R-RP-EN-1097

2016 State of the Environment Report Rail Operations

Final Report (ref. R-RP-EN-1097)

Prepared for

Fortescue Metals Group

Prepared by

Equinox Environmental Pty Ltd

13 March 2017

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Revision Schedule

Rev. No.	Date	Description	Prepared by	Checked by	Approved by
1	08/12/2016	Client Draft	D.Huxtable	F.Huxtable	D.Huxtable
2	13/02/2017	Final Draft	D.Huxtable	F.Huxtable	D.Huxtable
3	13/03/2017	Final Report	D.Huxtable	D.Huxtable	D.Huxtable

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Executive Summary

Fortescue Metals Group Limited (Fortescue) owns and operates a large-scale iron ore supply chain in the Pilbara region of Western Australia. This report provides an assessment of the impact of Fortescue's heavy rail network on the surrounding environment (the study area), based on baseline environmental surveys and environmental monitoring. The rail network includes approximately 430 linear km of heavy rail infrastructure (comprising 650 km of actual track) including:

- the 'Mainline' which is 297 km long and runs north-south from Port Hedland to Christmas Creek Mine Site between the Chichester Hub and the Port
- the 'Hamersley line' (Solomon line) which is 129 km long and runs east-west from the Mainline at approximately 175 km south of Port Hedland and connects with the Solomon Hub (≈total length 304 km)

Scope of Rail Operations monitoring program

Fortescue's Rail Operations environmental monitoring program has been developed to meet regulatory requirements prescribed in Ministerial Statements 690, 1033 (formerly 707) and 862 and Commonwealth EPBC Act approval decisions 2010/5513 and 2010/5567. This includes collecting information to test the following hypothesis:

'The Fortescue railway construction and operations are not causing any measurable impacts on the surrounding health of the ecosystem, based on predicted environmental outcomes as detailed in the relevant PER document'

The program addresses the following environmental factors:

- Conservation significant fauna,
- Mulga vegetation communities,
- Riparian vegetation communities,
- Surface water,
- Weeds, and
- Rehabilitation of disturbed areas.

Key findings from historical studies and monitoring data collected in the period 2005 to 2016 are summarised as follows.

Conservation significant fauna

Fortescue's heavy rail network intersects habitat used by the Greater Bilby, Northern Quoll and a number of bird species listed under the Commonwealth *Environment and Biodiversity Conservation Act 1999* (EPBC Act) and the *Wildlife Conservation Act 1950* (WC Act).

Greater Bilby populations are persisting in close proximity to Fortescue's heavy rail network. Much of the area occupied by these mammals has not experienced wildfires for 10 or more years. It appears that natural watercourses, rail and road infrastructure are functioning as firebreaks, thereby helping to protect Greater Bilby habitat.

Northern Quoll populations are also persisting in proximity to Fortescue's heavy rail network. The findings of the monitoring program suggests that the rail line is not affecting the ability of Northern Quolls to move across the landscape as they have been recorded using railway culverts at multiple locations. Similar findings apply to the Brush-tailed Mulgara, which was formerly monitored over the period 2012 to 2015 prior to this species being confirmed as not listed under the EPBC Act.

Conservation significant bird species recorded in the study area are highly mobile and wide ranging. The findings of the monitoring program are consistent with the Fortescue heavy rail network having a negligible effect on dispersal and other behaviours of these species.

Overall, there is no evidence to suggest that the Fortescue rail is impacting negatively on the local populations of conservation significant fauna and their habitats.

Mulga Vegetation

Fortescue's heavy rail network traverses several areas of groved mulga vegetation communities associated with the Jurrawarrina and Jamindie land systems. Monitoring transects have been established to evaluate the effect of the rail infrastructure on surface water regimes and vegetation health.

Consistent trends have been observed across all Mulga monitoring transects, with no significant change of Mulga community health within transects or discernible differences between reference and impact zones. Observed community-level responses are consistent with the functional behaviour of rain fed vegetation subject to cycles of moisture deficit.

Overall there is no evidence to suggest that Fortescue's heavy rail network has affected the health of the mulga vegetation communities during the period of monitoring.

Riparian vegetation

Photopoint monitoring of riparian vegetation has been undertaken biannually at seven major creek crossings along the Mainline since 2008. Additional monitoring using Normalised Difference Vegetation Index (NDVI) has been undertaken annually since 2012, supported by a ground validation survey in 2015 as well as a trial transect monitoring study at three major creek crossings.

Normalised Difference Vegetation Index (NDVI) metrics indicate no significant differences between riparian vegetation in upstream and downstream locations at all major drainages crossed by the heavy rail network. Fixed photo point monitoring also supports a finding of stable vegetation health over time.

On-ground tree health assessment transects established in 2015 validated the historical findings from the NDVI assessments, and further demonstrated that vegetation health was relatively good at all sites with no significant differences between upstream downstream locations.

Overall, the condition of riparian vegetation proximal to Fortescue's heavy rail network has not materially changed during the period of monitoring. These communities are in a healthy and stable condition.

Surface water

In September/October 2014, Fortescue installed a network of permanent surface water monitoring equipment in drainages and sheetflow areas traversed by Fortescue's heavy rail network. This includes:

1. stormwater water quality samplers;
2. peak level indicators;
3. water level loggers;
4. barometric loggers and;
5. rainfall stations.

Items (1) to (3) are configured in a nested design at locations upstream and downstream of the rail line and at bridge/culvert crossings. This hydrological monitoring network has been designed to collect information on the following aspects of the surface water regime:

- Single and multiple event water quality;
- Continuous water level;
- Single event peak water level; and
- Continuous rainfall.

Only a limited set of water quality data was available for inclusion in this 2016 State of the Environment report; however this data indicates that water quality is consistent with that of ephemeral creek systems of the Pilbara more generally. In combination with vegetation monitoring data, there is no evidence to suggest that Fortescue's heavy rail network has affected water quality or contributed to erosion, sedimentation and/or flooding near drainage crossing points or in sheetflow areas.

Weeds

Weeds have been monitored on a biennial basis, since 2012 along the Hamersley line and along the Mainline since 2014. Weed monitoring is undertaken at multiple sites both distant to, and proximal to the rail line.

Three weed species have been recorded on the Mainline plots and thirteen weed species have been recorded on the Hamersley plots. **Cenchrus ciliaris* was the most commonly recorded species.

