12 RECOMMENDATIONS

The following tables (Tables 12.1 and 12.2) summarize and prioritize all recommendations made in this report. For each recommendation, a high-level description, its purpose, and relationship to the conceptual model are provided.

TABLE 12.1
SUMMARY OF RECOMMENDATIONS

Priority	Recommendation	Description	Purpose	Relationship to Conceptual Model	Relationship to Potential Hazard Evaluation
1	Install monitoring bores that are designed and completed to ensure that the target formations are isolated from overlying and underlying formations. Compare monitoring methods developed for this gas seep investigation with those used elsewhere and make modifications, if appropriate.	Monitoring bores should be installed in WCM, Springbok Sandstone, and alluvium (older terraces and younger deposits associated with modern Condamine River). Given the thickness of the WCM, multiple monitoring bores should be installed at different depths (e.g. in the Upper and Lower Juandah and in the Taroom Coal Measures). As an example, the bores completed in different formations and/or at different depths could be located: • 1 group close to and downdip of gas seeps. • 1 group close to and updip of gas seeps. • 1 group in “background” areas that are away from gas seeps and CSG production.	Limited reliable formation pressure and water level data are available for the Springbok Sandstone and alluvium. For the WCM, drill-stem test (DST) pressure measurements were made in the Orana 8 pilot bore in 2008. Monitoring bores need to be installed to: • Monitor long-term pressure trends (both bottom-hole and wellhead). • Determine the hydraulic gradients. • Determine whether changes in pressure in different formations occur independently, or whether the formations are hydraulically connected. • Determine the presence of gas. detect depressurization and gas desorption; monitor changes in fluid level; and collect and analyse gas and water samples from target formations (discussed in Recommendation 5). However, a phased approached should be used in the installation of the monitoring bores. This way the design, location, and value of the data can be reviewed and recommendations for additional bores (if necessary) and modifications to design, location, etc. can be evaluated. DST and pre-production pressure data from CSG wells should be compiled and mapped to determine initial pressures in the WCM. Data should be used to determine whether pressure changes are related to CSG production (steady overall decline), seasonal changes (increase/decrease fluctuations related to precipitation and recharge), or water bore usage (increase/decrease fluctuations not related to precipitation and recharge). Data should be used to determine whether and when depressurization and gas desorption occur. Geological data from the monitoring wells should be used to further develop and refine the geological model for the investigation area. As the geologic model for the Condamine River gas seeps is further developed and refined, it could be compared to conditions in the San Juan and Raton Basins of Colorado and other basins throughout the world where gas leakage occurs and monitoring is performed to identify similarities and differences. Although the monitoring techniques proposed for Phase 3 (monitoring wells, seep mapping, flux measurements, etc.) are similar to those used in Colorado, they may need to be modified and adapted to the site specific geologic conditions encountered in this study area. Monitoring methods used in other basins may also be worth considering.	**Used to evaluate Mechanism**	

			Limited stable isotope and compositional data exist for gas originating from formations other than from the WCM; therefore, gas samples should be collected periodically from monitoring bores completed in all the different target formations, including the WCM, for stable isotope and compositional analysis. The analytical results of gas samples from the WCM, Springbok, and alluvium should be used to determine the stable isotope ratios and gas composition that are typical of each formation. Formation-specific data should be compared to determine whether methane in the Springbok Sandstone and WCM can be differentiated. Analytical results from periodic additional gas sampling should be compared with previous results to determine whether the stable isotope ratios or composition of the gas change over time. Changes may indicate mixing with gas from a new source that might require additional investigation.	**Used to evaluate Source**	
2	Continue to compile and periodically review data from wells in the Talinga, Argyle, Kenya, and Lauren/Codie fields.	Drilling and completion data, permeability, production, and pressure data, at an individual well level, from the Talinga, Argyle, Kenya, and Lauren/Codie fields should continue to be compiled and reviewed periodically. Periodically GIS maps and graphs presenting the data should be made for spatial and trend analysis. The above data should be used to: (1) assess communication (both permeability and continuity) between down-basin production and the gas seeps; (2) identify the presence of barriers, baffles, or high-permeability zones; (3) evaluate historic and post-production pressures in the WCM and Springbok relative to the critical desorption pressures of their coal seams.	CSG production records, such as volumes of gas and water produced, changes in reservoir pressures, gas desorption, and permeability trends, should continue to be compiled and reviewed periodically. GIS maps should be made periodically and used for spatial and trend analysis. Given the complexity of the geology and the potential interplay of different mechanisms and pathways, the need and value of preparing a CSG reservoir model and high resolution 3D geologic model should be evaluated.	**Used to evaluate Source, Mechanism, and Pathways**	

