. There are currently no ecosystem protection trigger values for sulfate in Queensland or elsewhere in Australia. This study has developed the first locally relevant ecosystem protection trigger values for sulfate in the Fitzroy River Basin.
Objectives	The objectives of the study were: • to conduct acute toxicological tests to determine the tolerances of aquatic macroinvertebrates from a section of the Fitzroy Catchment, to saline solutions those were representative of ionic compositions of mine waters • to undertake acute and chronic toxicity tests on representative mine waters ionic compositions using a standard suite of commercially available taxa • to determine if ionic composition influenced the toxicity of mine waters.
Outputs	Assessing the ecotoxicology of salinity on organisms in seasonally flowing streams in the Fitzroy Catchment http://www.acarp.com.au/abstracts.aspx?repId=C18033
Research themes	Co-produced water,water supplies, water dependent ecosystems
Project information source	ACARP website

4.8.2 Canada

Table 4.190 Project 190: Groundwater protection and unconventional gas extraction: the critical need for field-based hydrogeological research

Project characteristics	Details
Project title	**Groundwater protection and unconventional gas extraction: the critical need for field-based hydrogeological research**
Project location	Canada
Principal investigator	Jackson, R.E.; Gorody, A.W.; Mayer, B.; Roy, J.W.; Ryan, M.C.; Van Stempvoort, D.R.
Lead institution	Geofirma Engineering Ltd.
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Unconventional natural gas extraction from tight sandstones, shales, and some coal-beds is typically accomplished by horizontal drilling and hydraulic fracturing that is necessary for economic development of these new hydrocarbon resources. Concerns have been raised regarding the potential for contamination of shallow groundwater by stray gases, formation waters, and fracturing chemicals associated with unconventional gas exploration. A lack of sound scientific hydrogeological field observations and a scarcity of published peer-reviewed articles on the effects of both conventional and unconventional oil and gas activities on shallow groundwater make it difficult to address these issues. Here, we discuss several case studies related to both conventional and unconventional oil and gas activities illustrating how under some circumstances stray or fugitive gas from deep gas-rich formations has migrated from the subsurface into shallow aquifers and how it has affected groundwater quality. Examples include impacts of uncemented well annuli in areas of historic drilling operations, effects related to poor cement bonding in both new and old hydrocarbon wells, and ineffective cementing practices. We also summarize studies describing how structural features influence the role of natural and induced fractures as contaminant fluid migration pathways. On the basis of these studies, we identify two areas where field-focused research is urgently needed to fill current science gaps related to unconventional gas extraction: (1) baseline geochemical mapping (with time series sampling from a sufficient network of groundwater monitoring wells) and (2) field testing of potential mechanisms and pathways by which hydrocarbon gases, reservoir fluids, and fracturing chemicals might potentially invade and contaminate useable groundwater.
Outputs	Jackson et al. (2013). Groundwater protection and unconventional gas extraction: the critical need for field-based hydrogeological research. *Ground Water*. http://www.ncbi.nlm.nih.gov/pubmed/23745972
Key personnel	Jackson, R.E.; Gorody, A.W.; Mayer, B.; Roy, J.W.; Ryan, M.C.; Van Stempvoort, D.R.
Contact	Geofirma Engineering Ltd., 11 Venus Crescent, Heidelberg, Waterloo Region, Ontario, Canada.

Project characteristics	Details
Research themes	Co-produced/mine water, hydraulic fracturing, water supplies, water dependent ecosystems
Project information source	Literature

4.8.3 China

Table 4.191 Project 191: The hydrogen and oxygen isotope characteristics of drainage water from Taiyuan coal reservoir

Project characteristics	Details
Project title	**The hydrogen and oxygen isotope characteristics of drainage water from Taiyuan coal reservoir**
Project location	China
Principal investigator	Wang, Shan-Bo; Tang, Shu-Heng; Wan, Yi; Li, Zhong-Cheng; Zhang, Song-Hang
Lead institution	School of Energy Resources, China University of Geosciences, Beijing
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	To study water features and hydrodynamic conditions of the No. 15 Taiyuan formation coal reservoir and its roof limestone in the southern Qinshui basin, this paper collected 51 water samples from the river, coal-bed methane well drainage, coal reservoir and its roof limestone in the South Shizhuang region. Measurements of hydrogen and oxygen isotope and main ion concentration in the water samples show that the water discharged from CBM wells is a mixture of coal seam water and roof limestone water. The No. 15 coal seam has a strong hydraulic connection with the roof limestone fracture aquifer, and receives substantial recharge from roof limestone water. The sealing ability of the roof limestone fracture aquifer is weak, and the runoff speed of water in the limestone fracture is fast. Roof limestone water demonstrates a drift of 18O, and the water that is discharged from the CBM wells of the No. 15 coal seam has the drift of both of 18O and D. At the same time, water discharged from the CBM wells of the No. 3 coal seam mainly demonstrates a drift of D. All the water discharged from the CBM wells present a positive correlation with salinity (TDS), and the data of D and 18O can be used as reference factors for judging the runoff conditions of coal seam water.
Outputs	Wang et al. (2013). The hydrogen and oxygen isotope characteristics of drainage water from Taiyuan coal reservoir. *Meitan Xuebao/Journal of the China Coal Society.* Hepingli, Beijing, 100013, China: China Coal Society.
Key personnel	Wang, Shan-Bo; Tang, Shu-Heng; Wan, Yi; Li, Zhong-Cheng; Zhang, Song-Hang
Contact	School of Energy Resources, China University of Geosciences, Beijing 100083, China
Research themes	Water dependent ecosystems
Project information source	Literature

4.8.4 United States

Table 4.192 Project 192: How many mountains can we mine? Assessing the regional degradation of Central Appalachian Rivers by surface coal mining

Project characteristics	Details
Project title	**How many mountains can we mine? Assessing the regional degradation of Central Appalachian Rivers by surface coal mining**
Project location	US
Principal investigator	Bernhardt, Emily S.; Lutz, Brian D.; King, Ryan S.; Fay, John P.; Carter, Catherine E.; Helton, Ashley M.; Campagna, David; Amos, John
Lead institution	Duke Univ, Dept Biol, Box 90338, Durham, NC 27708 US
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Surface coal mining is the dominant form of land cover change in Central Appalachia, yet the extent to which surface coal mine runoff is polluting regional rivers is currently unknown. We mapped surface mining from 1976 to 2005 for a 19 581 km(2) area of southern West Virginia and linked these maps with water quality and biological data for 223 streams. The extent of surface mining within catchments is highly correlated with the ionic strength and sulfate concentrations of receiving streams. Generalized additive models were used to estimate the amount of watershed mining, stream ionic strength, or sulfate concentrations beyond which biological impairment (based on state biocriteria) is likely. We find this threshold is reached once surface coal mines occupy >5.4% of their contributing watershed area, ionic strength exceeds 308 mu S cm(-1), or sulfate concentrations exceed 50 mg L-1. Significant losses of many intolerant macroinvertebrate taxa occur when as little as 2.2% of contributing catchments are mined. As of 2005, 5% of the land area of southern WV was converted to surface mines, 6% of regional streams were buried in valley fills, and 22% of watersheds with >5.4% of their surface area converted to mines. the regional stream network length drained
Outputs	Bernhardt *et al.* (2012). How Many Mountains Can We Mine? Assessing the Regional Degradation of Central Appalachian Rivers by Surface Coal Mining. *Environmental Science & Technology*.
Key personnel	Bernhardt, Emily S.; Lutz, Brian D.; King, Ryan S.; Fay, John P.; Carter, Catherine E.; Helton, Ashley M.; Campagna, David; Amos, John
Contact	Duke Univ, Dept Biol, Box 90338, Durham, NC 27708 US
Research themes	Co-produced/mine water, water supplies, water dependent ecosystems
Project information source	Literature

Table 4.193 Project 193: Spatial variability of ecological and water quality impacts of acid mine drainage in an alpine wetland

Project characteristics	Details
Project title	**Spatial variability of ecological and water quality impacts of acid mine drainage in an alpine wetland**
Project location	US
Principal investigator	Turner, Benjamin F.; Graham, Andie S.
Lead institution	Pennsylvania State University, DuBoisCampus, DuBois, PA, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Acid mine drainage (AMD) can adversely affect aquatic and semi-aquatic life in impacted areas, resulting in a loss of species diversity and abundance, as well as an interruption of the food chain. Bilger Run Wetland, located in the Allegheny Plateau of central Pennsylvania, was impacted by AMD due to extensive bituminous coal mining operations within the watershed. The wetland, 16 ha in area, is supplied water by a watershed of 518 ha covered primarily by forest, reclaimed mine land, and farm land. In order to learn more about relationships between water quality and ecology at the site, we monitored pH and conductivity at 47 locations within a 9.5 ha portion of the wetland monthly for 12 months, in addition to observing vegetation, vertebrates and macroinvertebrates at these locations. Time-averaged pH and conductivity varied from 3.6 to 6.0 and 200 to 2160 uS/cm, respectively, within the wetland, representing a mix of dilute water, untreated AMD, and treated water entering the wetland from various sources. Despite direct inputs of untreated AMD and a relatively low spatially-averaged pH of 4.7, vegetative cover in the wetland was lush, albeit populated by acid-tolerant flora. However, macro-invertebrates observed throughout the wetland were limited to pollution-tolerant species, and no fish species were observed. Preliminary bird observations prompted us to conduct bird point count surveys at a subset of locations within the wetland twice monthly the following year from May to August. A positive correlation was found between mean spatially-interpolated water pH in the observation areas and bird species richness, suggesting that acidic conditions may have an adverse affect on bird species richness in a wetland environment.
Outputs	Turner and Graham. (2012). Spatial variability of ecological and water quality impacts of acid mine drainage in an alpine wetland. *Abstracts with Programs - Geological Society of America.* Geological Society of America (GSA), Boulder, CO, United States.
Key personnel	Turner, Benjamin F.; Graham, Andie S.
Contact	Pennsylvania State University, DuBoisCampus, DuBois, PA, United States
Research themes	Co-produced/mine water, water supplies, water dependent ecosystems
Project information source	Literature

Table 4.194 Project 194: Unconventional gas resources in the USA

Project characteristics	Details
Project title	**Unconventional gas resources in the USA**
Project location	US
Principal investigator	Schumann, J.;Vossoughi, S.
Lead institution	University of Kansas, Department of Chemistry & Petroleum Engineering, Lawrence
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Unconventional gas accounts for more than 40% of U. S. domestic gas production and more than 10% of world output. The amount of resources available is still uncertain and estimates vary to a large degree. In this paper, unconventional gas resources within the United States will be examined. This paper will take a brief look at all types of unconventional gas resources (there have been 6 identified) but will concentrate on shale gas and coal-bed methane, as they are the resources receiving the most attention. This paper will also delve into the technology in unconventional gas production and exploration, including recent innovations in the industry. Finally, environmental concerns unique to unconventional gas production will be addressed. Natural gas refers to naturally occurring hydrocarbons found trapped underground. It occurs as mixtures of hydrocarbons of various molecular weights (methane, butane, etc.) and was formed millions of years ago from fossilized organic matter. Natural gas can be used as a cleaner burning alternative to other fossil fuels for power generation. It produces half the amount of carbon dioxide as coal and roughly 25 percent less carbon dioxide than gasoline. Consequently, it is becoming more popular in today's environmentally conscious world. Worldwide demand is expected to increase at twice the rate of oil until at least 2030. Interest in natural gas is at an all-time high in the United States. Only recently have we learned about the vast unconventional resources that exist within our borders. The implications for reduced dependence on foreign sources of gas are promising for the future of this country. There may be sufficient resources within the United States to allow this energy source to thrive for many years to come. Natural gas can be divided into two categories: 1) Conventional gas which is found in reservoirs where the gas has been trapped by a layer of rock. Usually conventional gas refers to that which exists on top of crude oil reservoirs. Conventional gas is relatively easy to extract because once a well is drilled, the gas will naturally flow to the surface. 2) Unconventional gas which is referred to gas trapped in formations where it cannot easily flow such as in shale formations; or, gas that is tightly attached to the surface of the surrounding rock such as in coal-bed seams. Unconventional gas is more difficult to extract because it often requires fracturing the rock formation to allow the gas to accumulate in sufficient quantities and flow out of the well. There are six types of unconventional gas resources: shale gas, coal-bed methane, deep gas, tight gas, geopressurized zones, and methane hydrates. Each of these unconventional gas resources within the United States will be examined with a focus on their development and the unique challenges facing them.