In general, across all sites weed density and cover has not significantly changed over time. However, **Cenchrus ciliaris* cover increased slightly at seven Hamersley line sites during the 2012 to 2014 period where it was first recorded in 2012 (including 3 impact and 4 reference sites). This species was also newly recorded at two impact sites in 2014 and one additional impact site in 2016 in comparison with 2012. In contrast, at Mainline sites **Cenchrus ciliaris* cover did not materially change in the 2014 to 2016 period and at one impact site (site 20) was not recorded in 2016 despite being recorded in 2014.

Native vegetation condition was recorded at the Mainline and Hamersley line sites in 2014 and 2016[1], with no material change in vegetation condition over this time frame observed. The vegetation condition at all sites ranged from good to excellent.

Overall, weed burdens appear to be stable at most sites and general patterns of weed behaviour are similar in reference and impact areas. It is likely that prolonged hot and dry conditions since mid-2014 have limited the rate of weed species expansion in reference and impact areas, and in some cases contributed to weed species decline. When compared against the reference sites in the surrounding landscape, there is no evidence to suggest that Fortescue's heavy rail network has materially contributed to the introduction and/or spread of weeds.

Rehabilitation

During the construction of Fortescue's heavy rail network a variety of temporary disturbance areas were created including borrow pits, overburden stockpiles, access tracks and lay-down areas. As these areas have become operationally redundant, Fortescue has implemented a program of progressive rehabilitation since 2008 along the Mainline and 2012 along the Hamersley Line including revegetation with local native species. Fortescue has developed a structured methodology for evaluating rehabilitation efficacy in these areas.

Rehabilitation areas that have been progressively rehabilitated, exhibit broadly similar landscape function, vegetation density/cover and land surface stability indices relative to adjacent native vegetation reference areas. The results suggest a generally favourable rehabilitation trajectory. Vegetation establishment on rehabilitation areas may have benefited from the relatively wet period which occurred between 2012 and 2014. A decline in some Landscape Function Analysis (LFA) and vegetation cover indices since 2014 at control and rehabilitation site respectively correlates with prolonged dry conditions since about mid-2014.

Overall the rehabilitation metrics indicate that the majority of rehabilitated areas are tracking favourably to meet Fortescue's rehabilitation criteria. Drought conditions experienced in 2016 provide an important test of the resilience of vegetation communities on rehabilitated areas prior to the next monitoring event.

[1] As per the method of EPA and DPaW (2015)

Overall findings

Fortescue's Rail Operations monitoring program has included:

- Comprehensive spatial coverage of the study area including impact and reference sites,
- Frequent measurements (typically annually or biennially), and
- Consultation with regulatory agencies regarding the design of the monitoring program (in particular DPaW).

The monitoring program is considered to provide a sufficient basis for detecting change and time series trends in the environmental factors targeted by the program.

Overall, the findings of the monitoring program indicate that Fortescue's heavy rail network is not causing any significant impacts to general ecosystem health in surrounding areas. Conservation significant fauna (i.e. Greater Bilby, Northern Quoll and Conservation Significant Birds) are persisting in proximity to the heavy rail network. There is no evidence of significant indirect impacts to habitat used by these species; conversely the rail line may be contributing to the protection of habitat by providing a landscape scale firebreak. There is no evidence to suggest that the rail line is impeding fauna movement within the landscape. Adjunct monitoring data targeting Brush-tailed Mulgara collected in the period 2012-2015 is also consistent with these findings.

In broad terms the native vegetation in the landscapes surrounding the rail line has remained in good to excellent condition. There is no evidence to suggest that the health and integrity of mulga and riparian vegetation has been impacted by the heavy rail network. A number of weed species have been documented to occur in the study area, however there is no evidence to suggest that weed burdens have significantly increased as a consequence of the construction and operation of the heavy rail infrastructure. Climatic drivers appear to have had the greatest influence on vegetation dynamics across the study area.

Due to the paucity of flows in ephemeral drainages intersected by the heavy rail network, only limited surface water monitoring data has been collected to date. However, the available water quality data suggests that no significant impact on surface water quality arising from the construction and operation of the heavy rail network have occurred.

Native vegetation has successfully been re-established in disturbed areas that have been rehabilitated. The majority of rehabilitated areas are on a favourable trajectory for meeting targets for vegetation structure and function.

Recommendations

Key recommendations for applying the findings of the assessment to future monitoring and adaptive environmental management more generally include:

- Develop a Greater Bilby conservation Fire Management Plan for the approximately 50 km portion of the Macroy Land system where populations are persisting adjacent to Fortescue's Mainline.
- Undertake a risk assessment of the potential for Fortescue's Mainline to provide a vector for feral predator dispersal inland from the coastal plain; for example by contributing to more persistent drinking water availability. The potential for fox dispersal inland is of particular interest, given the potentially catastrophic impact of this species on Greater Bilby populations. Update the Conservation Significant Fauna Management Plan (100-PL-EN-0022) based on the findings of this risk assessment.
- Maintain timely, ongoing targeted monitoring of known Greater Bilby populations. Continue to align with DPaW Greater Bilby monitoring and research activities (e.g. genetic analysis of populations; regional scale meta-analysis) where this is consistent with the Rail Operations monitoring program objectives;
- Continue to align with DPaW Northern Quoll monitoring and research activities (e.g. genetic analysis of populations; regional scale meta-analysis) where this is consistent with the Rail Operations monitoring program objectives;
- Incorporate individual Mulga tree stem diameter measurements into the Mulga monitoring program and utilise this with ongoing photograph monitoring of individual trees. This will enable long term growth responses to environmental variables (in particular water availability) to be evaluated;
- Continue riparian vegetation monitoring using NDVI methods, complemented by periodic ground truthing to assist with results interpretation. It is recommended that the frequency of on-ground monitoring is aligned with Fortescue's mulga monitoring methodology as per the *Significant Flora and Vegetation Management Plan* (45-PL-EN-

0017). Include assessment of erosion in riparian areas as part of on-ground assessment, to complement surface water flow and water quality data sets;

- Continue to monitor surface water as per Fortescue's Surface Water Management Plan (100-PL-EN-1015);
- Continue to monitor weeds on a biennial basis as per Fortescue's Weed Management Plan (100-PL-EN-1017);
- Finalise rehabilitation completion criteria for Fortescue's heavy rail network, and review and update the Rehabilitation and Revegetation Monitoring Procedure (45-PR-EN-0027) to provide an efficient basis for confirming when these criteria have been achieved. It is anticipated that this task will involve consultation with regulatory agencies and relevant land managers/custodians;
- Improve data collation and management practices across all programs. As part of this review, a number of inconsistencies in plot identifiers were identified between monitoring events. Establish a generic site ID coding system for environmental datasets; and
- In connection with improved data collation, use simple visual tools, building on those developed as part of this study (refer to Appendices 6 - 9) to aid in data interpretation and inform the selection of quantitative methods for future data analysis.

