

## 9. SURFACE WATER

This chapter presents the findings of the supplementary geomorphology and hydrology study conducted by Alluvium Consulting Australia (Alluvium) and the supplementary water quality study conducted by NRA Environmental Consultants (NRA), which are attached as Appendix 5, Supplementary Surface Water Assessment Part A - Geomorphology and Hydrology, and Appendix 6, Supplementary Surface Water Assessment Part B – Water Quality, respectively. The chapter also presents the findings of the preliminary environmental flows assessment, also conducted by Alluvium and attached as Appendix 7, Supplementary Surface Water Assessment Part C – Preliminary Environmental Flows Assessment. The geomorphology and hydrology study, the water quality study and the preliminary environmental flows assessment comprise the supplementary surface water assessment.

The technical studies were undertaken to provide information on watercourse flow regimes, geomorphology, flooding, and overland flow at proposed production and water treatment facility sites. The technical studies also provide water quality information from watercourses in the receiving environment of the water treatment facility sites, where discharge of coal seam gas water is proposed. The revised project description is provided in Chapter 3, Project Description, with aspects relevant to the surface water assessment described further in this chapter. Additional information on subsidence is also provided in this chapter, along with a review of potential impacts, mitigation and management measures and commitments presented in the EIS. New and revised commitments that resulted from the studies conducted are presented at the end of this chapter.

In addition to the study findings, a list of broad surface water topics raised in submissions is presented in this chapter, with responses to all issues relating to these topics provided in Part B, Chapter 19, Submission Responses and Chapter 20, Response to DERM Submission.

Surface water impacts on aquatic ecosystems are described in Chapter 10, Aquatic Ecology. Chapter 8, Groundwater, provides further information on subsidence and identifies the potential for connectivity between groundwater and surface water systems.

### 9.1 Studies and Assessments Completed for the EIS

This section provides a summary of the fluvial geomorphology, hydrology and water quality studies completed for the Surat Gas Project EIS and the main conclusions from the assessments. Together, these studies formed the surface water impact assessment component of the Surat Gas Project EIS.

Alluvium was engaged to conduct the fluvial geomorphology and hydrology study, and NRA was engaged to conduct the water quality study. The findings of the studies are presented in the EIS Appendix H, Surface Water Part A: Fluvial Geomorphology and Hydrology Impact Assessment, and Appendix I, Surface Water Part B: Water Quality Impact Assessment, respectively.

The surface water impact assessment undertaken as part of the EIS comprised a desktop study and field investigation of representative sites to characterise the existing environment of watercourses in the project development area. The desktop assessment and subsequent field investigation identified environmental values associated with wetlands and watercourses in the study area on which to base the assessment of impacts and the development of mitigation measures. Environmental values were defined in accordance with the Environmental Protection

(Water) Policy 2009 (EPP (Water)). Characteristics and values of surface water features within the project development area that were considered in the assessment included:

- Physical integrity.
- Fluvial processes, form and morphology.
- Hydrology.
- Water quality and associated uses e.g., domestic, consumptive and productive, industrial and agricultural uses.
- Spiritual and cultural values.

The desktop study comprised a review of historical flood data, including extent, levels and frequency, for major watercourses using information sourced from the Bureau of Meteorology. It included a review of watercourses to aid the selection of field survey sites that encompassed the range of watercourse types found within the project development area.

The field investigation involved an assessment of watercourse geomorphology and hydrology and a baseline water quality survey at the selected sites. A total of 112 sites were visited in October (pre-wet season) and December 2009 (wet season) to categorise the geomorphology and hydrology of watercourses, including stream-order classification.

The water quality survey comprised sampling of 35 sites in October 2009, November 2009 (pre-wet season) and March 2010 (dry season). Another 11 sites were sampled as part of the aquatic ecology assessment in November 2009 and May 2010 (see Chapter 16 of the EIS). Water quality results were generally comparable to the reference data provided by the former Department of Environment and Resource Management (DERM) for relevant sub-basins and associated catchments and subcatchments. The project development area extends across the sub-basins of the Balonne River, Condamine River, Macintyre Brook, Moonie River, Dawson River and Macintyre and Weir rivers. The sub-basins can be further divided by catchment and subcatchment. In the project development area there are 64 subcatchments.

The assessment found that watercourses in the project development area were predominantly ephemeral in nature, with some semi-permanent watercourses. For example, minor watercourses in the Balonne River sub-basin were found to be ephemeral in nature, while the Condamine River in the Condamine River sub-basin was described as a semi-permanent watercourse and its tributaries described as ephemeral.

Site-specific assessments of the impact of project infrastructure on surface water and water quality values were not undertaken because the location of infrastructure was not known. However, impacts of the project activities required to construct, operate and maintain project infrastructure were known from existing operations and formed the basis for the assessment.

Conceptual layouts of production facilities and typical arrangements of gathering systems, high-pressure pipelines, production wells and access tracks were used to identify and assess the impacts by evaluation of the sensitivity to change of watercourses and surface water hydrology. The sensitivity to change of the surface water features underlay the magnitude of impact assessments and the mitigation measures required to manage the impacts and achieve the relevant water quality guideline values.

Mitigation and management measures proposed by Alluvium and NRA were presented as commitments in the EIS (Attachment 8 of the EIS). The commitments presented in the EIS are listed in Table 9.1.

**Table 9.1 Surface water commitments presented in the EIS**

No.	Commitment
C009	Routinely monitor water quality in dams.
C015	Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities.
C020	Minimise the disturbance footprint and vegetation clearing.
C024	Install and maintain diversion drains to divert clean surface runoff water around production facilities and away from construction areas.
C034	Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls.
C035	Apply appropriate international, Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants).
C048	Apply appropriate international, Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants).
C053	Avoid disrupting overland natural flow paths and, where avoidance is not practicable, maintain connectivity of flow in watercourses.
C066	Discharge water from project activities at a rate and location that will not result in erosion. Install additional erosion protection measures, including energy dissipation structures, at discharge outlets.
C069	Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of coal seam gas water under emergency conditions. Procedures will include water balance modelling, weather monitoring and forecasting, stream flow data, notification and reporting.
C107	Control sediment runoff from stockpiles.
C151	<p>When siting facilities, avoid wetlands and consider the following:</p> <ul style="list-style-type: none"> <li>• Stream processes that may result in channel migration (either over time or as a result of project activities) and areas that are highly susceptible to erosion (i.e., dispersive soils).</li> <li>• Downstream values of nearby watercourses or wetlands.</li> <li>• Minimising changes to natural drainage lines and flow paths.</li> <li>• Flooding regimes and areas subject to inundation.</li> </ul>
C152	Minimise watercourse crossings, where practicable, during route selection. Where required, select crossing locations to avoid or minimise disturbance to aquatic flora, waterholes, watercourse junctions and watercourses with steep banks.
C153	Avoid permanent pools, chains of ponds, and alluvial islands, where practicable, when selecting watercourse crossing points.
C154	Design water dams in accordance with relevant legislation and Queensland standards and DERM guidelines.
C155	Where practicable, site facilities above the 1-in-100-year average flood recurrence interval.
C156	Manage potential impacts on Lake Broadwater Conservation Park (Category A ESA) through implementation of the relevant buffer proposed in Table 2.
C170	Locate soil stockpiles away from watercourses and wetlands to minimise potential for sediment runoff to enter the watercourse or wetland.

**Table 9.1 Surface water commitments presented in the EIS (cont'd)**

No.	Commitment
C171	Develop and implement incident reporting, emergency response and corrective action systems or procedures. Include systems for reporting, investigation and communications of lessons learned.
C172	Segregate stormwater discharge from potential contaminant process areas.
C173	Inspect rehabilitated watercourse channels and banks following significant flow events and undertake remedial works as required.
C174	Maximise beneficial use of coal seam gas water.
C175	Establish water quality monitoring stations upstream and downstream of discharge points to watercourses as part of a monitoring program to ensure compliance with environmental authority conditions and relevant standards.
C176	Use coal seam gas water for dust suppression on roads or for construction and operations activities authorised in the environmental authority in accordance with the water quality parameters described in the environmental authority.
C177	Minimise the inventory of hazardous materials stored on site.
C178	Decommission infrastructure in such a manner that it will not adversely affect overland or flood flows and in accordance with relevant legislation and regulations.
C205	Identify strategies to minimise coal seam gas water surface storage and to promote increased efficiency.
C498	Develop a protocol for the discharge of coal seam gas water to watercourses in a controlled manner under emergency situations, taking the sensitivity of the receiving watercourse into consideration. Conduct discharge events in accordance with specific parameters, including discharge volumes, flows and duration, and water quality.
C505	Inspect erosion and sediment control measures following significant rainfall events to ensure effectiveness of measures is maintained.
C507	Visually inspect physical form and monitor hydrology, turbidity and pH upstream and downstream of crossings immediately prior to, during and after construction of watercourse crossings.
C509	Routinely monitor buffer zones and project footprint using satellite imagery.
C526	Visually inspect physical form and monitor hydrology, turbidity and pH upstream and downstream of central gas processing and integrated processing facility stormwater and coal seam gas water discharge points.
C527	Routinely visually inspect physical form integrity and monitor hydrology, turbidity, total suspended solids, pH, dissolved metals and total petroleum hydrocarbons upstream and downstream of authorised locations where water is to be discharged directly to a watercourse.
C529	Measure the volume and quality of treated coal seam gas water released to surface waters on a routine basis in accordance with regulatory requirements and approved release limits.
C530	Routinely measure the volume and quality of treated sewage effluent in accordance with regulatory requirements and approved release limits.

## 9.2 Study Purpose

The supplementary surface water assessment was undertaken to address updates to the project description, to provide additional information made available since publication of the EIS, and to incorporate legislative updates that may impact on the management of surface waters. A summary of relevant information is presented in the following sections.

### 9.2.1 Project Description Update

Updates to the project description presented in the EIS, that have the potential to change or refine the EIS surface water impact assessment are described below.

## Field Development Concept

A field development concept based on five development regions was presented in the EIS. The field development concept has evolved and is now based on eleven drainage areas. Each drainage area is defined by the production wells and associated water and gas gathering network required to service a central gas processing facility (CGPF). The CGPFs have been identified by the drainage basin in which they will be built, e.g., CGPF2 is located in drainage area 2 (DA2). The number of CGPFs has been reduced from the 12 described in the EIS, to 8, and the number of water treatment facilities has been reduced from six to two. The water treatment facilities will be co-located with CGPF2 and CGPF9.

## Siting of Facilities

Arrow has identified four properties on which CGPF2, CGPF7, CGPF8 and CGPF9 will potentially be located. A fifth property located in drainage area 9 has been identified by Arrow, potentially for a temporary workers accommodation facility (TWAF) identified as TWAF F. It is intended that all properties identified for major facilities will be either owned by Arrow or leased under a long-term arrangement.

The exact location of the facilities on each property is still being investigated. Consequently, this assessment has focused on identifying and assessing the site-specific impacts of development on the entirety of each of these five properties, not at a specific location within each property. For the purposes of this chapter, the properties will be referenced by the CGPF or TWAF to be developed on the property, e.g., CGPF2 property and TWAF F property. The findings of this study and environmental constraints identified in the EIS and updated as part of the SREIS will influence the final location of infrastructure on the properties.

Figure 9.1 shows the location of the properties identified to potentially site CGPF2, CGPF7, CGPF8, CGPF9, TWAF F and the water treatment facilities.

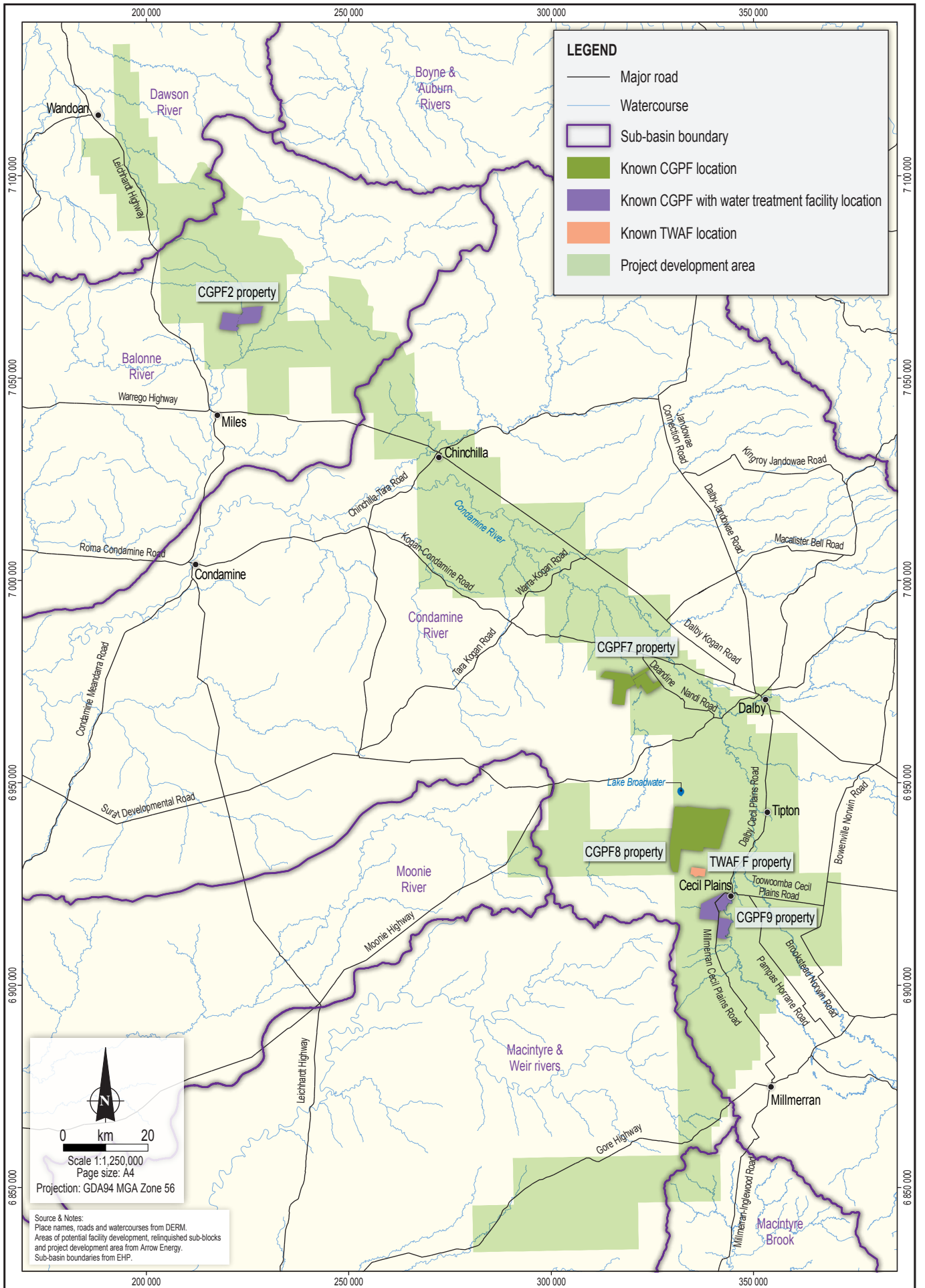
## Water Treatment Facility Capacities

The EIS stated that the six water treatment facilities would have a capacity of 30 to 60 ML/d each. The updated project description proposes only two water treatment facilities that will have larger capacities. The northern water treatment facility, co-located with CGPF2, will potentially treat approximately 35 ML/d of coal seam gas water. The southern water treatment facility, co-located with CGPF9, will potentially treat approximately 90 ML/d of coal seam gas water.

Both facilities will discharge coal seam gas water to nearby watercourses under both normal operations and emergency situations to manage variations in seasonal conditions and for distribution to existing and new water users for beneficial use and injection to a suitable aquifer. These discharges will occur as required and will be within the prescribed limits, to be determined by subsequent investigations that will support the application for an environmental authority.

## Project Development Area

Since publication of the EIS, Arrow has relinquished parcels of land as a result of ongoing exploration and improved knowledge of the coal seam gas reserves. The revised project development area (shown in Figure 9.1) has changed the extent of basins and sub-basins within the project development area. The updated extents are summarised in Table 9.2.



**Table 9.2 Updated extent of drainage divisions, basins and sub-basins within the project development area**

Drainage Division	Basin	Sub-basin	Extent of the Project Development Area within the Sub-basin (%)	Project Development Area as a percentage of the Sub-basin area (%)
Murray-Darling	Condamine-Balonne	Balonne River	17.23	2.74
		Condamine River	61.01	12.24
	Border Rivers	Macintyre Brook	1.5	2.12
		Macintyre and Weir Rivers	12.42	4.91
	Moonie	Moonie River	0.98	0.4
North-East Coast	Fitzroy	Dawson River	6.86	0.82

### 9.2.2 Additional Information

Since publication of the EIS, additional information has become available on subsidence including the results of a collaborative study, Baseline Report on InSAR Monitoring on the Surat-Bowen Basin (Altamira Information, 2012a), on the potential for natural surface deformation as a result of coal seam gas water extraction. The study utilised historical and baseline data from the Advanced Land Observation Satellite and covers a time lapse period from December 2006 until February 2011. The findings of the collaborative study are described in Chapter 8, Groundwater. A review of the significance of the collaborative study findings for potential impacts on surface water and, in particular, overland flow is presented in Section 9.7.

The supplementary surface water assessment has also incorporated light detection and ranging (LiDAR) data and new high-resolution imagery of the project development area collected in June 2012. This information was used to refine the geomorphic assessment of the watercourses and overland flows.

### 9.2.3 Investigations Undertaken

Four site-specific investigations were undertaken for the supplementary surface water assessment. They were:

- *Geomorphic Assessment.* This assessment was undertaken to describe the existing geomorphology of wetlands and watercourses traversing or adjacent to properties identified to locate project facilities, particularly those potentially affected by the proposed discharges. The assessment was also undertaken to identify preferred sites for the discharge points.
- *Overland Flow and Flooding Assessment.* This assessment was undertaken to identify areas within each property that are vulnerable to flooding, and the extent and direction of overland flow resulting from localised rainfall.
- *Discharge Assessment.* This assessment was undertaken to determine the capacity of potentially affected watercourses to accept the proposed discharge and to determine the water quality of those watercourses. The preliminary environmental flows assessment was carried out as part of the discharge assessment.

- *Subsidence Literature Review*. This review was undertaken to provide an update on research into subsidence and the potential for it to affect surface waters within the project development area.

### 9.3 Legislative Update

Legislation, policies and guidelines related to the protection of surface water environmental values in the project development area are described in Chapter 15 of the EIS. Updates to legislation, policies, guidelines and plans that may impact on the management of surface water are summarised below:

- *The Basin Plan*. The Murray Darling Basin Plan was prepared under the *Water Act 2007* (Cwlth) and adopted in November 2012. The plan was prepared to improve ecological health, water quality and water management for the basin. It includes long-term average sustainable diversion limits which will restrict the amount of water that can be taken for consumption so as not to compromise key ecosystem functions, key environmental assets, the productive base of the water resource and key environmental outcomes for the water resource. The Condamine-Balonne, Border Rivers and Moonie basins within the project development area are within the Murray-Darling drainage division.
- *EPP (Water) Dawson River Sub-basin Environmental Values and Water Quality Objectives*. This document was published in September 2011 and is listed under schedule 1 of the Environmental Protection (Water) Policy 2009 and sets out environmental values and water quality objectives for surface waters in the Dawson River sub-basin (excluding Callide Creek catchment).
- *Coal Seam Gas Water Management Policy 2012*. This policy replaces Queensland's Coal Seam Gas Water Management Policy 2010, which was developed to provide direction on the treatment and disposal of coal seam gas water and of the role the government has in facilitating greater beneficial use. The updated policy presents a hierarchy of the methods to be employed by coal seam gas operators to manage coal seam gas water and saline waste. This policy was reviewed as part of the discharge assessment.
- *Water Resources (Fitzroy Basin) Plan 2011*. The purpose of this Queensland Government regulation is to provide a framework for managing water resources, which includes reversing degradation that has occurred to natural ecosystems, including stressed rivers, where practicable. The Dawson River sub-basin within the project development area forms part of the Fitzroy Basin.
- *Queensland Regional Natural Resource Management Framework 2011 (DERM, 2011f)*. This document sets out the framework for managing the biophysical, sociopolitical and economic aspects of water and other resources at a regional level to achieve healthy environments in Queensland.