Project characteristics	Details
Outputs	Schumann and Vossoughi. (2012). Unconventional Gas Resources In The USA. *Porous Media and Its Applications in Science, Engineering, and Industry.* Melville: Amer Inst Physics.
Key personnel	Schumann, J.; Vossoughi, S.
Contact	[Schumann, Jon; Vossoughi, Shapour] Univ Kansas, Dept Chem & Petr Engn, Lawrence, KS 66045 USA
Research themes	Water dependent ecosystems
Project information source	Literature

Table 4.195 Project 195: Effects of coal mining on freshwater mussels in the New River Basin; a test using Corbicula as biomonitors

Project characteristics	Details
Project title	**Effects of coal mining on freshwater mussels in the New River Basin; a test using Corbicula as biomonitors**
Project location	US
Principal investigator	Mincy, Grant
Lead institution	University of Tennessee, Geology Department, Knoxville, TN, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The New River basin (NRB) of Tennessee is home to a number of rare endemic aquatic communities. One such community of particular importance to the area, experiencing a precipitous population decline due to the fouling and pollution of their freshwater systems, is that of freshwater mussels (Bogan 2006). This study in the NRB involves measuring the mortality rates of live Asian clam (Corbicula fluminea) assemblages. A common property of aquatic systems influenced by anthropogenic activity is increased conductivity (a proxy correlated to the ability of water to pass an electric current because of increased metal and dissolved solids concentrations) which studies show may impair clam health. Our study of five, coal surface mining, impacted streams within the NRB and a control stream of similar geology tests this correlation. Silos containing live Corbicula fluminea were placed in several localities in streams of the NRB that receive mining drainage as mine drainage is commonly associated with elevated conductivity. The growth rates of these specimens were periodically measured, over the course of 120 days, to determine the effect of water resistivity on clam health. We found that growth and mortality rates of the life assemblages are correlated with conductivity and water temperature level. Specifically, growth rate increased with temperature but growth rate decreased with conductivity, after temperature was accounted for. Overall mortality was low so our findings imply that mining is not immediately lethal to these mussels but does have a negative health impact on them.
Outputs	Mincy. (2012). Effects of coal mining on freshwater mussels in the New River basin; a test using Corbicula as biomonitors. *Abstracts with Programs - Geological Society of America.* Geological Society of America (GSA), Boulder, CO, United States.
Key personnel	Mincy, Grant
Contact	University of Tennessee, Geology Department, Knoxville, TN, United States
Research themes	Co-produced/mine water, cumulative impact assessment
Project information source	Literature

Table 4.196 Project 196: Effects of coal mining on survivorship and taphonomy of the Asian clam

Project characteristics	Details
Project title	**Effects of coal mining on survivorship and taphonomy of the Asian clam**
Project location	US
Principal investigator	Mincy, Grant; McKinney, Michael L.
Lead institution	University of Tennessee, Geology Department, Knoxville, TN, United States
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	We propose that mining activity occurring in the New River Basin (NRB) of Tennessee is greatly enhancing dissolution rates of freshwater mussel shells, increasing mortality and thus negatively impacting aquatic ecosystems and our ability to access their record. Our study, in mining impacted waters of the NRB, involves measuring the mortality rates of live Corbicula fluminea assemblages and the shell dissolution rates of their death assemblages to gather information supporting this hypothesis. The freshwater molluscan record provides information on paleoecology and paleoclimates. The freshwater record also helps us understand species composition changes on part of anthropogenic activities (Cummins 1994). Surface coal mining activity is capable of erasing this record. The taphonomic effects of changing water chemistry can have an important impact on paleontological analysis including live/dead fidelity, size frequency distributions, numerical abundance, and biomass estimates (Cummins 1994). A long history of such surface coal mining exists in the NRB of Tennessee and in recent years these mining practices have escalated (Bullock 2007). To measure the effects of mining on living mussels, silos containing live Corbicula fluminea were placed in several localities in creeks of the NRB that receive mining drainage. To measure the effects of mining on shell dissolution rates, mesh bags containing shells of Corbicula fluminea were also placed in several localities in creeks of the NRB that receive mining drainage. The weight of these shells were periodically measured, over the course of many weeks, to determine the rate of dissolution. To assess the factors affecting mortality rates and dissolution rates of shells, we measured water velocity as well as several chemical parameters: calcium, pH, sulfate, and conductivity. Our preliminary findings indicate that survivorship is influenced by most of these variables. We find that dissolution rates of the dead shells are also influenced by these factors and that the rates are relatively high, on the order of 5-10% per year, indicating that all fossil evidence of the dead will be gone in a time frame of less than a few decades.
Outputs	Mincy and McKinney. (2012). Effects of coal mining on survivorship and taphonomy of the Asian clam. *Abstracts with Programs - Geological Society of America.* Geological Society of America (GSA), Boulder, CO, United States.
Key personnel	Mincy, Grant; McKinney, Michael L.
Contact	University of Tennessee, Geology Department, Knoxville, TN, United States
Research themes	Water dependent ecosystems
Project information source	Literature

Table 4.197 Project 197: Effects of mountaintop mining on fish distributions in Central Appalachia

Project characteristics	Details
Project title	**Effects of mountaintop mining on fish distributions in Central Appalachia**
Project location	US
Principal investigator	Hopkins, R. L.; Roush, J. C.
Lead institution	USDA, Nat Resources Conservat Serv, Point Pleasant, WV USA
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Mountaintop mining with valley fills (MTM/VF) is the main source of landscape change in central Appalachia. While our knowledge of the local-scale effects of MTM/VF on stream chemistry and biotic assemblages has recently improved, the effects at the landscape scale are less well known. In this study, we explore the effects of MTM/VF on the distributions of six fish species with contrasting ecologies in the upper Kentucky River basin, an area heavily affected by MTM/VF. Using a museum-based data set of 239 occurrence records, land use/land cover data and boosted regression tree modelling, we were able to create robust predictive models for the focal species (AUCs=0.82-0.93). Models explained from 41.2 to 71.9% of the variation in species distributions. We detected a marked negative influence of MTM/VF in four of the six species distribution models - with relative influences ranging from 5.9-12.7%. Species typically inhabiting faster-flowing riffle and run mesohabitats appeared to respond more strongly to MTM/VF. Interestingly, the mean patch size of MTM/VF was more influential than the overall proportion of the watershed affected by MTM/VF in our models. Thus, our data suggest the spatial pattern of mining disturbance is very important in determining the cumulative impact of MTM/VF. Considering the central Appalachian region is a continental hot spot for freshwater biodiversity, establishing a firm understanding of the effects of MTM/VF at the landscape scale is essential if we wish to protect these natural resources.
Outputs	Hopkins and Roush. (2013). Effects of mountaintop mining on fish distributions in central Appalachia. *Ecology of Freshwater Fish.*
Key personnel	Hopkins, R. L.; Roush, J. C.
Contact	University of Rio Grande, Dept Biol, Rio Grande, USA
Research themes	Co-produced/mine water, water dependent ecosystems
Project information source	Literature

4.9 Cumulative impact assessments

Cumulative impact assessments recognise that that the cumulative impact of multiple industries may be far greater than that of either the individual impacts or even the sum of the individual industries. Thirteen (13) projects were collated regarding cumulative impact assessments; 12 of which were from Australia.

4.9.1 Australia

Table 4.198 Project 198: Coal seam gas – Toward a risk management framework for a novel intervention

Project characteristics	Details
Project title	**Coal seam gas – Toward a risk management framework for a novel intervention**
Project location	Australia
Principal investigator	Randall
Lead institution	Unknown
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	Coal seam gas (CSG) extraction is a recent development in Australia and is projected to make a substantial contribution to the nation's domestic and export energy supplies for the next several decades. CSG is a spatially dispersed industry with a much greater footprint on land and environment than the more modest surface area devoted to well-heads would suggest. Its potential impacts – including massive demands for water, contaminated waste water, disruption of aquifers, disturbance and contamination of geosystems, atmospheric pollution, degradation of landscape aesthetics, and stress on infrastructure and sense of community – raise important issues of human and ecosystem health and compatibility with agriculture, rural communities and the environment. Regulation and management of these impacts is a major concern, and the substantial uncertainty attached to some of them raises explicit issues of risk management. For novel interventions, risk management should balance the benefits of innovation and the need for protection from serious threats of harm. I introduce an integrated risk management framework for proposed innova- tions that includes a structured program of screening, pre-release testing and post-release surveillance. Application to CSG is more problematic, because there is much less scope for secure testing at pilot scale – after all, much that is novel and risky about CSG relates to the cumulative impacts of rapid expansion. Integrated risk management starts with a comprehensive assess- ment of the cumulative impacts and risks of planned CSG development to guide go/no-go decisions and design of an adequate regulatory structure. But risk management decisions should be attentive also to the costs of impeding genuinely beneficial innovation.
Outputs	Randall. (2012). Coal seam gas – Toward a risk management framework for a novel intervention. *Environmental and Planning Law Journal*.

