Potential environmental impact	Potential causes	Knowledge and science relating to impact	Data gaps
Contamination of surface waters, groundwater and wells from chemicals, fracking fluids and wastewater/ produced water.	➢ Spills and well blowouts of drilling fluids/fracking fluids (which contain hazardous chemicals) and wastewater/produced water (which can be highly saline, sodic, and contain toxic chemicals and metals) into surrounding surface waters. ➢ Leaking of waste/produced water from containment ponds. ➢ Discharge of inadequately treated waste/produced water into rivers and streams. ➢ Leaking of fracking fluids and wastewater from pipes and seals into groundwater. ➢ Leaking of fracking fluids and wastewater upwards through the rock into overlying aquifers.	➢ Surface spills of waste water and chemicals have been well documented in the US. ➢ In Australia in the Pilliga, NSW, numerous spills and leaks of chemicals and wastewater have occurred and have reportedly resulted in vegetation dieback and the death of wildlife. ➢ Modelling of the potential for contamination of groundwater from leaks through the rock body found the risks to be low, but this depends on the local geology and the distances between aquifers. ➢ Contaminated water is one of the most common sources of exposure to chemicals from unconventional gas operations, and studies have documented health impacts to people, domestic animals and wildlife, including death, reproductive problems including infertility and birth defects, respiratory problems, gastrointestinal problems, neurological problems, headaches, vascular issues and sensory impacts. ➢ Limited studies have investigated the ecosystem and species impacts from water contamination.	➢ Data on chemicals used in the development of unconventional gas are limited and often not disclosed by gas companies, which makes it difficult to assess the impacts from contamination. ➢ More information is needed on the chemical content and toxicity of wastewater and produced water, which can be discharged directly into surface waters, or spill into surrounding water bodies; in Australia the water quality of treated waste water is not assessed prior to discharge. ➢ Baseline studies of water quality and ecosystem health are needed. ➢ Ongoing monitoring of water quality and the health of organisms is essential, particularly where wastewater has been discharged. ➢ Rapid and timely assessments of water quality and ecosystem health where contamination has been reported is lacking in Australia. ➢ Ecotoxicology studies are needed to assess impacts from contamination. ➢ Understanding of local geology and hydrology, including the connectivity of water systems, is needed to understand the potential for fracking fluids and wastewater/produced water to travel throughout the rock and contaminate groundwater systems and springs.
Methane contamination of groundwater, wells, and surface waters.	➢ The migration of methane through fractures into surrounding aquifers, rivers and streams, and water wells, caused by the over-pressurisation of natural gas in wells.	➢ Many reports from the US have documented high concentrations of methane in drinking wells near gas operations, including levels which are an explosive hazard. ➢ Methane contamination of rivers is well documented in the US, including river systems over 2km away from gas operations. ➢ In Australia methane contamination of river systems and bores has recently begun to be reported.	➢ Understanding of local geology and hydrology is needed to understand the potential for methane to travel throughout the rock body. ➢ Baseline studies and continued monitoring of aquatic systems is needed to assess levels of contamination. ➢ Environmental and health impacts from methane contamination are largely unknown and need investigation.

Sedimentation and erosion.	➢ The construction of well pads, roads, pipelines, and other infrastructure can lead to erosion, stormwater run-off and sedimentation above ground. ➢ Stream bank erosion and sedimentation can occur from the discharge of produced water into rivers and streams. ➢ Vegetation loss, particularly riparian vegetation, is a major cause of erosion and sedimentation.	➢ Studies in the US have shown a positive correlation between sediment levels in rivers and the number of surrounding gas wells. ➢ Studies of erosion and sediment levels from unconventional gas development are limited. ➢ Sedimentation is a major existing problem in many Australian waterways, particularly in agricultural areas where coal seam gas developments are located.	➢ Baseline studies and monitoring of erosion and sedimentation in aquatic ecosystems is needed. ➢ Local studies are needed to assess risks prior to project operations, including the current ecosystem health and resilience, and the presence of species vulnerable to increased sedimentation. ➢ Research should be conducted into ways of limiting sedimentation and erosion.
Drawdown of aquifers/ disruption of groundwater hydrology.	➢ The extraction of water (dewatering) from the coalbed during coal seam gas production to depressurise the seam and allow for gas flow. ➢ The extraction of water from surrounding systems to consume in the production process, particularly during hydraulic fracturing.	➢ The depletion of coal bed aquifers due to water extraction has been documented in the US and Australia. ➢ Aquifers and springs surrounding coal beds could also be affected by drawdown - this depends largely on hydrological connectivity. ➢ In Australia modelling has shown that water extraction from coal beds will impact underlying and overlying aquifers, lowering pressure and water levels.	➢ More data are needed on local geology and hydrology to assess the amount of drawdown likely to occur from dewatering at any particular site. ➢ Better understanding of local and regional connectivity is needed to quantify potential impacts to surrounding aquifers and springs. ➢ More studies are needed into the impacts of creating depressurised zones from dewatering. ➢ More research is needed into the age and rates of replenishment of groundwater. ➢ Baseline studies and continued monitoring of local and regional water systems are needed. ➢ Uncertainty exists over the actual and projected quantities of water consumption and extraction, which makes it difficult to model impacts.