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1 Introduction

Fortescue Metals Group Limited (Fortescue) owns and operates a large-scale iron ore supply chain in the Pilbara region of Western Australia comprising:

- mines in the Chichester Range (the Chichester Hub[2]);
- mines in the northern Hamersley Range (the Solomon Hub[3]);
- approximately 430 linear km of heavy rail infrastructure (comprising 650 km of actual track) including:
    - the 'Mainline' that runs between the Chichester Hub and the Port (297 km);
    - the 'Hamersley line' that spurs to the west from the Mainline at approximately 175 km south of Port Hedland and connects with the Solomon Hub (129 km)
- the Herb Elliott Port (the Port) at Anderson Point, Port Hedland.

This report provides an assessment of the impact of Fortescue's 'Mainline' and 'Hamersley line', herein referred to as Fortescue's heavy rail infrastructure/network, on the surrounding environment based on baseline environmental surveys and monitoring along the rail.

1.1 Scope and objectives

Equinox Environmental Pty Ltd (Equinox) was commissioned by Fortescue to complete a desktop review of Fortescue's historic baseline data and monitoring results collected during the construction and operation of the Fortescue's heavy rail network.

The scope-of-work (Fortescue Ref. R-SW-EN-0016) included:

1. Collate and summarise environmental data and monitoring results collected between 2005 and 2015 associated with the following environmental factors:
    a. Rare fauna (Greater Bilby, Mulgara, Northern Quoll and Conservation Significant Birds),

[2] Including the Cloudbreak and Christmas Creek mines.
[3] Including the Firetail and Kings mines.

   b. Native vegetation (mulga, riparian vegetation, and weeds),
   c. Surface water flow and quality,
   d. Compile the data into a Rail Operations Master Database (MS Excel format) including summary statistics, data tables and figures.

2. Identify trends and correlations within/between factor specific monitoring programs.

3. Based on the findings of (1) and (2), provide a scientific assessment of the extent of environmental impacts (if any) caused by construction and/or operation of the Fortescue Rail. This task will address the hypothesis '*The Fortescue railway construction and operations are not causing any measurable impacts on the surrounding health of the ecosystem, based on predicted environmental outcomes as detailed in the relevant PER document*' and include the following sub-tasks:
   a. A review of predicted environmental outcomes as detailed in the relevant PER documentation.
   b. Refinement of conceptual models of potential environmental impacts on Item (1) factors (a) to (c) listed above, based on current knowledge.
   c. Evaluation of the hypothesis based on findings of the data analysis as per (2).
   d. Based on the outcomes of (3), evaluate the adequacy of the existing monitoring program for detection of impacts on environmental factors (as per Item 1 factors (a) to (c) listed above).
   e. Identify opportunities to improve the efficiency and effectiveness of the Rail Operations monitoring program.

This report provides a summary of the environmental data and monitoring results collected between 2005 and 2015 for relevant environmental factors, identified trends and correlations within/between factor specific monitoring programs, and an assessment of the extent of environmental impacts (if any) caused by construction and/or operation of the Fortescue Rail.

2 Environmental setting

The location of Fortescue's Pilbara operations is shown in Figure 1. A summary of the major environmental features of the landscape traversed by Fortescues heavy rail network (hereafter referred to as the 'study area') follows. More detailed information is contained in environmental impact assessment (EIA) documentation prepared by Fortescue for the various components of the company's overall supply chain (Fortescue 2004, 2005, 2010, 2011, 2015).

2.1 Climate

The climate of the Pilbara is classified as hot and arid. The region experiences a climate of extremes, where severe droughts and major floods can occur at close intervals. Annual potential evaporation exceeds annual rainfall by an order of magnitude, resulting in a large moisture deficit in the environment which exerts a profound influence on vegetation and fauna (McKenzie et al. 2009).

Mean annual rainfall varies from 250 to 400 mm/year across the study area. Rainfall patterns are strongly influenced by tropical cyclones. Roughly 70% of annual precipitation falls in summer and early autumn (December to March); however inter-annual rainfall may vary considerably (Charles et al. 2015). Rainfall events tend to be of high-intensity and short-duration, resulting in surface water runoff and transient flooding of drainages that are interspersed with long dry periods.

A summary of recent patterns of rainfall at selected locations along Fortescue's rail network is provided in Appendix 1; based on Data Drill gridded data at 0.05° resolution obtained from the SILO dataset[4]. There is a progressive reduction in annual rainfall moving north from the junction of the Mainline and Hamersley line, with rainfall near Port Hedland roughly 70% of that received near Fortescue's mining areas. This difference is most pronounced during late spring to mid-summer suggesting a spatially variable cyclonic influence. In the period mid-2015 to December 2016 relatively little rainfall was been received particularly near the coast. Other notable dry phases since 2000 include 2005 and the 2009 to 2010 period.

[4] The SILO dataset is a comprehensive archive of Australian rainfall and climate data constructed from ground-based observational data (Jeffrey et al., 2001). Refer to (http://www.longpaddock.qld.gov.au/silo/).

High temperatures are experienced from November to February, with mean monthly maximum temperatures often over 40°C and average maximum winter temperatures falling to approximately 25°C. Mean minimum daily temperatures may exceed 25°C during the summer months and decline to less than 10°C in the winter months. Temperature ranges are generally greater in inland areas away from the moderating effects of onshore winds common in coastal areas (Appendix 1).

In broad terms the period 1995-present has been wetter than the long-term average, with palaeoclimatic evidence suggesting it has been one of the wettest periods in the past millennium (Rouillard et al. 2016). The consecutive seasons of 1998/99 and 1999/00 in particular saw the highest rainfall totals on record and were characterised by a high frequency of tropical cyclones. This sustained period of higher rainfall has influenced the water regime, contributing to higher groundwater levels and more-frequent flooding of ephemeral drainages and wetlands. It is unclear if this trend will be sustained; climate change projections indicate that the Pilbara may become slightly drier by 2030 and 2050 although wetter projections cannot be discounted (Charles et al. 2015).