Project characteristics	Details
Key personnel	Randall
Research themes	Cumulative impact assessment
Project information source	Literature

Table 4.199 Project 199: Energy from the food bowl: an uneasy coexistence

Project characteristics	Details
Project title	**Energy from the food bowl: an uneasy coexistence**
Project location	Australia
Principal investigator	Everingham, Jo-Anne; Rifkin, Will; Collins, Nina
Lead institution	Unknown
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	This project aims to identify the barriers, challenges and opportunities that inform current thinking and behaviour in relation to combined or alternative land uses and managing their impacts; to build knowledge about the priorities and roles of various sectors and organisations in managing the cumulative impacts of resource extraction and agriculture in rural regions such as the Darling Downs; and to understand how agriculture and energy production can coexist in ways that create a better future for local communities.
Outputs	*Everingham et al. (2013). Energy resources from the food bowl: an uneasy coexistence. Identifying and managing cumulative impacts of mining and agriculture.* Centre for Social Responsibility in Mining, Sustainable Minerals Institute, The University of Queensland. https://www.csrm.uq.edu.au/publications/energy-resources-from-the-food-bowl-an-uneasy-co-existence-identifying-and-managing-cumulative-impacts-of-mining-and-agriculture
Key personnel	Everingham, Jo-Anne; Rifkin, Will; Collins, Nina
Research themes	Cumulative impact assessment
Project information source	Literature

Table 4.200 Project 200: Cultivating collaboration: Lessons from initiatives to understand and manage cumulative impacts in Australian resource regions

Project characteristics	Details
Project title	**Cultivating collaboration: Lessons from initiatives to understand and manage cumulative impacts in Australian resource regions**
Project location	Australia
Principal investigator	Porter; Franks; Everingham, Jo-Anne
Lead institution	Centre for Social Responsibility in Mining, The University of Queensland, Sustainable Minerals Institute
Project budget	Unknown
Source of funding	Isaac Regional Council, Queensland Government and the Australian Coal Association Research Program
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Australia has experienced rapid development within its resource regions, with traditional mining sectors like coal, iron-ore and natural gas expanding and new industries such as coal seam gas emerging. As a result, there is an increasing prevalence and awareness of the cumulative impacts of the extractive resource industries on the society, environment and economy of these regions. Collaborative governance is emerging as a means of addressing cumulative impacts. This article undertakes an analysis of 30 case studies of collaborative governance in the resources sector of Australia. The initiatives analysed range from those focussed on information exchange and coordination to higher degrees of collaboration that involve shared resources and shared risks. The study demonstrates that there are challenges in using collaborative approaches to tackle cumulative impacts, but that significant benefits can be realised. The study highlights the need to nurture and cultivate collaborative relationships in order to provide the foundation for long-term solutions.
Outputs	Porter et al. (2013). Cultivating collaboration: Lessons from initiatives to understand and manage cumulative impacts in Australian resource regions. *Resources Policy*. http://www.sciencedirect.com/science/article/pii/S0301420713000184
Key personnel	Porter; Franks; Everingham
Research themes	Cumulative impact assessment
Project information source	Literature

Table 4.201 Project 201: CSG water use proposals in the QMDB (assessing the impact on aquatic ecosystems)

Project characteristics	Details
Project title	**CSG water use proposals in the QMDB (assessing the impact on aquatic ecosystems)**
Project location	Queensland, Australia
Principal investigator	Science Delivery Division, Department of Science, Information Technology, Innovation and the Arts (Queensland Government)
Lead institution	Queensland Government Department of Environment and Resource Management
Project budget	This project was one component (Activity 9) of the $5 million Healthy HeadWaters Coal Seam Gas Water Feasibility Study
Source of funding	Australian Government Water for the Future initiative
Project duration	Literature output March 2013
Current status	Completed
Project summary	This activity developed an overarching framework for assessing the cumulative impacts on aquatic ecosystems of the release of CSG treated water at multiple sites into the surface water systems of catchments in the QMDB. A range of scenarios were developed to assess flow-related cumulative impacts based on existing and proposed CSG water locations and discharge schedules (volumes and timing) nominated by the CSG companies, as well as using current scientific understanding to nominate alternate sites and varied discharge arrangements.
Outputs	http://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-9 http://www.dnrm.qld.gov.au/__data/assets/pdf_file/0009/106020/act-9-cumulative-impacts-assess-framework.pdf
Research themes	Cumulative impact assessment
Project information source	UQ CCSG Online Portal, Queensland Government website

Table 4.202 Project 202: Assessing the cumulative impact of mining scenarios on bioregional assets in the Namoi Catchment

Project characteristics	Details
Project title	**Assessing the cumulative impact of mining scenarios on bioregional assets in the Namoi Catchment**
Project location	Australia
Principal investigator	Eco Logical Australia
Lead institution	Eco Logical Australia
Project budget	Unknown
Source of funding	Namoi Catchment Management Authority
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The coal mining industry is experiencing a period of rapid expansion in NSW. Forward estimates of global demand for coal have resulted in expansion of the mining sector in the Gunnedah Basin which lies immediately north of the Hunter Valley within the central parts of the Namoi Catchment in northern NSW. Some existing mines in the Gunnedah Basin are up scaling, and several new mines are seeking approval or are otherwise planned for the region. Concern about the cumulative impacts of multiple mines on natural resources assets in the Namoi Catchment have evoked concerns in the Namoi from both environment and farming interest groups and the broader Catchment Community. The Namoi Catchment Management Authority has responded by commissioning this study to develop a tool for quantifying the risk of cumulative impacts across ten natural resource assets in the Catchment, namely land use; soils; carbon; surface water; groundwater; vegetation extent; vegetation type; vegetation condition (intactness); vegetation connectivity and threatened species.
Outputs	Eco Logical Australia. (2012). *Assessing the cumulative impact of mining scenarios on bioregional assets in the Namoi Catchment- Development and trial of a GIS tool – NCRAT Version 1*, Namoi Catchment Management Authority.
Key personnel	Eco Logical Australia
Research themes	Cumulative impact assessment
Project information source	Literature

Table 4.203 Project 203: General Purpose Standing Committee No. 5 Inquiry into coal seam gas

Project characteristics	Details
Project title	**General Purpose Standing Committee No. 5 Inquiry into coal seam gas**
Project location	Australia
Principal investigator	Unknown
Lead institution	General Purpose Standing Committee No. 5 Inquiry into Coal seam gas
Project budget	Unknown
Source of funding	New South Wales Government
Project duration	2012
Current status	Unknown
Project summary	This document reports the findings of the General Purpose Standing Committee No. 5 inquiry into and report on the environmental, economicand social impacts of coal seam gas (CSG) activities, including exploration and commercial extraction activities, allowable under the NSW Petroleum (Onshore) Act 1991 (the Act).
Outputs	New South Wales. Parliament. Legislative Council. General Purpose Standing Committee No. 5, *Inquiry into coal seam gas* / General Purpose Standing Committee No. 5. [Sydney, N.S.W.] : The Committee, 2012. – xxi, 330 p.; 30 cm. (Report No. 35) https://www.parliament.nsw.gov.au/prod/parlment/committee.nsf/0/318a94f2301a0b2fca2579f1001419e5/$FILE/Report%2035%20-%20Coal%20seam%20gas.pdf
Research themes	Co-produced/mine water, water supplies ,water dependant ecosystems
Project information source	UQ CCSG Online Portal

Table 4.204 Project 204: An analysis of coal seam gas production and natural resource management in Australia Issues and ways forward

Project characteristics	Details
Project title	**An analysis of coal seam gas production and natural resource management in Australia Issues and ways forward**
Project location	Australia
Principal investigator	Williams, John; Stubbs, Tim; Milligan, Ann
Lead institution	John Williams Scientific Services Pty Ltd
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	This report outlines a review and analysis of some of the rapidly growing published literature, grey literature, and documentation on coal seam gas (CSG) production, from perspectives of government, industry and community. The first chapters describe and examine the science and engineering which underpin CSG production in Australia and overseas, with a view to considering potential impacts of the industry on natural resource management issues in the Australian landscape. Next, an outline is provided of the social, economic and community development issues associated with expansion of the CSG industry, with particular attention to research and analysis in Queensland and to a lesser extent in NSW.
Outputs	Williams et al. (2012). An analysis of coal seam gas production and natural resource management in Australia Issues and ways forward. John Williams Scientific Services Pty Ltd. http://wentworthgroup.org/wp-content/uploads/2014/01/An-analysis-of-CSG-production-and-NRM-in-Australia-Oct-2012-FULL.pdf
Key personnel	Williams, John; Stubbs, Tim; Milligan, Ann
Research themes	Cumulative impact assessment
Project information source	Literature

Table 4.205 Project 205: Managing cumulative risks to assets from mining

Project characteristics	Details
Project title	**Managing cumulative risks to assets from mining**
Project location	Australia
Principal investigator	Namoi CMA
Lead institution	Namoi Catchment Management Authority
Project budget	Unknown
Source of funding	Namoi CMA
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	Based on the critical thresholds identified for natural resource assets in the Namoi Catchment Action Plan (2010-2020), Namoi CMA initiated a project to investigate developing a framework to assess the cumulative risk of multiple mines to natural resource assets in the Namoi Catchment. Namoi CMA wanted to see if it was possible to develop an interactive GIS tool based on best available science and mapping that would allow the testing of different scenarios to produce cumulative risk statements and associated maps.
Outputs	Namoi CMA. (2013). Assessing the cumulative risks of mining and extractive industries to the Namoi Catchment's natural resource assets. Namoi Catchment Management Authority. http://www.namoi.cma.nsw.gov.au/41885.html?5
Key personnel	CMA, Namoi
Contact	francesca.andreoni@cma.nsw.gov.au
Research themes	Water supplies, cumulative impact assessment
Project information source	Literature

Table 4.206 Project 206: Underground water impact report for the Surat Cumulative Management Area

Project characteristics	Details
Project title	**Underground water impact report for the Surat Cumulative Management Area**
Project location	Australia
Principal investigator	Queensland Water Commission
Lead institution	Office of Groundwater Impact Assessment (Queensland Government)
Project budget	Unknown
Source of funding	Queensland Water Commission
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The Underground Water Impact Report (UWIR) for the Surat Cumulative Management Area (CMA) provides assessments on the impacts of water extraction by petroleum tenure holders on underground water in the Surat CMA, and specifies integrated management arrangements.
Outputs	Queensland Water Commission. (2012). Underground water impact report for the Surat Cumulative Management Area. Office of Groundwater Impact Assessment (Queensland Government). http://www.dnrm.qld.gov.au/ogia/surat-underground-water-impact-report
Key personnel	Queensland Water Commission
Research themes	Cumulative impact assessment
Project information source	Literature

Table 4.207 Project 207: Regulating coal seam gas in Queensland: Lessons in an adaptive environmental management approach?

Project characteristics	Details
Project title	**Regulating coal seam gas in Queensland: Lessons in an adaptive environmental management approach?**
Project location	Australia
Principal investigator	Swayne
Lead institution	Queensland University of Technology
Project budget	Unknown
Source of funding	Australian Research Council, Discovery Project 1094061 “An integrated legal, regime for a sustainable carbon cycle”.
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	The current regulatory approach to coal seam gas projects in Queensland is based on the philosophy of adaptive environmental management. This method of “learning by doing” is implemented in Queensland primarily through the imposition of layered monitoring and reporting duties on the coal seam gas operator alongside obligations to compensate and “make good” harm caused. The purpose of this article is to provide a critical review of the Queensland regulatory approach to the approval and minimisation of adverse impacts from coal seam gas activities. Following an overview of the hallmarks of an effective adaptive management approach, this article begins by addressing the mosaic of approval processes and impact assessment regimes that may apply to coal seam gas projects. This includes recent Strategic Cropping Land reforms. This article then turns to consider the preconditions for land access in Queensland and the emerging issues for landholders relating to the negotiation of access and compensation agree- ments. This article then undertakes a critical review of the environmental duties imposed on coal seam gas operators relating to hydraulic fracturing, well head leaks, groundwater management and the disposal and beneficial use of produced water. Finally, conclusions are drawn regarding the overall effectiveness of the Queensland framework and the lessons that may be drawn from Queensland’s adaptive environmental management approach.
Outputs	Swayne. (2012). Regulating coal seam gas in Queensland: Lessons in an adaptive environmental management approach? *Environmental and Planning Law Journal*.
Key personnel	Swayne
Research themes	Co-produced/mine water, well integrity, hydraulic fracturing, cumulative impact assessment
Project information source	Literature

Table 4.208 Project 208: Namoi Catchment Water Study independent expert interim final report

