The Geology of the Shrub Swamps within Angus Place, Springvale and the Springvale Mine Extension Project Areas

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TABLE OF CONTENTS

LIST OF FIGURES

1. Introduction

The current report discusses the influence of the upper geological strata in the Angus Place, Springvale and Springvale South mine extension project areas on the occurrence and morphology of the Newnes Plateau Shrub Swamps (NPSS).

The Newnes State Forest comprises the majority of the study area and the Angus Place/Springvale/Springvale South leases contain two NSW State listed Endangered Ecological Communities (EECs), namely the Newnes Plateau Shrub Swamps (NPSS) and the Newnes Plateau Rush Sedge Snow Gum Hollow Wooded Heath Grassy Woodland (NPRSSG). The Newnes Plateau Hanging Swamps (NPHS) are also present in the study area and, together with the former communities, form part of the Federally listed Temperate Highland Peat Swamp on Sandstone (THPSS). The present study focuses on the Newnes Plateau Shrub Swamps (NPSS) in the study area.

2. Regional Geology

Angus Place and Springvale Collieries are located near the outermost portion of the Western Coalfield, being situated on the central western margin of the Sydney Basin. Strata of Permian and Triassic age overlie folded Silurian and Devonian rocks which sit on a Palaeozoic basement. Quaternary alluvium is present in river valleys.

During the Permian, two major periods of peat deposition occurred across the Sydney Basin, the second phase resulting in the formation of the Illawarra Coal Measures in the study area, of which the Lithgow Coal Formation is mined at Angus Place and Springvale collieries. As the Sydney Basin thins towards its western margin, both the Illawarra Coal Measures and the overlying Triassic Group are attenuated in thickness when compared to lateral equivalents in the Southern Coalfield.

The Western Coalfield contains minimal structural disturbance, with a regional dip in the Lithgow area of less than one degree with a dip direction of approximately 65 degrees. Monoclinal structures trend roughly north-south in the Western Coalfield accompanied by associated sub-parallel faulting. Basaltic flows and igneous intrusions occur in the general region but are absent from the study area.

3. Local Geology

The Angus Place/Springvale lease areas, located on the extreme western margin of the Sydney Basin, display a diminution of the full Permo-Triassic sequence present in other areas of the basin. Consequently, the Illawarra Coal Measures are comparatively thin in the study area and the overlying Triassic strata incorporate only the Narrabeen Group, with the Hawkesbury Sandstone and Wianamatta Group absent. Figure 1 shows the stratigraphic sequence present in the study area.

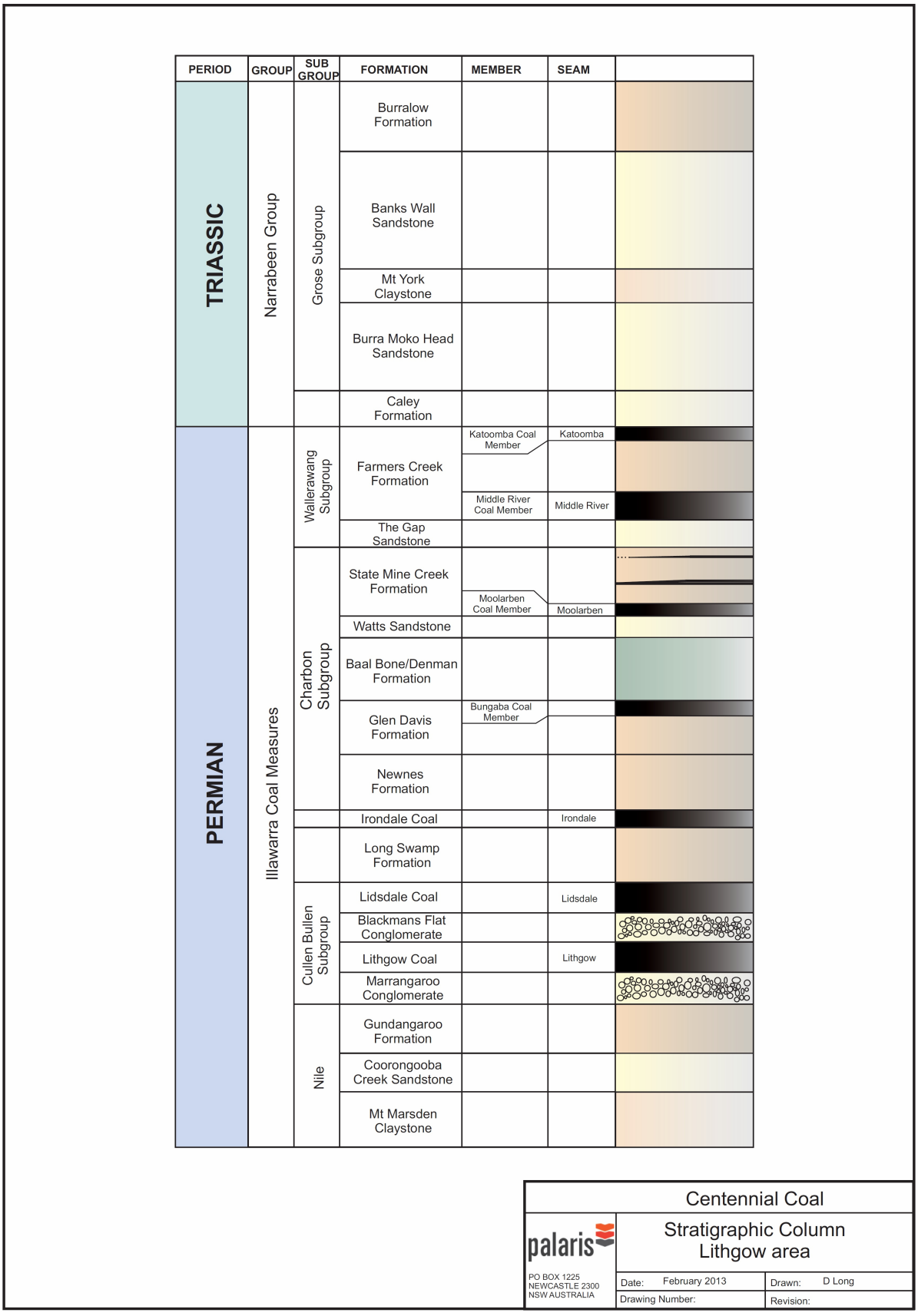

Figure 1 Stratigraphic Column for Angus Place/Springvale

The Permian strata in the Angus Place and Springvale lease areas include several coal-bearing units interspersed with sandstones, shales and minor tuffaceous claystones.

The Triassic sequence consists predominately of fine-to-coarse-grained sandstones, shales, siltstones and claystones of the Narrabeen Group. This fluvial sequence is punctuated by the Mt York Claystone Formation, a persistent and characteristic non-tuffaceous claystone unit described below.

4. Structure and Topographic Expression

The topography of the study area (Figure 2) is characterized by significant NNW- and NNE- trending lineaments in association with minor east-west features. It has been noted by previous workers, for example, SRK (2012), that surface lineaments, such as ridges, rivers and creeks, reflect underlying geological structures.

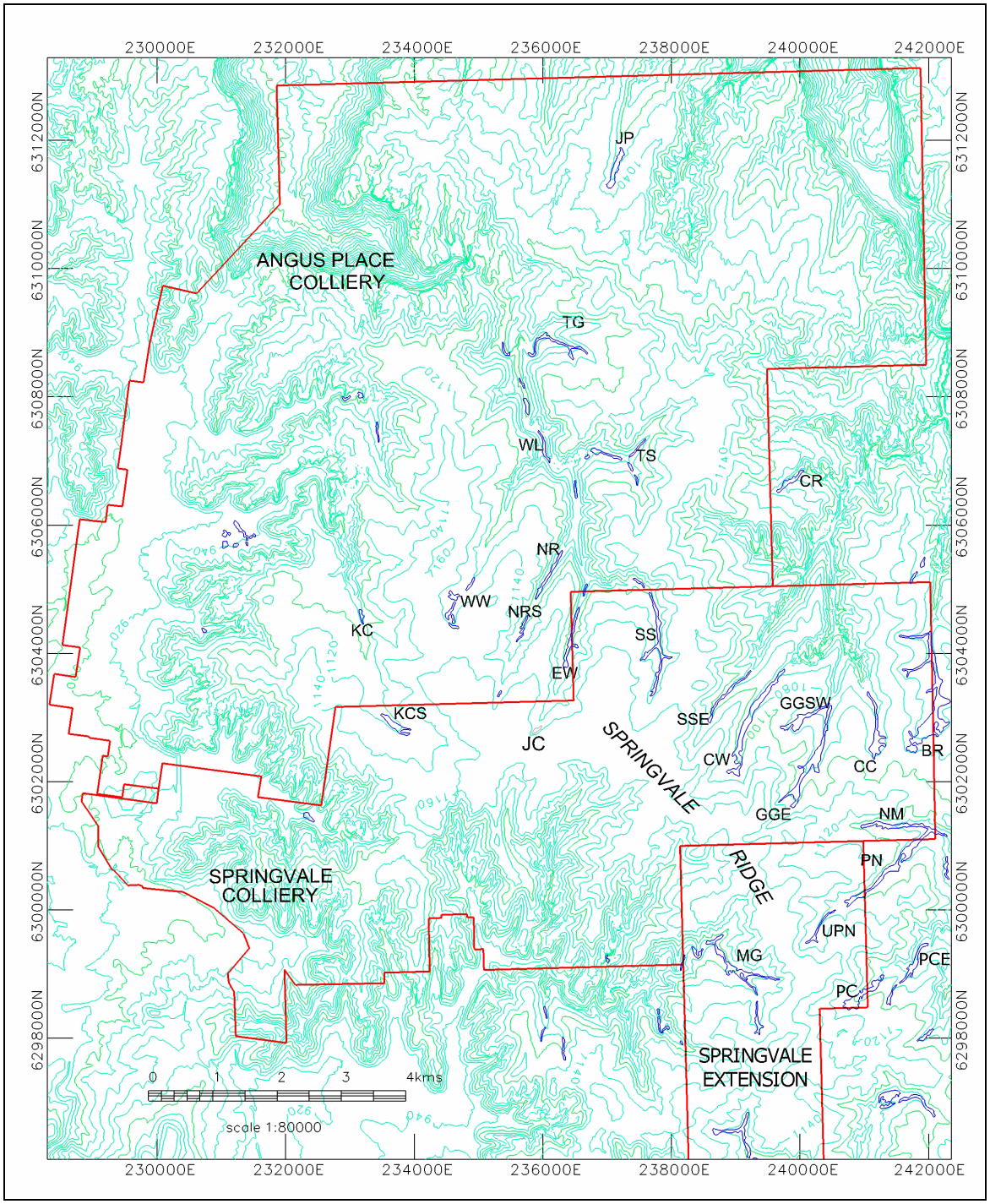

Figure 2 Topography of Angus Place/Springvale/Springvale South Extension
(Shrub swamps shown in blue)

