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Environmental considerations for the proposed goldfields gas pipeline route through Wanjarri Nature Reserve

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ENVIRONMENTAL CONSIDERATIONS FOR THE PROPOSED GOLDFIELDS GAS PIPELINE ROUTE THROUGH WANJARRI NATURE RESERVE

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(Based on a report provided for Goldfields Gas Transmission Pty Ltd – September 1994)

RESOURCE MANAGEMENT TECHNICAL REPORT **148**

CONTENTS

Summary and recommendations

This report provides a broad description of the biophysical environment on Wanjarri Nature Reserve, discusses land management hazards, assesses and suggests an alternative alignment for the proposed Goldfields Gas Pipeline and briefly discusses environmental monitoring.

From a purely environmental perspective the optimal alignment for the proposed Goldfields Gas Pipeline might be to the east of the mulga plains, in the spinifex for most of the way, and west of the sand ridge field near the track down to South Bore. The compromise suggested in this report falls within the 5 km corridor identified in the PER. The rationale behind the revised alignment described in this report include:

1. fragile duplex soils are avoided;
2. sand ridges are avoided;
3. by moving east (downslope) of the originally proposed alignment through the mulga section of the route, drainage patterns are generally more diffuse and downslope impacts are likely to be more localised;
4. the proximity to the Environment Centre is reduced.

The revised alignment within the constraints of the 5 km corridor was developed according to landscape characteristic and process criteria alone. Modifications due to other criteria such as nature conservation values or cost may be required by the proponents.

The impact of the proposed pipeline's construction and future management will depend to a substantial degree on the sensitivity to the environment shown by its constructors and subsequent managers. This report provides a basis for such an environmentally sensitive approach. It does not propose detailed regeneration techniques, but again, provides the basis from which these can be prescribed.

Introduction

This study is the result of a request from Goldfields Gas Transmission in response to concerns, particularly from the Department of Conservation and Land Management, regarding the likely environmental impacts of the preliminary proposed route of the Goldfields Gas Pipeline through Wangarri Nature Reserve as described in the PER undertaken by Dames and Moore (unpublished) environmental consultants. Wanjarri Nature Reserve lies approximately 380 km north of Kalgoorlie and 100 km south-east of Wiluna in the north eastern Goldfields of Western Australia. It covers 53,248 hectares and is bordered by Barwidgee, Mt Keith, Yakabindie and Yandal pastoral leases.

The study focuses primarily on the land systems and catchments of Wanjarri Nature Reserve in assessing the optimal route for the proposed pipeline within a pre-defined 5 km corridor. Nature conservation values are not addressed in any direct manner, although any impacts on the characteristics of land systems may have implications for nature conservation.

This study consists of four sections:

- The provision of a general environmental inventory of the reserve (land systems etc.).
- An assessment of the land management hazards associated with the land systems identified in the general inventory.
- Recommended changes to the preliminary proposed alignment to minimise potential environmental degradation.
- An assessment of environmental monitoring requirements.

1. Environmental inventory

This study provides a general environmental inventory in terms of patterns of surface drainage and landforms, soil and vegetation (land systems). Land systems consist of recurring patterns of topography, landform, soils and vegetation that are recognisable on aerial photography (Christian and Stewart 1953, 1968) and sometimes on satellite imagery (Pringle 1994, Pringle *et al.* 1994).

(i) Drainage patterns

Sub–catchments, their drainage direction and major drainage lines are depicted in Figure 1. Most drainage affecting the proposed pipeline corridor is from west to east, dissipating into sandplain or deviating northwards towards Mount Keith pastoral lease. For much of the corridors length, drainage features consist of episodic diffuse, unchannelled, shallow, sheet flows. Occasional more concentrated flows occur on mulga drainage tracts and minor incised drainages occur on stony plains upslope of these tracts. A large area of sandplain south of the Environment Centre has very few drainage features. The breakaway system running across the south of the Reserve drains southwards into mulga plains and spinifex sandplain along the boundary.

(ii) Land types and land systems

The land systems within the Reserve are described briefly according to land type below, and in more detail in Pringle *et al.* (1994). Land types are groups of land systems with similar position in the landscape and similar major habitats. Figure 2 is a schematic diagram placing common land types in their spatial and toposequence context. A land system map of Wanjarri Nature Reserve is also presented (Figure 3). Fourteen land systems in nine land types make up Wanjarri Nature Reserve. Information regarding the Reserve's representativeness of the region has been produced by Pringle (1993).