2.2 Hydrology

The study area is crossed by several rivers in the Port Hedland Coast Drainage Basin including the Turner River, Yule River and associated tributaries (Figure 2). These drainages arise from the Chichester Range (up to 550 mAHD) before flowing across the Granite Greenstone Terrane Hydrogeological Province and discharging onto a coastal plain and then into the Indian Ocean. Streamflows are mostly a direct response to cyclonic and monsoonal rainfall and are therefore highly seasonal and variable, depending on which catchments receive rainfall (DoW 2014).

Significant creek crossings associated with the Mainline (from north to south) include South West Creek, East Turner River, Chinnamon Creek, Gillam Creek, Turner River, Coorong Creek, Yule River, Coonarie Creek and Western Shaw River. Significant creek crossing associated with the Hamersley Line (from west to east) include several tributaries of the Fortescue River South branch, Joffre Creek, Fortescue River and Cockeraga River (Figure 2).

There is little information on streamflows in the major creek systems. Time series data is available from two gauge stations operated by the Department of Water (Figure 2):

- Turner River-Pincunah located 23 km upstream of the Fortescue rail crossing (DoW ID 709010; records since 1985);
- Yule River located 128 km downstream of the Fortescue rail crossing (DoW ID 709005; records since 1973).

A summary of the station records is provided in Appendix 2. Multiple flow events typically occur in most years, predominantly in the January to June period. However prolonged no-flow periods (i.e. exceeding 12 months) have been recorded at both stations (e.g. in the early 1990s).

There is little information regarding water quality on the river systems of the study area. Across the Pilbara region more generally surface water is typically fresh (TDS <1,000 mg/L), although poor reliability of river flow, high evaporation, and turbidity may contribute to variable quality (DoW 2014). Much of the study area supports pastoral beef cattle production and riparian areas, which are more productive than the surrounding landscape, are prone to erosion and eutrophication by concentrated cattle activity (Norris et al. 2005).

2.3 Land systems

The Pilbara region includes over one hundred land systems classified on the basis of landform, geology, geomorphology, soils and vegetation (Van Vreeswyk et al. 2004). These provide useful information about key landscape elements and processes. In addition, land system attributes often correlate with vegetation types and habitat of conservation interest.

The majority of Fortescue's heavy rail network is contained within 21 land systems, extending from the foothills of the Chichester Range to the coastal plain near Port Hedland (Figure 3). Key geomorphic and vegetation attributes of these are further described in Appendix 3. Many of these land systems comprise uplands or broad plains dominated by hummock grasslands with scattered shrubs and trees. The major vegetation types are regionally well represented and subsist on rainfall and locally redistributed runoff. Apart from contributing to regional catchment area, these land systems have a low level of hydrological connectivity with surrounding areas and are not vulnerable to indirect hydrological impacts from rail infrastructure.

Several land systems are of conservation interest owing to their greater level of hydrological connectivity with surrounding landscapes, functional importance for landscape scale ecological processes and uncommon/restricted distribution flora and fauna. These include:

- River Land System - comprising the channels and associated floodplains of major drainages. These areas support forest and woodlands dominated by *Eucalyptus camaldulensis* subsp. *refulgens* and *E. victrix*, and where soil moisture is more abundant and persistent *Melaleuca argentea*. Flow events are important for replenishing moisture in deep alluvial sediments and persistent pools, and for contributing to focused groundwater recharge. In some areas shallow groundwater systems support groundwater dependent ecosystems.
- Coolibah Land System – comprising alluvial flats of the lower Fortescue River supporting woodlands of *E. victrix* and mulga with a tussock grass understorey. Periodic flooding is important for replenishing soil moisture that is progressively depleted during subsequent dry phases.
- Jamindie Land System – stony plains commonly underlain by hardpans, including groved mulga shrublands/woodlands occasionally with a spinifex understorey. This land system is extensive between the Fortescue Marsh and the base of the Chichester Range. Sheetflow is considered to be an important mechanism for sustaining the groved mulga communities, by augmenting rainfall (i.e. soil water replenishment) and importing sediment and nutrients.
- Jurrawarrina Land System - Plains flanking the lower Fortescue River Valley receiving overland sheetflow and characterised by groved mulga shrublands/woodlands. Sheetflow is considered to be an important mechanism for sustaining the mulga communities, by augmenting rainfall (i.e. soil water replenishment) and importing sediment and nutrients.

By virtue of their connectedness with landscape-scale surface water redistribution processes, the biotic elements of these land systems are potentially vulnerable to indirect hydrological impacts from rail infrastructure. Groved mulga formations in the Jamindie and Jurrawarrina land systems have been targeted by Fortescue for the assessment of hydrological disturbance caused by rail infrastructure. Riparian vegetation has also been targeted near intersections of the Mainline and major rivers north of the Mainline and Hamersley line junction.

The Wona Land System has recognised conservation values, owing to the occurrence of several unusual tussock grass and herb vegetation communities within this land system i.e. 'the Four plant assemblages of the Wona Land System' Priority Ecological Community (DPaW 2016). These occur on basaltic upland gilgai plains and by virtue of their landscape context are considered to subsist on rainfall and locally redistributed runoff. As such these communities are not vulnerable to indirect hydrological impacts from rail infrastructure.

2.4 Vegetation

McKenzie et al. (2009) provide a synthesis of the broad patterns of vegetation in the study area, which complements the land system descriptions of van Vreeswyk et al. (2004). Relevant findings are summarised below:

- Along the southern escarpment of the Chichester Range, short, parallel drainages empty onto the alluvial plains of the Fortescue Valley. Open woodlands of mulga (*Acacia aneura* and its close relatives), shrublands of snakewood (*A. xiphophylla*) and hard hummock grasslands with emergent Hamersley bloodwoods (*Corymbia hamersleyana*, *C. semiclara*) or Snappy Gums (*Eucalyptus leucophloia*) occupy these slopes.
- Protrusions of the Chichester Range into the Fortescue Valley support *Acacia* low shrubland (*A. trachycarpa*, *A. arrecta*) over hummock grasses.
- Hardpan plains between the Chichester Range and the Fortescue Marsh support open mulga woodland and snakewood shrubland over tussock grasses (*Themeda triandra*, *Chrysopogon fallax*, *Eragrostis* spp.) or open hummock grasses (*Triodia pungens*, *T. wiseana*).
- Moving north, tablelands of eroding basalt are a distinguishing feature of the southern Chichester Plateau. These tablelands constitute the Wona Land System and include gilgai plains or self-mulching cracking clays supporting tussock grasslands dominated by Mitchell grass (*Astrebla* spp.), sorghum (*Sorghum* spp.) and Roebourne Plain grass (*Eragrostis xerophila*) and/or herbfields of ephemeral Papilionaceae (*Desmodium* spp., *Glycine* spp., *Rhynchosia* spp.), and Amaranthaceae (*Ptilotus* spp.).
- An extensive zone of granitic and greenstone terrain separates the aforementioned areas from the coastal plain near Port Hedland (e.g. Macroy Land System). Throughout this zone, rolling stony and sandy plains and gently undulating hills

support a shrubland characterised by wattles, in particular *Acacia inaequilatera*, *A. ancistrocarpa*, *A. tumida* var. *pilbarensis* and *A. orthocarpa/arida*, over hard spinifex (*T. wiseana, T. lanigera*, *T. secunda*) hummock grassland. Scattered snappy gums over open *Acacia* shrublands occur ubiquitously on uplands and ranges.