Project characteristics	Details
Project title	**Namoi Catchment Water Study independent expert interim final report**
Project location	Australia
Principal investigator	Price, Gareth W.; Murphy, Sean; Anderson, Mark
Lead institution	Schlumberger Water Services
Project budget	Unknown
Source of funding	New South Wales Government
Project duration	Unknown- literature output 2012
Current status	Unknown- literature output 2012
Project summary	In response to community concerns regarding the potential impacts of coal and gas mining and development in the Namoi Catchment, the then NSW Minister for Mineral and Forest Resources commissioned the study to investigate the potential impacts on water resources in the Namoi catchment from mining and CSG activities. The Study was to consider the whole of the Namoi catchment and the long-term, cumulative effects of coal resources development on catchment water resources.
Outputs	Price et al. (2012). Namoi Catchment water study, indepdendent expert, iterim final report. Schlumberger Water Services. http://www.namoicatchmentwaterstudy.com.au/client_images/1082348.pdf
Key personnel	Price, Gareth W.; Murphy, Sean; Anderson, Mark
Research themes	Water supplies ,water dependant ecosystems, cumulative impact assessment
Project information source	Literature

Table 4.209 Project 209: Modeling the impact of revegetation on regional water quality: A collective approach to manage the cumulative impacts of mining in the Bowen Basin, Australia

Project characteristics	Details
Project title	**Modeling the impact of revegetation on regional water quality: A collective approach to manage the cumulative impacts of mining in the Bowen Basin, Australia**
Project location	Australia
Principal investigator	Sonter, L.J.; Moran, C.J.; Barrett, D.J.
Lead institution	Sustainable Minerals Institute, University of Queensland, Brisbane, QLD 4072, Australia
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	In this paper we quantify the additional water quality benefits that can be achieved through coordinated cumulative impact management. To do this we simulate coordinated and un-coordinated revegetation investments and compare their impact on achieving regional water quality goals. Our results show that coordination between multiple mining companies achieves additional benefits since prioritization is enabled across a broader range of investment opportunities. Additionally, when coordinated investment is permitted beyond the boundaries of coal mining leases, results show that additional benefits are greatly enhanced since these regions provide more rewarding investment opportunities. Results illustrate (a) how regional coordination may influence reputational benefits of investments, and (b) that coordination is beneficial when investment opportunities are unevenly distributed across the landscape. When additional benefits are achievable, we suggest that mining companies should develop collective investment projects with an understanding of how coordination influences project costs. Similarly, investment projects should be developed with an understanding of investment tradeoffs and how these may adversely impact on regional stakeholders and hence industry reputation. The mining industry has significant potential to contribute to regional wellbeing; however, land management policies must be flexible and promote incentives to enable companies to invest beyond compliance. © 2013 Elsevier Ltd.
Outputs	Sonter et al. (2013). Modeling the impact of revegetation on regional water quality: A collective approach to manage the cumulative impacts of mining in the Bowen Basin, Australia. *Resources Policy.* Langford Lane, Kidlington, Oxford, OX5 1GB, United Kingdom: Elsevier Ltd. http://dx.doi.org/10.1016/j.resourpol.2013.02.007
Key personnel	Sonter, L.J.; Moran, C.J.; Barrett, D.J.
Contact	Sustainable Minerals Institute, University of Queensland, Brisbane, QLD 4072, Australia
Research themes	Cumulative impact assessment
Project information source	Literature

4.9.2 Canada

Table 4.210 Project 210: Legitimizing industry and multi-sectoral regulation of cumulative impacts: A comparison of mining and energy development in Athabasca, Canada and the Hunter Valley, Australia

Project characteristics	Details
Project title	**Legitimizing industry and multi-sectoral regulation of cumulative impacts: A comparison of mining and energy development in Athabasca, Canada and the Hunter Valley, Australia**
Project location	Canada
Principal investigator	Boutilier; Black
Lead institution	Simon Fraser University
Project budget	Unknown
Source of funding	Unavailable
Project duration	Unknown- literature output 2013
Current status	Unknown- literature output 2013
Project summary	The Alberta oil sands industry and the New South Wales coal industry both faced controversies related to their cumulative impacts. In an attempt to generate hypotheses, we compared their attempts to maintain legitimacy, in its various aspects, for both their industries and the regulatory regimes that evolved as the controversies persisted. Both the existing literature and the two cases suggest that greater use of multi-sectoral stakeholder forums for the governance of cumulative impacts can bolster the legitimacy of both the industry and its regulatory regime, including those aspects handled through self-regulation. The cases suggested the additional hypotheses that (a) the importance of the decisions allocated to the multi-stakeholder regulatory forum affects legitimacy perceptions generally, and (b) the multi-stakeholder approach to regulation does little to bolster legitimacy when stakeholders include activists who are more interested in transnational issues than local cumulative impacts.
Outputs	Boutilier and Black. (2013). Legitimizing industry and multi-sectoral regulation of cumulative impacts: A comparison of mining and energy development in Athabasca, Canada and the Hunter Valley, Australia. *Resources Policy*.
Key personnel	Boutilier; Black
Research themes	Cumulative impact assessment
Project information source	Literature

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Appendix A - Project survey

Literature and Science Review of Coal Seam Gas and Coal Mining
Recently Commissioned Research 2000-

The Office of Water Science at the Department of the Environment, Australia (http://www.environment.gov.au) is seeking to identify recently commissioned or completed projects researching the potential impacts of coal seam gas (coal bed methane) and coal mining on water resources and water dependent ecosystems in China, India, the United Kingdom, Russia, North America and Australia since 2000.

To be included in this important international review, please complete the following form for **each** of your projects researching the potential impacts of coal seam gas (coal bed methane) and coal mining on water resources and water dependent ecosystems. Thank you for your participation.

Return completed forms to Alexandra Badenhop,
Email: a.badenhop@wrl.unsw.edu.au
Fax: +612 9949 4188

If you have any questions, please call +612 8071 9867.

Project title	Click here to enter text.	
Project location	Click here to enter text.	
Principal researcher	Click here to enter text.	
Lead institution	Click here to enter text.	
Project budget/cost	Click here to enter text.	
Source of funding	Click here to enter text.	
Project duration	**Start:** Click here to enter a date.	**Finish:** Click here to enter a date.
Current status	Choose an item.	
Project summary		
Click here to enter text.		
Objectives		
Click here to enter text.		
Achievements		

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Outputs (*Please enter references or links to available reports/journal articles/conference paper etc*)	
Click here to enter text.	
Key personnel 1	
Name:	Click here to enter text.
Phone:	Click here to enter text.
Email:	Click here to enter text.
Key personnel 2	
Name:	Click here to enter text.
Phone:	Click here to enter text.
Email:	Click here to enter text.
Which of these research areas best describe your work (*Please check as many as are relevant*)	

☐Aquifer interconnectivity

- **☐ Baseline information (water quality and quantity)**
- **☐ Field based and modelling approaches for assessing connectivity**
- **☐ Groundwater flow and solute transport dynamics**

☐ Disruption of surface water flow pathways

- **☐ Subsidence**
- **☐ Mine cone of depression**
- **☐ Stream diversions**
- **☐ Infrastructure**

☐ Co-produced water and salt management (CSG) and mine water & salt management (coal mines)

- **☐ Aquifer injection and/or water treatment (technologies, relative cost benefit)**
- **☐ Effect on land and water resources (including. Irrigation)**
- **☐ Effect on Water dependent ecosystems (streams, rivers, floodplains, wetlands, GDEs, peat swamps)**

☐ Seismicity

☐ Integrity of wells - installation, operation, decommissioning

☐ Hydraulic fracturing

- **☐ Chemical - Surface and groundwater quality**
- **☐ Physical - Aquitard disruption, borehole collapse**

☐ Quality and reliability of water supplies including environmental health

- **☐ Mine site and gas field remediation, including well decommissioning and post mining voids**

☐ **Long term impacts, including, timescales for water levels to return to pre-development levels (quality/quantity)**

☐ **Chemical migration and toxicity**

☐ **Managing salt and heavy metals**

☐ **Water dependent ecosystems**

☐ **Prediction of potential impacts to water dependent ecosystems(streams, rivers, floodplains, wetlands, GDEs, peat swamps)**

☐ **Response and tolerances of water dependent ecosystems to changes in water regime (surface and groundwater quantity, seasonal patterns, variability, interactions) and water quality**

☐ **Mitigation measures**

☐ **Monitoring techniques**

☐ **Cumulative impact assessments**

☐ **Other:** Please list all

Do you know of other colleagues or counterparts involved with relevant research?

☐**Yes** ☐**No**

Name:	Click here to enter text.
Research Institution:	Click here to enter text.
Email:	Click here to enter text.
Phone:	Click here to enter text.

Name:	Click here to enter text.
Research Institution:	Click here to enter text.
Email:	Click here to enter text.
Phone:	Click here to enter text.

Appendix B - Project survey recipients

A listing of the personnel contacted (as of 28/05/2014) for information regarding relevant research is summarised in Table B1.

Table B1 Contacted personnel

Country	Research institution	Contact name	Response received
Australia	Alluvium Consulting QLD	Rohan Lucas	Yes
Australia	Central QLD University	Dr Claire Sellens	Yes
Australia	Mine Subsidence	Arthur Waddington	Yes – but unable to provide information
Australia	CSIRO	Dr Deepak Adhikary	Yes
Australia	CSIRO	Dr Peter Dillon	Yes
Australia	CSIRO	Dr Henning Prommer	Yes
Australia	CSIRO	Leif Wolf	No
Australia	CSIRO	Dr Sebastien Lamontagne	Yes
Australia	CSIRO	Dr Rob Jeffrey	Yes
Australia	CSIRO	Dr Sunil Varma	No
Australia	CSIRO	Dr Reem Freij-Ayoub	No
Australia	Curtin University	Kelly Pilgrim-Byrne	No
Australia	Curtin University	Prof Brian Evans	Yes
Australia	Curtin University	Jeff Charrois	Yes
Australia	DNRM	Ms Joan Meecham	No
Australia	DNRM	Evan Marshall	Yes
Australia	Geoscience Australia	Kriton Glenn, Ph.D	Yes
Australia	Healthy Headwaters CSG Water Feasibility Study	Angus Veitch	No
Australia	NICNAS	Ms Sneha Satya	Yes
Australia	NSW Department of Trade and Investment, Regional Infrastructure and Services	Steve Cozens	Yes- No relevant research
Australia	Queensland University of Technology	Prof Mal Cox	No
Australia	School of Earth, Environmental & Biological Sciences,	Dr Maree Corkeron	No
Australia	Queensland Water Commission	Sanjeev Pandey	Yes

Country	Research institution	Contact name	Response received
Australia	RPS	Bob Pearson	Yes
Australia	RPS	Hugh Middlemis	Yes
Australia	RPS	David Freebairn	Yes
Australia	School of the Environment, Flinders University	Prof Craig Simmons	Yes
Australia	Stellar Corp	James Butterworth	No
Australia	Sydney Catchment Authority	Dr Jerzy Jankowski	Yes
Australia	The University of Queensland	Prof Chris Moran	No
Australia	The University of Queensland	Alistair Innes-Walker	Yes
Australia	The University of Queensland	Helen Schultz	Yes
Australia	The University of Queensland	Dr Sue Vink	No
Australia	University of Newcastle; School of Engineering	Prof Garry Willgoose	Yes
Australia	University of Newcastle; School of Engineering	Prof Stephen Fityus	No
Australia	University of Southern Queensland; Faculty of Engineering and Surveying	Prof Steven Raine	No
Australia	UNSW	Prof Bruce Hebblewhite	No
Australia	UNSW	Dr Bryce Kelly	Yes
Australia	UNSW	Dr Wendy Timms	Yes
Australia	UQ	Prof Damien Barrett	No
Australia	UQ	Prof Ling Li	No
Australia	UQ	Dr Alan Woodley	No
Australia	UQ	Dr Peter Erskine	No
Australia	UQ	Dr Andrew Fletcher	No
Canada	Alberta Environment & Sustainable Resource Development	Curtis Brock	No
Canada	Alberta Environment & Sustainable Resource Development	Richard Casey	No
Canada	Alberta University	Tayfun Babadagli	No
Canada	Coal Association of Canada	Linda Kool	Yes – no relevant research
Canada	Encana	Jay Averill	No
Canada	Environment Canada	Jim Roy	Yes – no relevant research