3	Collect additional gas samples for composition and stable isotope analysis.	Gas samples should be collected from gas seeps, monitoring bores, CSG wells, water and coal exploration bores. Sampling and analyses should be done periodically.	When the gas seeps were first observed in 2012, the first questions asked were “What is the source and from where is the gas coming?”. There were 3 possible answers: (1) biogenic methane formed by acetoclastic reactions (“swamp gas”; (2) biogenic methane formed by CO_2 reduction; and (3) thermogenic methane. Based on stable isotope analysis of gas samples collected during this investigation biogenic methane formed by CO_2 reduction has been identified as the primary type of the methane discharging at the gas seeps and biogenic methane formed by acetoclastic reactions and thermogenic methane have been eliminated as primary types. Both the WCM and the Springbok Sandstone produce biogenic methane formed by CO_2 reduction; therefore either or both could be the source of the methane discharged at the gas seeps. With the analytical results collected to date it is not possible to differentiate between methane from the WCM and Springbok Sandstone. Collecting and analysing gas samples from the monitoring wells that target specific formations and do not allow commingling of gas from the WCM and the Springbok Sandstone will provide data to determine whether stable isotopes and gas composition can be used to differentiate between methane from these two sources. If the methane from the WCM and the Springbok Sandstone can be differentiated, then the analytical results of gas samples from the gas seeps and water and coal bores can be compared to the formation-specific data and used to identify the source of the methane discharging from the seeps and in the bores.	**Used to evaluate Source**	
			Gas samples from producing CSG wells (both production and bradenhead or other annulus gas) should be analysed for composition and stable isotopes to determine whether the character of produced CSG gas is changing, and to determine whether there is communication between the production or intermediated casing annulus and the surface casing annulus.	**Used to evaluate Pathway**	**Used to evaluate Potential Hazards** CSG gas migrating or leaking out of the productions string (casing or wellhead), flowing up unsealed annuli, and thence into overlying formations and groundwater, would be a potential hazard. It should be evaluated to determine what mitigation action (if any) should be taken.
4	Monitor gas flux from the four gas seeps.	Develop the method and equipment for measuring the flux of methane from the four gas seeps Develop a strategy for identifying and quantifying the magnitude of methane seepage that may be occurring in areas other than the four seeps, i.e. open bores, coal outcrop and subcrop, river seeps, agriculture, water treatment, other sources as identified. Use gas flux data to put the flux from the four seeps in an overall context, i.e. % overall methane emission.	The source, mechanism, and pathways for the methane must be capable of generating, sustaining, and conveying the volume discharging at the gas seeps; therefore the volume should be quantified and used as a criterion for identifying the most likely source, mechanism, and pathway.	**Used to evaluate Source, Mechanism, and Pathway**	**Used to evaluate Potential Hazards** Long-term monitoring of gas flux should be used to determine whether changes occur. If flux were to increase, then the potential hazard would need to be re-evaluated to determine what mitigation actions (if any) should be taken.