In the Angus Place/Springvale area, basement geological structures are believed to impact strongly on the overlying Permo-Triassic sequence, particularly as the latter is comparatively thinner than in the southern and eastern regions of the Sydney Basin, where the stratigraphic sequence is more extensively developed.

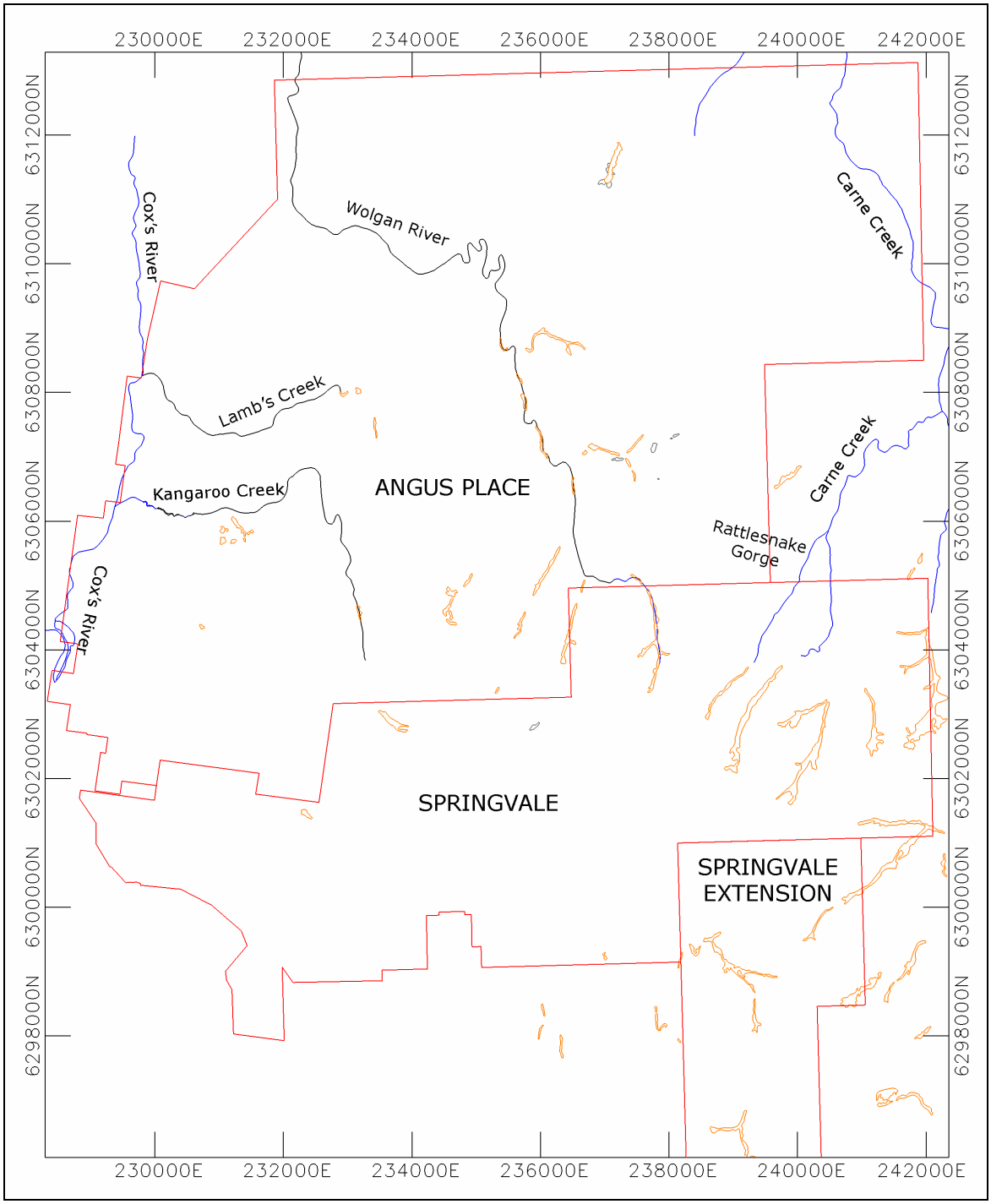

Figure 3 Angus Place / Springvale Major Rivers and Creeks

Cox's Creek to the immediate west of the study area reflects the predominantly north-south trending pattern of lineation that characterizes the study area (Figure 3). Within the Angus Place/Springvale lease areas, the Wolgan River assumes a NNW direction as it flows from its headwaters at the base of the elongated ridge system in Springvale (Figure 2) and continues downstream in the same northwesterly direction to the northern extent of the study area. The east-west topographic feature present in the area is denoted along the length of the Wolgan River by numerous short-term swings in this river from the east to the west. These diversions increase in size and frequency as the Wolgan travels north-west from its headwaters.

Similar occurrences are noted in Kangaroo Creek where the upper reaches reflect the NNW flow direction of the Wolgan River. Again, the east-west topographic feature is apparent in several minor swings from east to west before this creek assumes a final westerly swing before joining the north-south oriented Cox's River. Lamb's Creek, immediately north of Kangaroo Creek is influenced solely by this east-west topographic feature.

Carne Creek displays a NNW orientation in its lower reaches to the north-east of the study area, but adopts a NNE lineation in its upper reaches, such that the Sunnyside East, Carne West and Gang Gang tributaries also follow the same NNE trend. West Wolgan, East Wolgan, Narrow Swamp and West Wolgan watercourses to the west also adopt the NNE trend.

Rattlesnake Gorge (Figure 3), a western tributary of Carne Creek, displays a marked east-west lineation, similar to that of Lamb's Creek, while Twin Gully Swamp and Tri-Star Swamp in Angus Place also favour the east-west lineation present. The latter host watercourse is influenced by the NNE and NNW lineations, where the upper reaches follow both regional preferences.

Perhaps the best illustration of the interaction of the NNW-NNE and east-west structural/topographic systems occurs near the confluence of the upper tributaries of the Wolgan River, where the NNW trending Sunnyside Shrub Swamp host creek makes an abrupt westerly change in direction and then is met by the NNW-trending East Wolgan Creek. All structural elements are present at this site, before the Wolgan River resumes its predominant NNW-trending direction.

SRK (2012) noted three structural trends in the Angus Place/Springvale area. These included a north-south trend, (including NNE and NNW), a marked NW trend and a less dominant NE trend. These lineaments are considered to represent surface expressions of basement trends. Hence the east-west trending features which are present in the study area are likely to be less persistent, shallow level features, possibly en-echelon features linking the dominant NNE-NNW structural zones which occur throughout the study area and beyond.