Country	Research institution	Contact name	Response received
Canada	Geofirma Engineering Ltd	Richard Jackson	Yes – no relevant research
Canada	Laval University	John W Molson	Yes – no relevant research
Canada	University of British Columbia; Department of Chemistry	William R. Cullen	Yes- no relevant research
Canada	University of Calgary	Cathy Ryan	No
Canada	University of Guelph	Beth Parker	No
Canada	University of Waterloo	David Rudolph	No
Canada	University of Waterloo	Ramon Aravena	No
China	China Coal Research Institute	Weiyue Hu	No
China	China University of Mining & Technology	Qiang Wu ·	No
China	Chinese Academy of Geological Sciences	Chen Zongyu	No
China	College of Earth Sciences, University of Chinese Academy of Sciences		No
China	College of Resources and Environment University of Chinese Academy of Sciences	WANG, Mingyu, Ph.D., CGWP	No
China	Department of Applied Chemistry, South China University of Technology,	Zhi Dang	No
China	Department of International Cooperation, Ministry of Environmental Protection	MU Zhaojing	No
China	Embassy of the Peoples Republic of China in Australia		No
China	Energy Research Institute	Liu Hong	No
China	Foreign Economic Cooperation Office (FECO)	ZOU Yueyu	Yes
China	Jiangsu Key Laboratory of Resources and Environmental Information Engineering, China University of Mining and Technology, Xuzhou, China	Ran Jin Choi	No
China	Ministry of Science and Technology		No
China	National Natural Science Foundation	Wei Quin	No

Country	Research institution	Contact name	Response received
China	School of Water Resources and the Environment China University of Geosciences	Guangcai Wang	No
China	Sichuan University	Xie Heping	No
India	Advanced Center for Water Resources Development and Management (ACWADAM)	Dr.Himanshu Kulkarni,	No
India	Central Pollution Control Board	Dr. Sanjeev Aggarwal	No
India	Centre for Environmental Research and Engineering, Indian Institute of Technology, Bombay		Yes- no relevant research
India	Department of environmental Studies, North-Eastern Hill University,	Prof O.P. Singh	Yes
India	Department of Science and Technology	Dr. Sadhana Relia	No
India	Directorate General of Hydrocarbons	D. Dash	No
India	Indian Institute of Mines,	Prof Gurdeep Singh	Yes
India	Indian Institute of Technology Guwahati	Dr. Arup Kumar Sarma	No
India	Indian Institute of Technology Kanpur	Professor Rajiv Sinha	Yes
India	Indian Institute of Technology Kanpur	Dr. Vinay K. Gupta	No
India	Indian Institute of Technology Kharagpur	Prof. Jayanta Bhattacharya	No
India	Pollution Ecology Research Laboratory, Centre of Advanced Study in Botany, Banaras Hindu University		No
India	School of Environmental Studies, University of Delhi	Dr. M.K. Pandit	No
India	School of Petroleum Technology, Pandit Deendayal Petroleum University, Gandhinagar,	Shah, Sarthak	No
India	Science and Engineering Research Board		No
India	The High Commission of India in Australia		No
India	University of Pune	Dr. Nanasaheb Parulekar Paryavaran Bhavan,	No
International	International Mine Water Association		No

Country	Research institution	Contact name	Response received
Russia	Directorate of Global Energy Dialogue, International Energy Agency		No
Russia	Embassy of the Russian Federation in Australia	Alexander Odoevskiy	Yes – could not help
Russia	Engineering Faculty, Peoples Friendship University of Russia		No
Russia	Faculty of Science, Peoples Friendship University of Russia		No
Russia	Gazprom Promgaz	Galina Nazarkina	Yes – cannot provide
Russia	Gubkin Russian State University of Oil and Gas	Professor Elena Mazlova	Yes – no relevant research
Russia	Institute of Mining Siberian branch Russian Academy of Sciences	Anwar I. Chanyshev	No
Russia	Institute of Petroleum Geology and Geophysics of Siberian Branch Russian Academy of Sciences	Sergey Kazantsev	No
Russia	InvSib Investment Agency	Taras Demidenko	No
Russia	Kemerovo Region Administration		No
Russia	Moscow State Mining University		No
Russia	Moscow State University	Viktor Antonovich Sadovnichy	No
Russia	Moscow State University of Environmental Engineering	Prof Manuk'yan David Ashikovich	No
Russia	Moscow State University of Environmental Engineering	Dr. Lagutin Natalia	No
Russia	National Scientific Centre of Mining, Skachinskiy Institute of Mining	Alexey Leonidovich Zapadinskiy	No
Russia	Russian Academy of Sciences	V.A. Chudaeva , O.V. Chudaev	
Russia	Tomsk Polytechnic University	Olga A. Mazurina	No
United Kingdom	Environment Agency	Dr Alwyn Hart	Yes
United Kingdom	Natural Resources Wales		No
United Kingdom	Northern Ireland Environment Agency		No
United Kingdom	Scottish Universities Environmental Research Centre	Prof. Fin Stuart	No
United Kingdom	University of Cardiff	Geroni Jennifer N.	No

Country	Research institution	Contact name	Response received
United Kingdom	University of Glasgow	Susan Waldron	No
United Kingdom	University of Glasgow, Systems, Power & Energy Group, School of Engineering	Professor Paul Younger	Yes
United Kingdom	University of Newcastle; School of Civil Engineering and Geosciences	Dr Jarvis Adam Paul	No
United Kingdom	British Geological Survey	Dr Jonathon Busby	Yes
United Kingdom	RPS	Gordon Taylor	No
United Kingdom	School of Earth and Environment Leeds University	Prof Simon Bottrell	No
United Kingdom	School of Earth and Environment Leeds University	Dr Nigel Mountney	No
United Kingdom	School of Earth and Environment Leeds University	Professor Joseph Holden	Yes
United Kingdom	School of Geosciences, University of Edinburgh	Simon Haunch	No
United Kingdom	Scottish Environment Protection Agency	Emma Taylor	Yes
United Kingdom	The Coal Authority	Abby Moorhouse	Yes
United States	Geological Survey of Alabama	Dr Jack Pashin	No
United States	Office of Research Development, U.S. EPA	Dayna Gibbons	No
United States	U.S. Geological Survey	Richard W. Healy	No
United States	U.S. Geological Survey	Zack Bowen	No
United States	U.S. Geological Survey	William Orem	Yes
United States	U.S. Geological Survey	Mark Engle, Ph.D	No
United States	University of Rio Grande	Dr. Robert Hopkins II	No
United States	University of Wyoming	Scott Quillinan	Yes
United States	University of Wyoming	Prof K J Reddy	No
United States	USGS	Charles Cravotta	No
United States	Virginia Tech	Carl Zipper	No
United States	Wyoming State Geological Survey	Jim Rodgers	No

Appendix C - Literature search methodology

Search methodology

The emphasis of the searching was on a high degree of sensitivity (recall) rather than specificity. To ensure the widest 'capture' the search employed keyword searching. This involved identifying in each question relevant keywords and synonyms and word variations. Search strategies were developed for each question employing standard techniques: Boolean logic operators and truncation. Multiple keyword searches were carried out across multiple databases indexing literature from: Engineering, Geosciences, Mining, Environmental and Agricultural Sciences, Health Sciences, and Science.

The specific database search systems employed were Proquest, Web of Science, Scopus, Engineering Village (Compendex, GeoRef, Geobase), OnePetro and Informit Australian databases.

The database included references from a wide variety of information resources: journal articles, conference papers, book chapters, books, reports, etc. (see full description of database below for resource coverage). Across the different database search systems, search functionality, search syntax, indexing, field structures, sort and display options, and download options varied greatly. Limited time availability and competing work demands meant library catalogues have not been included in this search. Limiting keyword searching of the Internet to supplement database searching was also carried out by consultant engineers.

The keyword searches were performed an 'all fields' search on the databases. This approach allowed for different field structures on different search systems. A standard strategy was employed, creating groups or 'sets' of the different keyword concepts, then combining these sets which were then further limited (by countries and publication year). This strategy generally worked well in reducing the volume of search results. However, in cases where excessive numbers of records retrieved were deemed to have a high degree of irrelevance, further refinements were applied. This included:

- adding extra keywords
- excluding irrelevant topics (e.g. power stations)
- limiting keyword searching to title, abstract fields.

The ability to refine the search was based largely on the degree of functionality provided by the specific search interface.

To ensure specificity, search results were further refined by WRL consultant engineers viewing and deleting records deemed irrelevant.

Databases

The following information regarding the databases searched within this report is provided below.

Web of Science

Type: Citations/Abstracts.

Description: The Web of Science delivers web-based access to the citation indexes. Complete coverage is now provided. The citation indexes include:

- Science Citation Index 1899+
- Social Sciences Citation Index 1898+
- Arts & Humanities Citation Index 1975+
- Conference Proceedings Citation Index: Science 1990+
- Conference Proceedings Citation Index: social Sciences & Humanities 1990+

The database covers over 8000 journals across all disciplines worldwide, with about 22 000 articles being added weekly. The journals are selected as the most influential and relevant peer-reviewed titles across all disciplines.

Keywords: Anthropology; Architecture; Art; Art Education; Arts; Astronomy; Aviation; Biochemistry; Biology; Biomedicine; Biotechnology; Chemical Engineering; Chemistry; Computer; Computer Science; Criminology; Dance; Demography; Design; Digital Media; Economics; Education; Engineering; Folklore; Geography; Geomatic Engineering; History; Humanities; Industrial Chemistry; Industrial Relations; Information Science; International Relations; Language; Law; Librarianship; Life Sciences; Linguistics; Literature; Management; Marketing; Materials Science; Mathematics; Media and Mass Communication; Medicine; Mining Engineering; Multidisciplinary; Music; Optometry; Pharmacology; Philosophy; Photovoltaics; Physics; Plant Sciences; Poetry; Political Science; Psychiatry; Psychology; Public Administration; Public Health; Religion; Safety Science; Science Technology; Social Issues; Social Work; Sociology; Statistical Sciences; Substance Abuse; Surgery; Surveying; Technology Management; Theatre; Town Planning; Transportation; Urban Studies; Veterinary Sciences; Women's Studies; Zoology.

Coverage: International.

Search hints: Year can only be searched as part of a Boolean search and may provide results from different years.

ISSN/ISBN search is not supported.

Publisher: Thomson Scientific.

Additional publisher name: formerly Institute for Scientific Information (ISI).

Scopus

Type: Database.

Description: Scopus is an abstract and citation database of research literature including peer-reviewed titles, Open Access journals, conference proceedings, trade publications, patent records, scientific web pages, and seamless links to full text articles and other library resources. It is updated daily.

Search hints: External links lead to a login page that requires a Username/Password.

Author searches are done on the last name only.

Subject searches are performed in All Fields.

Publisher: Elsevier.

Science Direct

Type: Fulltext.

Description: Fulltext journal titles published by Elsevier.