- Drainage floors associated with the major river systems (e.g. Yule, Turner) support fringing riparian woodlands or forests including Silver Cadjeput (*Melaleuca argentea*), River Red Gum (*Eucalyptus camaldulensis* subsp. *refulgens*), Western Coolibah (*E. victrix*) and *Acacia coriacea*. Their understorey is dominated by introduced tussock grasses (e.g. **Cenchrus* spp., **Echinochloa colona*) in many areas.
- Moving towards the coast, alluvial and aeolian coastal sub-coastal plains comprise a mixture of sandy to heavy clay substrates. Where the rail line crosses the coastal plain (the Uaroo and Mallina land systems) the vegetation is dominated by hard (*T. lanigera*) and soft (*T. pungens*, *T.epactia, T. schinzii*) spinifex with scattered *Acacia* shrubs (*A. stellaticeps, A. inaequilatera, A. tumida, A. ancistrocarpa*).

Much of the vegetation of the Pilbara is adapted to prolonged conditions of water deficit, either through drought tolerance (deep root systems) or drought avoidance (e.g. pseudo-dormancy, ephemeral life histories) strategies. Some riparian and valley floor vegetation types are considered to rely on stored soil water deriving from infrequent flooding.

Fire is also a key environmental factor affecting Pilbara vegetation communities. In broad terms Spinifex (*Triodia* spp.) grasslands are highly flammable and prone to regular burning, typically at intervals of up to a decade (Myers *et al*. 2004). Periods of above-average rainfall are associated with increased fuel loads and propensity for landscape scale fires. Some *Acacia* shrublands (e.g. mulga) are vulnerable to floristic and structural alteration caused by regular fires (Ward et al. 2014).

Over 100 weed species are known from Pilbara landscapes (Keighery 2010). Most originated in tropical Africa, America or Asia and were introduced intentionally as garden, amenity or fodder plants post European settlement. Fourteen species affect the region at a landscape scale by altering fire patterns, modifying soil characteristics or competing directly with native species. The most significant of these is Buffel Grass (**Cenchrus ciliaris*), a highly invasive perennial grass that occurs extensively on coastal plains and inland alluvial floodplains. Buffel Grass has been implicated in structural vegetation change by increasing fuel loads and fire severity in some vegetation types (e.g.

mulga communities); however it is a favoured species by pastoralists and some 350,000 ha of Buffel Grass pasture has been developed across the Pilbara region (Payne and Mitchell 2002). A number of additional species are highly invasive in wetland environments (e.g. *Cynodon dactylon*, *Parkinsonia aculeata*).

Note that in the Pilbara environment the behaviour of many weed species is unlikely to follow a stable trajectory. Weed encroachment is more likely to be responsive to specific combinations of environmental factors (e.g. interactions between climate, fire regimes, grazing pressure and other human disturbance) in accordance with state-and-transition model theory (e.g. Briske et al. 2008; Bestelmeyer et al. 2009).

2.5 Terrestrial fauna

The fauna of the Pilbara region is typified by arid-adapted vertebrates, with generally wide-ranging regional distributions. Many species, particularly mammals and reptiles, tend to have affinities with land surface substrates and vegetation structure (Gibson and McKenzie 2009; Doughty et al. 2011). Pilbara landscapes tend to be relatively uniform with respect to terrestrial bird assemblages; however riparian vegetation communities have distinctive assemblages (Burbidge et al. 2010). Climatic variables tend to have a weaker influence on fauna species distributions but may affect patterns of behaviour. For example, persistent and permanent pools constitute important refugia during prolonged droughts.

Fire is an additional factor influencing terrestrial fauna in the Pilbara. Large-scale fires directly impact food resources and habitat structural complexity. Many Pilbara fauna species avoid fire through high mobility and dispersal. Rocky outcrops and riparian habitats provide important fire refugia for some species. An increasing body of research is demonstrating a synergistic negative interaction between large, intense fires and introduced predators (e.g. cat, fox) on Australian native fauna (Doherty et al. 2015; Cramer et al. 2016); which exacerbates the importance of fire regimes for native fauna persistence.

With relevance to Fortescue's heavy rail network, species of conservation significance in the study area include:

- Greater Bilby (*Macrotis lagotis*) - (EPBC Act[5], Vulnerable; WC Act[6], Vulnerable):

  Known from a variety of habitats in the Pilbara including spinifex hummock grassland, *Acacia* shrubland, open woodland and cracking clays. In arid settings bilbies typically occur in low densities and can be highly mobile in response to resource availability (Southgate et al. 2007). They are omnivorous and exhibit high dietary flexibility. Although they construct burrows, these may only be transiently occupied and as such burrows are not a reliable indicator of either bilby presence or abundance. These traits make it difficult to locate and follow individuals and populations over time.

  Key recognised threats to the greater bilby include introduced predators, introduced herbivores that compete for food resource and burrowing space (e.g. rabbits, cattle) and unfavourable fire regimes that eliminate food resources and accentuate predation (Cramer et al. 2016a; Woinarski et al. 2014). Bilbies are particularly susceptible to fox predation and are unlikely to persist where foxes are common. Feral cat predation may also be severe, however in north-western Australia (i.e. Pilbara and Kimberley regions) bilbies are able to coexist with feral cats (Martin Dziminski, Department of Parks and Wildlife research scientist, pers. comm. 2016).

- Northern Quoll (*Dasyurus hallucatus*) - (EPBC Act, Endangered; WC Act, Endangered):

  Once common across northern Australia, northern quoll populations have been drastically reduced by the combined effects of predation by cats and foxes, unfavourable fire regimes and the spread of the cane toad (*Rhinella marina*). The Pilbara is currently free of the cane toad and therefore constitutes an important 'refuge' area for northern quolls, however it is anticipated that cane toads will eventually reach the region and therefore constitute a future threat (Tingley et al. 2013).