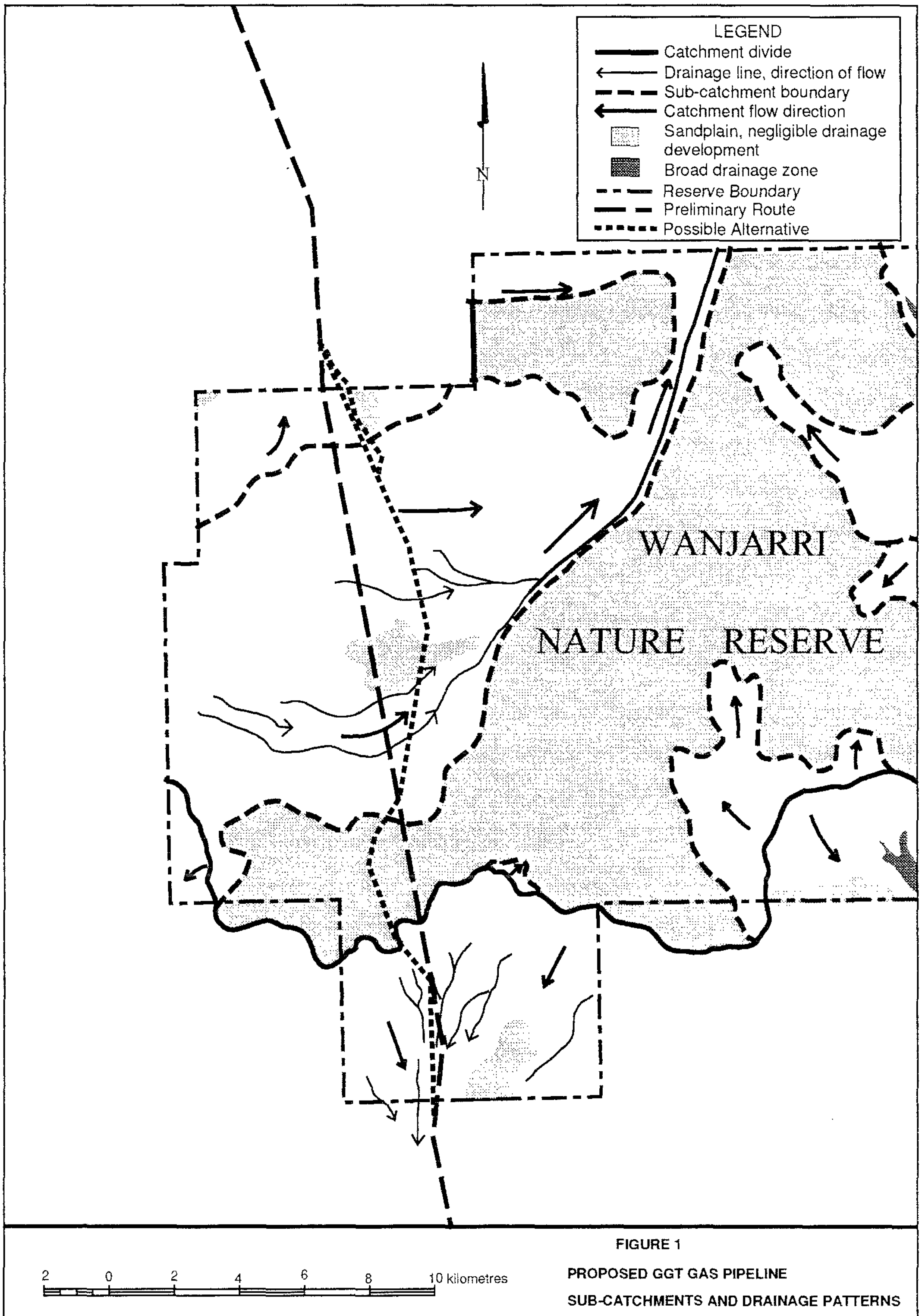


FIGURE 1

PROPOSED GGT GAS PIPELINE

SUB-CATCHMENTS AND DRAINAGE PATTERNS