Keywords: Anthropology; Architecture; Astronomy; Aviation; Biochemistry; Biology; Biomedicine; Biomedical Engineering; Biotechnology; Building; Chemical Engineering; Chemistry; Civil Engineering; Computer Science; Criminology; Design; Design Environments; Digital Media; Economics; Education; Educational Technology; Energy; Engineering; Environmental Engineering; Geography; Geomatic Engineering; Graphic Design; Humanities; Industrial Chemistry; Industrial Design; Industrial Relations; Information Science; International Relations; Landscape Architecture; Law; Librarianship; Life Sciences; Management; Marketing; Materials Science; Mathematics; Manufacturing Engineering; Marketing; Mechanical Engineering; Media and Mass Communication; Medicine; Mining Engineering; Multidisciplinary; Object Design; Optometry; Petroleum Engineering; Pharmacology; Philosophy; Photovoltaics; Physics; Plant Sciences; Political Science; Psychiatry; Public Administration; Public Health; Real Estate; Safety Science; Science Direct; Science Technology; Social Issues; Social Work; Sociology; Substance Abuse; Surgery; Surveying; Technology Management Psychology; Textile Technology; Theatre; Town Planning; Urban Studies; Veterinary Sciences; Waste Management; Zoology.

Coverage: International.

Search hints: Author searches are done on the last name only.

Subject searches are supported, but subjects are not presented within the records.

Truncation is not supported in phrases.

Publisher: Elsevier.

Additional publisher name: Elsevier Science B.V.

Publisher URL: http://www.elsevier.com/

Engineering Village (Compendex, GeoRef, Geobase)

Type: Database.

Keywords: Astronomy; Biomedical Engineering; Chemistry; Computer Engineering; Computer Technology; Computers; Computing; Computing Sciences; Communications Technology; Digital Media; Electrical Engineering; Electronics; Energy; Information Systems; Information Technology; Manufacturing; Manufacturing Engineering; Materials; Materials Science; Mechanical Engineering; Optometry; Photovoltaics; Physics; Statistical Sciences; Telecommunications.

Publisher: Elsevier Engineering Information.

Publisher URL: http://www.ei.org/eicorp/

OnePetro

Type: Database.

Description: OnePetro.org is a multi-society library that provides a simple way to search for and access a broad range of technical literature related to the oil and gas exploration and production industry. The database includes full-text from numerous organisations, including the Society of Petroleum Engineers (SPE).

Keywords: Petroleum; Resources Engineering; SPE.

Publisher: The Society of Petroleum Engineers (SPE).

Link to Database Guide: http://www.onepetro.org/search_help.htm

Australian databases (Informit)

Type: Fulltext.

Publisher: Informit.

Additional publisher name: RMIT Publishing.

Publisher URL: http://www.informit.com.au/

Databases searched:

- Australia's National Geosciences, Minerals and Petroleum Reference Database (AESIS)
- Australasian Medical Index (AMI)
- Agriculture and Natural Resources Index [formerly ABOA and STREAMLINE] (ANR-Index)
- Agriculture and Natural Resources Index Archive (ANR-Index Archive)
- Agriculture and Natural Resources Research (ANR-Research)
- Agriculture and Natural Resources Research Archive (ANR-Research Archive)
- Australian Public Affairs Information Service (APAIS)
- Aboriginal and Torres Strait Islander Health Bibliography (ATSIhealth)
- Australian Engineering Database (ENGINE)
- Engineering Collection (Engineering Collection)
- Environmental Abstracts (EVA)
- Health Collection (Health Collection)
- Australia's Natural Resources Database (STREAMLINE)

Proquest Databases

Type: Fulltext.

Description: ProQuest Central is the largest multidisciplinary database with over 11 000 titles, with over 8000 titles in full-text.

It serves as the central resource for researchers at all levels in all markets.

Over 160 subjects areas are covered extensively in this product including business and economics, health and medical, news and world affairs, technology, social sciences and more.

Publisher: ProQuest Information and Learning Company.

Publisher URL: http://www.il.proquest.com/

Databases searched:

- AGRICOLA (1970 - current)
- Aqualine (1960 - current)
- ASFA: Aquatic Sciences and Fisheries Abstracts (1971 - current)
- Biological Sciences (1946 - current)
- Dissertations & Theses @ University of New South Wales
- ebrary® e-books
- Environmental Impact Statements: Full Text (1985 - current)
- Environmental Sciences and Pollution Management (1967 - current)
- Meteorological & Geoastrophysical Abstracts (1974 - current)
- ProQuest Biology Journals (1998 - current)
- ProQuest Health & Medical Complete
- ProQuest Research Library
- ProQuest Science Journals
- ProQuest Dissertations & Theses: UK & Ireland
- ProQuest Dissertations & Theses Full Text
- ProQuest Illustrata: Technology
- ProQuest Natural Science Collection (1693 - current)
- Technology Research Database (1962 - current)
- Water Resources Abstracts (1967 - current)

Search Methodology

A brief summary of the search methodology and keywords used within each database is shown in Table C1.

Table C1: Search methodology

Search method	Main Research Theme	Search terms – level 1		Search terms – level 2		Search terms – level 3		Search terms – level 4
A	Aquifer interconnectivity (R1)	csg OR cbm OR "coal seam gas" OR "coal bed methane" OR "coalbed methane"	AND	water OR aquifer OR aquiclude OR "groundwater basin*" OR "groundwater reservoir" OR "ground water basin" OR "ground water reservoir" OR "underground basin" OR mulitaquifer OR "water bearing formation*"	AND	connect* OR connexion* OR interconnect* OR interconnexion OR link*	LIMITED TO	Australia OR Australian OR England OR UK OR "United Kingdom" OR Canada OR Canadian OR USA OR "United States" OR US OR "United States Of America" OR China OR Chinese OR India OR Indian OR Russia OR Russian
B	Aquifer interconnectivity (R1)	csg OR cbm OR "coal seam gas" OR "coal bed methane" OR "coalbed methane"	AND	"Water Quality" OR Contaminant* OR pollut* OR "Water Purity" OR "Freshwater quality" OR "Ground water quality" OR "quality of water" OR impurit* OR "Water Quantity" OR volume OR yield OR amount OR Model* OR "Field based" OR "Groundwater flow" OR "Ground water flow" OR "Ground water movement" OR "subsurface flow" OR "flow of groundwater" OR Solute* OR chemicals OR matter OR materials OR substances OR inorganic OR organic OR "Transport dynamic*" OR dispers* OR flow OR movement OR pathway*	AND	connect* OR connexion* OR interconnect* OR interconnexion OR link*	LIMITED TO	Australia OR Australian OR England OR UK OR "United Kingdom" OR Canada OR Canadian OR USA OR "United States" OR US OR "United States Of America" OR China OR Chinese OR India OR Indian OR Russia OR Russian

Search method	Main Research Theme	Search terms – level 1		Search terms – level 2		Search terms – level 3		Search terms – level 4
C	Surface water (R2)	csg OR cbm OR "coal seam gas" OR "coal bed methane" OR "coalbed methane"	AND	"surface water" OR stream OR river OR lake OR wetland OR ocean OR creek OR estuary OR dam OR reservoir OR watercourse AND (Flow OR pathway OR path OR movement)	AND	Disrup* OR diversion OR divert* OR impact* OR assess* OR evaluat* OR chang* subsid* OR sink* "mine cone of depression" OR "cone of depression"	LIMITED TO	Australia OR Australian OR England OR UK OR "United Kingdom" OR Canada OR Canadian OR USA OR "United States" OR US OR "United States Of America" OR China OR Chinese OR India OR Indian OR Russia OR Russian
D	Co-produced/ mine water (R3)	csg OR cbm OR "coal seam gas" OR "coal bed methane" OR "coalbed methane"	AND	"produced water" OR "co-produced water" OR "mine water" OR salt OR "salt management" OR saline	AND	aquifer inject* OR "water treatment" OR "water technolog*" OR "advanced Water Treatment Technolog*" OR AWTT OR Effect*OR impact* OR outcome*	LIMITED TO	Australia OR Australian OR England OR UK OR "United Kingdom" OR Canada OR Canadian OR USA OR "United States" OR US OR "United States Of America" OR China OR Chinese OR India OR Indian OR Russia OR Russian
E	Seismicity (R4)	csg OR cbm OR "coal seam gas" OR "coal bed methane" OR "coalbed methane"	AND	seismicity OR seismic OR seismology OR earthquake*	AND	nil	LIMITED TO	Australia OR Australian OR England OR UK OR "United Kingdom" OR Canada OR Canadian OR USA OR "United States" OR US OR "United States Of America" OR China OR Chinese OR India OR Indian OR Russia OR Russian

Search method	Main Research Theme	Search terms – level 1		Search terms – level 2		Search terms – level 3		Search terms – level 4
F	Well integrity (R5)	csg OR cbm OR “coal seam gas” OR “coal bed methane” OR “coalbed methane”	AND	“well integrity” OR “integrity of well*” OR installation OR drill* OR “wellbore” OR bore*	AND	nil	LIMITED TO	Australia OR Australian OR England OR UK OR “United Kingdom” OR Canada OR Canadian OR USA OR “United States” OR US OR “United States Of America” OR China OR Chinese OR India OR Indian OR Russia OR Russian
G	Hydraulic fracturing (R6)	csg OR cbm OR “coal seam gas” OR “coal bed methane” OR “coalbed methane”	AND	surface OR water OR “Water Supply” OR River* OR lake OR stream OR ocean OR creek* OR dam OR floodplain OR wetland* OR Estuar* OR Reservoir OR Groundwater OR Aquifer OR Aquitard OR “water table”	AND	quality OR chemical* OR contaminat* OR toxic* OR chemical* OR metal* OR solute* OR “heavy metals” OR salt OR saline OR pollut* OR spill* OR “backflow” OR “back flow” OR “flow back”	LIMITED TO	Australia OR Australian OR England OR UK OR “United Kingdom” OR Canada OR Canadian OR USA OR “United States” OR US OR “United States Of America” OR China OR Chinese OR India OR Indian OR Russia OR Russian
H	Water supplies (R7)	csg OR cbm OR “coal seam gas” OR “coal bed methane” OR “coalbed methane”	AND	Quantity OR “water level” OR reliability OR depletion OR sustainability OR “aquifer stress”	AND	Remediat* OR Regenerat* OR Rehabilitat* OR “well decommissioning” OR “post mining voids” OR “Pre development” OR “Post development” OR “Pre mining” OR “Post mining” OR	LIMITED TO	Australia OR Australian OR England OR UK OR “United Kingdom” OR Canada OR Canadian OR USA OR “United States” OR US OR “United States Of America” OR China OR Chinese OR India OR Indian OR Russia OR Russian

Search method	Main Research Theme	Search terms – level 1		Search terms – level 2		Search terms – level 3		Search terms – level 4
						“Water level” OR “Water quality”		
I	Water dependent ecosystems (R8)	csg OR cbm OR “coal seam gas” OR “coal bed methane” OR “coalbed methane”	AND	Predict* OR Estimat* OR Forecast* OR Respon* OR Quality OR Projection OR Impact OR Influence OR Effect OR Affect	AND	Ecosystem OR Environment OR “surface water” OR River* OR lake OR stream OR ocean OR creek* OR dam OR floodplain OR wetland* OR GDEs OR “Peat swamp*” OR Estuar* OR Reservoir OR “Water course” OR Water	LIMITED TO	Australia OR Australian OR England OR UK OR “United Kingdom” OR Canada OR Canadian OR USA OR “United States” OR US OR “United States Of America” OR China OR Chinese OR India OR Indian OR Russia OR Russian
J	Cumulative impact assessment (R9)	csg OR cbm OR “coal seam gas” OR “coal bed methane” OR “coalbed methane”	AND	"Cumulative impact" OR "impact assessment"	AND	nil	LIMITED TO	Australia OR Australian OR England OR UK OR “United Kingdom” OR Canada OR Canadian OR USA OR “United States” OR US OR “United States Of America” OR China OR Chinese OR India OR Indian OR Russia OR Russian