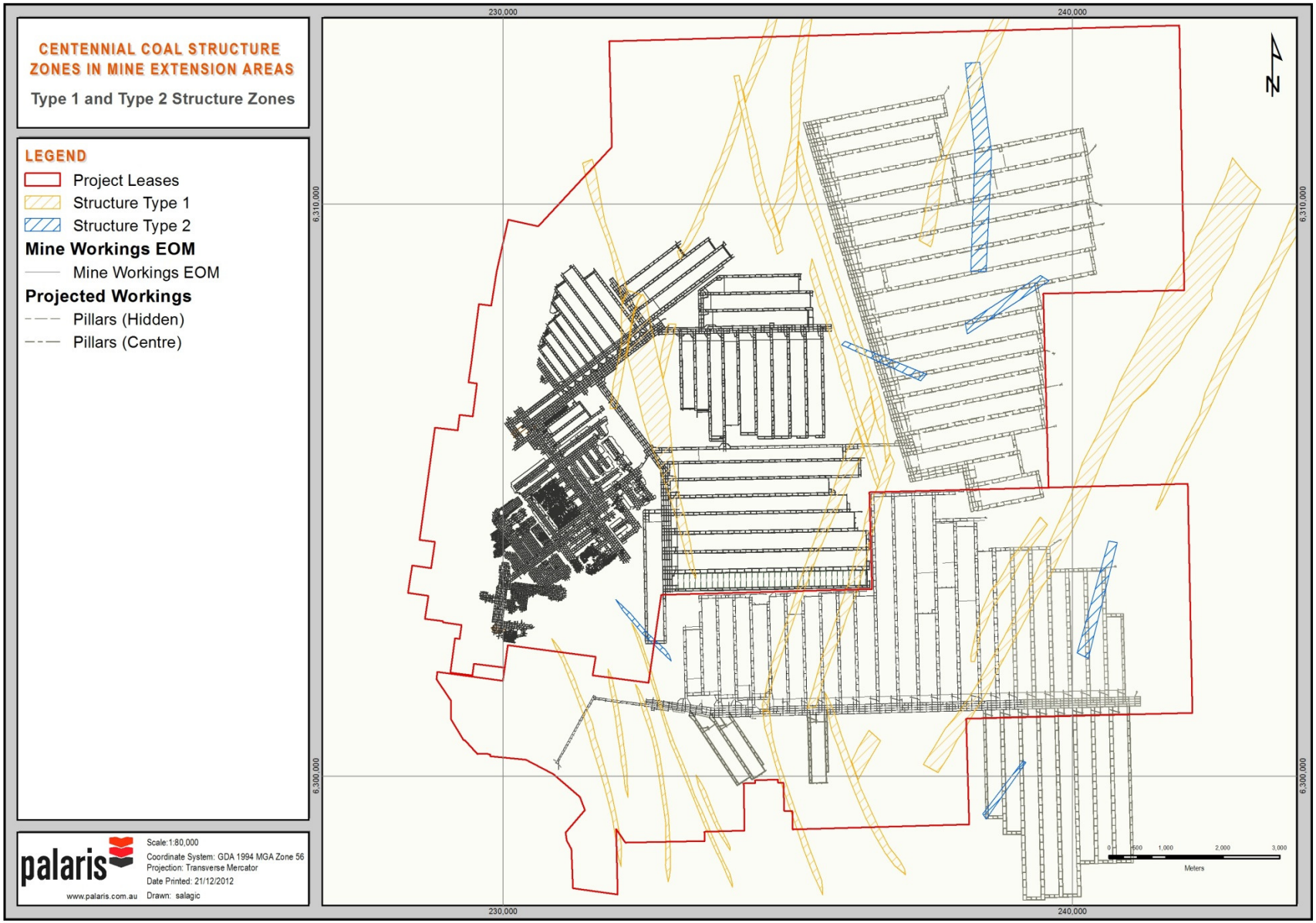

Figure 4 Angus Place / Springvale – Structure Zones (Palaris 2012)

The Type 1 features shown on Figure 4 are NNW- and NNE-trending basement-to-surface structural zones throughout the Angus Place and Springvale leases. Wolgan River and Carne Creek and their respective tributaries represent surface expressions of the two Type 1 lineament directions.

Hence there exists a dominant north-south structural trend across the study area, with a persistent but less significant east-west trend also present. The Springvale Ridge system (Figure 2), which will be discussed in subsequent sections, displays a predominant east-west orientation, continuing into Clarence Colliery to the east of the study area. However, this ridge system, at its southern extension, adopts a north-south lineation. In addition, the elevated ridge system which extends from Angus Place to Springvale via Sunnyside ridge trends in a NNE direction. The area south of the Springvale Ridge system displays more dominant north-south lineaments as reflected both in Figures 2 and 4, with minor east-west topographic expressions, such as the Marrangaroo Creek and Farmers Creek watercourses, together with the creek to the south-west of the Springvale lease which incorporates the shrub swamp near the downcast shaft.

It would appear that the geological structures in the basement rocks which form part of the Lachlan Fold Belt are reflected, at least in part, in the surface topography of the Triassic sequence above.

5. Stratigraphy

In the present report, only the Triassic strata of the Banks Wall Sandstone and the overlying Burralow Formation will be discussed in detail, since it is only within these two units in which the Newnes Plateau Shrub Swamps (NPSS) are situated. However, the Mt York Claystone Formation is also included due to the important role it plays in the hydrology of both the shrub and hanging swamp systems of the Newnes Plateau.

I. Burralow Formation

This formation consists of medium- to coarse-grained sandstones interbedded with frequent sequences of fine-grained, clay-rich sandstones, siltstones, shales and claystones. These latter fine-grained units can be several metres in thickness and their presence differentiates the Burralow Formation from the underlying Banks Wall Sandstone. The base of the Burralow Formation is defined in this study as the base of the lowermost significant fine-grained, clay-rich unit above the more sandstone-rich lithology of the Banks Wall Sandstone.

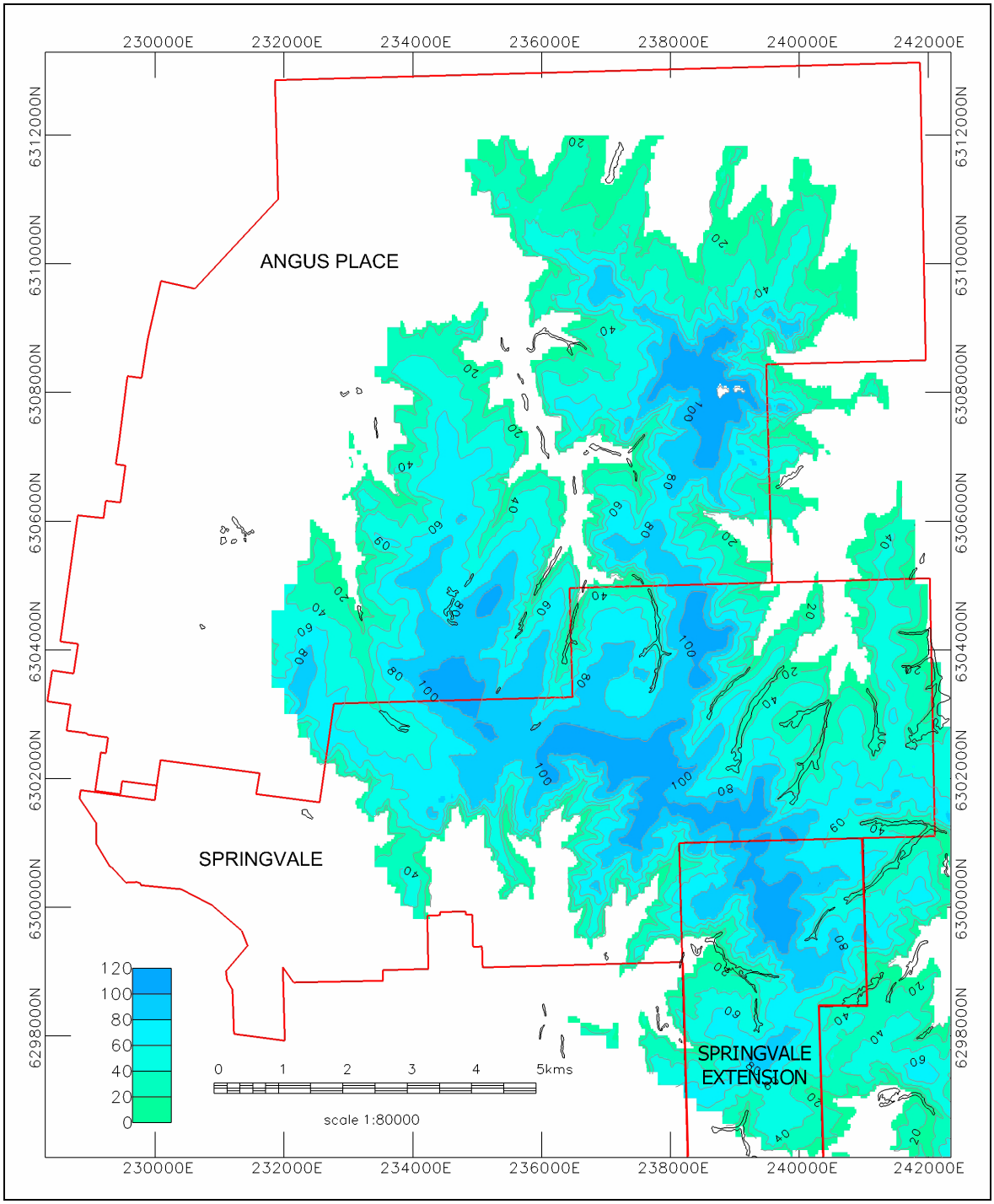

Figure 5 Burralow Formation Isopach
(Note: shrub swamps shown with black outline)

Figure 5, an isopach of the Burralow Formation, shows maximum thicknesses of approximately 110 metres, principally in the north-east of Angus Place East and the south-eastern extent of Springvale Colliery at the headwaters of East Wolgan, Sunnyside, Sunnyside East, Carne West, and Gang Gang Shrub Swamps. Hence the Burralow Formation, as defined in the study area, is thicker than previously proposed in the general Lithgow region in earlier works, for example, Goldbery (1972) and Herbert and Helby (1980).

McHugh (2011, 2013) studied the upper stratigraphy of the Angus Place/Springvale leases, in particular the Burralow Formation, and identified both a lithological and topographic link between the presence of the Burralow Formation and the occurrence of the Newnes Plateau Hanging Swamps (NPHS). Several of the claystone horizons, together with clay-rich, fine-to-medium grained sandstones and shales were found to be acting as aquitards, or semi-permeable layers within the stratigraphic sequence of the Burralow Formation. These aquitards decrease the hydraulic gradient of rainwater and groundwater movement percolating through the weathered and semi-weathered strata of the Burralow Formation and form a permanent water source for the formation and maintenance of the hanging swamps. In total, McHugh identified seven units, designated YS1 to YS6 (including the areally-limited YS5a), which were capable of sustaining the hanging swamps in the area, provided the topographic conditions were amenable to the formation of a hanging swamp.