WANJARRI NATURE RESERVE

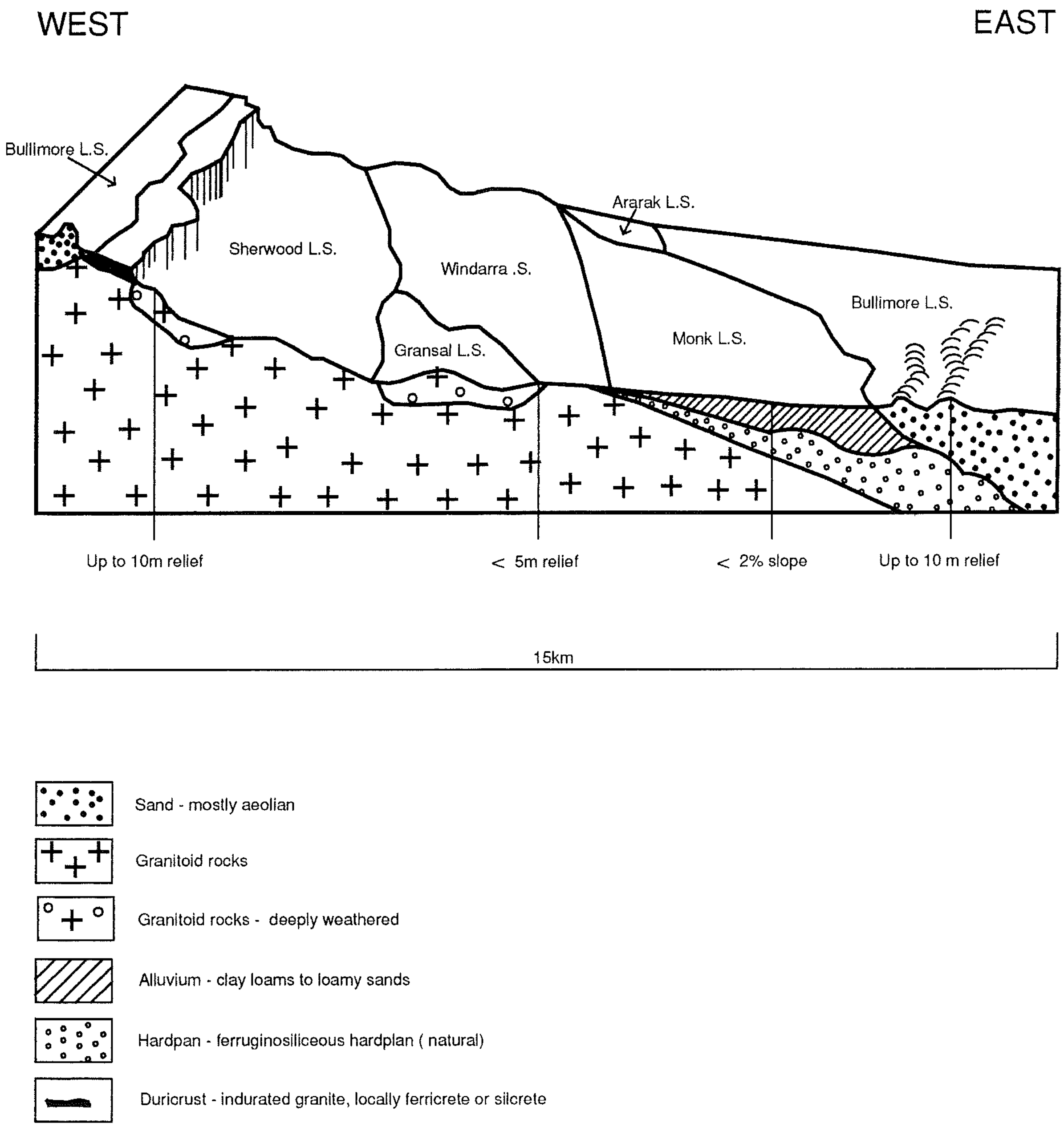
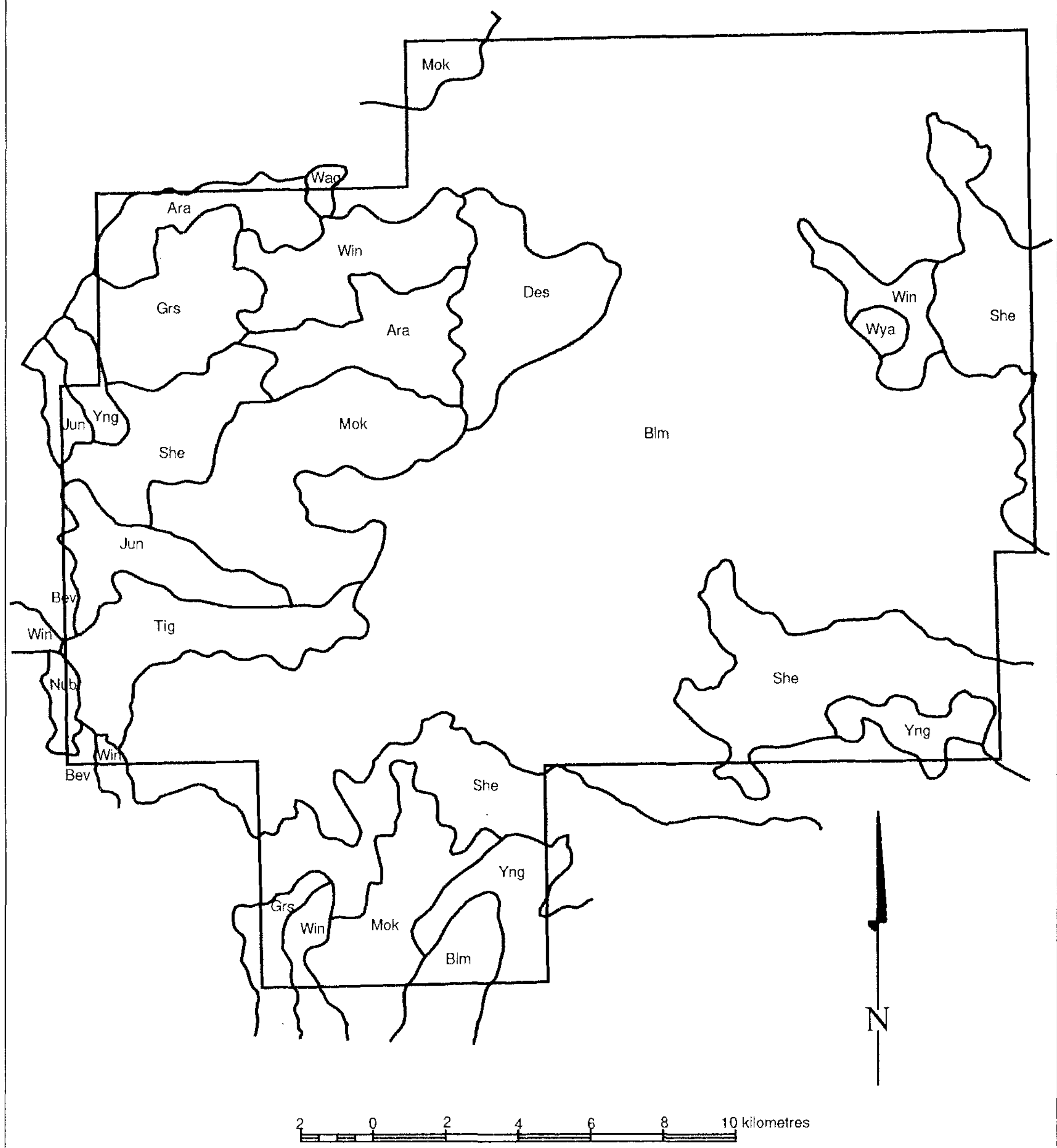