In addition to the above acts, policies, guidelines and plans, the supplementary surface water assessment has considered the following documents released by various committees and community groups:

- *Queensland Murray-Darling Committee Policy Document: Mining and Energy Industry Impacts on Natural Resources in the Queensland Murray-Darling Basin (Todd et al., 2011)*. This document was released by the Queensland Murray-Darling Committee. The purpose of the document is 'to address the impacts of the mining and energy industry on the Queensland Murray-Darling Basin's natural resources' and 'to provide a framework for best practice and



policy decision-making, risk management and responses to the specific and cumulative impacts of the mining and energy industry on the Queensland Murray-Darling Basin's natural resources'. The Murray-Darling is the main drainage division covered by the project development area.

- *Condamine Catchment Natural Resource Management Plan 2010 (Condamine Alliance, 2010a) and CSG & Mining Policy (Condamine Alliance, 2010b)*. These documents, released by the Condamine Alliance, were developed to define appropriate targets for water use, water quality, monitoring and reporting in the Condamine River sub-basin in consideration of economic, social and environmental aspects.
- *Other Community Documents*. The risks associated with changes to overland flow paths and concentrations of overland flow have been identified as a community priority in the Condamine River sub-basin, e.g., by the Brigalow-Jimbour Floodplains Group. Documents such as the Report of the Upper Condamine Floodplain Management Project (Natural Heritage Trust Project - 972976) (McLatchey & Knowles-Jackson, 2002) and updated floodplain management plans released by groups such as the Brigalow-Jimbour Floodplains Group, have been considered. The Report of the Upper Condamine Floodplain Management Project stated that 'uncoordinated runoff along with inappropriately sited development infrastructure has led to unnatural flow concentrations and extensive land degradation' on the Condamine floodplain.

## 9.4 Geomorphic Assessment

The purpose of the geomorphic assessment was to characterise the geomorphology of floodplains, watercourses and wetlands at the five properties. The assessment identified potential impacts on overland flow and watercourse stability from the construction of project infrastructure. The assessment of the CGPF2 and CGPF9 properties, which are each proposed to contain a water treatment facility, also identified potential impacts from coal seam gas water discharges to the watercourses and identified potential stable locations for the discharge points. The method, findings, potential impacts and management measures for the assessment are described below.

### 9.4.1 Method

The geomorphic assessment comprised a desktop study and field surveys of the receiving environment of the five properties. The receiving environment included floodplains, watercourses and wetlands within and surrounding properties identified as being potentially affected by project activities. Downstream reaches of the watercourses traversing properties identified to site water treatment facilities, were also included.

The desktop assessment of watercourses involved the use of high resolution aerial imagery and LiDAR derived contour data to validate the geomorphic categories mapped in the EIS and to identify areas requiring closer inspection on the ground. The desktop assessment of wetlands involved the identification of wetlands mapped in the Queensland Wetlands Program (Version 3, released February 2012) that could be impacted by project activities within or adjacent to the properties.

The field survey involved a visual inspection of the watercourses and wetlands of the receiving environment of the five properties, particularly the two properties proposed to contain water treatment facilities. Inspections of the watercourses proposed to receive discharges were conducted from the upstream boundary of the property to a downstream feature that would potentially limit downstream geomorphic change. The sensitivity or resilience of the watercourses to changes in hydrologic conditions was determined through an assessment of various

parameters including channel dimension, channel boundary material, geomorphic units, riparian vegetation and pre-existing instabilities.

Following desktop and field assessments, watercourses were divided into reaches defined by the predominant geomorphic characteristics.

The watercourse that will potentially receive discharge from the water treatment facility at the CGPF2 property is Bottle Tree Creek, a tributary of Dogwood Creek, which flows into the Balonne River approximately 8 km downstream of Miles. The Bottle Tree Creek and Dogwood Creek subcatchments are part of the Dogwood Creek catchment, which is located within the Balonne River sub-basin. The watercourses of the Dogwood Creek catchment are 'intermittent, with surface waters receding to disconnected pools during the dry winter months' (Appendix 6, Supplementary Surface Water Assessment Part B – Water Quality). Figure 9.2 shows the field assessment sites inspected along the watercourses and in the wetlands of the receiving environment of the CGPF2 property.

The water treatment facility at CGPF9 will potentially discharge to the Condamine River. The hydrology of the Condamine River has been greatly altered since European settlement through clearance of vegetation, the construction of weirs and dams, and the extraction of water for agriculture. A tributary of the Condamine River, Crawlers Creek, intersects the western part of the CGPF9 property. The Condamine River and Crawlers Creek subcatchments are part of the Condamine River catchment, which is located within the Condamine River sub-basin. Figure 9.3 shows the field assessment sites inspected along the watercourses and wetlands of the receiving environment of the CGPF9 property.

The properties where CGPF7, CGPF8 and TWAF F are planned to be located are intersected by a number of watercourses, some of which are tributaries of the Condamine River. Geomorphic assessments of these properties were conducted to determine potential impacts from the construction of project infrastructure, such as erosion and runoff. Figure 9.4 shows the field assessment sites inspected for watercourses within and surrounding the CGPF7, CGPF8 and TWAF F properties.

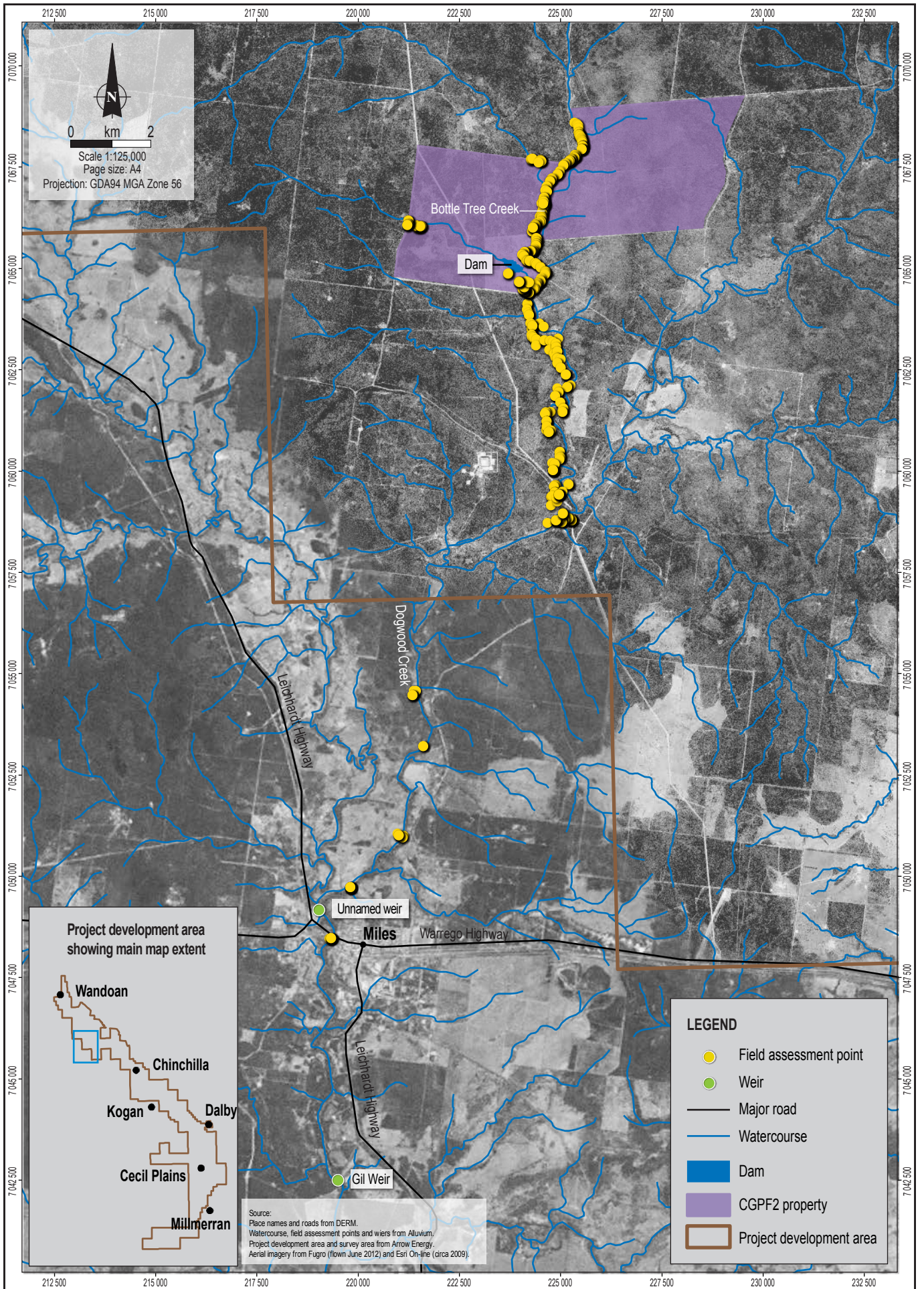
#### **9.4.2 Study Findings, Impacts and Management Measures**

The geomorphology of nominated sections of watercourses intersecting the five properties is summarised below and described in further detail in Appendix 5, Supplementary Surface Water Assessment Part A – Geomorphology and Hydrology. Geomorphic impacts were identified as occurring naturally or artificially.

##### **CGPF2 Property**

The major watercourse running through the CGPF2 property is Bottle Tree Creek, which joins Dogwood Creek approximately 7 km downstream of the southern property boundary. Overall, the watercourse is stable and is generally characterised by a single thread sand bed channel. Some instability exists in the form of localised slump erosion of the upper sand banks and minor gully erosion in the downstream section of Bottle Tree Creek.

Within the CGPF2 property, Bottle Tree Creek and its two tributaries were divided into seven reaches based on geomorphic characteristics as presented in Figure 9.5. South of the property, Bottle Tree Creek and Dogwood Creek were divided into two reaches, with the upper reach encompassing Bottle Tree Creek from the southern property boundary to downstream of its confluence with Dogwood Creek. The downstream reach extended along Dogwood Creek to near Miles. A description of the key features of each reach follows.



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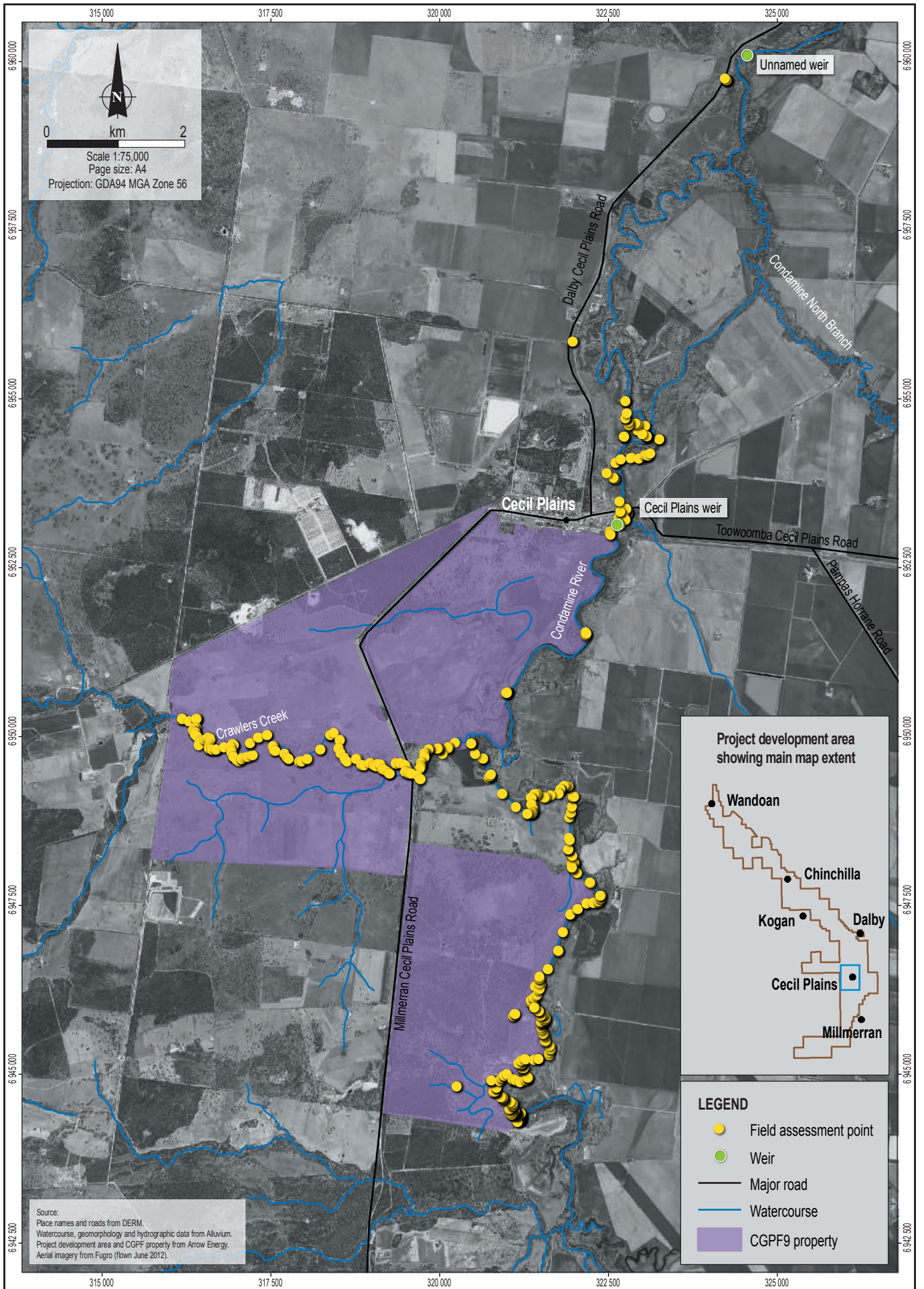
**Project development area showing main map extent**

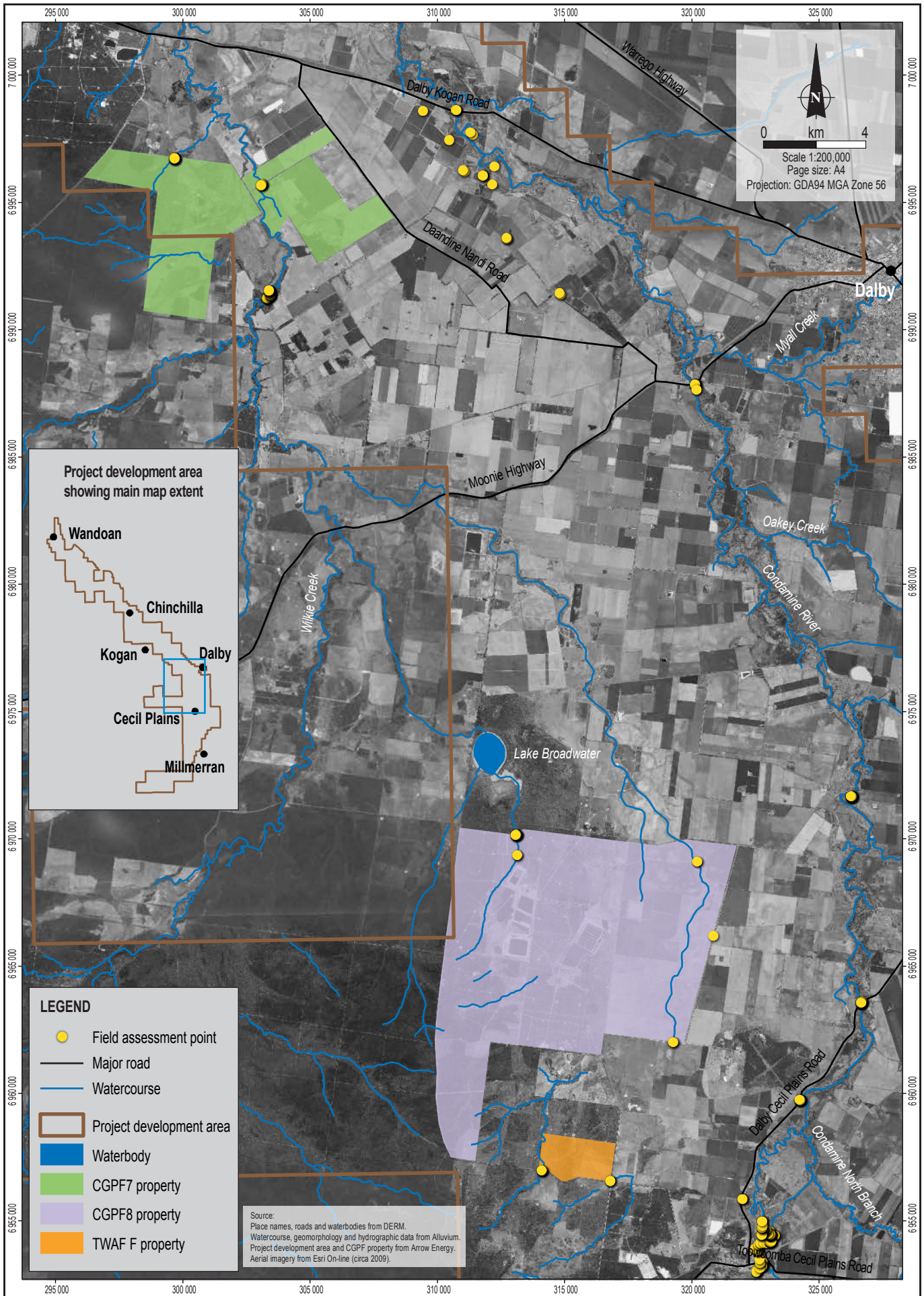
Wandoan  
 Chinchilla  
 Kogan  
 Dalby  
 Cecil Plains  
 Millmerran

Source:  
 Place names and roads from DERM.  
 Watercourse, field assessment points and weirs from Allium.  
 Project development area and survey area from Arrow Energy.  
 Aerial imagery from Fugro (flown June 2012) and Esri On-line (circa 2009).