[5] Commonwealth *Environment and Biodiversity Conservation Act 1999*
[6] *Wildlife Conservation Act 1950*

The areas of highest habitat quality for northern quolls are generally considered to be rugged, rocky areas, often in close association with permanent water (Cramer et al. 2016b); although recent evidence suggests that cat predation may have forced a contraction of Pilbara northern quolls from broader plains habitat to these areas (Hernansez-Santin et al. 2016). Rocky landforms provide a diversity of environments, denning opportunities, protection from weather and diurnal predators and immediate refuge from fire.

Key recognised threats to the northern quoll include habitat fragmentation and loss, predation by cats, foxes and dingos/wild dogs, habitat modification by weeds, grazing and fire and the interactive effects between all of these factors (Woinarski et al. 2014; Cramer et al. 2016b).

Until recently the study area was considered to support another rare and endangered mammal, the Crest-tailed Mulgara (*Dasycercus cristicauda*) (EPBC Act, Vulnerable). However, with broad acceptance of the taxonomic revision of Woolley (2005), the Pilbara taxon has been confirmed as the less threatened Brush-tailed Mulgara (*D. blythi*). The Brush-tailed Mulgara is not listed under the EPBC Act but is classified as a Priority 4[7] taxon by the Western Australian Department of Parks and Wildlife (DPaW).

Parts of the Pilbara provide important refugia for a variety of conservation significant bird species (Johnstone et al. 2013). Habitats utilised by these species include diverse coastal habitats (e.g. the area from Eighty Mile Beach to Port Hedland saltworks, including Madora Marsh), major river systems and the Fortescue Marsh. Within the study area, key habitat for conservation significant bird species is likely to be associated with the major drainages (e.g. Yule River, Turner River, Fortescue River; refer to Figure 2). Species of interest include[8]:

- Cattle Egret (*Ardea ibis*) – (EPBC Act, Migratory)
- Great Egret (*Ardea alba*) – (EPBC Act, Migratory)
- Grey Falcon (*Falco hypoleucos*) – (WC Act, Endangered)

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[7] Species that are adequately known, are rare but not threatened, or meet criteria for near threatened, or that have been recently removed from the threatened species or other specially protected fauna lists for other than taxonomic reasons.

[8] as identified in Fortescue's Conservation Significant Fauna Management Plan (100-PL-EN-0022)

- Peregrine Falcon (*Falco peregrinus*) – (WC Act, Endangered)
- Rainbow Bee Eater (*Merops ornatus*) – (EPBC Act, Migratory; WC Act, Endangered)

The Night Parrot (*Pezoporus occidentalis*) – (EPBC Act, Critically Endangered; WC Act, Endangered) was considered likely to be extinct in the Pilbara until a sighting was made at Minga Well near Fortescue's Cloudbreak operations in 2005 (David and Metcalf 2008). The principle habitat for this species is considered to be *Triodia* (Spinifex) grasslands and samphire shrublands located to the south of Fortescue's rail infrastructure. Despite considerable survey effort at the Fortescue Marsh and surrounding areas over the past decade (Bamford 2012), no further evidence of the presence of this species has been found to date.

3 Rail operations overview

3.1 Operations overview

Fortescue currently has an average of 28 train movements per 24 hours (both directions) along the Mainline and Hamersley Line network, with an average product throughput of 169 Mtpa. This consists of 2 locomotives with a total of 231 ore cars.

Construction of the Mainline commenced in February 2007, with the first haulage from the Cloudbreak mine to Port Hedland occurring in April 2008. The rail line was subsequently extended further east to the Christmas Creek mine, with haulage commencing in May 2011. The Hamersley line servicing the Solomon Hub commenced haulage in December 2012.

Rail sections (in 250 m increments) are described with reference to their 'chainage' distance from the start of the rail line in Port Hedland. For example, CH270.5 refers to the section of rail between 270.50 and 270.75 km from Port Hedland. The junction of the Mainline and Hamersley Line occurs at CH175.

3.2 Regulatory context

Fortescue's heavy rail network has been approved and constructed in different stages:

- 'Stage A' consisting of a two-berth iron ore export facility at Port Hedland and a north-south railway from the central Pilbara to Port Hedland, approved under Ministerial Statement 690 (MS690) (chainage 0 to 182).
- 'Stage B' consisting of iron ore mines in the eastern Pilbara (Christmas Creek) and an east-west spur rail line connecting to the 'Stage A' railway; approved under Ministerial Statement 707 (MS707[9]) (chainage 182 to Christmas Creek).
- Solomon iron ore project consisting of two new mines and a new rail section (the Hamersley line) connecting to the existing Fortescue rail line, approved under Ministerial Statement 862 (MS862) and Commonwealth approval under the EPBC Act (EPBC 2010/5567) in 2011.

[9] Note that August 2016 MS707 was superseded by MS1033.

- Additional rail infrastructure between Herb Elliott Port Facility and Cloudbreak Mine Site (e.g. spurs, sidings, marshalling yards), approved under Ministerial Statements 690 and 707 and Commonwealth approval under the EPBC Act (EPBC 2010/5513).

Within this regulatory framework, Fortescue is required to undertake broad ranging environmental monitoring applicable to the Rail Operations addressing the following environmental factors:

- Conservation significant fauna[10] (Greater Bilby, Northern Quoll, Migratory Birds);
- Significant flora and vegetation (Mulga and Riparian vegetation);
- Surface water;
- Weeds; and
- Rehabilitation of disturbed areas.

Specific requirements are outlined in a series of factor based Environmental Management Plans (EMP's), developed by Fortescue in accordance with Ministerial Statements 690, 707, 862, and Controlled Actions EPBC 2010/5513 and 2010/5567 (FMG 2016). These are further described in Appendix 4. Note that owing to the evolutionary nature of the approvals framework for Fortescue's operations, there is a significant degree of connectivity between these plans.

In August 2016, MS707 was superseded by Ministerial Statement 1033 (MS1033). MS1033 sets out a basis for transitioning to an outcome-based environmental management approach, in accordance with a regulatory model adopted by the Western Australian Environmental Protection Authority (EPA). At the present time, consistent with MS1033, Fortescue is required to continue to implement environmental management plans addressing Hydrological Processes and Inland Waters Environmental Quality (surface water) and Flora and Vegetation (vegetation health) prescribed under MS707.

[10] Note: prior to confirmation of the taxonomic status of the Mulgara (Woolley 2005) under the EPBC Act, the Brush-tailed Mulgara (*Dasycercus blythi*) was also subject to monitoring requirements.