FIGURE 2: MAJOR LAND TYPE SEQUENCES AND LAND SYSTEM PATTERNS ON WANJARRI NATURE RESERVE

FIGURE 3 LAND SYSTEMS OF WANJARRI NATURE RESERVE



Source: Pringle *et al.* 1994

LEGEND

Land type 1: Hills with acacia shrublands (Pastoral value mainly low to very low)

Bev	BEVON	Low hills and rises with limonitic duricrust and stony plains.
Wya	WYARRI	Hills, domes and tor fields on granite with occasional quartz dykes.

Land type 3: Breakaways and stony plains with mulga shrublands and minor halophytic shrublands (Pastoral value moderately high)

She	SHERWOOD	*Breakaways, kaolinised footslopes and extensive* gently sloping plains on granite and gneiss.

Land type 5: Irregular plains and low rises supporting mulga, bowgada and halophytic shrublands (Pastoral value variable)

Nub	NUBEV	Gently undulating plains and low rises with limonite above alluvial plains with saline soils (moderately high pastoral value)
Vio	VIOLET	Undulating plains with stony and gravelly mantles and low rises with limonite (low pastoral value)
Wag	WAGUIN	Stripped surfaces with small breakaways, short lower plains and sandplain on granite (moderate pastoral value).

Land type 6: Stony plains and lower alluvial plains with predominantly saline soils and halophytic shrublands (Pastoral value moderately high)

Grs	GRANSAL	Gently undulating plains, low rises and alluvial plains on granite.

Land type 8: Stony plains and occasional low rises with acacia-eremophila shrublands (Pastoral value low to moderate)

Win	WINDARRA	Level to gently undulating plains with quartz mantles on granite.

Land type 10: Wash plains on hardpan with mulga shrublands (Pastoral value low to moderate)

Jun	JUNDEE	Level to very gently inclined wash plains with *mantles of fine ironstone gravel.*

Land type 11: Wash plains and sandy tracts on hardpan, with mulga shrublands and wanderrie grasses (Pastoral value mainly moderate)

Mok	MONK	Very gently inclined wash plains with occasional wanderrie banks in lower areas.
Tig	TIGER	Very gently inclined wash plains with numerous parallel wanderrie banks with gravelly mantles.
Yng	YANGANOO	Wash plains with concentrated drainage zones and sandy tracts.

Land type 12: Plains with deep sandy soils supporting acacia shrublands (occasionally with mallees) and wanderrie grasses (Pastoral value mainly moderate)

Ara	ARARAK	Level to gently undulating plains with mantles of fine ironstone gravel.
Des	DESDEMONA	Extensive plains with sandy surfaces and very few surface drainage features.

Land type 13: Sandplains with spinifex hummock grasslands, acacia shrublands, heath and eucalypts (Pastoral value very low)

Blm	BULLIMORE	Extensive gently undulating sandplains locally with reticulate or parallel sand dunes (predominantly spinifex grasslands).

Land type 1 – Hills with acacia shrublands

Bevon land system (Bev) occurs along the western edge of the Reserve and consists of low hills and rises with limonitic duricrust and stony plains (about 75 hectares).

Wyarri land system (Wya) occurs towards the eastern boundary and consists of hills, domes and tor fields on granite with occasional quartz dykes (about 145 hectares).

Land type 3 – Breakaways and stony plains with mulga shrublands and minor halophytic shrublands

Sherwood land system (She) is common on Wanjarri Nature Reserve, occurring along the eastern boundary around the Bates Creek, further south around Coondie Soak, between Mount Phillipson and Mount Pasco (both on Yakabindie station) and near the western boundary west of Blue Bore. It consists of breakaways, kaolinised footslopes and extensive gently sloping plains on granite and gneiss (about 7095 hectares).

Land type 5 – Irregular plains and low rises supporting mulga, bowgoda and halophytic shrublands

Nubev land system (Nub) occurs in a very small patch near Six Mile Well and the south western entrance to the Reserve. It consists of gently undulating plains and low rises with limonite above alluvial plains with saline soils (about 10 hectares).

Waguin land system (Wag) occurs in a small area along the northern boundary, north of Bullock well. It consists of stripped surfaces, sometimes with breakaways, short lower plains and sandplain on granite. On the Reserve, Waguin consists primarily of scattered sclerophyll shrubland without breakaways and halophytic footslopes (about 35 hectares).

Land type 6 – Stony plains and lower alluvial plains with predominantly saline soils and halophytic shrublands

Gransal land system (Grs) occurs north west of Blue Bore and west of South Bore. It consists of gently undulating plains, low rises and alluvial plains on granite (supporting predominantly halophytic low shrublands) (about 1580 hectares).