**LEGEND**

- Field assessment point
- Weir
- Major road
- Watercourse
- Dam
- CGPF2 property
- ▭ Project development area





0 km 4

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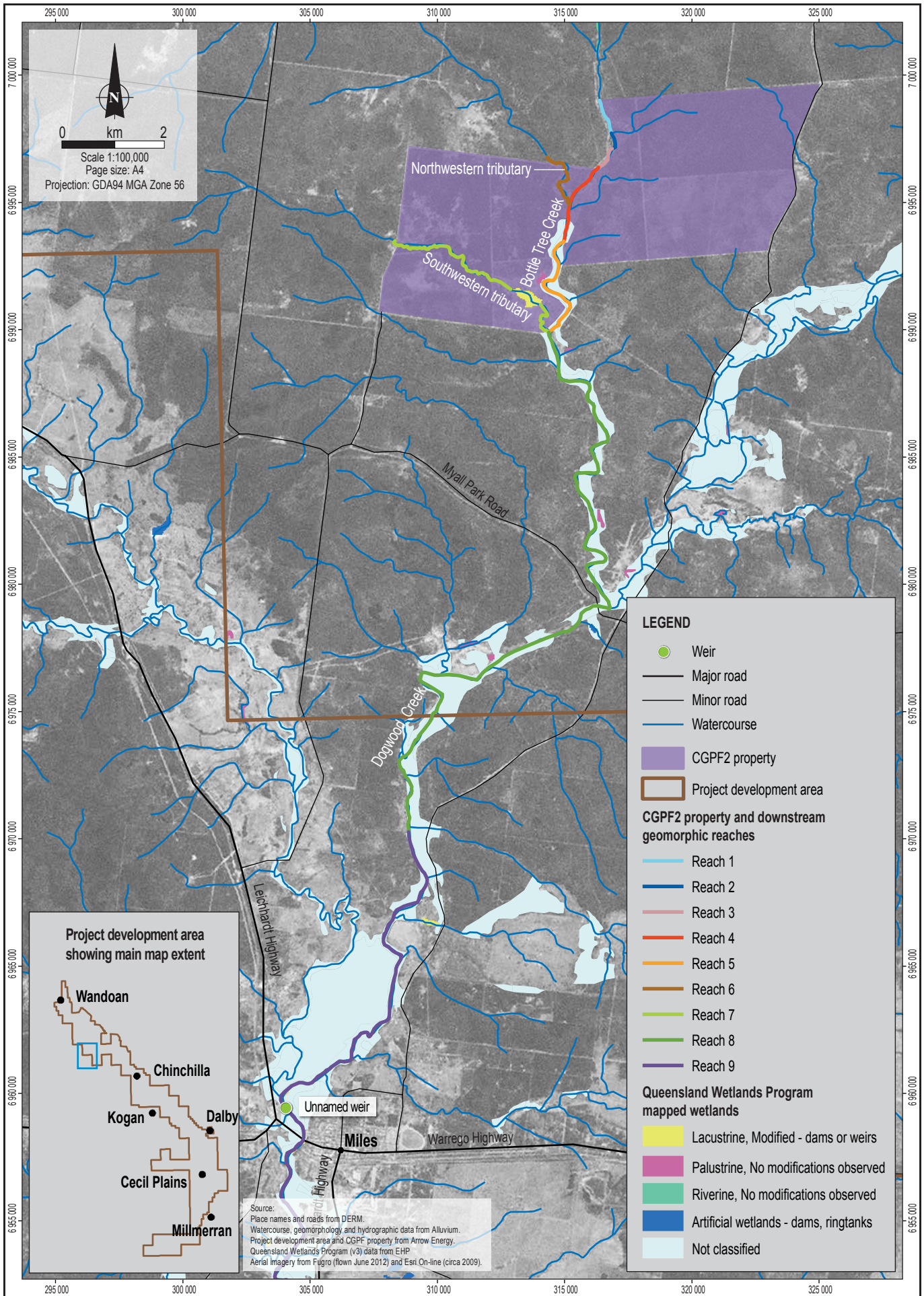
**Project development area showing main map extent**

Wandoan  
Chinchilla  
Kogan  
Dalby  
Cecil Plains  
Millmerran

**LEGEND**

- Field assessment point
- Major road
- Watercourse
- Project development area
- Waterbody
- CGPF7 property
- CGPF8 property
- TWAF F property

Source:  
Place names, roads and waterbodies from DERM.  
Watercourse, geomorphology and hydrographic data from Alluvium.  
Project development area and CGPF property from Arrow Energy.  
Aerial imagery from Esri On-line (circa 2009).



Reach 1, the most upstream reach of Bottle Tree Creek, is approximately 700 m long and is characterised by a single channel that sits within a partly-confined valley with high, steep banks mostly comprised of sands and silts. Overstorey riparian vegetation is moderately dense however groundcover is reduced and there are areas of localised bank erosion.

Reach 2 is a low flow channel that meanders through thick sand deposits. A lateral sand bar has formed in the channel and has been colonised by vegetation, leading to bank erosion.

Reach 3 is relatively robust and is partly-confined to confined, allowing slightly higher channel velocities and sediment transport capacity. Sand bars are present at the downstream areas of the reach due to a widening of the channel leading to reach 4.

Reach 4 is almost linear and is the second longest reach along Bottle Tree Creek within the CGPF2 property. There is a natural levee on the right bank of the reach which has allowed back swamps to develop on the floodplain and flood channels that drain the floodplain to begin forming. This reach is capable of storing both sediment and floodwaters from the floodplain and may be susceptible to erosion with changed hydrology.

Reach 5 along Bottle Tree Creek is the longest reach within the CGPF2 property and is characterised by alternating areas of narrow channel with impinging bedrock and slightly wider symmetrical sand channels without bedrock. Bedrock is present in the watercourse channel at several places in this reach, two of which have been identified as potential suitable sites for locating a discharge outfall (Plate 9.1). These two locations are approximately 40 m apart. Although reach 5 is resilient because of the prevalence and location of bedrock, there are instabilities in the downstream sections of the reach. For example, tunnel erosion has begun on the earthen bund blocking the natural outlet point of the mapped wetland (Plate 9.2). The wetland has been mapped as a 'palustrine wetland, no modifications observed'. Notwithstanding this categorisation, the construction of the earthen bund has modified the wetland, which has resulted in the retention of water within the wetland for extended periods of time.

Reach 6 is the unnamed watercourse intersecting the property at the northwestern boundary. The reach is characterised by a relatively stable, single-thread, low-capacity channel with low banks comprised predominantly of mud drapes. Gully erosion has begun in some unvegetated areas, which has contributed a significant pulse of sediment into the channel.

Reach 7, the southwestern tributary of Bottle Tree Creek, is a highly resilient series of pools formed by bedrock in a partly-confined valley with a well-vegetated associated floodplain. The downstream areas of the reach turn to a single-thread, mud-lined channel with low transport capacity and a discharge outlet to a farm dam. A large gully complex located at the outlet to the dam is likely to advance further upstream and threaten stability in this reach (Plate 9.3).

Reach 8, is downstream from the property and includes parts of both Bottle Tree Creek and Dogwood Creek. This reach is similar in geomorphic characteristics to reach 5 in that moderate vegetation coverage and bedrock intrusions provide stability and resilience to the bed and banks. The confluence of Bottle Tree Creek and Dogwood Creek is stable (Plate 9.4). A large gully complex is present in Bottle Tree Creek approximately 700 m upstream of the Myall Park Road crossing and headward erosion in this complex could, in time, potentially affect the right of way of a recently constructed high-pressure gas pipeline. Three existing crossings of this reach could be impacted by altered flow conditions:

- A private vehicle access track at watercourse bed level in Bottle Tree Creek that may be inundated if the duration of flows is extended.



Photo credit: Alluvium

**Plate 9.1**  
Localised bedrock exposure in reach 5 of Bottle Tree Creek; preferred locations for potential discharge



Photo credit: Alluvium

**Plate 9.2**  
Tunnel erosion on the earthen bund built over the original wetland outflow path in reach 5 of Bottle Tree Creek



Photo credit: Alluvium

**Plate 9.3**  
Gully showing evidence of headward erosion at the outlet of the farm dam at reach 7 (Bottle Tree Creek tributary)



- Myall Park Road crossing over Dogwood Creek (Plate 9.5).
- The recently constructed high pressure gas pipeline crossing downstream of the Myall Park Road crossing, protected on the lower banks by gabion baskets (wire mesh boxes filled with rock). A gully complex is forming on the right bank on the upstream end of the baskets.

Reach 9 on Dogwood Creek has altered flow conditions due to the weirs constructed along the watercourse (Gil Weir and an unnamed weir, both shown in Figure 9.2). The channel becomes increasingly wider downstream and groundcover vegetation is intact although several gullies have formed on the left bank (Plate 9.6). These gullies are unlikely to be affected by increased flows.

The geomorphic assessment found that reach 5 on Bottle Tree Creek was the most stable reach and that the bed rock outcroppings in the upstream section of the reach were most suitable for a discharge point. The recommended discharge points in reach 5 were assumed for the discharge assessment.

The assessment identified erosion at several locations, particularly in reach 7 at the spillway of a farm dam and in the downstream section of reach 5 at the bund covering the original outlet point of the natural wetland. Encroachment of infrastructure could also disturb mapped wetlands. Mitigation measures to reduce the impacts associated with construction of project infrastructure at the property, such as erosion and runoff have not changed from the EIS and are outlined in Section 15.6 of Chapter 15 of the EIS. The assessment has identified potential localised impacts on the affected watercourses that will need to be addressed in erosion and sediment control management plans to be prepared prior to construction commencing.

### **CGPF9 Property**

The Condamine River flows in a northerly direction along the eastern boundary of the CGPF9 property. Crawlers Creek, a tributary of the river that traverses the property, joins the river approximately 5.5 km upstream of the Cecil Plains weir, which is located upstream of the Toowoomba Cecil Plains Road bridge and downstream of the northern boundary of the property.

Overall, the Condamine River exhibits low stability with extensive gully erosion in some sections and active meander migration through other sections. The Cecil Plains weir pool at the downstream end of the property provides some stability to this section of the river.

The two watercourses were divided into six reaches based on their geomorphic characteristics with reaches 1, 2, 3 and 6 located on the Condamine River and reaches 4 and 5 located on Crawlers Creek (Figure 9.6). The reach of the Condamine River downstream of the Cecil Plains weir was considered to be relatively homogenous in geomorphic character and consequently, was considered as one reach. A description of the key features of each reach follows.

Reach 1, the most upstream reach of the Condamine River, is a moderately sinuous, single-thread channel set in a partly-confined valley setting. The left bank valley margin is comprised predominantly of dispersive clays and weathered siltstones, and extensive gully erosion is present (Plate 9.7). There is also an intact valley fill inset into the terrace on the left bank, which is highly sensitive and has a low resilience to erosion. The existing conditions indicate that the watercourse will continue to adjust under the current hydrological regime and is consequently an undesirable discharge location.

Reach 2 is a relatively linear reach set into a floodplain comprised of black cracking clays. Small flood channels drain water into the Condamine from back swamps on the floodplain, and gully erosion has initiated at the head and tail of some of these channels. Slumping in the downstream section has caused minor bank erosion, although overall, it is relatively stable.



Photo credit: Alluvium

**Plate 9.4**  
Confluence of Bottle Tree Creek and  
Dogwood Creek in reach 8



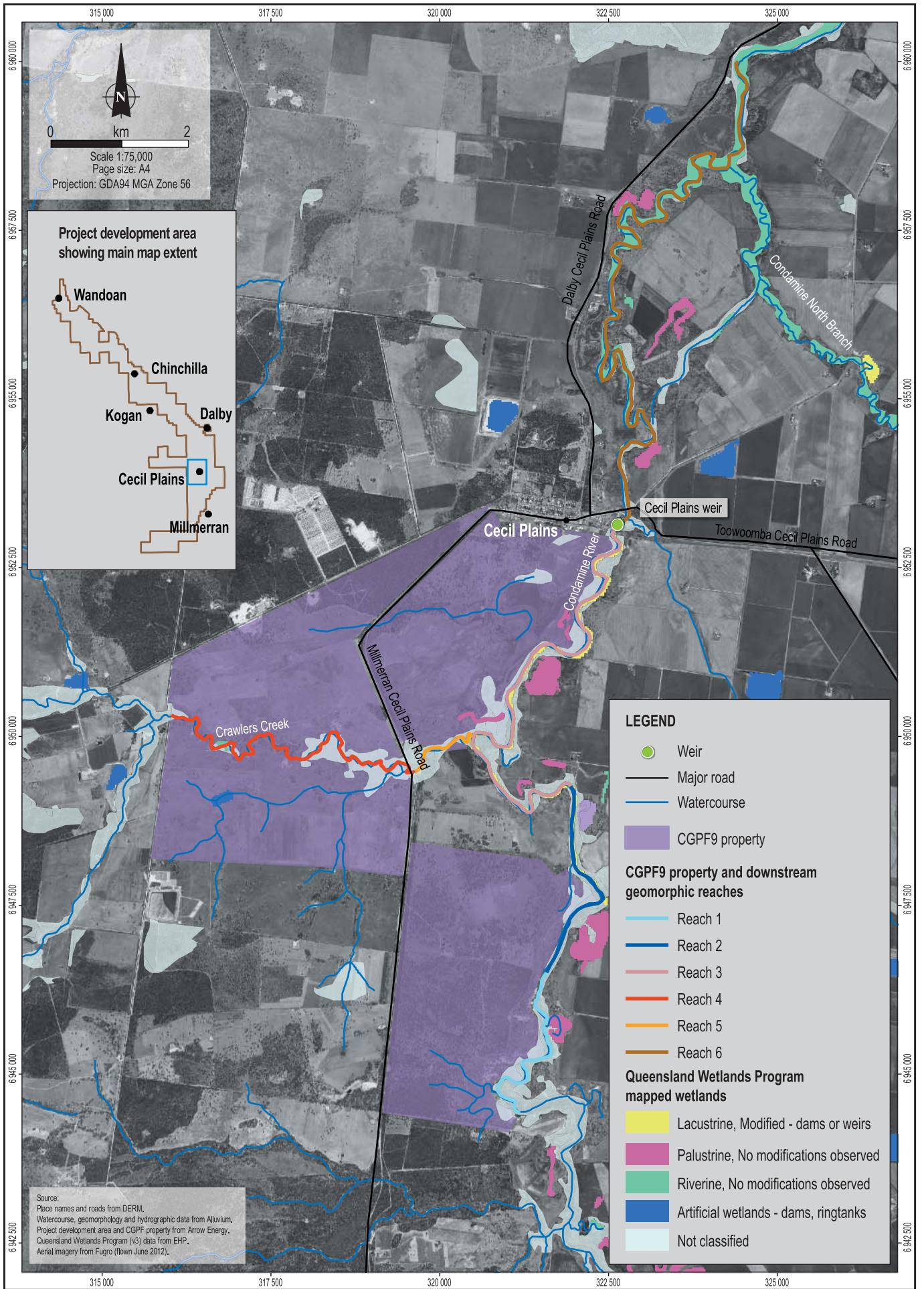
Photo credit: Alluvium

**Plate 9.5**  
Myall Park Road crossing over  
Dogwood Creek in reach 8



Photo credit: Alluvium

**Plate 9.6**  
Extensive gullying on the left bank of  
Dogwood Creek in reach 9



Scale 1:75,000  
Page size: A4  
Projection: GDA94 MGA Zone 56

**Project development area showing main map extent**

Wandoan  
Chinchilla  
Kogan  
Dalby  
Cecil Plains  
Millmerran

**LEGEND**

- Weir
- Major road
- Watercourse
- CGPF9 property

**CGPF9 property and downstream geomorphic reaches**

- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5
- Reach 6

**Queensland Wetlands Program mapped wetlands**

- Lacustrine, Modified - dams or weirs
- Palustrine, No modifications observed
- Riverine, No modifications observed
- Artificial wetlands - dams, ringtanks
- Not classified

Source:  
Place names and roads from DERM.  
Watercourse, geomorphology and hydrographic data from Alluvium.  
Project development area and CGPF9 property from Arrow Energy.  
Queensland Wetlands Program (V3) data from EHP.  
Aerial imagery from Fugro (flown June 2012).

Reach 3 is the most downstream section along the CGPF9 property that was assessed in the Condamine River and is characterised by deeper watercourse depths due to back-pooling behind the Cecil Plains weir. The channel is more sinuous than reach 2; but sections of it are generally more stable than reach 1, including the confluence of Crawlers Creek with the Condamine River (Plate 9.8).

Reach 4, the most upstream reach of Crawlers Creek, is characterised by significantly reduced vegetation on the terrace and floodplains, which has resulted in the formation of large complex gullies (Plate 9.9). The reach is laterally unstable with active meander migration and widening of the channel occurring throughout the upstream section. Continued accumulation of sediment in the watercourse bed level may exacerbate meander erosion and gully erosion. These processes are likely to be further exacerbated if flows in Crawlers Creek are increased e.g., through discharge to the watercourse.

Reach 5, the downstream section of Crawlers Creek, is a single-thread channel characterised by banks and associated floodplains comprised of dispersive clays. There are areas of localised bank retreat; and the reach has a large gully complex at the head, which has the potential to encroach on the Millmerran Cecil Plains Road reserve. The downstream section of the reach is more stable, including the confluence with the Condamine River.

Reach 6 is the downstream section of the Condamine River, encompassing the Cecil Plains weir (Plate 9.10). Reach 6 is similar in geomorphology to reach 2, with black clay upper banks. There are strong bedrock influences on the lower banks in the area immediately downstream of the Cecil Plains weir to the area downstream of the Toowoomba Cecil Plains Road bridge (Plate 9.11). This section is not likely to be sensitive to increased flows. A flood channel that links the Condamine River and the Condamine River (North Branch) was observed on the right bank downstream of the Toowoomba Cecil Plains Road bridge (Plate 9.12). The flood channel has existing bank erosion most likely due to the lack of riparian vegetation. Extended and prolonged flows in this channel could potentially exacerbate these processes.

A number of palustrine wetlands are mapped within and adjacent to the CGPF9 property. A mapped palustrine wetland is located on the right floodplain of the Condamine River approximately 600 m downstream from the Toowoomba Cecil Plains Road bridge. The wetland is located in an unstable area of the Condamine River with evidence of significant bank erosion occurring near the downstream end of the wetland.

The geomorphic assessment found that reach 3 along the Condamine River is the most stable reach and that the Cecil Plains weir pool would be a suitable location for the planned discharge point. Areas with bedrock influences in reach 6, downstream of the Cecil Plains weir pool, would also be suitable discharge points.

Existing erosion was identified at several locations, particularly in reach 1 of the Condamine River, in flood channels associated with reach 2 and in the gully complexes in reach 4. Disturbance to mapped wetlands could also occur as a result of inappropriate siting of project infrastructure. Where practicable, these areas would be avoided as they lie within the 1-in-100-year average recurrence interval (ARI) flood extent.

Mitigation measures to reduce the impacts associated with construction of project infrastructure at the property, such as erosion and runoff, have not changed from the EIS and are presented in Section 15.6 of Chapter 15 of the EIS. The assessment has identified potential localised impacts on the affected watercourses that will need to be addressed in erosion and sediment control management plans to be prepared prior to construction commencing.



Photo credit: Alluvium

**Plate 9.7**  
Extensive gully on the left bank of reach 1 of the Condamine River



Photo credit: Alluvium

**Plate 9.8**  
Looking upstream toward confluence of the Condamine River (reach 3) and Crawlers Creek



Photo credit: Alluvium

**Plate 9.9**  
Lateral gully forming through terrace in reach 4 of Crawlers Creek

**Plate 9.10**  
Cecil Plains weir in reach 6  
of the Condamine River



**Plate 9.11**  
The Toowoomba Cecil Plains Road  
bridge in reach 6 of the  
Condamine River



**Plate 9.12**  
Flood channel linking Condamine River  
and the Condamine River North Branch



### **CGPF7, CGPF8 and TWAF F Properties**

Figure 9.7 shows the wetlands and geomorphic characteristics for watercourses potentially affected by project activities on the CGPF7 property, and Figure 9.8 shows the wetlands and geomorphic characteristics for watercourses potentially affected by project activities on the CGPF8 and TWAF F properties.