Further, the presence of these aquitards in the Burralow Formation sequence also performs a vital function in the presence and persistence of the Newnes Plateau Shrub Swamps. The importance of the hydrological implications of these aquitards in the study area will be discussed in subsequent sections.

II. Banks Wall Sandstone

The dominant lithology of the Banks Wall Sandstone is medium- to coarse-grained sandstone, with the formation having an average thickness of just under 100 metres. The steep-sided cliff faces comprising the banks of the Wolgan River and Carne Creek consist of the massive sandstones of the Banks Wall Sandstone.

A significant characteristic of this unit is its deep weathering pattern, with zones of iron-stained sandstone alternating with zones of relatively unweathered sandstone. This trend continues throughout the formation and also extends into the sandstone layers of the Mt York Claystone, the Burra-Moko Sandstone and the Caley Formation. Core photographs from Angus Place and Clarence Colliery to the south-west of the study area indicate that the depth of weathering extends to approximately 210 metres.

The minimal gamma response of the Banks Wall Formation, as shown in downhole geophysical logs, reflects the overall low clay content and relative absence of fine-grained units. This has resulted in the informal term “muted zone” used to describe this unit in terms of its geophysical response. The significance of this term will be discussed in subsequent sections.

The Banks Wall Sandstone is underlain by the first significant claystone band of the Mt York Claystone.

III. Mt York Claystone

The top of the Mt York Claystone is partly gradational with the overlying Banks Wall Sandstone and is defined for the purposes of the present study as the uppermost fine-grained horizon that is thicker than 2 metres. Stratigraphically, it is situated approximately 100-110 metres above the Katoomba Seam. Typically the unit comprises up to three discrete claystone bands up to 4 metres thick, the principal

horizon displaying the characteristic red-brown colour of the unit. These two- to three claystone horizons are interbedded with sandstone/siltstone bands up to 8 metres in thickness. The average thickness of the correlated Mt York Claystone in the study area is 22 metres and the unit has a gradational lower boundary with the Burra-Moko Sandstone below. That is, thick claystone bands also occur within the underlying formation and it is sometimes debatable where the boundary should be defined.

Petrographic analysis of selected horizons in the Burralow Formation, Banks Wall Sandstone and the Mt York Claystone and their significance in terms of weathering patterns, fabric and hydrological impact will be discussed in a subsequent report.

6. Newnes Plateau Shrub Swamp Morphology

Previous studies of the Angus Place/Springvale area do not typically include the presence of the Burralow Formation, and instead refer to the Banks Wall Sandstone as the uppermost outcropping unit. The Burralow Formation is crucial in the development and maintenance of both the Newnes Plateau Shrub Swamps (NPSS) and, in particular, the Newnes Plateau Hanging Swamps (NPHS). However, the present study focuses predominantly on the Newnes Plateau Shrub Swamps.

Figure 6 shows the distribution of Newnes Plateau Shrub Swamps throughout the study area in relation to Burralow Formation outcrop.

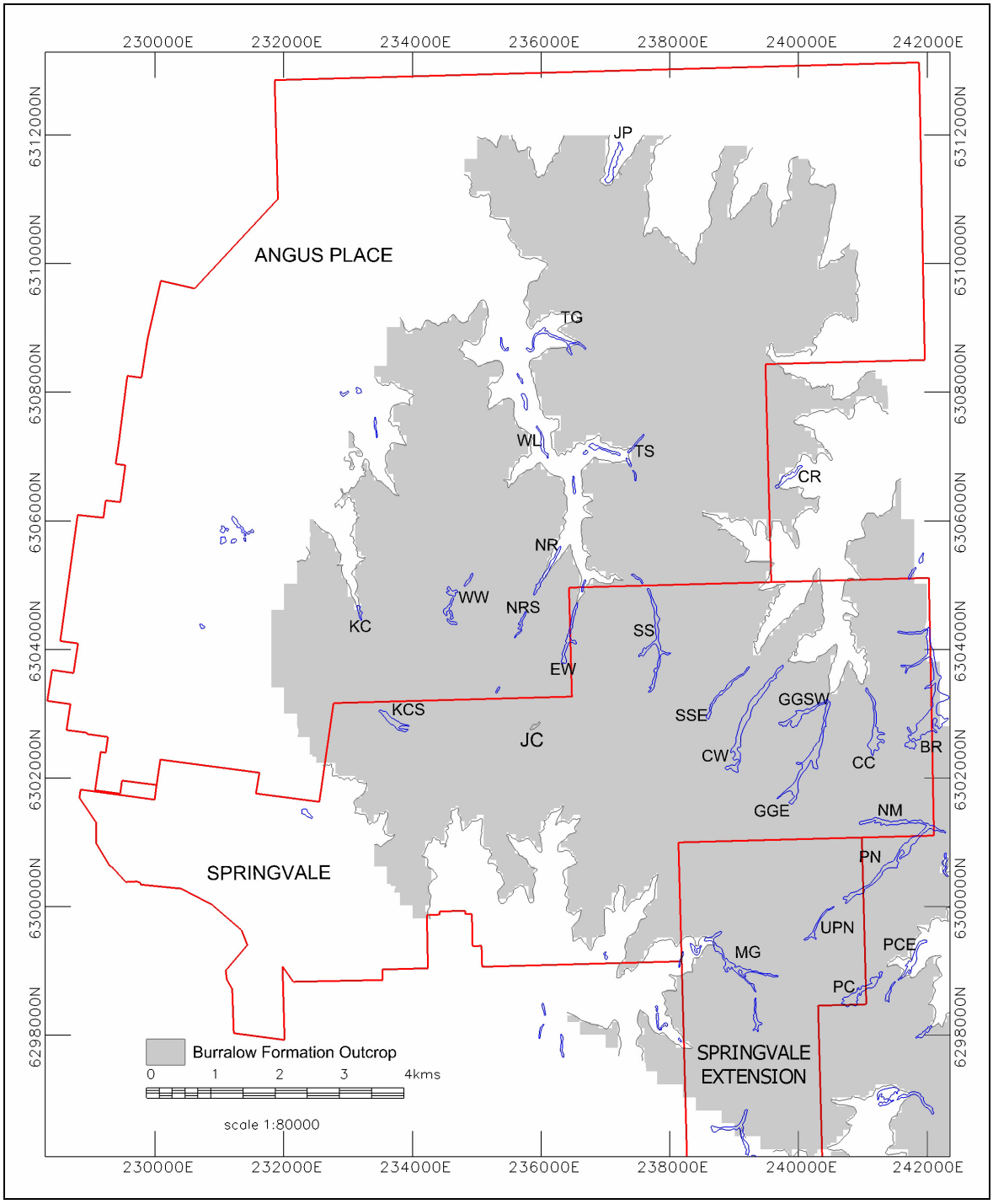

Figure 6 Shrub Swamp Locations and Burralow Fm Outcrop

Key to swamp abbreviations:
JP: Japan (Trail 6), TG: Twin Gully, WL: Wolgan, TS: Tri-star, CR: Crocodile, NR: Narrow, NRS: Narrow South, WW: West Wolgan, EW: East Wolgan, KC: Kangaroo Creek, KCS: Kangaroo Creek South, JC: Junction, SS: Sunnyside, SSE: Sunnyside East, CW: Carne West, GGSW: Gang Gang Southwest, GGE: Gang Gang East, CC: Carne Central, BR: Barrier, NM: Nine Mile, PN: Pine, UPN: Pine Upper, PC: Paddy's Creek, PCE: Paddy's Creek East, MG: Marrangaroo

The majority of the shrub swamps are located within the confines of the Burralow Formation, particularly in the Springvale lease and are defined in this report as "Burralow-type" shrub swamps. However, two shrub swamps are situated wholly within the Banks Wall Sandstone in the Angus Place lease, and are denoted as "Banks Wall-type" shrub swamps, while a third population comprises "mixed-type" swamps. These latter shrub swamps are situated stratigraphically such that their upper reaches are located within the Burralow Formation but terminate in the Banks Wall Sandstone, which occurs as the host creek erodes into the country rock distally from the watershed areas where these shrub swamps are predominantly located.

The underlying lithology of each shrub swamp controls its morphology and areal extent. Topography also plays a role in shrub swamp morphology; however the presence or absence of a Burralow Formation substrate largely dictates the shape and extent of a particular shrub swamp. Hence Banks Wall-type and "mixed-type" shrub swamps are generally smaller in area and occur in relatively steep-sided gullies.

In comparison, the Burralow-type shrub swamps characteristically occur in much broader and gently sloping depressions (Figure 6) and are commonly longer and permanently waterlogged in their lower reaches.

7. Burralow Formation Aquitards (YS6 to YS1)

As previously indicated, the aquitard units of the Burralow Formation play a critical role in the formation of the Newnes Plateau Hanging Swamps, and a similarly important role in the presence and maintenance of the Newnes Plateau Shrub Swamps.

Aquitards are semi-permeable lithological units which permit only relatively small amounts of water to percolate through them into the underlying strata. Aquitards retard water flow underground; that is, they act as a partial barrier to downward groundwater movement. Aquitards separate aquifers and partially disconnect the flow of water underground, directing water downdip to discharge points in nearby gullies.

Due to the number of suitably thick aquitards in the Burralow Formation, there is a significant decrease in the flow of water vertically through the strata due to gravity in this upper unit. This effectively retains increased volumes of water within the formation; water that would otherwise flow unimpeded down-gradient through to underlying formations.