Land type 8 – Stony plains and occasional low rises with acacia–eremophila shrublands

Windarra land system (Win) occurs west of South and Sawyer's Bores, north of Bullock Well and east of Bates Creek near the eastern boundary of the Reserve. It consists of level to gently undulating plains with quartz mantles on granite (about 2300 hectares).

Land type 10 – Washplains on hardpan with mulga shrublands

Jundee land system (Jun) carries sheet flows from the western boundary towards the Environment Centre. It consists of level to very gently inclined wash plains with mantles of fine ironstone gravel (supporting mulga and gidgee shrublands and woodlands) (about 1005 hectares).

Land type 11 – Wash plains and sandy tracts on hardpan, with mulga shrublands and wanderrie grasses

Monk land system (Mok) occurs north of the Environmental Centre and around Sawyer's Bore along the southern boundary. It consists of very gently inclined wash plains with occasional wanderrie banks in lower areas (about 4330 hectares).

Tiger land system (Tig) occurs around the Environment Centre and consists of very gently inclined gravelly wash plains and wanderrie banks. This pattern of bank and inter–bank system is clearly recognisable along the track immediately north of the Environment Centre (about 1555 hectares).

Yanganoo land system (Yng) occurs south of Coondie Soak and east of Sawyer's Bore along the southern boundary. It consists of wash plains with concentrated drainage zones and sandy tracts (about 1550 hectares).

Land type 12 – Plains with deep (generally > 60 cm) sandy soils supporting acacia shrublands (with occasional mallees) and wanderrie grasses

Ararak land system (Ara) occurs along the north west boundary of the Reserve and around Bullock Well. It consists of level to gently undulating plains with mantles of fine ironstone gravels in places (about 1910 hectares).

Desdemona land system (Des) occurs west of Bullock Well towards the spinifex sandplains and consists of extensive plains with sandy surfaces and very few drainage features (about 1580 hectares).

Land type 13 – Sandplains with spinifex hummock grasslands, acacia shrublands, heaths and eucalypts

Bullimore (Blm) is the most extensive land system on Wanjarri Nature Reserve, being absent only from the north west quarter of the Reserve where drainage features are most extensively developed. It consists of extensive gently undulating sandplains locally with reticulate or parallel sand ridges. Vegetation is usually dominated by *Triodia basedowii* (buck spinifex) except after fire in which a variety of seral communities may be encountered (about 30,076 hectares).

2. Land management hazards

(i) Alteration of existing surface drainage patterns

The following information refers to the new alignment suggested in this report. Along the Mount Keith boundary soils are generally sandy and surface drainage is minimal. Localised areas of more intense overland flow should be avoidable without much trouble. Drainage off the granites varies in direction locally, but is generally in a westerly or north westerly direction. The stony plains in lower parts of the granite landscape, recognisable by their topography and mantles of quartz, carry sheet flow in a generally westward direction and are initially susceptible to water starvation if surface flows are harvested rather than allowed to continue according to natural topography.

Water starvation is a considerably greater hazard along the alluvial plains with loamy soils and supporting mulga shrublands, downslope of the granite–greenstone terrain. This is particularly an issue around more concentrated drainage tracts and less so in extensive areas with deeper, sandier soils over the ubiquitous red brown ferruginosiliceous hardpan. These latter areas are characterised by sandy surfaces and the presence of wanderrie grasses, particularly *Eragrostis eriopoda* (woolly butt or wire wanderrie).

Around the Environment Centre drainage direction is towards the large claypan and hence impacts on drainage patterns are likely to be localised in this area. Care should be taken to avoid water starvation of groves of mulga surrounding the seasonally inundated claypan areas, which support *Eriachne flaccida* (claypan grass).

South of the Environment Centre soils are again sandy and surface drainage patterns are non-existent to poorly developed and hence are not generally environmentally sensitive with respect to alteration of hydrological regimes.

The sandplains and occasional dunes give way to breakaways and lower plains similar to those draining westwards off the Kilkenny–Keith fault to the north. In this instance, flows are generally parallel to the southerly direction of the pipeline. Care should be taken to prevent the pipeline turning into a water course as this will cause local water starvation and soil erosion.

(ii) Soil erosion hazards

Soil erosion hazards on the Reserve are principally confined to three major land units which are soil type/landform associations. These are sand ridges, breakaway footslopes with duplex soil profiles, and duplex soils on granite found on generally level to gently undulating plains. Localised track erosion can occur in any area receiving run on.

Sand ridges are particularly prone to soil erosion, as evidenced by the blowing out of dunes immediately adjacent to old station tracks cut through a sand ridge south east of the location of Eiffel Tower Bore. Wherever possible, the pipeline route should avoid traversing sand ridges. If this is unavoidable, the disturbed area should be brush covered to reduce surface wind velocities and concomitant erosivity. In particular, the pipeline should avoid traversing any dunes in a direction parallel to prevailing winds which are from the west to north west in winter and east to south–east in summer (Pringle *et al.* 1994).

Breakaways generally act as watersheds. Relatively concentrated episodic water flows and inherently fragile soil profiles confer on the footslopes a particularly high susceptibility to water erosion (Pringle *et al.* 1994, Curry *et al.* 1994, Pringle 1994). Wherever possible, the pipeline should avoid these areas, particularly in the area of breakaways draining southwards in the south of the Reserve. A preferred route through these breakaways would be in an area of local water shedding, where run off is generally generated rather than received.