Reaches that define the specific geomorphic features of the watercourses were not identified, as detailed information on which to base the location of discharge points was not required. Instead, the geomorphic assessment of the affected watercourses focused on identifying the characteristics that might be vulnerable to impacts from construction activities or project infrastructure siting, and on establishing a baseline for any subsequent investigations for environmental authority applications.

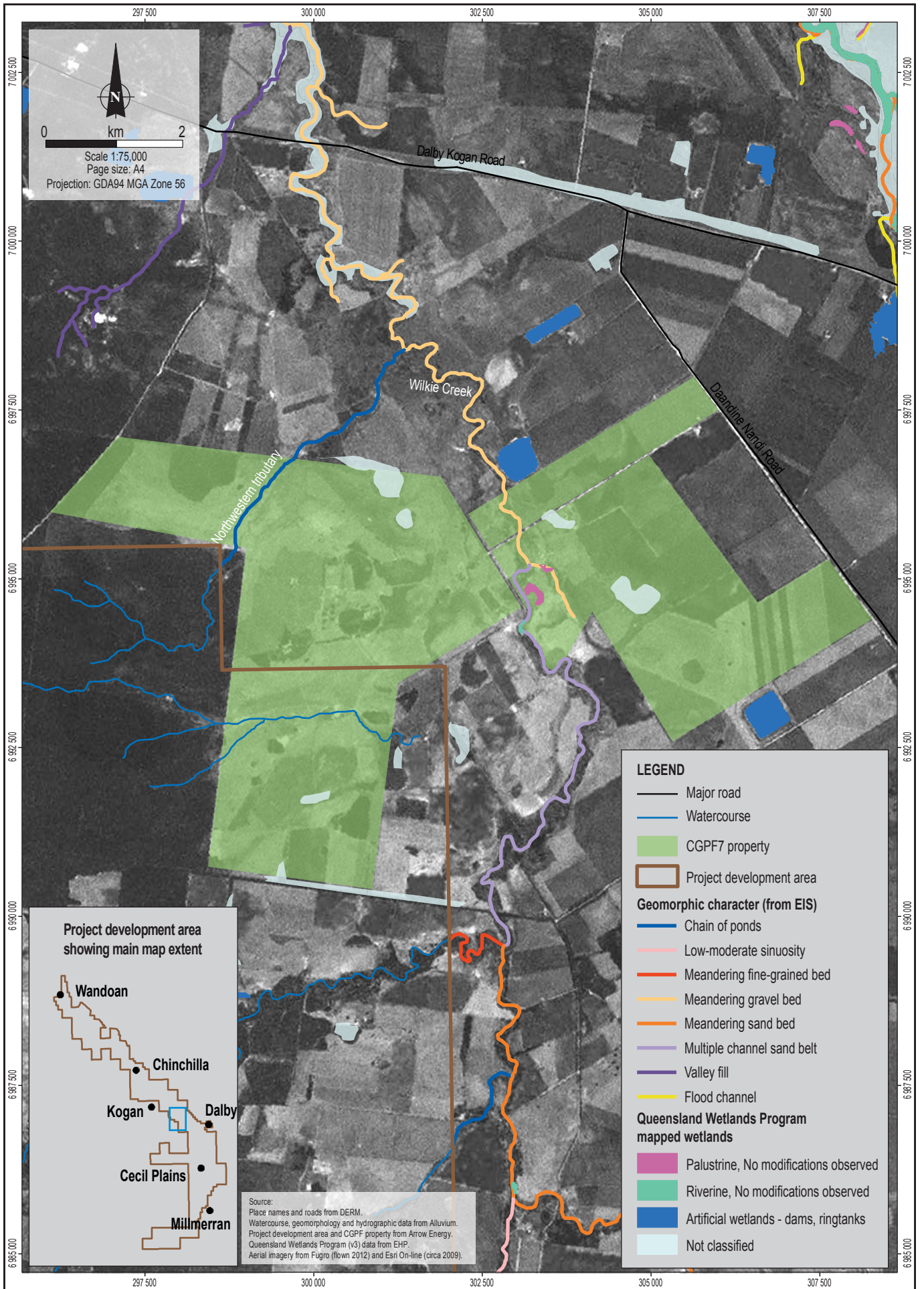
Two watercourses traverse the CGPF7 property including Wilkie Creek, which flows southeast to northwest. Wilkie Creek comprises a single thread moderately-sinuuous channel that alternates between wide, slow-moving reaches and pools, and smaller, low-flow channels (Plate 9.13). Riparian vegetation is relatively intact along most of the length of the watercourse, although bank erosion and meander migration could potentially occur. Gully erosion was observed in some sections. An unnamed watercourse was identified in the northwestern part of the property. This watercourse is a small, ephemeral, low-capacity chain of ponds with no areas of instability. Two palustrine wetlands are located within the property within the 1-in-100-year ARI flood extent.

Two watercourses run through the CGPF8 property, including one (called the northwestern tributary) that is a tributary of and feeds into Lake Broadwater, which is located approximately 5 km north of the property (Plate 9.14). Riparian vegetation, including canopy trees, sedges and grasses, is relatively intact along the northwestern tributary. This type of watercourse is highly susceptible to erosion and an increase in streamflow or removal of vegetation could initiate erosion and incision. The second watercourse is a former channel of the Condamine River known as 'Longswamp'. This watercourse runs south to north, is inundated in large flood events and is also prone to erosion. It is mapped as a palustrine wetland and lies within the 1-in-100-year ARI flood extent.

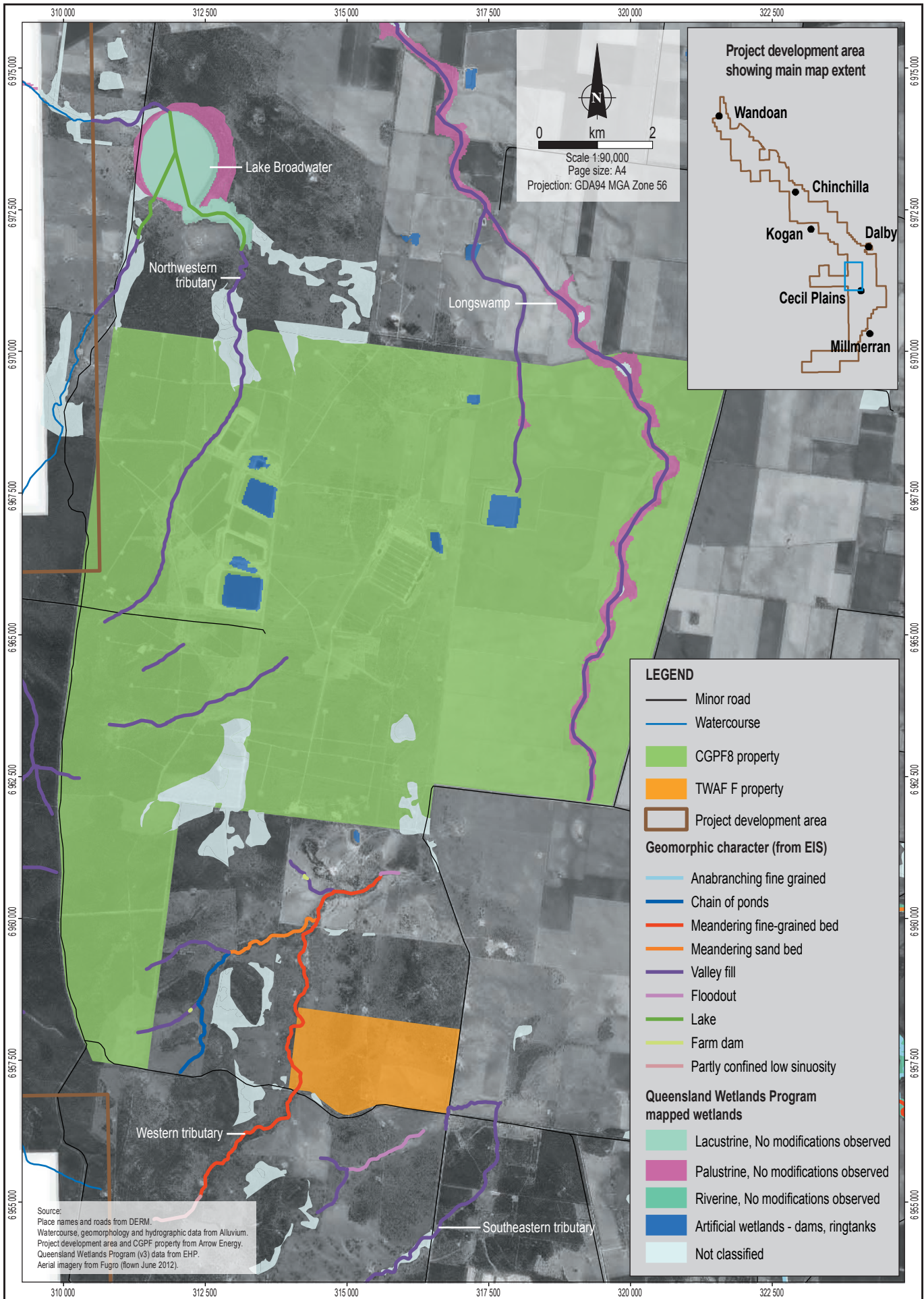
Two small watercourses run through the TWAF F property. The western watercourse (Plate 9.15) is an incised fine-grained meandering watercourse that has formed a small low-flow channel. Increased flows are likely to exacerbate erosion in this watercourse. The currently relatively stable southeastern watercourse is a low-capacity incised floodout, with low banks. The geomorphology of both watercourses is influenced by the road that forms the southern boundary of the property. Back-pooling of water behind the road culverts has resulted in a wider channel in the southeastern watercourse and a terrace potentially caused by erosion on the western watercourse. The loosely consolidated bed and bank materials, comprising sands, are susceptible to erosion from increased flows.

Increased flows in watercourses on all of these properties could exacerbate erosion of unstable bed and bank materials. In particular, downstream transport of eroded material from the northwestern watercourse running through the CGPF8 property could impact on Lake Broadwater.

Any construction of significant water storage infrastructure on the CGPF8 property could potentially reduce water feeding into Lake Broadwater due to a reduction in the catchment area size. While in wet years a reduction of the catchment area may have a negligible impact, in drier years any decrease in catchment area could have an adverse impact on inflows to the lake.







**Plate 9.13**  
Typical pool section of Wilkie Creek  
within the CGPF7 property



Photo credit: Alluvium

**Plate 9.14**  
Northwestern tributary, in the  
CGPF8 property, which drains  
to Lake Broadwater



Photo credit: Alluvium

**Plate 9.15**  
Western watercourse within  
the TWAF F property



Photo credit: Alluvium

No water treatment facilities are proposed at CGPF8, and only small, temporary utility dams, and potentially holding dams, may be constructed to manage site runoff, hydrostatic testing water and compressor washdown.

Mitigation measures to reduce the impacts associated with construction of project infrastructure at the properties, such as erosion and runoff, have not changed from the EIS. The supplementary assessment has identified potential localised impacts on the affected watercourses that will need to be addressed in erosion and sediment control management plans to be prepared prior to construction commencing. Commitment C034 has been revised to emphasise that sites adjacent to highly sensitive areas, for example, sites in the Wilkie Creek sub-catchment adjacent to Lake Broadwater, will require additional erosion and sediment control measures. Revised commitments are presented in Section 9.10, Commitments Update.

## **9.5 Overland Flow and Flooding Regime Assessment**

The purpose of this assessment was to model overland flow and flooding regimes at the five properties to determine whether the proposed facilities could be sited to have negligible impact on overland flows and to avoid inundation during flood events. The study identified areas within each property that were flood free during a 1-in-100-year ARI flood event. The method, study findings and potential impacts and mitigation measures for the assessment are described below.

### **9.5.1 Method**

The assessment comprised a field assessment and modelling to predict flood levels and the extent of inundation in and adjacent to the properties. The modelling domain extended beyond the watercourses traversing the properties to the floodplain and tributaries of the major watercourse draining the affected subcatchments. Hydrological modelling of rainfall was undertaken to determine runoff, a key input to hydrodynamic modelling of simulated flood events.

The field assessment investigated the geomorphic characteristics and hydraulic structures (e.g., bridges, culverts and weirs) of the watercourses traversing the properties and in the associated subcatchments to identify features that might affect the duration and magnitude of flood flows and the extent of overland flow. Minor structures, including small bridges, small culverts and small weirs, were not included in sensitivity testing, as they were not deemed large enough to impede flows significantly.

### **Hydrologic Modelling**

Hydrologic modelling was undertaken to convert the rainfall from a 1-in-100-year ARI storm event into runoff. Catchment delineation was undertaken for two catchments, the catchment encompassing the CGPF2 property (Dogwood Creek catchment models, covering areas draining to Dogwood Creek and Bottle Tree Creek) and the catchment encompassing the properties for CGPF7, CGPF8, CGPF9 and TWAF F (Condamine River catchment models). Each of the catchment models were divided into subcatchments to identify locations for recording flow rates. Delineation of catchments was done using the CatchmentSIM software program, which defines subcatchments by interpreting a digital terrain model generated from LiDAR data and NASA Shuttle Radar Topography Mission (SRTM) 30-m-grid satellite imagery. The models developed using the CatchmentSIM software were exported to RORB (a hydrological software package) and were used to develop catchment hydrology data used in the hydrodynamic modelling.

The two hydrologic models were calibrated against values derived through a flood frequency analysis undertaken for suitable streamflow gauging stations within the respective catchments. Data from the Gilweir gauging station, located at Gil Weir in Dogwood Creek, was used for the

Dogwood Creek catchment as there are no gauging stations on Bottle Tree Creek. Data from the Cecil Weir gauging station, located just downstream from the Cecil Plains weir, was used for the Condamine River catchment. A review of additional available streamflow and rain gauge data from the Bureau of Meteorology was also undertaken and assessed for relevance to the study. Where suitable, it was used to calibrate the hydrologic models. The hydrologic models simulated flow rates at nominated locations, and these rates were input into the hydrodynamic models.

### **Hydrodynamic Modelling**

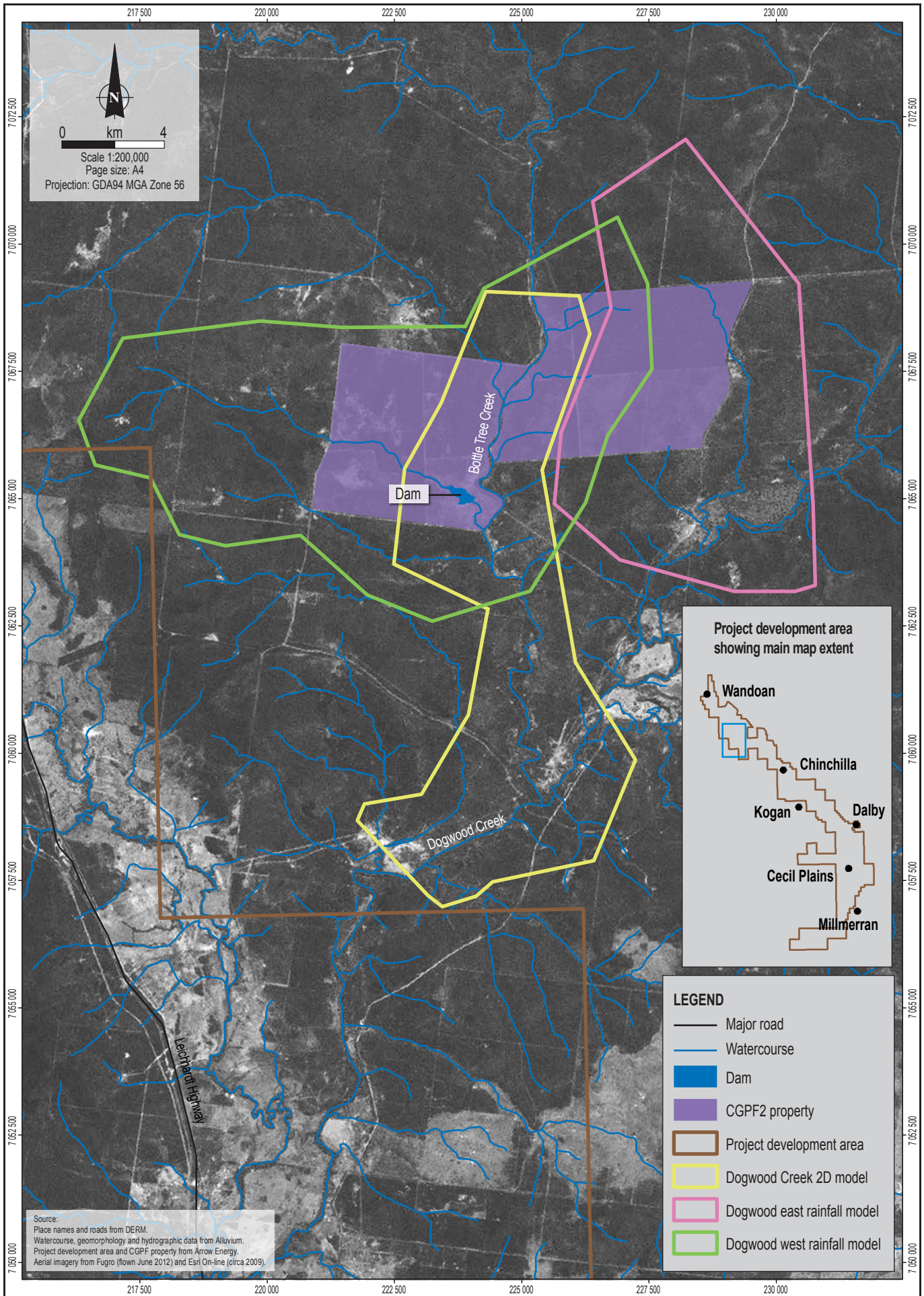
Hydrodynamic modelling using XPSWMM software was used to predict flood extents and depths for a 1-in-100-year ARI flood event at and adjacent to the nominated properties. Model inputs were derived from LiDAR data, NASA SRTM 30-m-grid data (Condamine River model only), high-resolution aerial imagery, information on land use and vegetation type (using Manning's  $n$  roughness coefficient, an empirically derived coefficient dependent on surface roughness, sinuosity and other factors) and catchment hydrology (which was determined using RORB). The critical duration, i.e., the storm duration that produces the highest water level for the 1-in-100-year ARI flood event, was determined for each model. Hydraulic structures, identified from the desktop study and subsequent field investigations, such as bridges, culverts and weirs, were used in sensitivity testing to determine whether they affected water levels predicted by the model.