5	Systematically and consistently compile and promptly respond to landowners observations about changes (either increases or decreases) in existing or appearance of new gas seeps.	Set up a method to systematically and consistently compile additional information from landowners regarding changes (either increases or decreases) in gas seeps, indications of new gas seeps (e.g. stressed or dead vegetation, gas bubbles in ponds, creeks, or river), and changes in the presence of gas in water bores. Ensure that landowners know about the process and that they are kept informed. Ensure that operators respond promptly. When appropriate, investigate the observation to determine whether changes (either increases or decreases) have occurred and what the cause of the change is. Provide landowners with the results of investigations in a timely manner.	Observations of a new area of seepage or increased seepage might indicate a new source, mechanism, or pathway of gas that would need to be incorporated into the monitoring network.	**Used to evaluate Source, Mechanism, and Pathway**	**Used to Evaluate Potential Hazards** If new or increased seepage were to occur, then it would need to be evaluated to determine whether it was a potential hazard and what mitigation actions (if any) should be taken.
6	Map and survey surface and shallow subsurface soil gas in the four areas of known gas seepage and inspect the Condamine River and Charleys Creek through the Talinga and adjacent tenements.	Periodically the locations of the four gas seeps should be mapped, gas samples should be collected and analysed, and representative photographs should be taken of the seeps, stressed vegetation, outcrops, and river stage to determine and document whether changes are occurring. Evaluate and use a technique (such as West Systems portable gas flux meter), for quickly and accurately detecting and recording, and measuring gas seepage at the ground surface. Inspect the Condamine River and Charleys Creek through the Talinga and adjacent tenements periodically to determine whether new areas of gas seepage appear.	The gas seep maps, soil gas surveys, and river inspection results complement the gas flux monitoring results and should be used as criteria for determining whether changes in gas seepage are occurring and whether those changes indicate a new source, mechanism, or pathway.	**Used to evaluate Source, Mechanism, and Pathway**	**Used to evaluate Potential Hazards** Long-term monitoring of the locations and extent of gas seepage should be used to determine whether changes occur. If extent were to increase or if new areas were to appear, then the potential hazard would need to be re-evaluated to determine what additional mitigation actions (if any) should be taken.

7	Monitor surface water quality and assess aquatic ecology.	Evaluate the analytical results from surface water sampling and develop a strategy for ongoing surface water quality monitoring (including DO) that integrates the needs of the ecological assessment. Implement systematic and ongoing monitoring of surface water at the four gas seep areas and at upstream and downstream locations. Coordinate this sampling with sampling required for assessing aquatic ecology. Ecological monitoring should be performed to determine seasonal and diurnal patterns. Ecological monitoring should be performed to determine whether stratification occurs as a result of high water levels. Regional ecological data should be included in future reports to provide context for the ongoing assessment related to the gas seeps and to provide information on longer term means, ranges, and fluctuations in data.	Surface water quality sampling would provide information to gain a better understanding about the relationship of water chemistry, discharge volumes, and water levels over time and to determine whether gas seeps are impacting surface water quality (including DO) and whether these changes affect aquatic ecology. A possible mechanism and pathway for gas migration to the seep areas is methane in the subsurface dissolving into groundwater, flowing with the groundwater as dissolved methane, and discharging with groundwater. Results from surface water quality monitoring along with the measurements from the surface water level gauging stations and new monitoring bores should be used to determine groundwater recharge/discharge relationships at the gas seeps and to determine whether groundwater and gas discharge are impacting the surface water quality.	**Used to evaluate Mechanism and Pathway**	**Used to evaluate Potential Hazards** Long-term monitoring of surface water quality and aquatic ecology should be used to determine whether changes in water quality occur and whether these have an impact on aquatic ecology. If negative impacts are detected then an evaluation can be made of what mitigation actions (if any) should be taken.
8	Monitor water bores and coal exploration bores, and monitoring bores (DNRM, UCG project, Surat Cumulative Management Area), if available and relevant.	Implement systematic and ongoing monitoring of water and coal exploration bores and available and relevant monitoring bores to estimate changes in the gas venting rate, and to identify changes in gas concentration, water quality, and water level or potentiometric surface that may be the result of CSG production. Plug and abandon water and coal bores that penetrate the Springbok Sandstone and/or the WCM if no future use is identified. Monitor nearby bores to determine whether changes in methane concentration occur as a result of plugging.	Increase in the production or concentration of methane with the stable isotope and composition of methane from the WCM in a water or coal exploration bore would indicate communication with or depressurization of the WCM. Geospatial analysis of the distribution of such increases could be used to help determine the pathways of gas flow and/or the orientation of pressure change within the formation. Similarly changes in water quality, water level, or potentiometric surface could indicate communication with WCM. Communication between bores would be indicated if plugging a bore resulted in increased gas production or concentration in another bore.	**Used to evaluate Source, Mechanism, and Pathway**	**Used to evaluate Potential Hazards** Increase in production or concentration of methane from water bores and coal exploration bores would increase the risk of fire and explosion and could trigger the need for mitigation (i.e., plugging bores or installing equipment to separate gas from water prior to use).