Areas of plains on weathered granites with duplex soil profiles occur principally in the granites towards Mt. Keith in the central north of the Reserve. They also occur downslope of the breakaways as pockets of alluvium in distributary fans which receive run off from slightly higher stony plains. Although slopes are generally lesser and run on slower and more localised than on breakaway footslopes, the duplex soils on alluvial fans are nevertheless susceptible to soil erosion. This is particularly the case in the upper sectors of alluvial fans.

Rilling, gullying and microterracing are the major forms of erosion encountered on duplex soils. Where disturbance is in the direction of local drainage patterns, rills and gullies form if water is harvested along the line of disturbance. This can in turn cause micro–terracing at right angles to perpendicular to the direction of water harvesting. Where disturbance is at right angles to natural flows, microterracing can occur upslope of the line of disturbance. This is likely to exacerbate water harvesting along the line of disturbance, and cause rilling and gullying downslope if water builds up and then breaches the induced water course.

In summary, soil erosion both by wind and water, and water harvesting and subsequent water starvation are the major environmental hazards identified in this study. Water harvesting is particularly problematic in this bevelled landscape (Churchward 1977) where vegetation has evolved under conditions of episodic sheet flows. Sheet flow is particularly important in localised areas with more concentrated run on and/or fragile soil profiles. Soils other than those on sandplains are typically shallow and store nutrients disproportionately heavily near and at the soil surface. Thus soil erosion has a severe impact in these generally weathered and infertile soils (Tongway 1990).

3. Re–alignment of the proposed route

(i) Rationale

As stated previously in this report, 'landscape' rather than 'nature' conservation has been the key criterion for evaluating the proposed pipeline alignment through Wanjarri Nature Reserve.