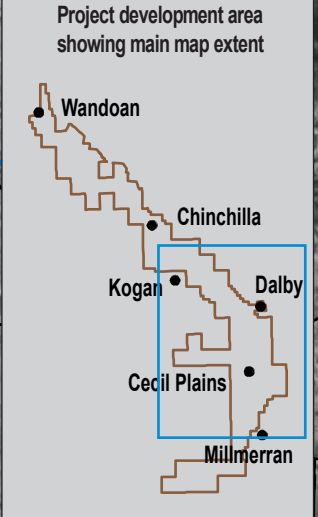
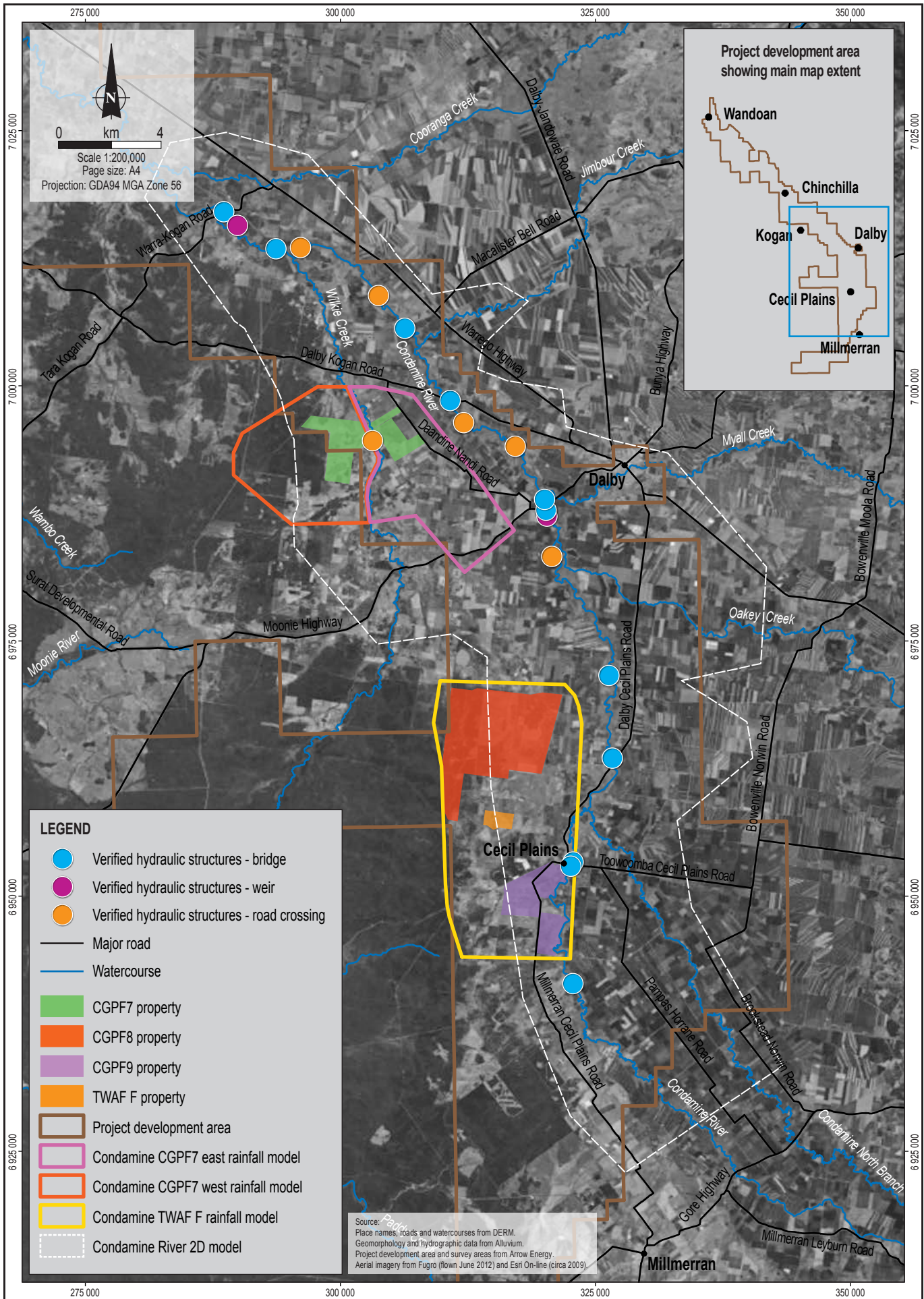
The Dogwood Creek models built for the Dogwood Creek and Bottle Tree Creek subcatchments (for the CGPF2 property) used a 15-m cell size and covered a combined area of approximately 100 km<sup>2</sup>. Three models were built: a riverine flood model to predict watercourse flow paths (Dogwood Creek 2D model), and two direct rainfall models to determine overland flow paths affecting the property (Dogwood east rainfall model and Dogwood west rainfall model). Figure 9.9 shows the extent of the model domains in relation to the CGPF2 property. The dam located on the west side of Bottle Tree Creek (visible in Figure 9.9) was identified as the only significant hydraulic structure and was used in sensitivity testing.

Seven hydrodynamic models were built for the Condamine River catchment. A Condamine River model that encompassed the CGPF7, CGPF8, CGPF9 and TWAF F properties (Condamine River 2D model) was built and used to inform hydrodynamic models for each of the CGPF7, CGPF8 and CGPF9 properties. Three direct rainfall models (CGPF7 east rainfall model, CGPF7 west rainfall model and TWAF F rainfall model, the latter encompassing the TWAF F, CGPF8 and CGPF9 properties) were built to predict the overland flow paths resulting from localised rainfall and runoff on those properties.

All models used a 15-m cell size except the model built to understand the broader Condamine River catchment (Condamine River 2D model), which used a 40-m cell size. In total, the modelled area covered approximately 2,670 km<sup>2</sup> of the Condamine River catchment. Figure 9.10 shows the extent of each of the model domains in relation to the properties, as well as the location of verified hydraulic structures. Two bridges located north of the CGPF9 property, the Cecil Plains rail bridge and Toowoomba Cecil Plains Road bridge (shown as verified hydraulic structures in Figure 9.10), were identified as significant structures and used in sensitivity testing. Predicted flood extents were compared to satellite imagery from the December 2010 flood event.

The potential effect of climate change on flood extents and levels was considered in the hydrodynamic modelling undertaken for the SREIS. The Queensland Government publication *Increasing Queensland's Resilience to Inland Flooding in a Changing Climate: Final Report on the Inland Flood Study* (DERM et al., 2010), was considered in defining the parameters for hydrodynamic modelling. Consistent with recommendations of the report, storm intensity and frequency were increased by 10% to account for climate change in the year 2050.





- LEGEND**
- Verified hydraulic structures - bridge
  - Verified hydraulic structures - weir
  - Verified hydraulic structures - road crossing
  - Major road
  - Watercourse
  - CGPF7 property
  - CGPF8 property
  - CGPF9 property
  - TWAF F property
  - Project development area
  - Condamine CGPF7 east rainfall model
  - Condamine CGPF7 west rainfall model
  - Condamine TWAF F rainfall model
  - Condamine River 2D model

Source: *Part 1*  
 Place names, roads and watercourses from DERM.  
 Geomorphology and hydrographic data from Alluvium.  
 Project development area and survey areas from Arrow Energy.  
 Aerial imagery from Fugro (flown June 2012) and Esri On-line (circa 2009).

## 9.5.2 Study Findings

The results of hydrodynamic modelling are presented in the following sections. A comparison is also presented of the modelled extent of flooding and the flood extents observed during the December 2010 flood event, as determined by interpretation of Landsat 5 imagery captured on 30 December 2010. Streamflow gauging station data was used to estimate the magnitude of the flood at the time the satellite imagery was recorded. Overall, the correlation between modelled flood extents and flood extents recorded in satellite imagery was strong enough to validate the model and its suitability for the study. Figures presenting the comparison of predicted flood extents with satellite imagery are included in Appendix 5, Supplementary Surface Water Assessment Part A – Geomorphology and Hydrology.

Modelling to determine the potential impacts of climate change on flood extents and levels predicted increased flows with consequential increased flooding throughout the Condamine River catchment. However, this modelling is not applicable to the catchments defined for the assessment, as those parts of the overall catchment were found to be only slightly sensitive to the increased flows. The predicted flood extents and levels were too small to affect the siting of infrastructure and consequently are not discussed further.

Detailed information on the results of hydrodynamic modelling is provided in Section 5.4 of Appendix 5, Supplementary Surface Water Assessment Part A – Geomorphology and Hydrology.

### **Dogwood Creek Catchment (CGPF2 property)**

Figure 9.11 shows the predicted flood extent from a 1-in-100-year ARI flood event on Bottle Tree and Dogwood creeks. The Bottle Tree Creek floodplain is inundated, with flood waters backing up its tributaries. The incised channel and undulating terrain in the upper parts of its catchment limit the extent of flooding. More extensive flooding is predicted for Dogwood Creek, a larger watercourse with a broader floodplain. The extent of predicted flooding affects only a small part of the CGPF2 property, resulting in some 1,500 ha being above the 1-in-100-year ARI flood level. A comparison with the December 2010 flood event was not possible at the CGPF2 property due to a lack of available satellite imagery for the Dogwood Creek catchment.

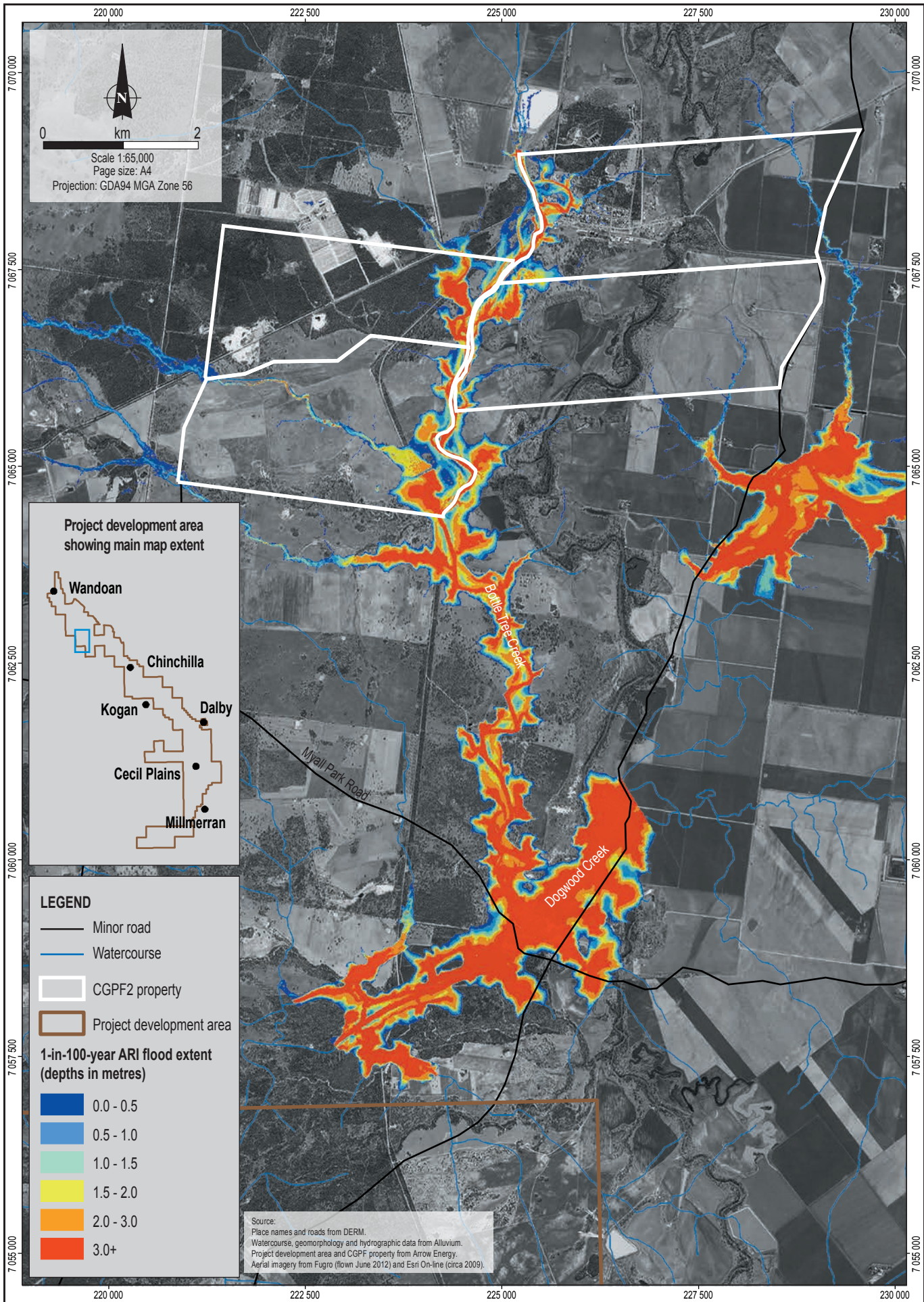
### **Condamine River Catchment (CGPF7 property)**

Modelling indicates that areas of land on the east and west sides of Wilkie Creek, which flows through the CGPF7 property, will experience significant inundation immediately adjacent to the creek during the 1-in-100-year ARI flood event, as shown in Figure 9.12. The flood flow path created by Wilkie Creek bisects the property. West of Wilkie Creek, significant parts of the western parcels lie outside the 1-in-100-year ARI flood extent.

Comparison of the predicted flood extent (1-in-100-year ARI) for the CGPF7 property with Landsat 5 imagery for the December 2010 flood event showed the predicted flood extent was slightly larger than that indicated by the satellite imagery, but the difference was minor (see Appendix 5, Supplementary Surface Water Assessment Part A – Geomorphology and Hydrology). Possible justification for the discrepancy is that the satellite image was not captured during the specific peak of the December 2010 flood event, or that the flood event was slightly less than a 1-in-100-year ARI flood event.

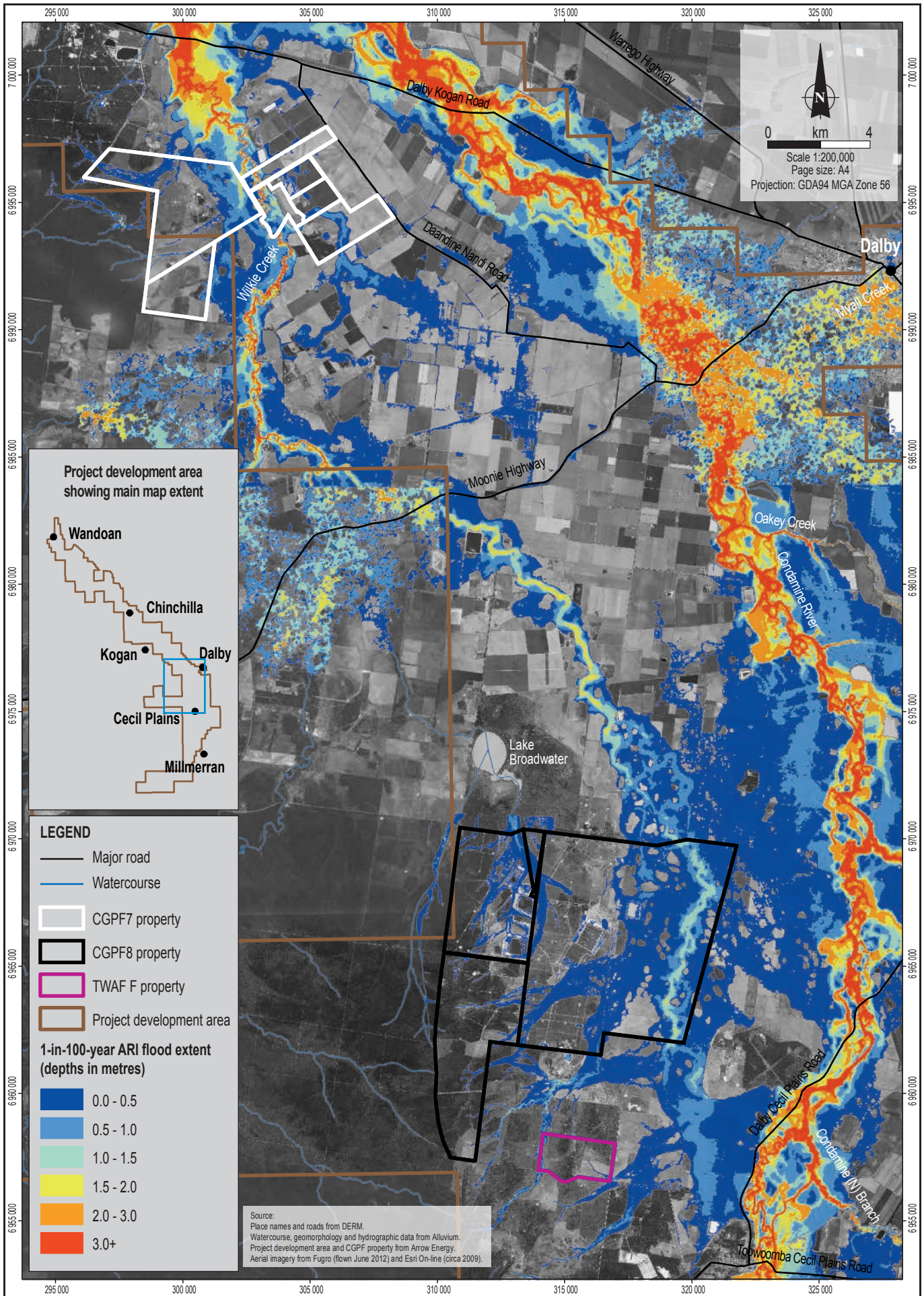
### **Condamine River Catchment (CGPF8 property)**

Modelling indicates that a substantial part of the CGPF8 property will be inundated, particularly in the north and east, which is exposed to overland flow from the Condamine River.



Source:  
 Place names and roads from DERM.  
 Watercourse, geomorphology and hydrographic data from Alluvium.  
 Project development area and CGPF property from Arrow Energy.  
 Aerial imagery from Fugro (flown June 2012) and Esri On-line (circa 2009).





The inundation is predicted to be less than 1 m, as indicated in Figure 9.12. A large area of land in the centre of the property (approximately 1,200 ha) is largely unaffected by flooding from a 1-in-100-year ARI flood event, with a smaller area in the southwest parcel also above that flood level.

Available satellite imagery of the CGPF8 property captured flood extents at 31 December 2010. Based on recorded data from the Cecil Weir gauging station, this timing was three days after the peak (estimated to be at least a 1-in-100-year ARI flood event). Consequently, the satellite imagery in Appendix 5, Supplementary Surface Water Assessment Part A – Geomorphology and Hydrology, indicates a significantly reduced flood extent in the area of the property.

#### **Condamine River Catchment (TWAF F property)**

The TWAF F property is predominantly above the modelled 1-in-100-year ARI flood level and not exposed to riverine flooding (Figure 9.12). The property is generally free of localised rainfall runoff, although some channelised flow occurs along the western boundary as a result of overland flow from nearby watercourses. The comparison of predicted flood extents with satellite imagery captured on 31 December 2010 was subject to the same limitations as for the CGPF8 property.

#### **Condamine River Catchment (CGPF9 property)**

Modelling showed that the eastern sections of the CGPF9 property adjacent to the Condamine River are vulnerable to riverine flooding, with flood depths exceeding 3 m in the flood runner channels and up to 1 to 1.5 m elsewhere. Localised rainfall runoff produces flooding along Crawlers Creek and its tributaries, which traverse the eastern parcel of the property. A 500-ha area in the southern parcel of the property is not vulnerable to flooding during a 1-in-100-year ARI flood event. Infrastructure could be located above the flood level on a 700-ha parcel of land in the north of the property, provided the northwestern flood path is diverted around development. The predicted 1-in-100-year ARI flood extents are shown in Figure 9.13. The comparison of predicted flood extents with satellite imagery captured on 31 December 2010 was subject to the same limitations as for the CGPF8 property.