9	Survey location and elevation of existing and install additional surface water level gauging stations.	Accurately survey locations and elevations of the transducers at the gas seeps. Install additional water level gauging stations in proximity to new monitoring bores.	Surface water level records provide a good context for the ecological assessment and water quality studies. The measurements from Origin's surface water level gauging stations are relative, they do not provide elevation; therefore the data cannot be compared with the 2012 bathymetric survey or to water levels measured elsewhere e.g. at Chinchilla Weir. They also cannot be used to determine when the river transitions from continuous flow to discontinuous pools and vice versa. Therefore the transducers locations and elevations should be accurately surveyed. Several of the possible mechanisms rely on the interaction of surface water and groundwater to displace and mobilize free gas trapped in the unsaturated zone or to dissolve methane into the groundwater and then for it to flow with the groundwater to discharge points. Surface water level and elevation data should be used to calculate the hydraulic heads that could then be compared to groundwater level data from new monitoring bores to determine the interaction between surface water and groundwater, recharge and discharge, and water level fluctuations.	**Used to evaluate Mechanism**	
10	Conduct bathymetric survey of the Condamine River at the gas seep locations.	Periodically conduct bathymetric surveys after significant flooding events. Conduct auger coring of the riverbed at selected surveyed transects to measure the thickness and character of stream-bed sediments, and seasonal/flooding changes.	In 2012 a bathymetric survey was conducted along a reach of the Condamine River that included the Pump Hole, Fenceline, and Camping Ground seeps. A bathymetric survey was not conducted at the Rock Hole seep. Gas seeps at the Pump Hole, Fenceline, and Camping Ground had not been observed prior to the 2012 flooding of the Condamine River. The hypothesis that the flooding may have caused erosion and/or redistribution of the bottom sediment that resulted in either creating new pathways or uncovering an existing pathways for gas migration has been proposed. Additional bathymetric surveys after large scale flooding events could be used to verify whether erosion or sediment redistribution on the scale necessary to open up new or expose or close existing pathways for gas migration occurs. For comparison a bathymetric surveys should also be conducted at the Rock Hole seep to determine whether erosion or sediment redistribution cause changes in the gas flux at this historic seep.	**Used to evaluate Pathway**	
11	Incorporate new and additional information into geologic map and cross sections.	Update geologic map, WCM structure map, and cross sections with additional information from new monitoring wells, CSG wells, and reinterpreted seismic data. Conduct field work to map surface geology in detail. Geologic work could be a cooperative effort between the QGS and CSG operators	Given the complexity of the geology and the potential interplay of different sources, mechanisms, and pathways consideration should be given to the value of updating the existing published geologic maps by conducting detailed mapping of the surface geology, incorporating data from the new monitoring wells and CSG wells, and seismic data. These data could be used in a high resolution 3D geologic model	**Used to evaluate Source, Mechanism, and Pathways**	
12	Evaluate disposition of the four Orana pilot wells.	Evaluate the future uses of the Orana pilot wells, including CSG production or pressure monitoring in the WCM. Plug and abandon wells, if no future use is identified. Conduct soil gas surveys around each periodically.	If any or all of the Orana pilot wells could be worked over and equipped with pressure transducers, then they could be used to monitor pressure changes in the WCM to determine whether down basin production is resulting in depressurization and gas desorption in the vicinity of the gas seeps. Regardless of the final disposition of the pilot wells, periodically soil gas surveys should be conducted around each to verify that gas seepage is not occurring and does not begin to occur in response to changing reservoir pressures.	**Used to evaluate Mechanism**	