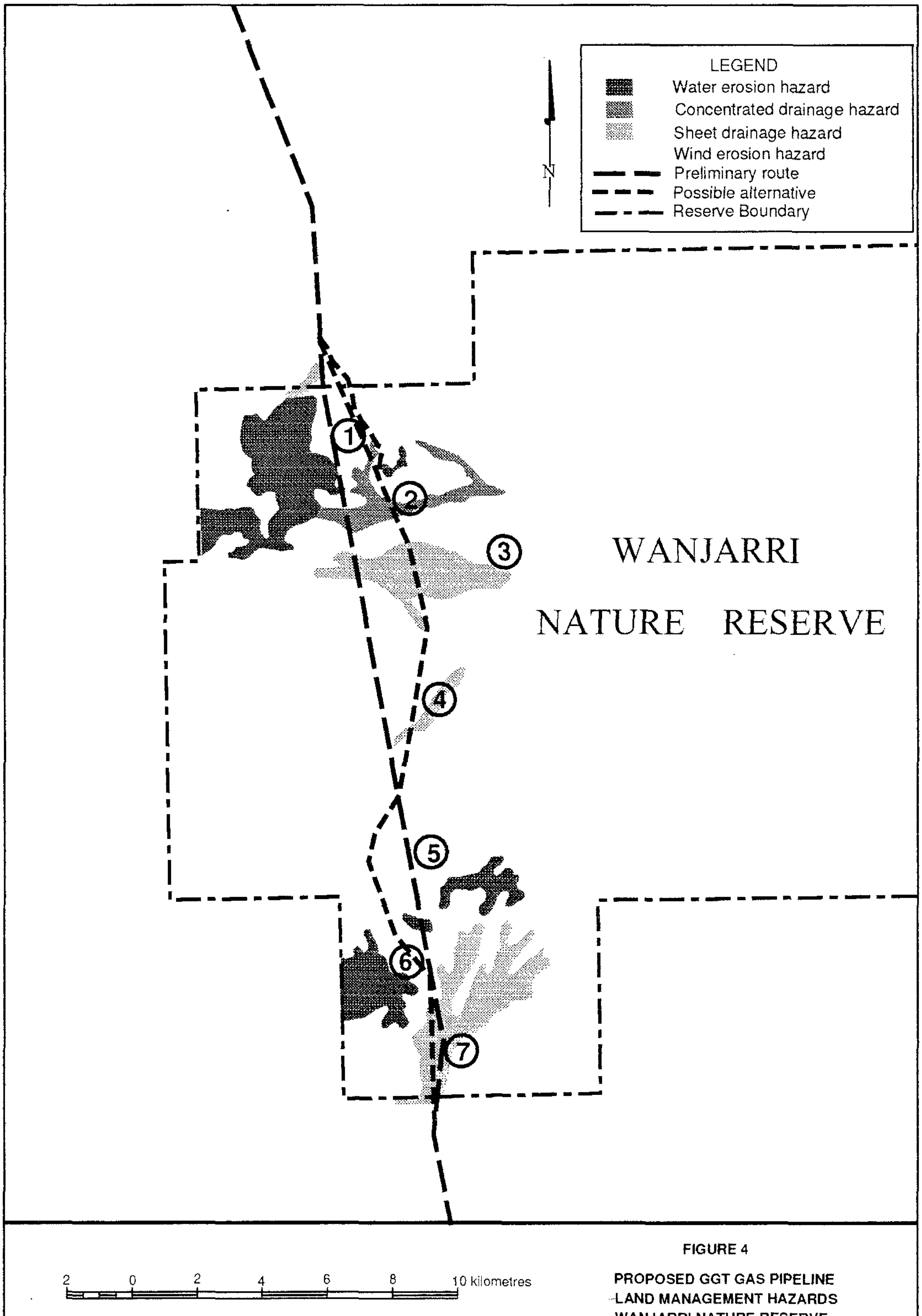


FIGURE 4

PROPOSED GGT GAS PIPELINE
LAND MANAGEMENT HAZARDS
WANJARRI NATURE RESERVE

The new alignment is generally east of the originally proposed alignment and has more deviations (Figure 4). A major advantage of the second, eastern alignment is that it is downslope of the original option. Hydrologically, this means that downslope impacts on natural water flows are more localised. Downslope the landscape becomes flatter, the soils sandier and deeper and run on more diffuse. This combination of edaphic and hydrologic factors clearly favours the eastern option in a general sense.

However, there have been trade offs in shifting the alignment eastwards. On the positive side, there is much less area of fragile duplex soils on granite traversed by the pipeline, however drainage tracts previously not affected, are now traversed.

Areas supporting mulga communities dependant on sheet flows are traversed by both alignment options. As illustrated with the sand ridge field immediately north of the breakaway system (draining southward) in the south of the Reserve, land hazards have largely been minimised or avoided by the modified route. Hazard areas along the 5 km wide corridor are discussed below within a discussion of the local environments (habitats) traversed by the revised alignment from the northern boundary of the Reserve southwards.

(ii) Habitats traversed by the revised alignment

It is suggested that the alignment enter the Reserve to the east of the fence–line followed by the original proposal so as to avoid the mulga run on community along the fence–line near the boundary fence (see Figure 4). The pipeline would enter the Reserve in Ararak land system, which has sandy soils and carries diffuse run on. Impacts along this stretch should be minimal and the clearing of sparse trees may be avoidable.

Windarra land system is traversed next (as opposed to the more fragile Gransal land system in the previous alignment). Key Area (1) (see Figure 4) is a mulga drainage line. As the alignment traverses this drainage feature relatively high in the landscape, the upslope catchment area is small and impacts should be manageable with careful management. An option of weaving between this drainage line and a smaller one to the east is offered for consideration. The pipeline alignment avoids substantial areas of fragile duplex soils through this stretch of granite country.

Key Area (2) is of concern as the revised alignment pipeline traverses a concentrated drainage tract north west of Bullock Well (derelict). This is unavoidable if the alignment is to follow the eastern option within the 5 kilometre investigation corridor defined for the project. The main concern is that the alignment traverses the drainage tract at right angles to the direction of flow (eastward) and could cause water harvesting and subsequent flow along the alignment and subsequent starvation of mulga communities downslope. Clearly, a substantial amount of mulga will need to be cleared, although this should be kept to a minimum over this relatively short stretch of less than 0.5 km of the alignment. To maintain the natural surface drainage pattern, the land affected will need to be levelled to the original surface and perhaps compacted although this may retard the natural regeneration of shrubs and trees. Particular care should be taken to prevent the access track becoming a new water course. Vehicular traffic should be kept to a minimum and the track rehabilitated after construction. Access along the pipeline from the track running approximately east–west to Bullock Well should be discouraged particularly along this section of the proposed alignment.

South of the drainage tract discussed above, the revised alignment traverses some sandy country supporting wanderrie grasses and subject to diffuse run on. Impacts along this stretch should be manageable. Shallow ripping of compacted surfaces may facilitate rehabilitation.

Key Area (3) consists of a scattered mulga sheet flow area, receiving run on from two more concentrated drainage tracts to the west, which gradually become more diffuse as they grade into sandplain to the east. As with Key Area (2), water starvation of mulga communities downslope is the key concern. Although a much longer stretch than that traversing Key Area

(2), water flows are likely to be more diffuse and hence more easily managed. Again, restoration of the natural topography will both maintain sheet flows and avoid turning the alignment into a new water course. Vegetation growing in this area is poorly defined and certainly not in arcuate bands along the contour of the land. This should make water flow management simpler.

The revised alignment next traverses a stretch of Bullimore land system with deep sandy soils. With almost no surface drainage, the only foreseeable land management hazard is minor wind erosion. As the proposed alignment is generally north–south and not in the direction of prevailing winds, this hazard should prove to be insignificant. Shallow ripping of compacted areas may facilitate natural regeneration of volunteer species. The role of fire in accelerating this process may also warrant consideration, but will require care to ensure fires do not get out of control.

Key Area (4) is similar to Key Area (3) but considerably narrower and should be managed similarly to minimise alteration of surface flows. South of this is an area of sandy country supporting perennial grasses and scattered shrubs and trees which receives very diffuse run on. As with Ararak land system, compacted areas might benefit from light ripping, and impacts should be manageable.

An alternative alignment even further to the east beyond the 5 kilometre corridor would take the pipeline further downslope toward the sandplain in Key Area (3) and avoid most of the mulga sheet flow areas to the south (including Key Area (4). Given the generally diffuse nature of run on, and the predominantly deep (> 60 cm), sandy soil along the alignment discussed, this may not be necessary, but would take the impact further away from the Environment Centre. Both new suggested alignments are further from the Environment Centre than the original proposal, and this will maintain visual amenity values in that vicinity.