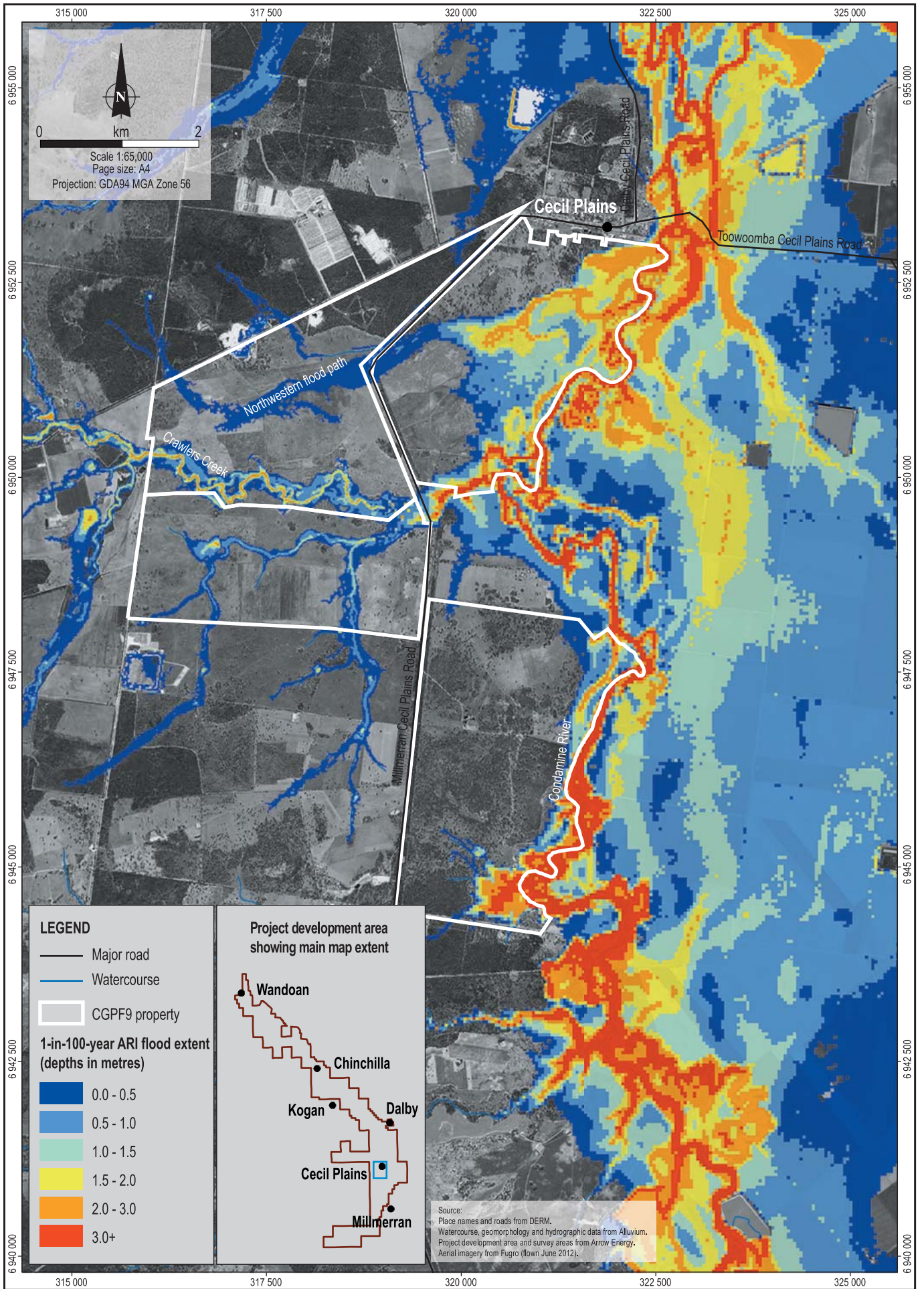
### **9.5.3 Potential Impacts and Management Measures**

Potential impacts from flooding are inundation of infrastructure and diversion of overland flows by inappropriately sited production facilities. Diverted flows can cause erosion, loss of topsoil and prolonged inundation of crops leading to losses. These impacts can be avoided by locating facilities above the 1-in-100-year ARI flood level and designing and constructing gathering lines and well pads so that they do not impede overland flows. Arrow will locate facilities above the 1-in-100-year ARI flood extent where practicable.

Hydrodynamic modelling validated by comparison with satellite imagery of the December 2010 flood event has shown that large areas of the properties on which CGPFs will be located are above the water level for a 1-in-100-year flood event. Modelling of localised rainfall runoff to identify overland flow paths has shown that these important drainage paths can be avoided when siting production facilities.

The mitigation measures (commitments) presented in the EIS have been reviewed for adequacy in managing the impacts of flooding. Commitment C155 has been revised to include the requirement to design infrastructure to reduce impacts on overland flows and flood behaviour both within and outside the property boundaries. Revised commitments are presented in Section 9.10, Commitments Update.

All other commitments in the EIS remain relevant for managing potential impacts from flooding.



**LEGEND**

- Major road
- Watercourse
- CGPF9 property

**1-in-100-year ARI flood extent (depths in metres)**

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0+

**Project development area showing main map extent**

Wandoan

Chinchilla

Kogan

Dalby

Cecil Plains

Millmerran

Source:  
 Place names and roads from DERM.  
 Watercourse, geomorphology and hydrographic data from Alluvium.  
 Project development area and survey areas from Arrow Energy.  
 Aerial imagery from Fugro (flown June 2012).

## 9.6 Discharge Assessment

Emergency discharge from water treatment facilities to maintain the structural and operational integrity of the water storage dams was proposed in the EIS. Review of the coal seam gas water management strategy has resulted in Arrow proposing discharge, under both normal operations and emergency situations, from the water treatment facilities to adjacent watercourses. Discharge of residual volumes of coal seam gas water is proposed under both of these scenarios to allow gas production to continue when the distribution of coal seam gas water to existing and new water users for beneficial use is constrained and/or during unforeseen significant weather events.

The revised project description proposes two water treatment facilities to be located on the CGPF2 and CGPF9 properties adjacent to the CGPFs to be established on those properties. Identification of the location of the water treatment facilities has enabled detailed investigations of the watercourses potentially affected by the discharges. The purpose of this study, which was conducted in conjunction with the aquatic ecology study, was to describe the streamflow (hydraulic parameters) and water quality of the receiving watercourses to determine the volumes and frequencies of coal seam gas water that could be discharged to the watercourses without causing adverse impacts on geomorphology, hydrology and water quality of the watercourses. The preliminary environmental flows assessment characterised existing flow regimes as input to the development of a discharge strategy that also aims to reduce potential impacts to watercourse aquatic ecology and terrestrial ecology (i.e., riparian vegetation).

The method, study findings and potential impacts and management measures for the discharge assessment are described below.

### 9.6.1 Method

Bottle Tree Creek, a tributary of Dogwood Creek, will be the receiving environment for potential discharges from the water treatment facility co-located with CGPF2. The water treatment facility co-located with CGPF9 will potentially discharge to the Condamine River. Each of these watercourses, as well as the tributary of the Condamine River that flows through the CGPF9 property (Crawlers Creek), were assessed, including potentially affected reaches of the watercourses downstream of the properties. The assessment of discharges involved both a desktop study and field surveys of the hydraulic performance and water quality of the potentially affected watercourses.

The desktop study involved the analysis of hydraulic parameters, hydraulic modelling, and the development of stage discharge curves, which allowed recorded depths at notional gauging stations on Bottle Tree Creek and the Condamine River to be converted into flow rate estimates (volumes) able to be carried by those watercourses. A spells analysis of the flow regimes of the two receiving environments and a subsequent workshop informed the preliminary environmental flows assessment.

Field surveys were conducted in conjunction with the geomorphic assessment to identify potential locations for the discharges and to undertake water quality sampling upstream and downstream of the potential discharge locations. Two locations on Bottle Tree Creek and two locations on the Condamine River were identified as being suitable as discharge points.

The methods used to undertake hydraulic modelling, stage discharge curves, water quality sampling and the preliminary environmental flows assessment of Bottle Tree Creek and the Condamine River are set out in the following sections.

## Hydraulic Models

The key hydraulic parameters used in hydraulic modelling (stream power, velocity and shear stress) were determined by reference to the Australian Coal Association Research Program (ACARP, 2002), which has established diversion design criteria for watercourses in the Bowen Basin. The criteria are considered industry best practice and are applied to the assessment of hydraulic conditions for watercourses across Queensland. They were developed to assist in the stable design of watercourse diversions. The criteria are appropriate for the investigation of the capacity of the potentially affected watercourses to accept the planned discharge volumes without affecting the geomorphic stability of the watercourses.

The hydrologic assessment described in Section 9.5.1 was a key input to the hydraulic models which were built and run using HEC-RAS. The model domains were defined as a 21.5-km reach encompassing Bottle Tree Creek and Dogwood Creek and a 5.9-km reach of the Condamine River. The reaches extended upstream and downstream of the potential discharge locations (see Figures 4-7 and 4-8 in Appendix 5, Supplementary Surface Water Assessment Part A – Geomorphology and Hydrology).

Hydraulic modelling for Bottle Tree Creek used the nominal output of the planned water treatment facility adjacent to CGPF2 of 35 ML/d as the discharge volume. The sensitivity of the watercourse to higher flows was also modelled using a discharge volume of 86 ML/d. This value was derived from the stage discharge curves calculated for Bottle Tree Creek. Hydraulic modelling of Bottle Tree Creek considered the following scenarios:

- No seasonal flow (and an additional 35 ML/d).
- No seasonal flow (and an additional 86 ML/d).
- The 1-in-2-year ARI flow event (no discharge).
- The 1-in-2-year ARI flow event (and an additional 35 ML/d).
- The 1-in-2-year ARI flow event (and an additional 86 ML/d).

Hydraulic modelling for the Condamine River used the nominal output of the planned water treatment facility to be located adjacent to CGPF9 (90 ML/d) as the discharge volume. The sensitivity of the watercourse to higher flows was also modelled using a discharge volume of 130 ML/d. This value was derived from the stage discharge curves calculated for the Condamine River. Hydraulic modelling of the Condamine River considered the following scenarios:

- No seasonal flow (and an additional 90 ML/d).
- No seasonal flow (and an additional 130 ML/d).
- The 1-in-2-year ARI flow event (no discharge).
- The 1-in-2-year ARI flow event (and an additional 90 ML/d).
- The 1-in-2-year ARI flow event (and an additional 130 ML/d).

## Stage Discharge Curves

Stage discharge curves convert water depths into flow rate estimates to compare existing flows with potential flows during discharge. Stage discharge curves are graphs showing the relationship between the stage, or depth, of water in the watercourse (in metres) and watercourse flow/discharge (in cubic metres per second). They were produced for the watercourse flow assessment to enable a comparison between existing flow conditions and potential flow conditions following discharge.

Stage discharge curves are produced for gauging stations. The location of an existing gauge at Gil Weir on Dogwood Creek (Gilweir gauging station) was not considered adequate for establishing baseline flows or monitoring streamflows in Bottle Tree Creek from proposed

discharge points. Locating gauging stations downstream of the potential discharge points was recommended.

Two locations suitable for receiving discharges from the water treatment facility to be located adjacent to CGPF2 were identified on Reach 5 of Bottle Tree Creek. The channel bed in this reach is covered with a mobile sand sheet with localised bedrock exposure, which would be relatively robust and would withstand increased streamflows. A gauging station will need to be established downstream from the selected discharge point.

Two geomorphically stable locations suitable for receiving discharges from the water treatment facility to be located adjacent to CGPF9 were identified on the Condamine River. One location is the Cecil Plains weir pool (in reach 3 of the Condamine River); the other location is downstream of the Cecil Plains weir in reach 6 of the river. If the discharge point is the Cecil Plains weir pool, the Cecil Weir gauging station just downstream of the pool would be suitable and adopted. If the discharge point is downstream of the Cecil Plains weir, a gauging station further downstream will need to be established.

Steady-state hydraulic modelling was undertaken using HEC-RAS software, and this was used to define stage discharge curves for the recommended gauging station locations on Bottle Tree Creek, at the Cecil Plains weir pool and downstream of the Cecil Plains weir on the Condamine River. Water levels were predicted by the models at the gauging station locations for a range of flows. Land use and vegetation type defined through interpretation of aerial imagery and field observations were used to determine runoff rates using Manning's n roughness coefficients.

The model for Bottle Tree Creek simulated flows between 0.1 and 1 m<sup>3</sup>/s (equivalent to between approximately 8 and 86 ML/d) to account for a range of flows below, at and above the nominal output of the water treatment facility of 35 ML/d. The model for the Condamine River simulated flows of between 0.1 and 1.5 m<sup>3</sup>/s (equivalent to between approximately 8 and 130 ML/d) to account for a range of flows below, at and above the nominal output of the water treatment facility of 90 ML/d.

The stage discharge curves will need to be updated following each substantial flow event, as such events may result in changes to the channel form and, hence, the volumes that can be passed by the watercourses.

### **Water Quality Sampling and Analysis**

The water quality assessment involved review of the environmental values, confirmation of the interim surface water quality guidelines and objectives, establishment of baseline water quality conditions, and recommendations for surface water quality monitoring and management. The approach to reviewing environmental values, establishing baseline water quality conditions and confirming appropriate surface water guidelines is described below.

### ***Environmental Values***

As mentioned in the EIS, the EPP (Water) does not define environmental values or water quality objectives for the Condamine River sub-basin (in which the CGPF9 property is located) or the Balonne River sub-basin (in which the CGPF2 property is located). EPP (Water) states that, where specific water quality objectives are not available, Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMICANZ, 2000) should be used to define environmental values and water quality objectives for the affected catchments, and all environmental values should be considered. The processes for nominating environmental values and deriving interim water quality objectives presented in the EIS, were reviewed as part of this assessment.

Since publication of the EIS, environmental values for the Fitzroy Basin have been scheduled. Schedule 1 of the EPP (Water) includes the *Dawson River Sub-basin Environmental Values and Water Quality Objectives*. As no discharges are planned for the Fitzroy Basin, the assessment did not include a review of the Dawson River values and objectives. They will be considered in subsequent applications for the construction of watercourse crossings associated with the installation of gathering systems and high-pressure gas pipelines. They will also be considered when deriving site-specific mitigation measures for protecting the nominated environmental values that could be impacted from project infrastructure and activities, such as the construction of a CGPF.

### **Water Quality Guidelines**

Interim water quality guidelines for the sub-basins affected by the Surat Gas Project were developed as part of the water quality assessment undertaken for the EIS. The nominated water quality indicators for the project were determined through a review of existing environmental authorities and water quality results for existing coal seam gas wells and coal seam gas water storage dams in the project development area.

The interim guideline values were derived by compiling surface water quality reference data maintained by the Department of Natural Resources and Mines (DNRM) (previously the Department of Environment and Resource Management – DERM, 2009e, 2011i), in combination with data collected during the EIS water quality surveys, to create a representative water quality database. Consistent with the Queensland Water Quality Guidelines (DERM, 2009b) and ANZECC & ARMCANZ (2000), local reference data was used in preference to DERM (2009b) or ANZECC & ARMCANZ (2000) default guidelines.

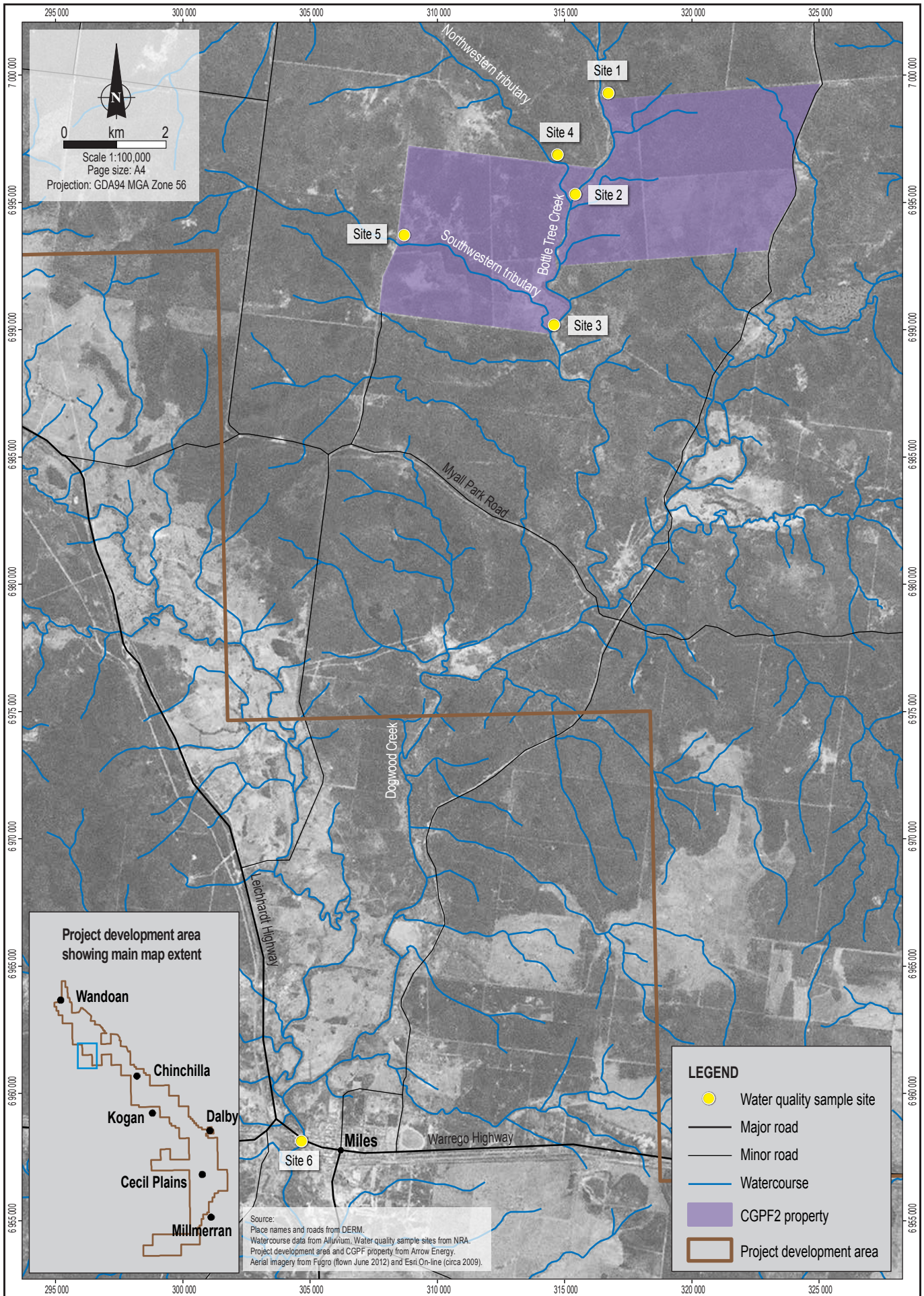
Water quality samples taken from Bottle Tree Creek and Dogwood Creek were compared to the larger reference dataset for the Balonne River sub-basin (CGPF2 property). Water quality samples taken from the Condamine River and Crawlers Creek were compared to the larger reference dataset for the Condamine River sub-basin (CGPF9 property) respectively.