While the dominant lithology of the Banks Wall Formation consists of medium- to coarse grained sandstones with only minor finer grained units, the Burralow Formation is relatively rich in interbedded fine-grained, clay-rich sandstones, shales, siltstones and claystones. Although the Burralow Formation consists of abundant fine-grained semi-permeable units, it was determined that only units of approximately one metre or above in thickness would be capable of acting as an aquitard that would alter the hydraulic gradient for a hanging swamp to form. The development of the latter feature would also depend on topographic constraints.

With seven such identified aquitards in total (YS6, YS5, YS5a, YS4, YS3, YS2 and YS1), there is a significant retardation of water percolation through the Burralow

Formation from surface to base to permit the formation not only of the Newnes Plateau Hanging Swamps, but to significantly contribute moisture at outcrop points in gullies containing the Newnes Plateau Shrub Swamps.

Apart from the seven named aquitard plies, additional thinner clay-rich horizons also exist within the Burralow Formation. While these units may not be of the required thickness or lateral continuity to form a hanging swamp or contribute significantly to in-gully groundwater levels in shrub swamps, they nevertheless act as a group to further decrease the hydraulic gradient of downward-percolating water within the Burralow Formation as a whole. Groundwater sourced from the presence of these aquitard units thus supplements input from precipitation, which assists in maintaining the floristic community of the resultant shrub swamps.

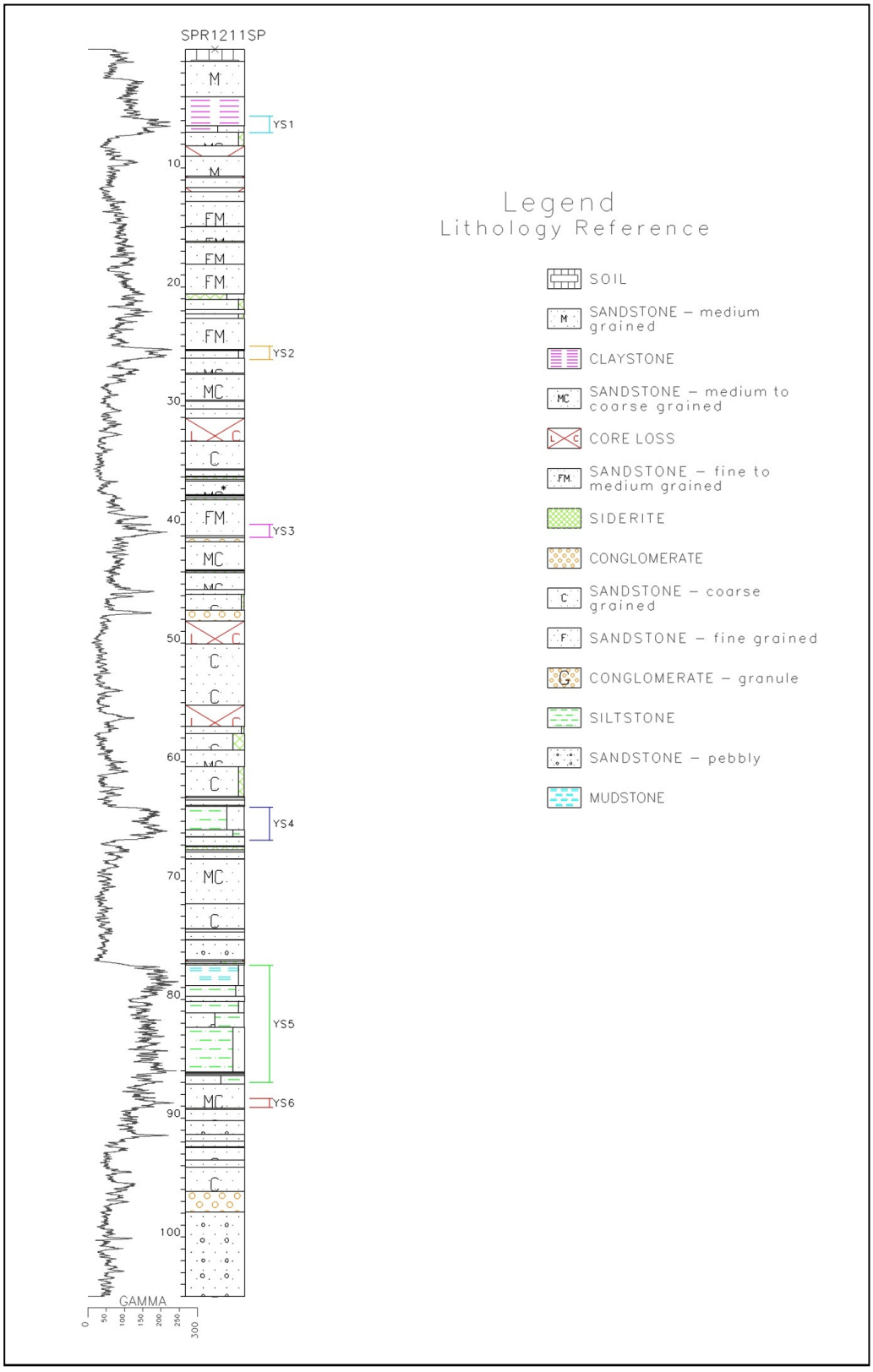

Figure 7 SPR1211SP Graphic Lithological Log

Figure 7 displays an example of the full suite of functioning aquitards from YS1 to YS6 (note YS5a is absent from this borehole). Appendix A shows core photographs covering the interval shown in Figure 7.

SPR1211SP is a fully-cored hole in the Springvale area and the resultant gamma response highlights the clay-rich shales, fine clayey sandstones and claystones that serve to act as a sequence of progressive semi-impermeable horizons within the Burralow Formation. These horizons essentially maintain the hydraulic head higher than would be expected and thus provide a permanent water source for both the associated hanging swamps and the shrub swamps that are located adjacent to down-dip discharge points.

The sole unconfined aquifer in the more elevated sites within the study area lie above the YS1, the remainder of the strata between aquitards in the Burralow Formation act as individual "aquifers" at surface points where the coarser sandstone units of the formation crop out on gully sides. The high degree of weathering of many of the sandstone units also assists in this process, and is also indicative of the degree of water movement through these units.

By contrast the Banks Wall Sandstone gamma response is considerably muted compared to that of the Burralow, containing relatively few semi-permeable units and hence is easily differentiated in downhole logging from the overlying Burralow Formation. In hydrogeological terms, the Banks Wall Sandstone is referred to as the "muted zone" for the purposes of this report, that is, it is not a major source of groundwater originating from the presence of aquitard horizons.

8. Hydrogeological Influence of the Mt York Claystone

The Mt York Claystone acts as a major hydrological confining unit and, as noted by McHugh (2011), effectively forms a more efficient hydrological barrier than the thinner aquitards of the upper sequences. This is due to its lithological composition, its greater thickness, which averages over 20 metres in the study area, and its lateral continuity within and beyond the Angus Place/Springvale leases.

The Mt York Claystone lies between the upper Narrabeen Group (Burralow Formation and Banks Wall Sandstone) and the underlying Burra-Moko Head Sandstone and Caley Formation as shown in Figure 8 below.