Environmental monitoring activities specified in Fortescue's EMPs are subject to a series of internally developed guidelines including:

- Conservation Significant Fauna Monitoring Guidelines (100-GU-EN-0034);
- Significant Flora and Vegetation Monitoring Guidelines (45-GU-EN-001);
- Mulga Monitoring Methodology– Solomon Rail Project (SO-RP-EN-0021);
- Weed Monitoring Guidelines (45-GU-EN-0003);
- Fortescue Rail Surface Water Monitoring Program Monitoring Plan (R-PL-EN-0032); and
- Surface Water Monitoring Guidelines (100-GU-EN-0037).

These are further described in Appendix 4.

4 Fortescue Rail environmental monitoring results

4.1 Reports reviewed

Environmental monitoring reports provided by Fortescue and reviewed for the purposes of this 2016 State of the Environment Report are described in Appendix 5.

Baseline environmental surveys and assessments associated with regulatory approvals (e.g. Fortescue 2004, 2005, 2010, 2011, 2015) were also reviewed. These baseline studies provide important contextual information relating to:

- vegetation mapping;
- flora richness and abundance (including weed taxa);
- fauna habitat mapping;
- fauna richness and abundance; and
- landscape physiography and hydrology.

Since 2011 Fortescue has implemented a structured monitoring program designed to address the regulatory requirements described in the EMPs applicable to Fortescue's heavy rail infrastructure (refer to Appendix 4). Time spans of data availability and key metrics for each environmental factor monitored over the period 2011 to 2016 are summarised in Tables 4-1 and 4-2 for the Mainline and Hamersley line rail sections respectively.

Fortescue has also accumulated time series photographic records from fixed points as part of long-term monitoring of native vegetation (e.g. riparian vegetation), weeds and rehabilitation areas. In light of the findings of more recent systematic monitoring these records were not systematically reviewed; however they provide a basis for retrospective analysis of environmental responses.

Monitoring results for each factor are discussed in detail in the proceeding sections. With respect to conservation significant species, in all cases the 'impact zone' is defined as within 1 km of the rail centreline.

Table 4-1 Fortescue Rail environmental monitoring - key monitoring metrics and time periods sampled at the Mainline

Environmental factor/aspect	Component	Metric(s)	2012	2013	2014	2015	2016
Conservation significant fauna (Attachment 1)	Greater Bilby	Presence/absence[11]		✓	✓	✓	✓
	Northern Quoll	Presence/absence[8]	✓	✓	✓	✓	✓
	Brush-tailed Mulgara	Presence/absence[8]		✓	✓	✓	n/a[12]
	Conservation Significant Birds	Opportunistic records; targeted survey in 2015	✓	✓	✓	✓	✓
	All EPBC listed species	Culvert usage		✓	✓	✓	✓
	All EPBC listed species	Rehabilitation area usage				✓	✓
Mulga vegetation communities (Attachment 2)	Mulga population structure	Age class counts			✓	✓	✓
	Native grass cover	Linear transect intersection			✓	✓	✓
	Weed cover	% cover by species			✓	✓	✓
	Litter	% cover and classification			✓	✓	✓
	Erosion	Erosion pole and visual score			✓	✓	✓
Riparian vegetation (Attachment 3)	Tree health	Visual score and stem diameter				✓	
	Vegetation	% cover by stratum				✓	

[11] Including target habitats, culverts and rehabilitation areas.
[12] Brush-tailed Mulgara not monitored in 2016 due to it being confirmed as a non-listed species under the EPBC Act

Environmental factor/aspect	Component	Metric(s)	2012	2013	2014	2015	2016
	Tree health	NDVI	✓	✓	✓	✓	✓
Surface water (Attachment 4)	Water quality	EC, pH, TDS, turbidity, Total-N, Total-P, SO4				✓	✓
Weeds (Attachment 5)	Occurrence and extent	% cover and area density by species			✓		✓
	Native vegetation condition	Visual rating (EPA & DPaW 2015)			✓		✓
Rehabilitation efficacy (Attachment 6)	Landscape Function Analysis	Stability, infiltration, nutrient cycling			✓	✓	✓
	Species richness	Species presence/absence			✓	✓	✓
	Veg. type extent	% cover and density by vegetation class			✓	✓	✓

Table 4-2 Fortescue Rail environmental monitoring - key monitoring metrics and time periods sampled at the Hamersley line

Environmental factor/aspect	Component	Metric	2011	2012	2013	2014	2015	2016
Conservation significant fauna (Attachment 1)	Northern Quoll	Presence/absence[8]		✓	✓	✓	✓	✓
	Brush-tailed Mulgara	Presence/absence[8]		✓	✓	✓	✓	n/a[13]
	Migratory Birds	Opportunistic records; targeted survey in 2015		✓	✓	✓	✓	✓
	All EPBC listed species	Culvert usage			✓	✓	✓	✓
	All EPBC listed species	Rehabilitation area usage			✓	✓	✓	✓

[13] Brush-tailed Mulgara not monitored in 2016 due to it being confirmed as a non-listed species under the EPBC Act

Environmental factor/aspect	Component	Metric	2011	2012	2013	2014	2015	2016
Mulga vegetation communities (Attachment 2)	Mulga population structure	Age class counts	✓		✓	✓		
	Native grass cover	Linear transect intersection	✓		✓	✓		
	Weed cover	% cover by species	✓		✓	✓		
	Litter	% cover and classification	✓		✓	✓		
	Erosion	Erosion pole and visual score	✓		✓	✓		
	Ant species diversity	Species richness and abundance	✓		✓	✓		
Surface water (Attachment 4)	Water quality	EC, pH, TDS, turbidity, Total-N, Total-P, SO_4				✓	✓	✓
Weeds (Attachment 5)	Occurrence and extent	% cover and area density by species		✓		✓		✓
Rehabilitation efficacy (Attachment 6)	Landscape Function Analysis	Stability, infiltration, nutrient cycling				✓	✓	✓
	Species richness	Species presence/absence				✓	✓	✓
	Veg. type extent	% cover and density by vegetation class				✓	✓	✓

[1] Including target habitats, culverts and rehabilitation areas.

4.2 Data compilation

Monitoring data derived from the reports described in Appendix 5 was collated into a series of MS Excel databases for conservation significant fauna, mulga vegetation communities, riparian vegetation, surface water, weeds and rehabilitation respectively. These databases (provided to Fortescue) include descriptive information for sampling locations, and summary statistics and time series charts for key monitoring metrics.