### **Water Quality Sampling**

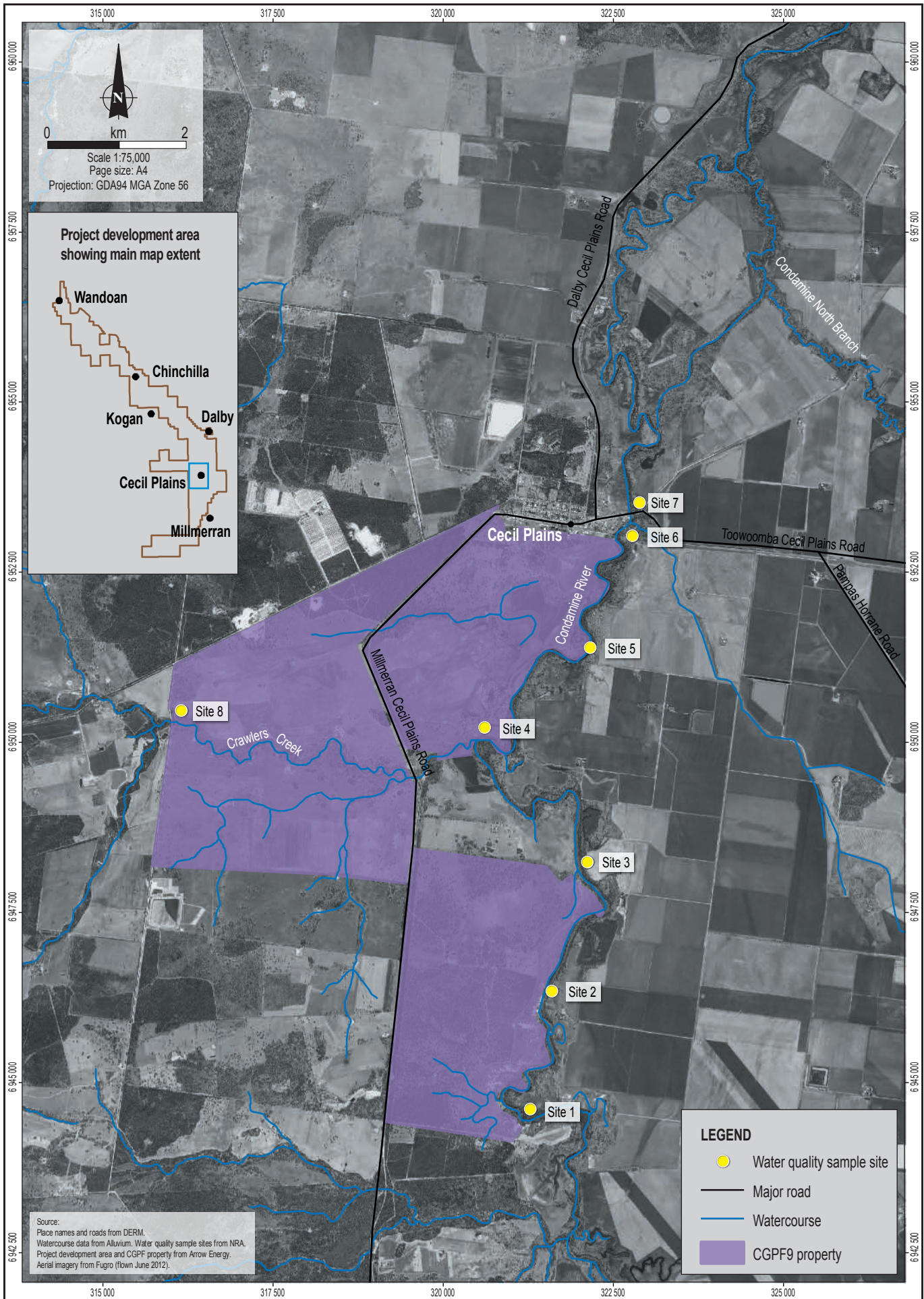
Water quality sampling sites were selected to provide a preliminary description of the baseline water quality of the potentially affected watercourses. Six sites were sampled in Bottle Tree Creek, its tributaries and Dogwood Creek (Figure 9.14) and eight sites in the Condamine River and its tributary, Crawlers Creek (Figure 9.15). As specific locations for the discharge points are currently unknown, sampling points were selected at the upstream and downstream limits of the properties, at sites along the watercourses where the properties were traversed, and downstream of the properties. Field data sheets, which describe each water sampling site, including land use, flow and general watercourse condition, are included in Appendix 6, Supplementary Surface Water Assessment Part B – Water Quality.

Water quality sampling was conducted between 12 and 14 February 2013. The methods used to collect, analyse and validate the water quality data were unchanged from the EIS, and were conducted in accordance with:

- AS 5667.1:1998 Water Quality-Sampling Part 1: Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples (Standards Australia, 1998a).







Scale 1:75,000  
Page size: A4  
Projection: GDA94 MGA Zone 56

**Project development area showing main map extent**

Wandoan  
Chinchilla  
Kogan  
Dalby  
Cecil Plains  
Millmerran

**LEGEND**

- Water quality sample site
- Major road
- Watercourse
- CGPF9 property

Source:  
Place names and roads from DERM.  
Watercourse data from Alluvium. Water quality sample sites from NRA.  
Project development area and CGPF9 property from Arrow Energy.  
Aerial imagery from Fugro (flown June 2012).

- AS 5667.6:1998 Water Quality-Sampling Part 6: Guidance on Sampling of Rivers and Streams (Standards Australia, 1998b).
- Monitoring and Sampling Manual (DERM, 2010f).

Water quality samples were analysed by laboratories accredited by the National Association of Testing Authorities, and were tested for the same analytes assessed in the EIS. Blank samples were used to determine if sample handling, equipment, transportation or laboratory analysis had introduced gross contamination to the water samples. Total and dissolved boron were detected in the blank samples, but the concentrations were not considered significant, as they were low relative to other samples and within laboratory reporting error. The concentrations recorded in the blank samples did not compromise interpretation of the water quality results.

### **Environmental Flows Assessment**

A preliminary environmental flows assessment based on a spells analysis was undertaken to determine the rate, duration and frequency of flows from the planned discharges that would not adversely affect the receiving environments of the CGPF2 and CGPF9 properties in terms of surface water attributes such as geomorphology and hydrology, water quality, aquatic ecology and terrestrial ecology (i.e., riparian vegetation). The assessment comprised a literature review, spells analysis and a workshop.

The literature review was undertaken to identify the approach to determining the flow regime required to achieve ecological function of the watercourses. The literature review helped to define the components of the current flow regime and to identify potential risks due to altering this regime. The method adopted in the SREIS preliminary environmental flows assessment was consistent with the steps outlined in the Healthy Headwater Coal Seam Gas Water Feasibility Study (DSITIA, 2012).

Standard flow components are outlined in the Victorian FLOWS method (DNRE, 2002) and were found appropriate to use for the watercourses of the CGPF2 and CGPF9 receiving environments. The following five flow components were adopted to describe the flow regime of watercourses:

- *Cease to flows*. No flow recorded in the watercourse, meaning the watercourse may reduce to a series of isolated pools. Cease to flow periods are typical of ephemeral and semi-permanent watercourses.
- *Base flows*. Low flow persistently maintained in the watercourse, typical of permanent watercourses.
- *Low flow freshes*. Relatively low flow events with typically short durations that can be observed in permanent, semi-permanent and ephemeral watercourses.
- *High flow freshes*. High flow events resulting from intense localised rainfall that are relatively short in duration. High flow freshes can be observed in permanent, semi-permanent and ephemeral watercourses.
- *Bankfull flows*. Flows that fill the watercourse channel but do not overflow onto the floodplain. Bankfull flows can be observed in permanent, semi-permanent and ephemeral watercourses.
- *Overbank flows*. Flows that overflow out of the channel onto the floodplain and which can be observed in permanent, semi-permanent and ephemeral watercourses.

A spells analysis of historical streamflow records was undertaken to determine the existing flow regime of the watercourses potentially affected by coal seam gas water discharge from the

CGPF2 and CGPF9 properties. The flow regime was considered for four climatic conditions, defined by the total annual flow; drought years, dry years, average years and wet years. The flow regime was further characterised by season, defined by changes in the existing flow regime. Seasons were determined from an analysis of the percentage of daily flows within defined flow ranges in each month, and were classed as either 'low-flow' or 'high-flow' seasons. The low flow season is characterised by extended periods of low flow or periods of no flow, with shorter infrequent periods of high flow (freshes) caused by localised rainfall events. The high flow season is typically characterised by a higher base flow with frequent, sometimes extended periods of higher flow from more widespread rainfall events.

Following completion of the spells analysis, a workshop was attended by professionals in the fields of geomorphology and hydrology (Alluvium), water quality (NRA), aquatic ecology (AMEC Environment and Infrastructure Australia Pty Ltd - AMEC) and terrestrial ecology (3D Environmental) in May 2013. The purpose of the workshop was to review the spells analysis and to discuss the potential impacts from coal seam gas water discharges on the existing flow regimes, which may subsequently impact on surface water attributes, aquatic ecology and terrestrial ecology (i.e., riparian vegetation). Potential risks and opportunities associated with the discharge of coal seam gas water were identified and management options were discussed.

## **9.6.2 Study Findings**

The results of the assessment of potential impacts of the planned discharges to watercourses are presented in the following sections.

### **Hydraulic Performance of Bottle Tree Creek**

Hydraulic modelling of the five discharge scenarios at Bottle Tree Creek showed that the average modelled hydraulic parameters (stream power, velocity and sheer stress) were well below the thresholds recommended by ACARP (2002), indicating that the reach is geomorphically stable under all scenarios. Modelling indicates that hydraulic parameters remain generally unchanged across the assessed reach for a no seasonal flow event (also referred to as a cease to flow event) or a 1-in-2-year ARI flow event, in combination with a discharge of 35 ML/d. Similar results were observed for a cease to flow event or a 1-in-2-year ARI flow event, in combination with a discharge of 86 ML/d, indicating geomorphic changes are unlikely to occur as a result of planned discharges, provided the flow is relatively continuous and varied gradually to reflect aquatic and terrestrial ecology requirements.

Stage discharge curves for the proposed gauging station sites on Bottle Tree Creek show the depth of water would range from 0.51 m for a 0.1 m<sup>3</sup>/s flow (8 ML/d) to 0.88 m for a 1.0 m<sup>3</sup>/s flow (86 ML/d).

### **Hydraulic Performance of the Condamine River**

Hydraulic modelling of the five discharge scenarios for the Condamine River shows that the average modelled hydraulic parameters (stream power, velocity and sheer stress) were well below the thresholds recommended by ACARP (2002), indicating that the reach is geomorphically stable under all scenarios. Modelling indicates that hydraulic parameters remain generally unchanged across the assessed reach for a cease to flow event or a 1-in-2-year ARI flow event, in combination with a discharge of 90 ML/d. Similar results were observed for a cease to flow event or a 1-in-2-year ARI flow event, in combination with a discharge of 130 ML/d, indicating geomorphic changes are unlikely to occur as a result of planned discharges, provided the flow is relatively continuous and varied gradually to reflect aquatic and terrestrial ecology requirements.

Stage discharge curves for the gauging station at the Cecil Plains weir pool show the depth of water would range from 0.16 m for a 0.1 m<sup>3</sup>/s flow (8 ML/d) to 0.36 m deep for a 1.5 m<sup>3</sup>/s flow (130 ML/d). Stage discharge curves for the proposed gauging station downstream of the Cecil Plains weir, show the depth of water would range from 0.33 m for a 0.1 m<sup>3</sup>/s flow (8 ML/d) to 0.83 m deep for a 1.5 m<sup>3</sup>/s flow (130 ML/d).

### **Water Quality**

This section summarises the findings of the water quality component of the assessment of discharge.

#### ***Environmental Values***

Water quality environmental values include present and potential water uses for the catchments in the project development area. They include drinking water, agriculture (irrigation of crops and pasture, stock watering), industrial, aquaculture and recreational use. Water is drawn from the Cecil Plains weir pool on the Condamine River for drinking water supply. Appendix Q of the EIS noted that the project development area contains a rich and varied cultural landscape that is of particular significance to the local Aboriginal communities.

Table 9.3 lists the environmental values for watercourses associated with the CGPF2 and CGPF9 properties, which lie within the Balonne River and the Condamine River sub-basins, respectively.

**Table 9.3 Environmental values nominated for waters in the Condamine River and Balonne River sub-basins**

<b>Environmental Value</b>	<b>Waters in the Condamine River and Balonne River Sub-basins</b>
Aquatic ecosystems	Slightly to moderately disturbed
Primary industries	Irrigation Farm water supply Stock watering Human consumer of aquatic foods Aquaculture
Recreation and aesthetic	Primary recreation Secondary recreation Visual recreation
Drinking water	Raw drinking water
Industrial uses	Minimal and manufacture
Cultural and spiritual values	Cultural and spiritual

The nominated environmental values were used to review the interim water quality guideline values, water quality objectives and control strategies that were presented in the EIS and will be used as the basis for developing the water quality monitoring program for the project.

#### ***Water Quality of Affected Watercourses***

The water quality objectives presented in the EIS have not changed. The EIS found that water quality in the watercourses of the Balonne River and Condamine River sub-basins varies in response to the seasonality of flow and generally exceeds ANZECC & ARMCANZ (2000) guideline values for the protection of slightly to moderately disturbed ecosystems (Appendix I of the EIS). Sampling and analysis of water quality samples taken during the SREIS field survey found that watercourses sampled (Bottle Tree and Dogwood creeks and the Condamine River) are typical of surface waters found in the Balonne River and Condamine River sub-basins. The

results also validated the EIS finding that water quality of watercourses in these sub-basins was of poorer quality than that nominated in ANZECC & ARMCANZ (2000) guidelines. Results showed that surface waters in the receiving environments of the CGPF2 and CGPF9 properties are slightly to moderately disturbed due to the influence of a range of human activities that have occurred and are occurring in the area.

Water quality sampling results obtained for the SREIS for watercourses in the receiving environment of the CGPF2 and CGPF9 properties are presented in Table A1T-2 and Table A1T-3 in Appendix A of Appendix 6, Supplementary Surface Water Assessment Part B – Water Quality. The results compare water quality sample data from Bottle Tree and Dogwood creeks to the interim water quality guidelines for the Balonne River sub-basin developed from DNRM reference data (DERM 2009e, 2011i) in combination with data collected during the EIS water quality surveys. Water quality sampling results from the Condamine River and Crawlers Creek were compared to the interim water quality guidelines for the Condamine River sub-basin. Results show that at the time of sampling, water quality at the 14 sample sites was generally comparable to the interim guideline values presented in the EIS. A summary of the water quality sampling results for each receiving environment is presented below.

#### ***Water Quality of Bottle Tree and Dogwood Creeks***

Analysis of water quality samples taken from Bottle Tree and Dogwood creeks produced the following results:

- Electrical conductivity at all sites except site 1 (located on Bottle Tree Creek) exceeded the interim guideline value for the Balonne River sub-basin (130  $\mu\text{S}/\text{cm}$ ), ranging from 170 to 200  $\mu\text{S}/\text{cm}$ .
- pH at all sites ranged from 5.5 to 6.0, which is below the interim guideline value for the Balonne River sub-basin of pH 6.4 to pH 7.8.
- Total suspended solids at site 6 (located on Dogwood Creek) was 120 mg/L, which is above the interim guideline value for the Balonne River sub-basin of 83 mg/L.
- Chloride concentrations at all sites ranged from 30 to 52 mg/L and were above the interim guideline value for the Balonne River sub-basin of 22 mg/L.
- Total nitrogen concentrations at all sites except site 3 ranged from 1.7 to 1.9 mg/L and were above the interim guideline value for the Balonne River sub-basin of 1.57 mg/L. They were also above the ANZECC & ARMCANZ (2000) guideline value nominated to protect surface waters from eutrophication.
- Hydrocarbons were detected at site 5 (located on the southwestern tributary of Bottle Tree Creek).

#### ***Water Quality of the Condamine River and Crawlers Creek***

Analysis of water quality samples taken from the Condamine River and Crawlers Creek produced the following results:

- pH at site 6 (pH 7.19) on the Condamine River and site 8 on Crawlers Creek (pH 6.62) was below the interim guideline value for the Condamine River sub-basin (pH 7.3 to pH 8.3).
- Total nitrogen (3.0 mg/L) and total phosphorus (1.2 mg/L) concentrations at site 8 on Crawlers Creek were above the interim guideline value for the Condamine River sub-basin, which is 1.89 mg/L total nitrogen and 0.25 mg/L total phosphorus.

- Concentrations of dissolved vanadium at all sites on the Condamine River ranged from 13 to 15 µg/L and were above the interim guideline values for this sub-basin, which is 10 µg/L.

## **Environmental Flows**

The results of the literature review, spells analysis and workshop are described below.

### ***Literature Review***

Relevant literature and studies were reviewed to identify an appropriate preliminary threshold for changes in the flow regime that would maintain ecological functioning in watercourses. In particular, the findings of a study on the watercourses in the Murray-Darling drainage division (Alluvium, 2010) found that a variety of watercourse flow conditions (referred to as flow components) were essential to ecological functioning of the watercourses within the Murray-Darling drainage division and to supporting aquatic and terrestrial ecology values. A review was also undertaken of a study on the impact of altered flow regimes on ecological functioning in the Mount Lofty Ranges (VanLaarhoven and van der Wielen, 2009).

Based on the review, a 20% deviation from the existing flow regime of watercourses, defined by the frequency and duration of the flow components, was identified as an appropriate preliminary threshold for maintenance of ecological functioning in watercourses.

### ***Spells Analysis***

The spells analysis used streamflow data from Dogwood Creek, as suitable flow data is not available for Bottle Tree Creek (a tributary of Dogwood Creek). The analysis used streamflow records from the Gilweir gauging station (at Gil Weir shown in Figure 9.2), dating back to 1949. This station is located approximately 14 km downstream of the confluence of Dogwood Creek and Bottle Tree Creek and was considered to adequately represent flow conditions in Bottle Tree Creek.

The low flow season at this site was found to be March to November and the high flow season was found to be December to February. The results of the spells analysis for all climatic condition years considered together, across all years for which data was available, showed that the flow regime in Dogwood Creek is comprised of the following flow components:

- *Cease to flows*. Cease to flow periods last for an average of 73 days and occur 2 to 3 times during the low flow season. During the high flow season, cease to flows last for an average of 27 days and occur 1 to 2 times.
- *Low freshes (flows exceeded 20% of the time)*. During the low flow season, flows of 20 ML/d last for an average of 15 days and occur 3 to 4 times. During the high flow season, flows of 83 ML/d last for an average of 10 days and occur 1 to 2 times.
- *High freshes (flows exceeded 5% of the time)*. During the low flow season, flows of 256 ML/d last for an average of six days and occur two to three times. During the high flow season, flows of 1,292 ML/d last for an average of four days and occur one to two times.
- *Bankfull flows (1-in-2-year ARI)*. During both the low flow and high flow seasons, bankfull flows of 12,275 ML/d last for an average of three days and occur once every two years.

The spells analysis of the Condamine River used streamflow records from Cecil Weir gauging station (at Cecil Plains weir shown in Figure 9.3) dating back to 1972. The low flow season was found to be March to October and the high flow season was November to February. The results of the spells analysis for all climatic condition years considered together, across all years for which

data was available, showed that the flow regime in the Condamine River is comprised of the following flow components:

- *Cease to flows*. Cease to flow periods last for an average of 30 days and occur 3 times during the low flow season. During the high flow season, cease to flows last for an average of 16 days and occur 2 to 3 times.
- *Low freshes (flows exceeded 20% of the time)*. During the low flow season, flows of 244 ML/d last for an average of 15 days and occur 3 to 4 times. During the high flow season, flows of 425 ML/d last for an average of eight days and occur three to four times.
- *High freshes (flows exceeded 5% of the time)*. During the low flow season, flows of 1,632 ML/d last for an average of six days and occur two times. During the high flow season, flows of 4,859 ML/d last for an average of five days and occur one to two times.
- *Bankfull flows (1-in-2-year ARI)*. Bankfull flows of 23,466 ML/d occur approximately once every two years and last for an average of five days in the low flow season and four days in the high flow season.