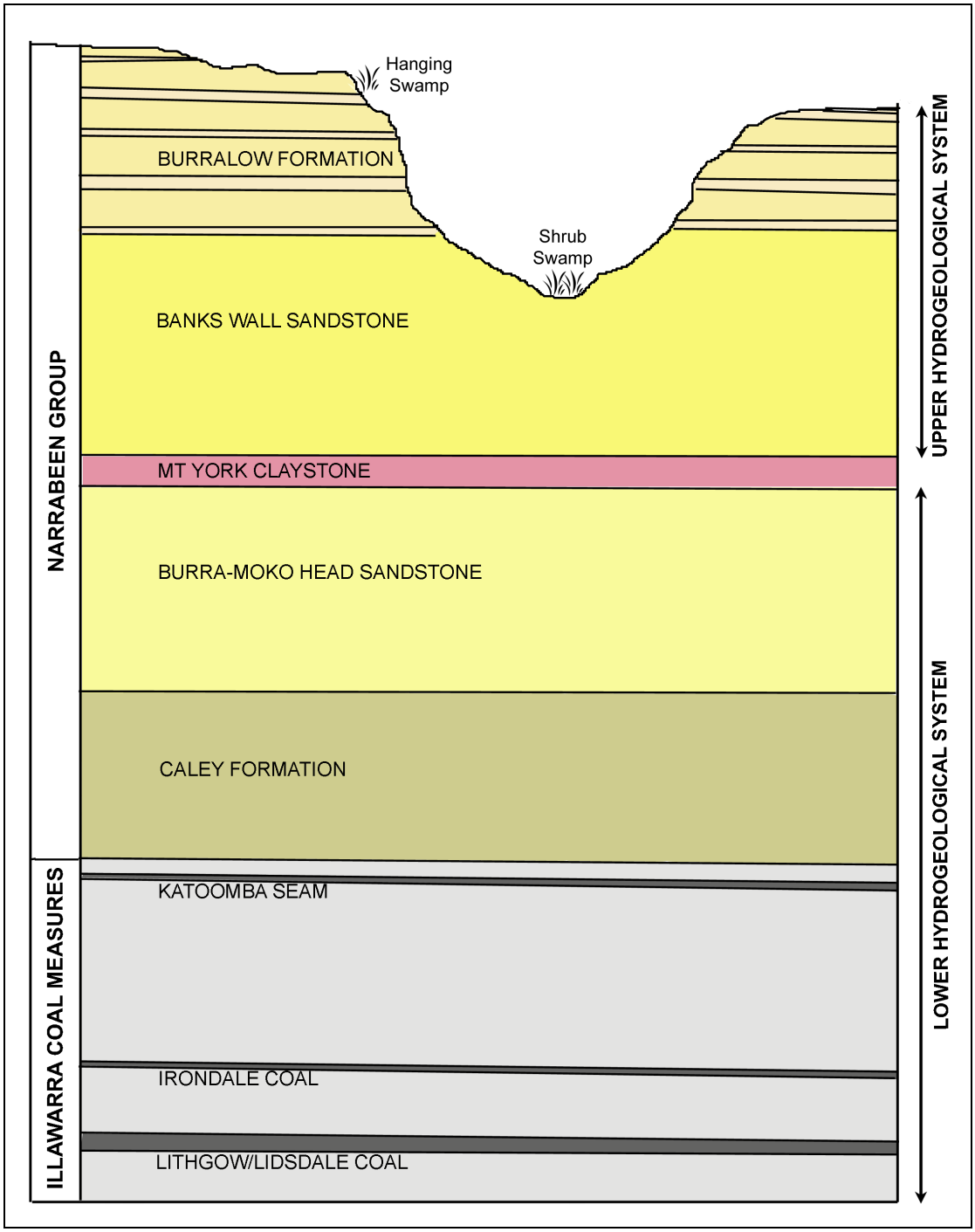

Figure 8 Schematic Hydrogeological Section

Figure 8 shows the presence of a dual hydrological system operating in the study area, with the upper hydrological system located above the Mt York Claystone and the lower hydrological system below the base of the Mt York Claystone. This diagram also illustrates schematically the manner in which Newnes Plateau Hanging Swamps are associated with outcropping aquitards of the Burralow Formation. The Newnes Plateau Shrub Swamps benefit from the presence of these aquitards by redirecting groundwater laterally to gully discharge points and valley wall seepage acts as a source of groundwater to shrub swamps in adjacent gullies. This diagram shows a Banks Wall-type shrub swamp. Burralow-type shrub swamps also receive direct in-

gully groundwater input from single or repeated aquitard intersection due to erosion of the host gully. Both sub-types of shrub swamps are discussed below.

9. Burralow-type Shrub Swamps versus Banks Wall-type Shrub Swamps

The presence of the Burralow Formation is essential to the formation of both the Newnes Plateau Shrub Swamps (NPSS) and the Newnes Plateau Hanging Swamps (NPHS). The series of aquitards present in the Burralow Formation are intimately linked, together with topographic factors, with the formation of the hanging swamps, which occur at outcrop points of suitable aquitards.

Similarly, the Newnes Plateau Shrub Swamps would not exist without the presence of the Burralow Formation and its characteristic groundwater-retaining properties, since the aquitards provide an important supplementary and permanent supply of water to the shrub swamps located within the Burralow Formation

Shrub swamps located wholly or partly within the Banks Wall Sandstone also attain substantial seepage from the Burralow Formation but do not in general benefit from the degree of groundwater seepage that shrub swamps in the Burralow Formation experience. Hence, the morphology of the Banks Wall-type shrub swamps differs significantly from that of the Burralow-type. A third shrub swamp category, “mixed-type”, refers to shrub swamps which contain both Banks Wall Sandstone and Burralow Formation gully substrates.

Swamp Name	Swamp Type	Associated Hanging Swamps	Colliery
Japan (Trail 6)	Banks Wall	Y	Angus Place
Twin Gully	Mixed	Y	Angus Place
Tri-Star (EW)	Banks Wall	Y	Angus Place
Tri-Star (NE)	Mixed	Y	Angus Place
Tri-Star (SE)	Mixed	Y	Angus Place
Crocodile	Mixed	Y	East of Angus Place
Narrow	Mixed	Y	Angus Place
Narrow South	Burralow	N	Angus Place
Kangaroo Creek	Mixed	N	Angus Place
West Wolgan	Burralow	Y	Angus Place
East Wolgan	Mixed	N	Angus Place/Springvale
Sunnyside	Burralow	Y	Angus Place/Springvale
Sunnyside East	Burralow	Y	Springvale
Carne West	Burralow	Y	Springvale
Gang Gang Southwest	Burralow	N	Springvale
Gang Gang East	Burralow	N	Springvale
Carne Central	Burralow	N	Springvale
Nine Mile	Burralow	N	Springvale/Clarence
Pine	Burralow	N	Springvale South/Clarence
Upper Pine	Burralow	Y	Springvale South
Paddy's Creek	Burralow	N	Springvale South/Clarence
Paddy's Creek East	Mixed	Y	Clarence
Marrangaroo	Mixed	Y	Springvale South

Table 1 Angus Place and Springvale Shrub Swamp Categorisation

Table 1 shows swamp category type for each shrub swamp in Angus Place, Springvale, Springvale South extension and the western area of Clarence colliery. "Mixed-type" swamps are characterized by dual gully substrates, that is, both Banks Wall Sandstone and Burralow Formation lithologies form the valley floor.

In the "mixed-type" scenario the upper reaches of the shrub swamp are located stratigraphically within the Burralow Formation while the lower reaches are situated within the Banks Wall Sandstone due to erosion of the host gully. Such swamps, as with the Banks Wall-type shrub swamps, are typically shorter in length than their Burralow Formation equivalents.

Carne West Swamp

Japan Swamp

Figure 9 Contrast in Swamp Morphology between Burralow-type and Banks Wall-type shrub swamps

The above photo demonstrates the effect of a Burralow Formation substrate versus a Banks Wall substrate on gully morphology. Burralow-type swamps, that is, swamps which are stratigraphically situated wholly within the Burralow Formation and which transect several aquitards as a result, generally comprise open, spoon-shaped valley floors. They are comparatively more extensive in both length and width due to sequential in-gully groundwater input as compared to Banks Wall or "mixed-type" shrub swamps. Carne West Shrub Swamp (Figure 9) which is situated in the Springvale lease is an example of a Burralow-type shrub swamp.

By contrast, Japan Shrub Swamp (Figure 9) is stratigraphically situated wholly within the Banks Wall Formation. Japan Shrub Swamp (also known as Trail 6 Shrub Swamp) is located within the Angus Place lease (Figure 6). As Figure 9 demonstrates, swamp width in general is significantly narrower than Burralow-type equivalents. Gully morphology is also steeper in Banks Wall substrates due to the differing lithological composition of the Banks Wall Sandstone and the Burralow Formation. These concepts are discussed in detail in subsequent sections.

Figure 10 below shows a longitudinal section down the centre-line of Carne West Shrub Swamp which is a Burralow-type shrub swamp. Carne West Shrub Swamp is located within the Springvale lease (Figure 6).

This swamp has a fall of approximately 55 metres and, as shown, the gully floor passes stratigraphically from above the YS3 through to the YS5 at the lower extremity of the swamp. Hence groundwater can be sourced from strata above YS2 and YS3 from the upper reaches to the endpoint of the swamp, from above YS4 midway along the swamp course to its endpoint and from above YS5 near the lower reaches.