13	Develop a comprehensive sampling and analysis plan (SAP) and quality assurance project plan (QAPP).		Because of the need to respond quickly to the appearance of gas a number of different groups of experts were deployed and samples were collected and measurements made for a variety of reasons. The methods used were not always the same or consistent. Going forward, SAP and QAPP documents will ensure that gas, water, soil, etc., samples are collected and analysed using the same methods and that field measurements (water levels, headspace gas, field parameters, etc.) are made and recorded using the same methods, measurement points, and equipment.		
14	Compile available and future data into a centralized database.		Samples have been collected and analysed and measurements have been made for baseline sampling of water bores, for investigations conducted by other parties, including the Queensland Government, for permit required monitoring, and for this investigation. Compiling the available and future data into a centralized database will facilitate data review and trend and geographic analysis	**Used to evaluate Mechanism, Source, and Pathways**	
15	Support the ongoing GISERA research program on regional-scale monitoring of methane emissions.	A joint industry group has initiated through GISERA[77] a separate and independent research program to characterise regional fluxes of methane in the Surat Basin. This work complements the Condamine River Gas Seep Investigation. The regional study includes the review and evaluation of available monitoring methods; provides for possible pilot testing of new and existing methods; and may ultimately recommend certain methods for deployment on a regional scale.	Systematic regional monitoring could be used to determine sources of methane (natural and anthropogenic) in the landscape, and could provide both context for the Condamine River Seeps and some insight into possible sources, mechanisms, and pathways of the seeps.	**Used to evaluate all regional sources of methane, not just seepage from underlying formations.**	**Used to evaluate Potential Hazards**

[77] http://www.gisera.org.au/research/ghg/ghg-proj-1-methane-seeps.pdf.

TABLE 12.2
SUMMARY OF RECOMMENDATIONS BASED ON THE ARGYLE FIELD ASSESSMENT

Priority	Recommendation	Description	Purpose	Relationship to Conceptual Model	Relationship to Potential Hazard Evaluation
1	Bradenhead testing (if possible)	In addition to the well integrity and leak detection monitoring conducted in accordance with the Petroleum and Gas Act and if the Argyle 4 and Argyle 162 wells are equipped with wellheads with access to the annular spaces, then measuring the pressure at the wellhead and the annular spaces is recommended to verify that the WCM is isolated.	Evaluate isolation of WCM.		**Verify whether the Argyle 4 and 162 are isolated.**
1	Soil gas survey	In addition to the well integrity and leak detection monitoring conducted in accordance with the Petroleum and Gas Act, a soil gas survey around the Argyle 4 and Argyle 162 wells is recommended to verify that the wells are not acting as conduits for gas migration to the ground surface.	Evaluate isolation of WCM.		**Verify whether the Argyle 4 and 162 are isolated.**
2	Continue to compile and periodically review data from wells in the Argyle, Talinga, Kenya, and Lauren/Codie fields. (see Table 12.1 Priority 2)	Drilling and completion data, permeability, production, and pressure data, at an individual well level, from the Talinga, Argyle, Kenya, and Lauren/Codie fields should continue to be compiled and reviewed periodically. Periodically GIS maps and graphs presenting the data should be made for spatial and trend analysis. The above data should be used to: (1) assess communication (both permeability and continuity) between down-basin production and the gas seeps; (2) identify the presence of barriers, baffles, or high-permeability zones; (3) evaluate historic and post-production pressures in the WCM and Springbok relative to the critical desorption pressures of their coal seams.	Evaluating potential connection between CSG production and the Condamine River gas seeps. Given the complexity of the geology and the potential interplay of different mechanisms and pathways, the need and value of preparing a CSG reservoir model and high resolution 3D geologic model should be evaluated.	**Used to evaluate Mechanism, Source, and Pathways**	