There was no base flow (flows exceeded 80% of the time and typical of permanent watercourses) for both the high and low flow seasons for Bottle Tree Creek and the Condamine River.

Detailed results of the spells analysis for years grouped by climatic condition (drought years, dry years, average years and wet years) are presented for Bottle Tree Creek (Dogwood Creek) and the Condamine River in Table 4 and Table 6 of Appendix 7, Supplementary Surface Water Assessment Part C – Preliminary Environmental Flows Assessment, respectively.

### **Workshop**

Following a review of the spells analysis and potential risks and opportunities of discharges, the workshop attendees came to the following conclusions:

- A 20% deviation from the existing flow regimes determined from the spells analysis, represents an acceptable level of deviation to reduce potential impacts to the various watercourse aspects and maintain ecological function.
- The environmental flows assessment is preliminary. Verification is required of the suitability of the 20% deviation guideline through a more detailed environmental flows assessment and implementation of an aquatic ecology monitoring program. The assessment should develop and extract current and modelled flow data from an Integrated Quantity Quality model and review the spells analysis using this model. Further hydraulic modelling should also be used to more accurately determine the magnitude of each flow component.
- Water treatment facilities will require adequate storage capacity to control the frequency and duration of individual flow components so that they do not deviate by over 20% and so that flow rates can be varied to a range exceeding the proposed daily production rating for each facility (i.e., 35 ML/d for the northern water treatment facility and 90 ML/d for the southern water treatment facility).

### **9.6.3 Potential Impacts and Management Measures**

Potential impacts from the discharge of treated and untreated coal seam gas water to watercourses include channel erosion and avulsion, resulting in increased turbidity and sedimentation; loss of riparian and aquatic flora and agricultural land; and adverse effects on

aquatic ecology, including competition between indigenous and exotic species, weed invasion and reduced water quality.

General and site-specific potential impacts of discharges to watercourses traversing the CGPF2 and CGPF9 properties, are described below in terms of watercourse geomorphology, hydrology and water quality. Recommended management measures and design considerations to mitigate adverse impacts are also presented. Impacts on aquatic ecology values are assessed in detail in Chapter 10, Aquatic Ecology.

The preliminary environmental flows assessment identified the following general potential impacts to geomorphology and hydrology that could potentially result from the discharge of coal seam gas water to the receiving environments:

- Mobilisation of bed and bank material thereby inducing erosion.
- Sudden drawdown of water levels, potentially inducing slumping in saturated banks.
- Increased growth of riparian and/or aquatic vegetation leading to geomorphic changes including trapping of sediment, reduced channel capacity and channel migration.
- Potential reduction of crossing opportunities for landholders, particularly at watercourse bed level crossings.

A potential opportunity was also identified relating to increasing flows to more closely replicate pre-European flow regimes, prior to the alteration of the watercourses from various human uses.

### ***CGPF2 property***

Site-specific potential impacts of discharges to the watercourses in the receiving environment of the CGPF2 property include:

- Changed hydrology (flow regime) in Bottle Tree and Dogwood creeks.
- Reduced access at vehicular and stock crossings on Bottle Tree and Dogwood creeks due to extended flows.
- Potential exacerbated erosion of identified areas of existing watercourse bank and bed erosion in Bottle Tree Creek and downstream in Dogwood Creek if recommended discharge rates are exceeded. This includes erosion of the bund covering the original outlet point of the natural wetland in reach 5 of Bottle Tree Creek. Slumping at the toe of creek banks in sandy soils could also occur if discharges are suddenly ceased.

The following recommendations will be considered in selecting and designing the discharge point on the CGPF2 property and in developing the discharge strategy:

- Locate the discharge point at one of the two sites identified in reach 5 of Bottle Tree Creek. The sites exhibit sound channel stability in an area of exposed bedrock.
- Design discharges to not exceed 1 m<sup>3</sup>/s (equal to approximately 86 ML/d) during 'no seasonal flow' and higher flow conditions to reduce the risk of erosion and geomorphic change. No geomorphic change is expected at this level of discharge assuming relatively continuous flows.
- Vary discharge rates gradually (including when reducing flows) to ensure that rapid drawdown of flow does not cause slumping, which would exacerbate bank erosion in susceptible reaches.



- Establish a gauging station on Bottle Tree Creek downstream of the selected discharge point to monitor seasonal variability in streamflow in order to develop an appropriate discharge regime.

### ***CGPF9 property***

Site-specific potential impacts of discharge on the watercourses in the receiving environment of the CGPF9 property include:

- Changed hydrology (flow regime) in the Condamine River.
- Exacerbated erosion of identified areas of existing watercourse bank and bed erosion in and downstream of the CGPF9 property, in particular, in reaches 1 and 2 of the Condamine River and reach 4 in Crawlers Creek. These reaches are currently unstable. Extensive tunnel and gully erosion is occurring on the left bank of reach 1. Bank erosion is likely to increase if discharge occurs in any of these reaches.
- Exacerbated bank erosion of the flood channel linking the Condamine River and the Condamine River (North Branch) if flows in this channel are increased due to discharge.
- Exacerbated bank erosion downstream of the palustrine wetland located downstream of the CGPF9 property if there are prolonged increased flows resulting from discharge.

The following recommendations will be considered in selecting and designing the discharge point on the CGPF9 property and in developing the discharge strategy:

- Locate the discharge point immediately upstream of the Cecil Plains weir pool (in reach 3) or downstream of the weir at a point of sound channel stability.
- If practicable, do not discharge coal seam gas water to Crawlers Creek due to its inherent instability and sensitivity to erosion. Significant mitigation measures would be required to reduce the likely exacerbation of existing gully erosion evident in the creek if discharges to this watercourse were proposed.
- Design discharges to not exceed 1.5 m<sup>3</sup>/s (equal to approximately 130 ML/d) during 'no seasonal flow' and higher flow conditions to reduce the risk of erosion and geomorphic change. No geomorphic change is expected at this level of discharge assuming relatively continuous flow.
- If the Cecil Plains weir pool is chosen as the discharge point, use the Cecil Weir gauging station to assess seasonal variability in streamflow to develop a suitable discharge regime.

### ***Mitigation and management measures***

Discharges to watercourses on both properties will need to reflect the rate, duration and frequency of flows appropriate to the aquatic ecology of the affected watercourses. Consequently, a discharge strategy that is not predicted to result in adverse impacts to geomorphology (i.e., does not exacerbate existing erosion and sedimentation) is also likely to reduce the potential impacts to aquatic ecology and riparian vegetation. The preliminary environmental flows assessment identified that a 20% deviation from the current flow conditions (as specified in the spells analysis) would be an acceptable level of deviation that would limit the extent of adverse impacts on the ecosystem function in the receiving environments for the discharges from the CGPF2 and CGPF9 properties.

Arrow will develop a strategy for the discharge of coal seam gas water to watercourses in accordance with relevant legislation. The strategy will incorporate a water quality monitoring

program with locations upstream and downstream of the discharge point to inform site-specific water quality objectives. A detailed environmental flows assessment informed by water quality monitoring data and an aquatic ecology monitoring program will inform the discharge strategy. Periodic inspections of the physical form and hydrology of the watercourse are to be incorporated in the strategy to monitor geomorphic performance (Commitment C498).

Two new measures have been developed to reduce potential impacts of discharges to existing infrastructure and watercourse geomorphology. Arrow will consult with landowners downstream of discharge points on access requirements for vehicular and stock crossings of the affected watercourse reaches, and will manage discharges to reduce disruption to existing access arrangements (Commitment C560). Arrow will also identify reaches vulnerable to bank erosion from the discharge of coal seam gas water and develop site-specific erosion control and management plans for vulnerable reaches (Commitment C561).

All other commitments in the EIS remain relevant for managing the discharge of coal seam gas water to watercourses.

### **Water Quality**

Management measures required to maintain water quality at the CGPF2 and CGPF9 properties have not changed from those presented in the EIS. Coal seam gas water will be treated and balanced (potentially using untreated coal seam gas water if of suitable quality) to meet the water quality guideline values for the protection of beneficial uses, including crop irrigation, stock watering, drinking water and aquatic ecosystem function.

A water quality monitoring program will be designed and implemented for the watercourses in the project development area likely to be affected by coal seam gas water discharges. The results of the program will inform the development of site-specific water quality guidelines for the proposed discharges, which will, in turn, form the basis for the development of a discharge strategy. The program will be designed in accordance with the Queensland Water Quality Guidelines (DERM (2009b)). The preliminary environmental flows assessment recognised the variability in the flow regime of Bottle Tree Creek and the Condamine River. The preliminary assessment also highlighted the need to derive water quality guidelines for various flow conditions, to ensure that the water quality of coal seam gas water released to watercourses accounts for variation in water quality due to flow condition.

#### **9.6.4 Cumulative Assessment of Discharge**

Chapter 28 of the EIS presented an assessment of cumulative impacts of the Surat Gas Project that took into account the potential impacts of other projects in the project development area that are discharging to or propose to discharge to watercourses within the project development area.

Queensland Gas Company has entered into an agreement with Sunwater to discharge treated coal seam gas water to the Chinchilla Weir pool. Sunwater manages the discharged water as part of its irrigation scheme. Specific details of the continuous discharge rates and volumes are not publicly available, and therefore cumulative impacts have not been assessed in detail. However, the reaches of the Condamine River affected by the Queensland Gas Company discharge to Chinchilla Weir pool are likely to be beyond the extent of predicted geomorphic change and potential mixing zones for coal seam gas water discharged at the CGPF2 and CGPF9 properties. The Queensland Gas Company discharge is located over 180 km downstream of Cecil Plains weir, the proposed discharge location (upstream or downstream) from the water treatment facility to be located on the CGPF9 property. Dogwood Creek, which will potentially receive discharges

(via Bottle Tree Creek) from the water treatment facility to be located on the CGPF2 property, discharges to the Condamine River over 170 km downstream of Chinchilla Weir.

Arrow has an Environmental Authority (EA) PEN100449509 to discharge treated coal seam gas water from a water treatment facility to an unnamed tributary of Wilkie Creek during natural flow events only. Wilkie Creek feeds into the Condamine River 16.6 km north of the authorised discharge point. The confluence of the two watercourses is 108.2 km downstream of the Cecil Plains weir. The confluence of Dogwood Creek and the Condamine River is 286.3 km downstream of the authorised discharge point. The reaches of the Condamine River affected by discharges to the unnamed tributary of Wilkie Creek are also likely to be beyond the extent of predicted geomorphic change and potential mixing zones for coal seam gas water discharged at the CGPF2 and CGPF9 properties. Although not assessed in detail, cumulative impacts are expected to be negligible given implementation of planned mitigation measures.

The development of the discharge strategy will consider potential impacts from these and other relevant discharges, to watercourses potentially affected by the proposed discharges at the CGPF2 and CGPF9 properties.

## 9.7 Subsidence Literature Review Update

A literature review of the potential for regional subsidence as a result of coal seam gas extraction was undertaken as part of the groundwater impact assessment in the EIS (Appendix G of the EIS). The literature review found that the risk of subsidence is not high but nevertheless cannot be entirely ruled out. An updated review of the mechanisms for subsidence and the likelihood of occurrence in the Surat Basin is included in Chapter 8, Groundwater. An additional literature review was undertaken for the SREIS to assess the potential impacts of subsidence on surface water. The following reports, two of which have become available since publication of the EIS, were reviewed:

- An Analysis of Coal Seam Gas Production and Natural Resource Management in Australia: Issues and Ways Forward (Williams, 2012). This report, prepared by John Williams Scientific Services Pty Ltd for the Australian Council of Environmental Deans and Directors in October 2012, provides an analysis of coal seam gas production and natural resource management in Australia.
- Summary of Advice in Relation to the Potential Impacts of Coal Seam Gas Extraction in the Surat and Bowen Basins, Queensland (Geoscience Australia and Habermehl, 2010). This report, prepared by Geoscience Australia for the Australian Government Department of Sustainability, Environment, Water, Population and Communities, recognises the issues raised by the multi-layered geologic formations and attempts to provide recommendations for assessing cumulative impacts.
- Baseline Report on InSAR Monitoring on the Surat-Bowen Basin (Altamira Information, 2012a). Compiled by Altamira Information, this report presents the results on the analysis of ground settlement (subsidence) using interferometric synthetic aperture radar (InSAR) satellite imagery technology of the Surat and Bowen basins. The high-resolution, wide-swath SAR data facilitates accurate measurement of local subsidence. It was used in the establishment of a baseline for monitoring subsidence in the Surat Basin by Arrow, Australia Pacific LNG Pty Ltd, Queensland Gas Company Pty Ltd and Santos Limited.

Williams (2012) noted that it is generally accepted that some degree of subsidence will occur in the landscape as a result of depressurisation of the groundwater formations for coal seam gas

extraction. Geoscience Australia and Habermehl (2010) noted that while groundwater extraction may cause some compaction of the aquifers, the structural integrity of the formations (in relation to groundwater transmission) was unlikely to be significantly affected. Geoscience Australia and Habermehl (2010) further noted, like Williams (2012), that the overriding issue is the potential cumulative effect of multiple developments on a regional scale.

Alluvium's review of the baseline study undertaken by Altamira Information (2012a), which covered the Surat Basin, found that the observed settlement between December 2006 and February 2011 was substantially smaller than the tolerances allowed for when configuring the hydrodynamic models, which include the accuracy of terrain data, configuration of hydrologic and hydrodynamic models and the reliability of model outputs. Alluvium concluded that small regional-scale settlement of the Condamine River floodplain would not adversely affect the geomorphology of watercourses, with the risk of geomorphic change assessed as low. Differential settlement at a local scale might induce geomorphic changes in low-resilience watercourses or alteration of overland flow and flood behaviour, although is not expected. If differential settlement were to occur, mitigation measures to protect vulnerable reaches of affected watercourses from erosion and channel migration would be effective in managing the impacts.

## 9.8 Conclusion

The potential impacts and mitigation measures presented in the EIS have been validated by the supplementary surface water assessment. Some measures have been revised, and new measures developed, to take account of the changes in the project description.

The assessment has provided detailed information about the potential impacts on watercourses traversing or adjacent to the properties purchased or leased by Arrow for the proposed siting of TWAF F, CGPF2, CGPF7, CGPF8, CGPF9 and water treatment facilities (to be located adjacent to CGPF2 and CGPF9).

The geomorphic assessment has identified sensitive areas and areas susceptible to geomorphic change in the affected watercourses. This knowledge was used to identify potential sites for the planned discharges at the CGPF2 and CGPF9 properties. The nominated locations were in stable sections of the affected watercourses at reaches with visible bedrock or immediately upstream of a weir pool.

Hydrodynamic modelling has shown good correlation between the predicted flood extents and flood extents interpreted by satellite imagery captured during the December 2010 flood event. The modelling has shown that, while all properties are variously affected by flooding from a 1-in-100-year ARI flood event, substantial areas remain flood free and capable of accommodating the footprint required for development of TWAF F and the CGPFs at the respective sites, as well as water treatment facilities at the nominated sites. Overland flow paths identified in the modelling are unlikely to be affected due to the availability of flood-free land.

The assessment of operational discharges from the proposed water treatment facilities at CGPF2 and CGPF9 has shown that geomorphic change is unlikely for flows up to 86 ML/d in Bottle Tree Creek and 130 ML/d in the Condamine River, provided the discharge flows are gradually increased and decreased to avoid excess pore pressure in watercourse banks, causing slumping and erosion of unstable soils, e.g., sandy and loamy soils. The selection of discharge points and the design of infrastructure will consider a range of measures to effectively manage potential impacts of the discharges.

Water quality sampling has confirmed the findings of the EIS and the validity of the relevant mitigation measures. The interim guideline values remain relevant until the proposed water quality monitoring program provides a more comprehensive site-specific dataset with which to review and update the guidelines.

The preliminary environmental flows assessment has provided a baseline description of the existing flow regimes in Bottle Tree Creek and the Condamine River to determine the parameters for managing the ecological aspects of discharges. A spells analysis, carried out as part of the assessment, has confirmed the ephemeral nature of the affected watercourses and formed the basis for the requirements for maintenance of ecological function and watercourse health. Specialists identified that a deviation of 20% from the existing flow regimes of Dogwood Creek (downstream from Bottle Tree Creek) and the Condamine River, defined by the frequency and duration of flow components, is acceptable to reduce adverse impacts to geomorphology, hydrology, water quality, aquatic ecology and terrestrial ecology (i.e., riparian vegetation). Arrow will develop a discharge strategy that will aim to verify this preliminary guideline through a detailed environmental flows assessment and implementation of an aquatic ecology monitoring program.

A review of recently published information on subsidence from coal seam gas extraction has confirmed the assessment presented in the EIS that anticipated settlement is expected to be too small to pose significant risks to the geomorphology and hydrology of surface water values in the project development area.

## 9.9 Issues Raised in Submissions

Submissions on the EIS raised a range of issues relating to surface water. The issues fall into broad topics, which are listed below:

- Consideration of legislation, policies, guidelines and management plans.
- Contamination affecting water quality.
- Cumulative impacts.
- Description of surface water cultural and environmental values.
- Disposal of coal seam gas water to watercourses.
- Erosion and sediment control (particularly in proximity to watercourses).
- Hydrostatic testing procedures.
- Impacts to wetlands.
- Inspection and monitoring.
- Overland flow and flooding regimes (impacts to and from the project).
- Site-specific assessment of surface water impacts.
- Suitability of mitigation measures.
- Supply of potable water.
- Water quality sampling method.

The topics list is provided to give an idea of the types of issues that have been raised in relation to surface water and for which responses have been provided under the heading 'Surface Water', in Part B, Chapter 19, Submission Responses and in Chapter 20, Response to DERM Submission.

## 9.10 Commitments Update

Several new and updated management measures (commitments) relevant to surface water have been identified in the course of the study. Two new and three revised commitments are presented in Table 9.4. Commitments C069 and C175, presented in the EIS are now redundant as they have been captured in the revised Commitment C498.

The full list of commitments, including those that remain unchanged from the EIS and details on those that have changed, are included in Attachment 4, Commitments Update.

**Table 9.4 Commitments update: surface water**

<b>No.</b>	<b>Commitment</b>	<b>Revised / New</b>
C034	Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls, established on the basis of the sensitivity of the surrounding environment.	Expanded to capture expert advice provided in supplementary assessment.
C155	Site facilities above the 1-in-100-year average flood recurrence interval, where practicable, and design infrastructure taking into consideration overland flow and flooding regimes to reduce impacts on immediate and surrounding areas.	Expanded to clarify the intent of the commitment.
C498	Develop a strategy for the discharge of coal seam gas water to watercourses in accordance with relevant legislation. The strategy will incorporate a water quality monitoring program with locations upstream and downstream of the discharge point to inform site-specific water quality objectives. A detailed environmental flows assessment informed by water quality monitoring data and an aquatic ecology monitoring program will inform the discharge strategy. Periodic inspections of the physical form and hydrology of the watercourse are to be incorporated in the strategy to monitor geomorphic performance.	Revised to account for changes to the project description and to encompass commitments C069, C175, C526 and C527 in one place.
C560	Consult with landowners downstream of discharge points on access requirements for vehicular and stock crossings of the affected watercourse reaches, and manage discharges to reduce disruption to existing access arrangements.	New commitment.
C561	Identify reaches vulnerable to bank erosion from the discharge of coal seam gas water and develop site-specific erosion control and management plans for vulnerable reaches.	New commitment.