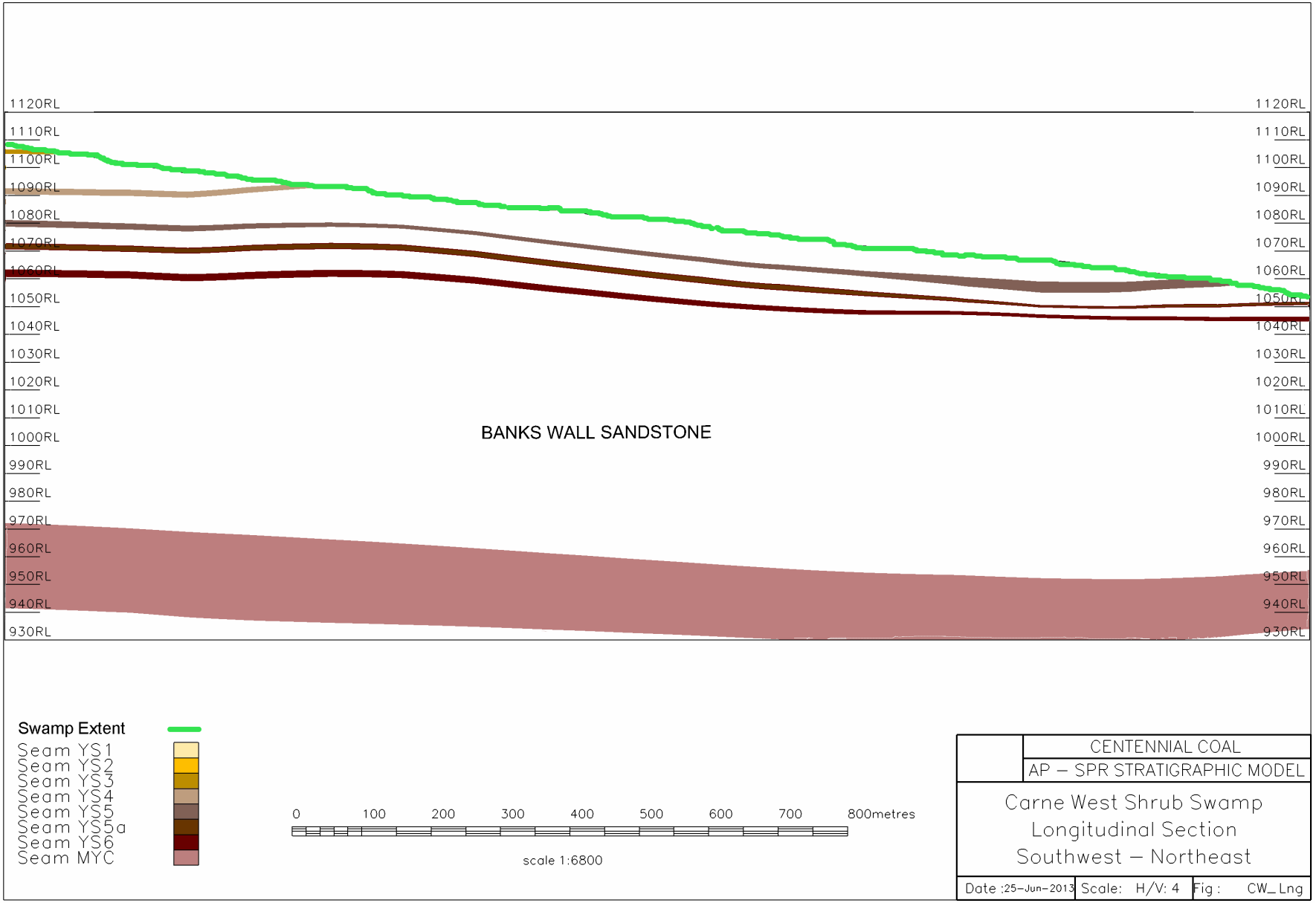

Figure 10 Longitudinal Stratigraphic Section of Carne West Shrub Swamp

Figure 11 shows Carne West Shrub Swamp (including Carne West Hanging Swamp) and the outcrop of the YS plies in plan form. The YS2 can be clearly seen to be a source of groundwater seepage in the far upper reaches of the swamp, augmented in the upper reaches by the YS3 and in the middle reaches by the YS4. Note that the YS1 ply would also retain groundwater in the upper sequences of the gully sides which would slowly percolate to assist in the maintenance of the Carne West Hanging Swamp as well as the extreme upper reaches of Carne West Shrub Swamp. Hence, the YS aquitards assist in providing supplementary groundwater to shrub swamps which are contained either wholly or partially within the Burralow Formation. Carne West Shrub Swamp acquires water via three sources; precipitation, valley wall seepage from several nearby aquitards and direct in-gully groundwater. In addition, Carne West Shrub Swamp has a relatively large recharge area as will be discussed in detail in subsequent sections.

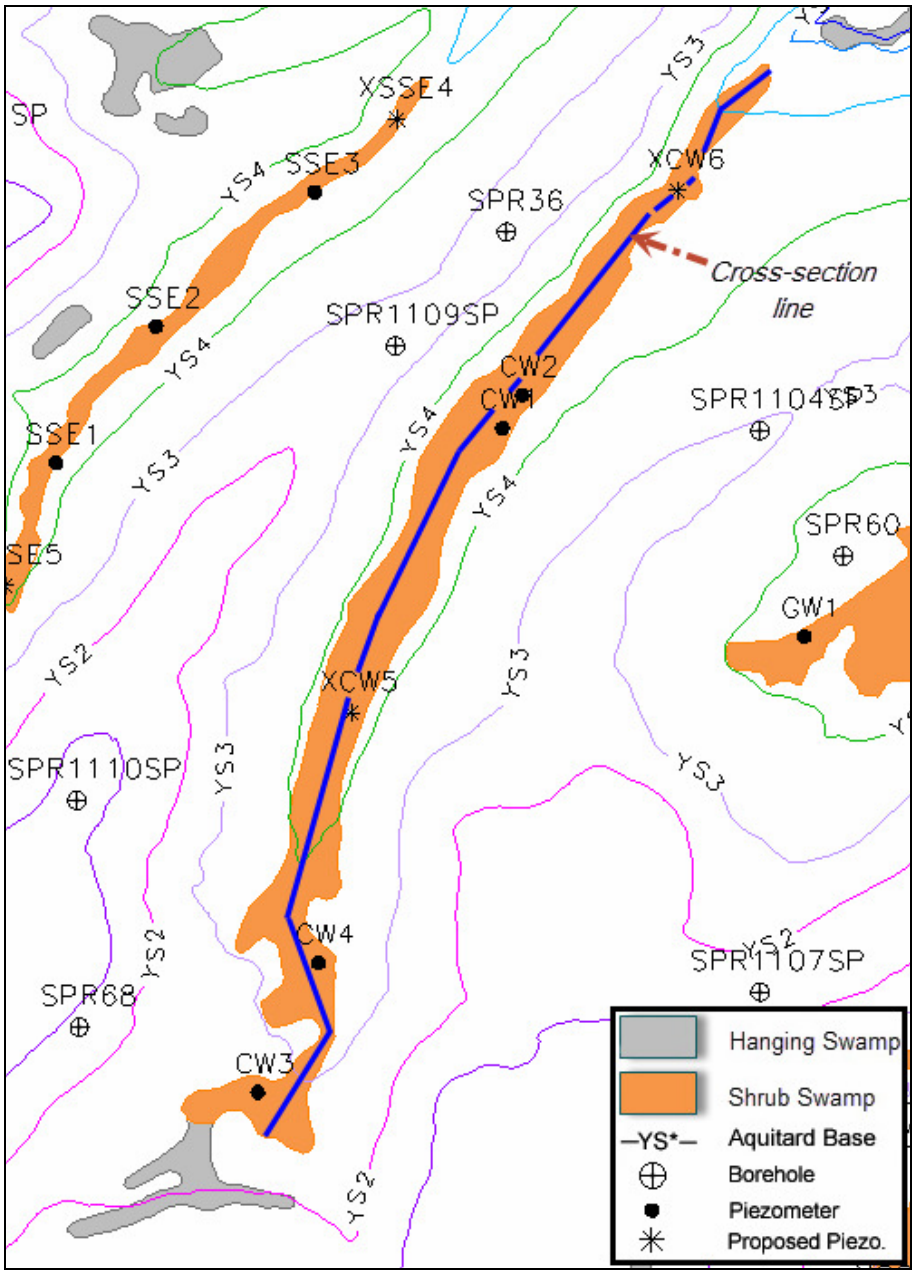

Figure 11 Plan of Carne West Shrub Swamp

Figure 12 shows a longitudinal section of this swamp. Occurring stratigraphically below the Burralow Formation, no significant aquitards are present to prevent unimpeded groundwater percolation or to direct groundwater laterally to discharge points along the length of the swamp. Groundwater input is reliant solely on precipitation and valley wall seepage, and Figure 12 demonstrates the lack of in-stream aquitards along the entire length of Japan Shrub Swamp.

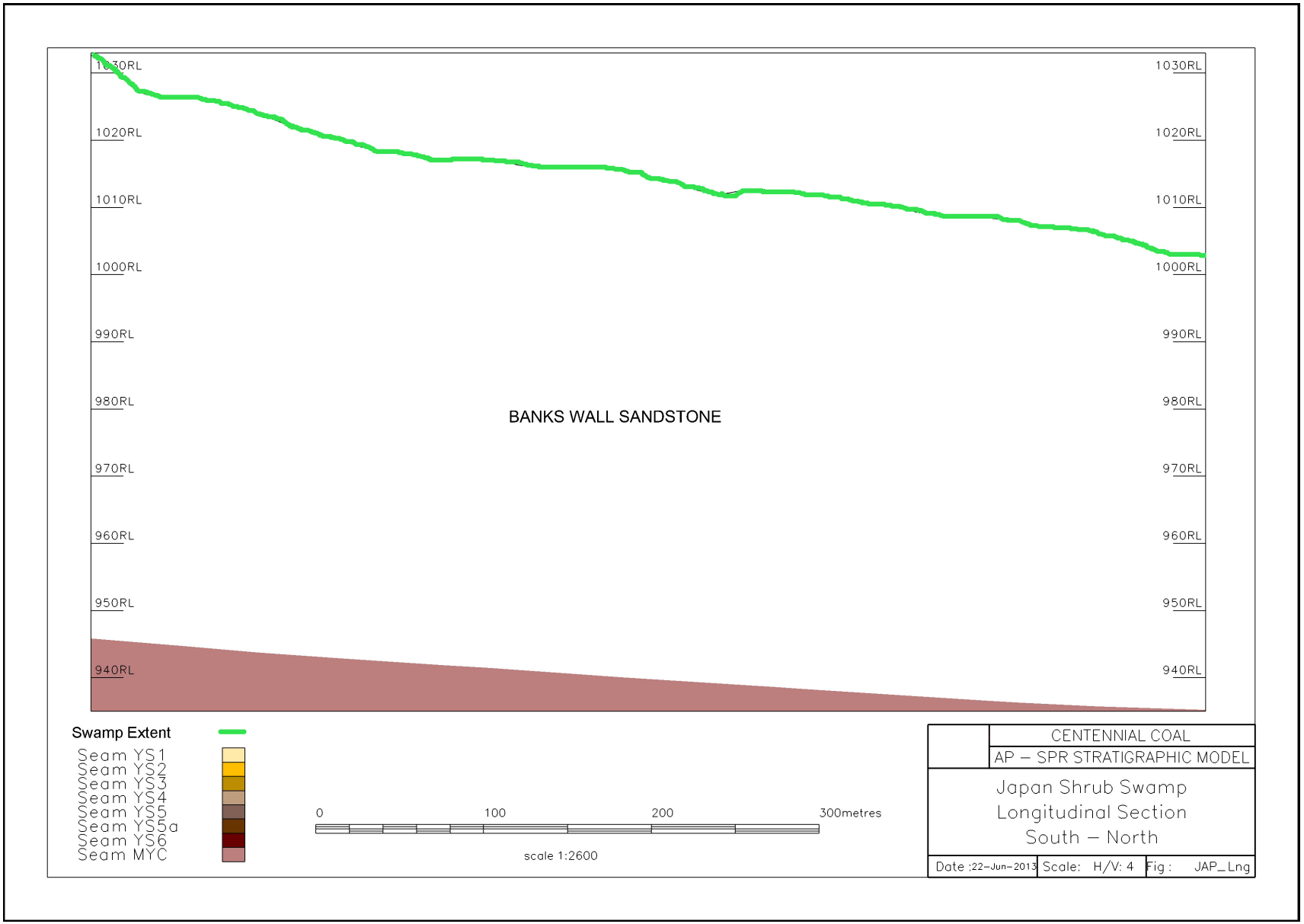

Figure 12 Longitudinal Stratigraphic Section of Japan Shrub Swamp

Figure 13 shows a plan of Japan Shrub Swamp and associated Japan Hanging Swamps. The latter are supported by groundwater seepage from above plies YS6 and YS5a, predominantly around the headwaters of the swamp.