Disruption of surface water hydrological flows.	➢ The extraction of water from surrounding rivers and streams to use in the production process, particularly during hydraulic fracturing, can lower water quantity and disrupt flows. ➢ The discharge of large amounts of produced water over years of operation into rivers and streams can alter flows. ➢ The dewatering of coal bed aquifers can lead to the depressurisation and drawdown of groundwater systems which feed surface flows.	➢ A report by leading Australian water experts expressed concern over the potential impacts to surface water hydrology from produced water discharge, but little data exist. ➢ Studies have stated that the drawdown and depressurisation of aquifers and springs could affect connected river systems, but limited data exist.	➢ Baseline studies and monitoring programs are needed to assess hydrological impacts for river systems where produced water is discharged. ➢ Understanding of local geology and hydrology, including the connectivity of water systems, is needed to understand the potential for surface waters to be affected by the lowering of groundwater systems. ➢ Quantities of water consumption and extraction are uncertain, which makes it difficult to understand impacts.
Soil contamination and associated impacts to terrestrial ecosystems.	➢ Spills of wastewater/produced water. ➢ Seepage of wastewater/produced water from storage ponds and inappropriate disposal. ➢ Spills of fracking/drilling fluids and chemicals. ➢ Seepage of methane from the rock formation up into soils.	➢ Methane contamination of soils has been documented in Australia and in the US. ➢ The death of vegetation has been linked to methane seepage, e.g. in Cataract River, Sydney. ➢ Studies of soil samples in areas contaminated by wastewater or chemical spills have shown elevated chemical concentrations, including metals and salts.	➢ Studies of the environmental impacts from methane seepage into soils are limited, and more research is needed. ➢ Studies into the local risks of methane seepage are needed, including geological surveys. ➢ Data on chemicals used and the composition of wastewater/produced water are needed to understand the impacts from spills. ➢ More studies investigating the environmental impacts from chemical contamination are needed.

Vegetation loss/ habitat fragmentation and degradation.	➢ Direct clearing of land for the building of wells, pipelines, access roads, and other infrastructure, and the associated habitat fragmentation. ➢ Unconventional gas developments have a larger scale of industrial operation and land use compared to conventional gas, and require a far greater number of wells.	➢ The impacts of habitat fragmentation on communities and species are well documented, including genetic impacts of isolation, increased disturbance and decreased resilience. ➢ An Australian report provides evidence indicating that the habitat impacts from unconventional gas extraction could be severe, particularly as many coal seam gas projects are located in agricultural areas where extensive vegetation clearing and fragmentation has already occurred. ➢ In the Pilliga, which is an ecologically important and unique forest in NSW, a biodiversity study found that fragmentation from coal seam gas development resulted in degraded habitat with increased edge effects, and an associated increase in predation of native species by introduced predators and an increase in other invasive species.	➢ Thorough biodiversity assessments are needed at project sites prior to development in order to assess the risks and the presence of threatened species or communities. ➢ Understanding of species mobility and landscape use is also essential to understanding impacts from habitat fragmentation. ➢ Ongoing biodiversity surveys are needed at unconventional gas sites.
Greenhouse gas emissions (contributing to climate change).	➢ The end-use combustion of gas accounts for the majority of greenhouse gas emissions. ➢ Emissions of methane from venting and flaring of gas. ➢ Fugitive emissions of methane can occur from: the flowback of injected waters; leaks from pipes and equipment; the transportation of gas; and diffuse seepage through soils. ➢ Indirect emissions from the intensive use of equipment in the extraction process, particularly diesel motors.	➢ Numerous studies have investigated the greenhouse gas footprint of unconventional gas, with the majority of studies coming from the US and focused on shale gas. ➢ Many reports state that unconventional gas has a much lower carbon footprint compared to coal; however, some recent studies contest this and state that when high levels of fugitive methane emissions are included, the unconventional gas footprint is comparable or higher than coal. ➢ In the US several studies have estimated fugitive methane emissions, but results have varied widely. ➢ In Queensland recent research has revealed high levels of fugitive methane emissions from a coal seam gas field.	➢ Accurate estimation of the overall greenhouse gas emissions from unconventional gas is constrained by uncertainties: data are limited and studies often reveal conflicting results. ➢ Levels of fugitive methane emissions are highly contested - more research needs to be conducted and better methodology developed for accurate modelling. ➢ Knowledge of diffuse emissions of methane through soil is lacking, and research is needed in this area. ➢ Data are needed on the exact content and hydrocarbon concentrations of unconventional gas, which is essential to assessing emissions from end-use combustion. ➢ More data are needed to accurately assess indirect emissions from industry operations, particularly for Australia where information is limited.