The new suggested alignment is diverted south westward from the track running westward into the Environment Centre to avoid disturbance to sand ridges. Sand ridge fields and clearly defined ridges are mapped in Figure 1. Wherever possible, the alignment should avoid these areas (e.g. Key Area (5)) as the sand ridges are susceptible to wind erosion when disturbed, as evidenced elsewhere on the Reserve where old station access tracks have been located through them. If unavoidable, the sides of disturbed ridges should be brush covered to reduce wind surface velocities and increase seed entrapment.

The new proposed alignment follows the sandplain as far as possible into the granite breakaway country to the south, and avoids areas with fragile soils (such as breakaway footslopes) and drainage features (Key Area (6)). The area traversed is an interfluve with minimal catchment area and impacts should be manageable. As with Key Area (1), where originally existing stone mantles should be restored to the surface to help maintain soil stability.

The suggested alignment traverses Key Area (7) on its way out of the Reserve. This area is similar to other mulga drainage tracts discussed previously. However, in this instance the alignment is approximately in the direction of flow (south south westwards). The main concern is that the impacted area should not be allowed to become a water course, and that flows not quite parallel to the alignment be allowed to traverse it without being diverted.

4. Environmental monitoring

Apart from a system of monitoring sites along the impacted area to follow regeneration, some additional monitoring in land management hazard areas may be warranted. Monitoring of the impacted area may be stratified according to the major habitats described above. Wherever possible, monitoring sites should be located near existing or proposed access routes to minimise the traffic along the alignment. Not only can natural regeneration be monitored; the emergence of undesirable (introduced) plant species can also be detected by monitoring. The dissipation of drainage features into sandplains to the east over much of the proposed alignment will help localise infestations of most common introduced species as they generally do not establish well in spinifex sandplains. This is as a consequence of infertile soils and lack of run on.

It is important to install monitoring sites in land management hazard areas prior to installation of the pipeline and associated disturbances. This will allow direct measurement of impact. In Key Areas (2), (3), (4) and (7), monitoring sites should preferably be installed both upslope and downslope of the alignment. This will provide useful comparative information as well as monitoring potential rill erosion downslope and sheet erosion (including microterracing) upslope. Should resources for monitoring be limited, key areas (2), (3) and (7) should be given priority, assuming sand ridges and substantial areas with fragile duplex soils will not be traversed.

The proponents may wish to develop their own monitoring systems, or they could adopt the Western Australian Rangeland Monitoring System (Holm *et al.* 1987) developed by the Department of Agriculture, Western Australia. This system focuses on perennial plant and soil health dynamics. Conceivably, the proponents may wish to address other attributes as well; ephemeral flora, soil flora and vertebrate and invertebrate fauna. In particular, there may be justification to monitor the return of the more sedentary fauna, which it is expected will be temporarily displaced during construction (Dames and Moore unpublished).

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References

Christian, C.S. and Stewart, G.A. (1953). Summary of general report on survey of Katherine–Darwin Region 1946. *Land Research Series 1,* p. 24, CSIRO.

Christian, C.S. and Stewart, G.A. (1968). Methodology of integrated survey. Aerial Surveys and Integrated Studies, UNESCO, Paris, p. 233–280.

Churchward, H.M. (1977). Soils, landforms and regolith of the sandstone. Mt. Keitha area of Western Australia. Land Resources Management Series No. 2 CSIRO.

Curry, P.J., Payne, A.L., Leighton, K.L., Hennig, P. and Blood, D.A. (1994). A range condition and inventory survey of the Murchison River catchment. Western Australian Technical Bulletin No. 84 Dept. Agric. West. Aust.

Dames and Moore (unpublished) Public Environmental Review of the proposed Goldfields Gas Pipeline.

Holm, A. McR., Burnside, D.G. and Mitchell, A.A. (1987). The development of a system for monitoring trend in range condition in the arid shrublands of Western Australia. *Australian Rangeland Journal* **9(1)**: 14–20.

Pringle, H.J.R. (1993). Nature conservation and pastoralism in the North–Eastern Goldfields – a case study. Proceedings of Green and Gold – Goldfields International Conference arid landcare, held in Kalgoorlie, Western Australia.

Pringle, H.J.R., Van Vreeswyk, A.M.E. and Gilligan, S.A. (1994). An inventory and condition survey of rangelands in the North–Eastern Goldfields, Western Australia. Western Australian Department of Agriculture, Technical Bulletin No. 87.

Pringle, H.J.R. (1994). Pastoral resources and their management in the north–eastern Goldfields, Western Australia. Department of Agriculture Miscellaneous Publication No. 22/94.

Tongway, D.J. (1990). Soil and landscape processes in the restoration of rangelands. *Australian Rangeland Journal* **12(1)**: 54–57.

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	TITLE	AUTHOR
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	TITLE	AUTHOR
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	TITLE	AUTHOR
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	TITLE	AUTHOR
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	TITLE	AUTHOR
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RESOURCE MANAGEMENT TECHNICAL REPORTS, ISSN 1039-7205

138.	THE ROLE OF TREES IN SUSTAINABLE AGRICULTURE, A NATIONAL CONFERENCE, REPRINTS OF WESTERN AUSTRALIAN PAPERS	P.R. SCOTT
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