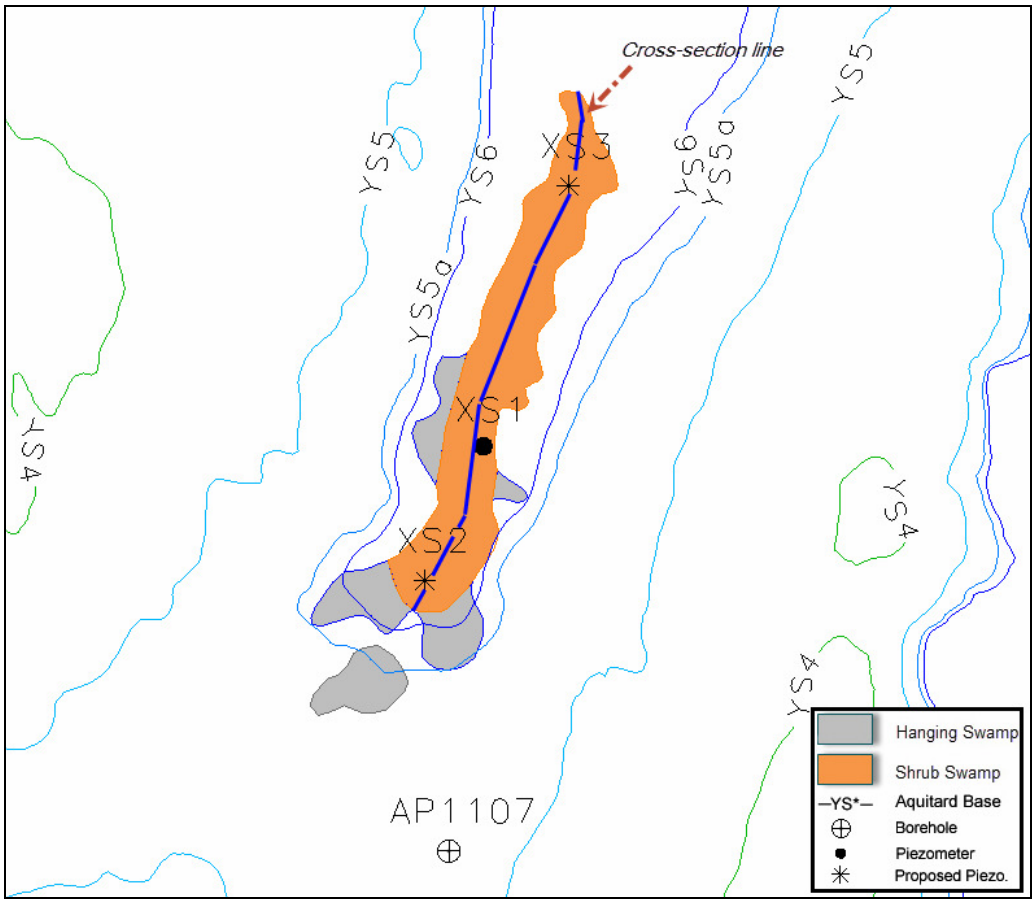

Figure 13 Plan of Japan (Trail 6) Shrub Swamp

Japan Shrub Swamp is located in a steep-sided gully in the Banks Wall Sandstone, and is 0.75km in length with a fall of 32 metres. Unlike Carne West Shrub Swamp discussed above, there are no aquitards outcropping along the length of the drainage line to assist with direct in-gully groundwater input. However, plies YS6, YS5a and to a lesser extent, YS5, would retain groundwater in the upper steep sides of this gully, which would eventually percolate down into the gully floor, thus providing a ready source of moisture in addition to annual precipitation. Ply YS4 to the west of the swamp is too distal to be a source of groundwater seepage. Japan Shrub Swamp is also adjacent to a relatively restricted recharge area. The importance of the latter phenomenon is discussed in a subsequent chapter.

Hence the Banks Wall Sandstone with its predominantly sandstone sequences results in areally smaller swamps. In addition, the lithological floor of the gullies of this swamp type allow for less erosion and thus form steeper-sided gullies as compared to the generally broader and shallower profiles of the Burralow-type shrub swamps. In comparison with swamps such as Carne West above, the morphology of Japan Shrub Swamp is also restricted as shown a subsequent section where Japan Shrub Swamp is discussed in further detail.

In a further comparison of differing swamp morphologies based on varying lithological substrates, Figure 14 shows a plan diagram illustrating the relative locations of Sunnyside Shrub Swamp, Sunnyside East and Carne West Shrub Swamps in the Springvale lease area. All three swamps are located wholly within the Burralow Formation and are thus Burralow-type shrub swamps.

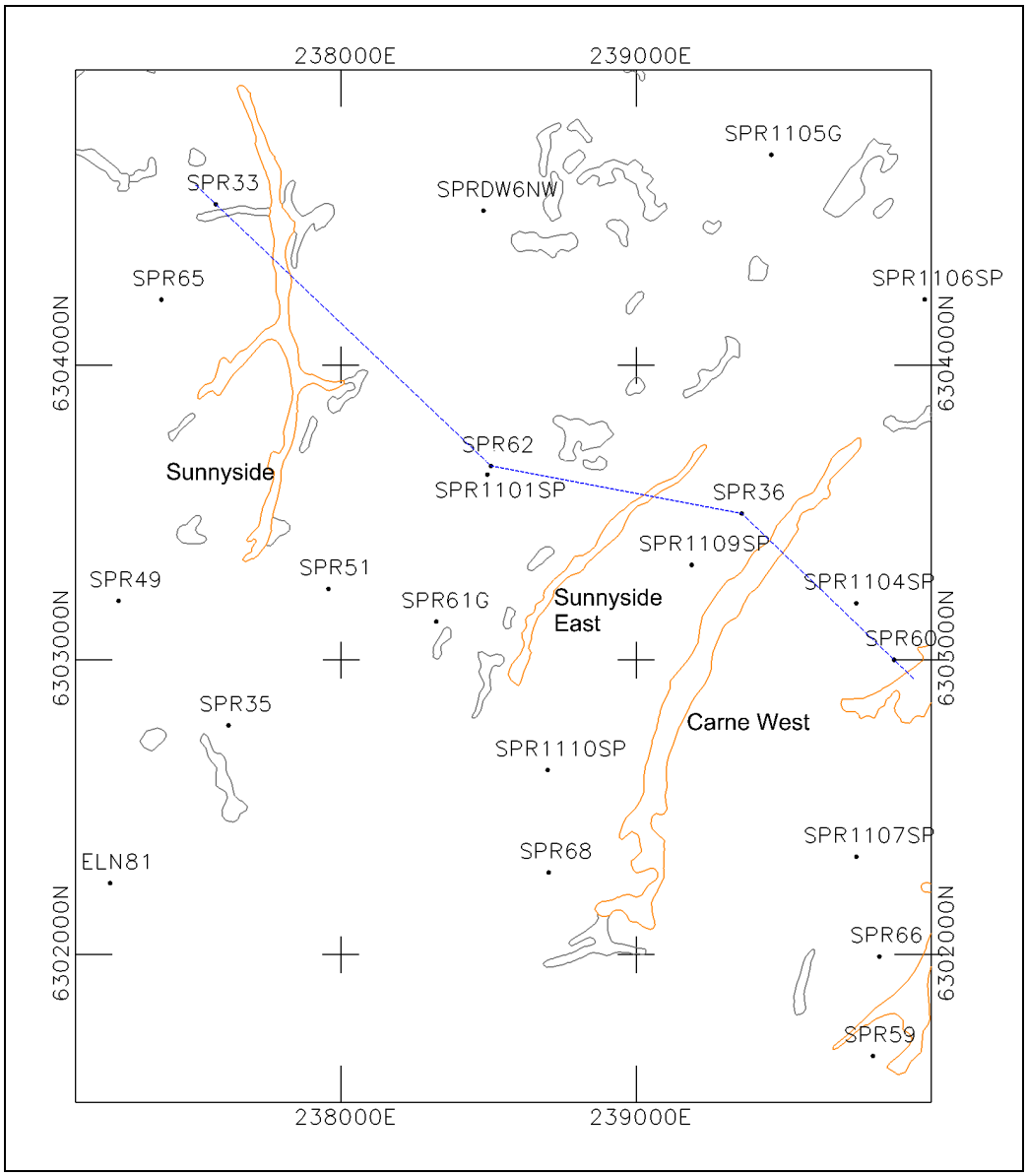

Figure 14 Plan of Sunnyside, Sunnyside East and Carne West Shrub Swamps

Figure 14 shows the location of Sunnyside, Sunnyside East and Carne West shrub swamps (in orange) in addition to the numerous hanging swamps in the vicinity (in grey). Relevant borehole locations are also shown. Figure 15 (below) is a cross-section of the above diagram.