Appendix D - Project index

Table D1 Research projects titles and themes

Project no.	Project title	Aquifer Connectivity	Disruption of surface water	Co-produced/ mine water & salt management	Seismicity	Integrity of wells	Hydraulic fracturing	Water Supplies	Water dependent ecosystems	Cumulative impact assessments
1	Groundwater monitoring report for April - May 2012: Angus Place and Springvale groundwater monitoring program, Australia	✓								
2	Conceptualisation of the Walloon Coal Measures beneath the Condamine Alluvium, Australia	✓								
3	Using hydrogeochemistry to understand inter-aquifer mixing in the on-shore part of the Gippsland Basin, southeast Australia, Australia	✓								
4	2013 Annual Report: Surat Underground Water Impact Report, Australia	✓								
5	Integrated water model, Australia	✓								
6	Vertical hydraulic connectivity studies, Australia	✓								
7	New insights into the hydrodynamics of the Surat Basin, Australia	✓								
8	Connectivity between MNES Springs and Walloon Coal Measures (QGC, Santos, Australia Pacific LNG), Australia	✓								
9	Groundwater Visualisation System (GVS): A software framework for integrated display and interrogation of conceptual hydrogeological models, data and time-series animation, Australia	✓								
10	Linking 3D geological modelling and multivariate statistical analysis to define groundwater chemistry baseline and inter-aquifer connectivity, Clarence-Moreton Basin, southeast Queensland, Australia, Australia	✓					✓			
12	Observations of ground movements within the overburden strata above longwall panels and implications for groundwater impacts,		✓				✓	✓		

Project no.	Project title	Aquifer Connectivity	Disruption of surface water	Co-produced/ mine water & salt management	Seismicity	Integrity of wells	Hydraulic fracturing	Water Supplies	Water dependent ecosystems	Cumulative impact assessments
	Australia									
13	Geotechnical centrifuge permeater for characterizing the hydraulic integrity of partially saturated confining strata for CSG operations., Australia	✓								
14	Leading practices for assessing the integrity of confining strata: Application to mining and coal-seam gas extraction, Australia	✓	✓							
15	Impacts of Longwall Mining and Coal Seam Gas Extraction on Groundwater Regimes in the Sydney Basin, Australia	✓					✓			
16	Surface water and groundwater interactions in an extensively mined watershed, upper Schuylkill River, Pennsylvania, USA, USA			✓			✓			
17	Criteria for functioning river landscape units in mining and post mining landscapes, Australia		✓							
18	Subsidence: an overview of causes, risks and future developments for coal seam gas production, Australia		✓							
19	Subsidence monitoring - technical background paper for NSW Chief Scientist and Engineer, Australia		✓							
19	Subsidence monitoring - technical background paper for NSW Chief Scientist and Engineer, Australia		✓							
20	Some interesting abandoned mine stabilization projects in Australia, Australia		✓							
21	Assessment of mine subsidence in an area with a major pillar crushing event - Newcastle, Australia, Australia		✓							

Project no.	Project title	Aquifer Connectivity	Disruption of surface water	Co-produced/ mine water & salt management	Seismicity	Integrity of wells	Hydraulic fracturing	Water Supplies	Water dependent ecosystems	Cumulative impact assessments
22	Seismic imaging of stressed pillars in abandoned coal mines: Case studies from Australia, Australia		✓							
24	Building new bridges on the hunter expressway over abandoned coal mines, Australia		✓							
25	Managing mine subsidence along railways and highway pavements in the southern coalfield, Australia		✓							
26	Continuous monitoring of mining induced strain in a road pavement using fiber Bragg grating sensors, Australia		✓							
27	Hunter Expressway, Australia: Dealing with poor ground and subsidence, Australia		✓							
28	Rail corridor mine remediation - from investigation to verification, Australia		✓							
29	Study on regulations of coal mining under highway, China		✓							
30	Present situation of research on coal mining subsidence under highway in China, China		✓							
31	Effects of coal mining subsidence on the changes of soil nutrient in Shenfu-Dongsheng coal field, China		✓							
32	Changes of precipitation infiltration recharge in the circumstances of coal mining subsidence in the shen-dong coal field, China, China		✓							
33	Dynamic monitoring of land subsidence in mining area from multi-source remote-sensing data - a case study at Yanzhou, China, China		✓							
34	Analysis on distribution characteristics of soil carbon pool in mining		✓							

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	subsidence wetlands, China									
35	The monitoring of ecological reclamation evolution and landscape ecology remodeling technology in mining subsidence area, China		✓							
36	Water quality variation of mining-subsidence lake during the initial stage: cases study of Zhangji and Guqiao Mines, China		✓							
37	Study on the deformation and stability of building foundations in mining subsidence areas, China		✓							
38	Surface subsidence prediction for the WUTONG mine using a 3-D finite difference method, China		✓							
39	Huge thick conglomerate movement induced by full thick longwall mining huge thick coal seam, China		✓							
40	Management of water quality information in mining subsidence waterlogged area, China		✓							
41	Quantitative prediction of mining subsidence and its impact on the environment, China		✓							
42	Highway construction across heavily mined ground and steep topography in southern China, China		✓							
43	Earth surface subsidence in the kuznetsk coal basin caused by manmade and natural seismic activity according to ALOS PALSAR interferometry, Russia		✓							
44	Relationship between joint movement and mining subsidence, United Kingdom		✓							

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45	Numerical modelling of shallow abandoned mine working subsidence affecting transport infrastructure, United Kingdom		✓							
46	Exploring the legacy effects of surface coal mining on stream chemistry, USA		✓							
47	Templeton gap floodway levees, investigation and mitigation of mine subsidence, USA		✓							
48	Enhanced subsurface subsidence prediction model that considers overburden stratification, USA		✓							
49	Applications of DInSAR for Measuring Mine-Induced Subsidence and Constraining Ground Deformation Model, USA		✓							
50	Mitigation and Monitoring of Structural Distress in the Whitely Electrical Substation Due to Mine Subsidence, USA		✓							
51	Geotechnical Aspects of a 16 m High Steep Embankment in Eastern Pennsylvania, USA		✓							
52	Applications of Surface and Subsurface Subsidence Theories to Solve Ground Control Problems, USA		✓							
53	Identifying root causes for subsidence over abandoned coal mine - A case study, USA		✓							
54	Assessment of options for using coal seam gas water in the Central Condamine Alluvium: Business case, Australia			✓						
55	Coal Seam Gas, Coal and Agriculture: Water Implications, Australia			✓						
56	Chemicals associated with coal seam gas exploration: towards			✓			✓	✓	✓	

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	understanding their ecological risks, Australia									
57	CSIRO's Water for a Healthy Country Flagship, Australia			✓			✓		✓	
58	Optimal reinjection strategies for the management of coal seam gas production water, Australia			✓				✓		
59	Healthy HeadWaters Coal Seam Gas Water Feasibility Study, Australia			✓						
60	Assessment of salinity impacts of CSG water on landscapes and surface streams, Australia			✓						
61	Coal seam gas (CSG): What becomes of produced water? Regulation and strategies, Australia			✓						
62	Infrastructure options for delivering coal seam gas water to the Central Condamine Alluvium, Australia			✓			✓			
63	CSG water use in the Central Condamine Alluvium: Substitution issues, Australia			✓						
64	Hydrochemical compatibility assessments of aquifer injection of treated coal seam gas water into Surat Basin aquifers, Australia			✓						
65	Injection of coal seam gas water into the Central Condamine Alluvium: Site prioritisation, Australia			✓						
66	Feasibility of injecting coal seam gas water into the Central Condamine Alluvium, Australia			✓						
67	Produced Water - technical background paper for NSW Chief Scientist and Engineer, Australia			✓						

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68	Coal seam gas associated water treatment and management; opportunities and limitations, Australia			✓						
69	Coal seam gas and associated water: A review paper, Australia			✓			✓			
70	Initial report on the Independent Review of Coal Seam Gas Activities in NSW, Australia			✓			✓			
71	Modelling of drainage and salinity, Australia			✓			✓			
72	Selective Salt Recovery Trials, Australia			✓						
73	Brine injection, Australia			✓						
74	Selective Salt Recovery - Brine Management (QGC, Australia Pacific LNG, Arrow Energy), Australia			✓			✓			
75	Treatment methods for CSG production waters, Australia			✓						
76	Testing application of CSG production waters, Australia			✓						
77	Design of beneficial use schemes for disposal of treated CSG production water, Australia			✓			✓			✓
78	Injection of coal seam gas water into the Central Condamine Alluvium: Field program design, Australia			✓						
79	1: Field trial to measure and model water use of range of forage crops to be irrigated by CSG water 2: Glasshouse trial to ascertain the root zone salinity tolerance of range of forage crops, Australia			✓						
80	Compatibility of injected concentrated brines with formation waters and their tendency for scaling, Australia			✓			✓			

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81	Algal growth and community structure in a mixed-culture system using coal seam gas water as the water source, Australia			✓						
82	Assessment of alternative use options for coal seam gas water proposed for Central Condamine Alluvium recharge schemes, Australia			✓						
83	Fracture delineation and monitoring of geothermal and coal seam gas areas using magnetotellurics, Australia			✓						
84	Evaluating the effect of bicarbonate in coal seam gas water on soil threshold electrolyte concentration relationships, Australia			✓			✓			
85	Assessing impacts of CSG amended water application: soil chemistry equilibrium as influenced by solution volume and time, Australia			✓			✓			
86	Coal seam gas water as a medium to grow Dunalliella Tertiolecta for lipid extraction, Australia			✓						
87	CSG water as a medium to grow microalgae for biofuel production, Australia			✓						
88	Renewed Demands for Mine Water Management, Australia			✓						
89	Spatial analysis of coal seam water chemistry, Australia			✓			✓			
90	CSG water; desalination and the challenge for the CSG industry; developing a holistic CSG brine management solution, Australia			✓						
91	A treatment process for coal-bed-methane-extraction water, China			✓						
92	A treatment study of acid mine wastewater and the performance of electricity generation by coupling system using sludge anaerobic			✓						

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	fermentation-sulfate reducing bacteria, China									
93	A harmless treatment for coal bed methane produced water and its reuse, China			✓						
94	A pilot-scale demonstration of reverse osmosis unit for treatment of coal-bed methane co-produced water and its modeling, China			✓						
95	Design of Water Purification Plant of Micro-polluted Source Water in Shendong Mine Area, China			✓						
96	Underground direct treatment and recycle of coal mine water, China			✓						
97	National Science and Technology Major Project (No. 2011ZX05060-005), China			✓						
98	Mine Water Treatment Technology Analysis, China			✓						
99	Mechanism and experimental research on treatment of coal chemical wastewater by external circular anaerobic reactor, China			✓						
100	Small Experiment of High - efficiency Intelligent Coal Mine Water Recycling Equipment, China			✓						
101	Treatment of coal mine drainage with high turbidity, high iron and manganese in the use of coagulation and sedimentation process, China			✓						
102	A nitrogen foam fluid with low formation damage for CBM fracturing treatment, China			✓						
103	New technologies of purification and utilization on mine water, China			✓						
104	Comment on "identifying well contamination through the use of 3-D			✓						

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	fluorescence spectroscopy to classify coalbed methane produced water", China									
105	Hydraulic performance assessment of passive coal mine water treatment systems in the UK, United Kingdom			✓						
106	Mine water management post-closure, United Kingdom			✓			✓			
107	Potential for beneficial use of coal-bed methane produced water in western Alabama to augment water supplies during intense drought, USA			✓						
108	Forward osmosis treatment of drilling mud and fracturing wastewater from oil and gas operations, USA			✓						
109	Photo-induced graft polymerization of N-isopropyl acrylamide on thin film composite membrane: Produced water treatment and antifouling properties, USA			✓						
110	Performance and microbial community dynamics of a sulfate-reducing bioreactor treating coal generated acid mine drainage, USA			✓						
111	Radium and Barium Removal through Blending Hydraulic Fracturing Fluids with Acid Mine Drainage, USA			✓						
112	The role of ownership in environmental performance: Evidence from coalbed methane development, USA			✓						
113	An estimate of the near-term electricity generation potential of co-produced water from active oil and gas wells, USA			✓						
114	Disclosure of Hydraulic Fracturing Fluid Chemical Additives: Analysis of Regulations, USA			✓						

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115	Geochemical and microbial community dynamics of a remediation system treating coal-derived acid mine drainage, USA			✓						
116	Minerals and mine drainage, USA			✓						
117	Deep subsurface drip irrigation using coal-bed sodic water: Part I. Water and solute movement, USA			✓						
118	The effect of coal-bed methane water on spearmint and peppermint, USA			✓						
119	Analysis of Reserve Pit Sludge from Unconventional Natural Gas Hydraulic Fracturing and Drilling Operations for the Presence of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM), USA			✓						
120	Shallow groundwater and soil chemistry response to 3 years of subsurface drip irrigation using coalbed-methane-produced water Reponse de la chimie de la nappe superficielle et du sol a 3 ans d'irrigation souterraine au goutte a goutte avec de l'eau produi, USA			✓						
121	Seismicity - technical background paper for NSW Chief Scientist and Engineer, Australia				✓					
122	Seismicity and induced earthquakes (background paper to NSW Chief Scientist and Engineer), Australia				✓					
123	Introduction to this special section: Passive seismic and microseismic—Part 2, USA				✓					
124	Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 Mw 5.7 earthquake sequence,				✓					

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	USA									
125	Earthquake catalogs for New Mexico and bordering areas: 2005-2009, USA				✓					
126	Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons, USA				✓					
127	Enhanced Remote Earthquake Triggering at Fluid-Injection Sites in the Midwestern United States, USA				✓					
128	Injection-Induced Earthquakes, USA				✓					
129	Life cycle of coal seam gas projects: technologies and potential impacts (Report for the New South Wales Office of the Chief Scientist and Engineer), Australia					✓			✓	
130	Low cycle cement fatigue experimental study and the effect on HPHT well integrity, Australia					✓				
131	Anisotropic damage mechanics as a novel approach to improve pre- and post-failure borehole stability analysis, Australia					✓				
132	The "U-type" wells history of fuzzy ball drilling fluids for CBM drilling in china, China					✓				
133	A Mechanical Model of Borehole Stability for Weak Plane Formation Under Porous Flow, China					✓				
134	Study on Borehole Stability of Unconsolidated Sandstone in Depleted Reservior, China					✓				
135	Borehole Stability Analysis and Its Application in Xujiahe Formation of					✓				

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	ZJ Block, China									
136	Wellbore Stability Analysis of Coal Seam Based on Hoek-Brown Criterion, China					✓			✓	
137	Discrete element model for coal wellbore stability, China					✓				
138	Analysis of failure criterions on wellbore stability prediction, China					✓				
139	Study on Borehole Stability in Haita Basin, China					✓				
140	Effect of Pore Pressure Variation on Borehole Stability of Drilling in Sandstone Reservoir, China					✓				
141	Environmental risk arising from well construction failure: Difference between barrier and well failure, and estimates of failure frequency across common well types, locations and well age, USA					✓				
142	Identifying well contamination through the use of 3-D fluorescence spectroscopy to classify coalbed methane produced water, USA							✓	✓	
143	Modeling reveals hidden conditions that can impair wellbore stability and integrity, USA					✓				
144	What are we going to do with all these wells then?, USA						✓		✓	
145	Historical Analysis of Oil and Gas Well Plugging in New York: Is the Regulatory System Working?, USA					✓	✓			
146	Environmental regulation of hydraulic fracturing in Queensland, Australia								✓	
147	Link between rocks, hydraulic fracturing, economics, environment, and the global gas portfolio, Canada								✓	

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148	Effect of interface defects on shear strength and fluid channeling at cement-interlayer interface, China								✓	
149	Community-Based Risk Assessment of Water Contamination from High-Volume Horizontal Hydraulic Fracturing, USA			✓			✓	✓		
150	History and development of effective regulation of hydraulic fracturing; the genesis of Colorado Rule 205A, USA								✓	
151	Opportunities and challenges to coal bed methane production in Australia, Australia						✓			
152	Toxicity and eco-toxicity testing for stimulation chemicals and flowback waters, Australia						✓		✓	
153	Ecological Assessment of Areas Requiring Remediation and Stabilisation within East Wolgan and Narrow Swamps at Angus Place and Springvale Coal Mines, Newnes Plateau, Australia		✓				✓			
154	The Potential Impacts of Coal Seam Gas on Biodiversity, Australia						✓			
155	The National Harmonised Regulatory Framework for Natural Gas from Coal Seams, Australia			✓		✓	✓		✓	
156	Literature Review: Coal Seam Gas impacts on water resources, Australia			✓			✓			
157	Vulnerability of aquifers to coal seam gas water extraction, Australia						✓			
158	Stable isotope and water quality analysis of coal bed methane produced water in the southern Qinshui Basin, China, China			✓			✓			
159	Ecological Restoration of Abandoned Mine Land in China, China		✓				✓	✓		

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160	Variational characteristics of water quality of produced formation water in coalbed methane production area, China						✓			
161	Hydrogeochemical evolution of Ordovician limestone groundwater in Yanzhou, North China, China	✓					✓			
162	Assessment of Water Quality Around Surface Coal Mine in India, India			✓			✓	✓		
163	Environmental geochemistry and quality assessment of mine water of Jharia coalfield, India, India						✓	✓		
164	Multivariate statistical analysis for assessment of groundwater quality in Talcher Coalfield area, Odisha, India			✓			✓	✓		
165	Effect of mining on geochemistry of groundwater in Permo-carboniferous Gondwana coalfields: Raniganj Basin, India, India			✓			✓			
166	Modified Multi-phase Stability Diagrams: An AMD Case Study at a Site in Northumberland, UK, United Kingdom			✓			✓			
167	Science project SC030136/SR41, United Kingdom						✓			
168	Flow dependent water quality impacts of historic coal and oil shale mining in the Almond River catchment, Scotland, United Kingdom						✓			✓
169	Geochemical tracing of methane from unconventional gas production, United Kingdom			✓			✓	✓	✓	
170	Advanced characterization of coalbed methane produced water quality in the Rocky Mountain region, USA for consideration as a potential water resource, USA			✓			✓	✓		

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171	Stream reconstruction under SMCRA burning star #4: A case study, USA						✓	✓		
172	Assessing Different Mechanisms of Toxicity in Mountaintop Removal/Valley Fill Coal Mining-Affected Watershed Samples Using Caenorhabditis elegans: e75329, USA		✓					✓		
173	Analyses of geological and hydrodynamic controls on methane emissions experienced in a Lower Kittanning coal mine, USA						✓			
174	Water chemistry in areas with surface mining of coal, West Virginia, USA, USA			✓			✓	✓		
175	Geochemical and stable isotopic analysis of the Tongue River and associated tributaries in the Powder River Basin: An analysis of the cause of annual elevated salinity in spring runoff, USA	✓	✓	✓			✓	✓		
176	Carbon isotope characterization of Powder River Basin coal bed waters: Key to minimizing unnecessary water production and implications for exploration and production of biogenic gas, USA	✓		✓		✓		✓		
177	Spatial variability of coalbed natural gas produced water quality, Powder River Basin, Wyoming: Implications for future development, USA	✓		✓			✓			
178	Guidelines for establishing ecologically sustainable discharge criteria in seasonally flowing streams, Australia			✓			✓			
179	Reducing the impact of longwall extraction on groundwater systems, Australia	✓								✓
180	Impact of multi-purpose aquifer utilisation on a variable-density		✓				✓	✓		

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	groundwater flow system in the Gippsland Basin, Australia, Australia									
181	Upscaling hydraulic processes and properties to assess impacts on groundwater from coal seam gas abstractions, Australia							✓		
182	Simulating the impact of coal seam gas water production on aquifers, Australia							✓		
183	Great Artesian Basin Water Resource Assessment, Australia									
184	Coal seam gas water - River discharge: Context matters, Australia			✓			✓	✓		
185	Direct toxicity assessment, Australia			✓			✓			
186	Condamine River Seep Investigation, Australia						✓			
187	Literature and Science Review of Coal Seam Gas and Coal Mining Impacts on Water-Related Environmental Values, Australia		✓				✓			
188	Condamine River Gas Seep Investigation, Australia	✓					✓			
189	Stage One Report: Development Of Ecosystem Protection Trigger Values For Sodium Sulfate In Seasonally Flowing Streams Of The Fitzroy River Basin, Australia			✓			✓	✓		
190	Groundwater protection and unconventional gas extraction: the critical need for field-based hydrogeological research, Canada			✓			✓	✓	✓	
191	The hydrogen and oxygen isotope characteristics of drainage water from Taiyuan coal reservoir, China							✓		
192	How Many Mountains Can We Mine? Assessing the Regional Degradation of Central Appalachian Rivers by Surface Coal Mining, USA			✓			✓	✓		

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193	Spatial variability of ecological and water quality impacts of acid mine drainage in an alpine wetland, USA			✓			✓	✓		
194	Unconventional Gas Resources In The USA, USA							✓		
195	Effects of coal mining on freshwater mussels in the New River basin; a test using Corbicula as biomonitors, USA			✓						✓
196	Effects of coal mining on survivorship and taphonomy of the Asian clam, USA							✓		
197	Effects of mountaintop mining on fish distributions in central Appalachia, USA			✓				✓		
198	Coal seam gas – Toward a risk management framework for a novel intervention, Australia									✓
199	Energy from the Food bowl: an uneasy coexistence, Australia									✓
200	Cultivating collaboration: Lessons from initiatives to understand and manage cumulative impacts in Australian resource regions, Australia									✓
201	CSG water use proposals in the QMDB (assessing the impact on aquatic ecosystems), Australia									✓
202	Assessing the cumulative impact of mining scenarios on bioregional assets in the Namoi Catchment, Australia									✓
203	General Purpose Standing Committee No. 5 Inquiry into Coal seam gas, Australia			✓			✓			
204	An analysis of coal seam gas production and natural resource management in Australia Issues and ways forward, Australia									✓

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205	Managing Cumulative Risks to Assets from Mining, Australia						✓			✓
206	Underground Water Impact Report for the Surat Cumulative Management Area, Australia									✓
207	Regulating coal seam gas in Queensland: Lessons in an adaptive environmental management approach?, Australia			✓		✓			✓	✓
208	Namoi Catchment Water Study Indepdendent Expert Iterim Final Report, Australia						✓			✓
209	Modeling the impact of revegetation on regional water quality: A collective approach to manage the cumulative impacts of mining in the Bowen Basin, Australia, Australia									✓
210	Legitimizing industry and multi-sectoral regulation of cumulative impacts: A comparison of mining and energy development in Athabasca, Canada and the Hunter Valley, Australia, Canada									✓