4.3 Conservation Significant Fauna

4.3.1 Greater Bilby

4.3.1.1 Sampling methods

Greater Bilby monitoring has occurred along the Mainline from near Port Hedland (CH1.5) to the Hamersley line intersection. A summary of the number of bilby sampling sites and records is provided in Table 4-3. A summary of the spatial distribution of survey effort and sampling records is provided in Figure 4. Throughout the period of monitoring, targeted sampling for bilby has occurred in late autumn – early winter (May/June).

Table 4-3 Greater Bilby monitoring – number of sampling locations and records

Site type	Number of locations sampled				Number of locations with records			
	2013	2014	2015	2016	2013	2014	2015	2016
Control	2	20	20	3	2	1	1	3
Impact	2	20	20	3	2	2	1	1
Reconnaissance	70	0	0	0	0	0	0	0

Prior to the commencement of monitoring in 2013, evidence for the presence of the Greater Bilby along the Mainline from historical fauna surveys was reviewed (Ecologia 2014). These surveys, completed in the period 2004 to 2010, documented secondary evidence of bilbies (diggings and burrows), although there were no actual sightings or captured individuals (ATA 2007; Bamford 2010; Biota 2004, 2005). However, in May 2012 during a wild dog and fox baiting survey along the Mainline, a Greater Bilby was recorded exiting a burrow by a motion camera proximal to CH143 (Figure 4).

Potential bilby habitat was ground-truthed through the establishment of a series of reconnaissance sites in 2013. This involved searching on foot for evidence of recent bilby activity along a 1 km long transect at each site. Ecologia (2014) reported that the zone between CH155 and CH225 was inspected in 2013 and considered to have a low likelihood of supporting bilbies; consequently, no sampling sites were located in this zone. This is consistent with the transition into different landscape geology and substrates associated with the Chichester Range, which do not comprise favourable habitat for the Greater Bilby.

Across 70 reconnaissance sites assessed in 2013, four locations with active bilby burrows were identified. All sites were within a zone between CH118 to CH171. Each of these sites was in a similar landscape setting, consisting of a fringing sand plain adjacent to a minor drainage line. Motion cameras were installed at each site, and at one site (proximal to CH143) 14 cage traps were set from 20 to 26 May 2013 (42 trap nights of survey effort).

In the period 2014 to 2016 annual surveys for the Greater Bilby were completed using a combination of the following methods:

- 1 km transect searches for secondary evidence on foot (20 locations in 2014 and 2015 respectively[14]). Detailed scat transects were then undertaken at sites assessed as likely to have recent bilby activity;
- cage and camera trapping where recent bilby activity was detected from secondary evidence:
    - in 2014 – 140 trap nights at one location near CH121; motion cameras for 7 consecutive nights at two locations (near CH121 and a control site 48 km east of CH150 respectively);
    - in 2015 - 20 traps for 7 consecutive nights at one location (near CH121);
    - in 2016 - Motion cameras for 12 consecutive nights at six locations (near CH121, two sites near CH143, CH171, CH177 and the reference site 48 km east of CH150 respectively).

Note that due to low efficacy of cage traps for detecting/capturing bilbies, and logistical constraints in checking traps putting captured individuals at risk of injury, trapping methods have only been used to a limited extent in Fortescue's monitoring program. The 2016 survey included the collection of scats for analysis of population metrics using genetic markers. The population genetics component was implemented in collaboration with DPaW.

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[14] Note in 2016 targeted sampling in areas on known bilby activity (20 person-hours per site) was adopted in preference to broad scale transect surveys.

4.3.1.3 Results

In summary, Greater Bilby records cluster into three broad 'impact' zones proximal to the Mainline and one control site as follows (Figure 4):

- Zone 1 – approximately defined by CH117 to CH122, four consecutive years of records (2013-2016)
- Zone 2 - approximately defined by CH142 to CH145, records from 2012, 2013, 2014 and 2016
- Zone 3 - approximately defined by CH170 to CH178, active burrow detected in 2013 and scats recorded in 2016.
- Zone 4 – control site approximately 48 km east of CH150. Three consecutive years of records (2014-2016)

In 2016, secondary evidence of Greater Bilby (fresh diggings) was also opportunistically recorded adjacent to a rehabilitated area along the Turner River (near CH81.5); indicating the possible existence of a more northerly population.

All of Greater Bilby records to date are associated with the Macroy Land System, in areas of sandy substrates dissected by significant drainages. Hence, within the study area it appears that bilbies have a distinct habitat type preference.

The results to date indicate that Greater Bilby populations are persisting in close proximity to Fortescue's heavy rail network.

4.3.2 Northern Quoll

4.3.2.1 Sampling methods

Northern Quoll monitoring has occurred mainly in proximity to areas of rocky uplands (e.g. Boolaloo, Rocklea and Granitic land systems), which are regarded as the preferred habitat for this species. A summary of the number of Northern Quoll sampling sites and records in the period 2012 to 2016 is provided in Table 4-4. A summary of the spatial distribution of survey effort and sampling records is provided in Figure 5. For the purpose of the following discussion quoll records include animal captures and firm evidence of quoll activity deriving from motion cameras, scats or fresh tracks. The majority of Northern Quoll sampling has been completed in late winter – early spring (August/September); with exceptions being Hamersley Line 2014 (19 to 27 June) and Mainline 2016 (30 July to 4 August).

Table 4-4 Northern Quoll monitoring – number of sampling locations and records

Site type	Number of locations sampled					Number of locations with records				
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Mainline										
Control	3	4	4	3	RC[15]	1	0	0	0	RC[13]
Impact	9	4	4	3	3	1	1	2	2	1
Opportunistic	6	3	0	0	0	6	3	0	0	0
Culvert	n/a	12	18	6	10	n/a	0	3	0	0
Rehabilitation area	n/a	n/a	n/a	8	3	n/a	n/a	n/a	0	0
Hamersley line										
Control	4	4	4	3	RC[13]	0	0	0	1	RC[13]
Impact	16	7	7	3	3	2	2	3	3	1
Opportunistic	0	0	0	2	0	0	0	0	2	0
Culvert	0	24	24	6	6	0	7	12	0	0
Rehabilitation area	0	9	12	3	3	0	1	4	0	0

n/a = no sampling undertaken
RC = Regional Control sites

In 2012, monitoring site selections were informed by historical Northern Quoll records, the presence of suitable habitat identified during a Level 1 baseline survey and targeted conservation significant fauna surveys in 2010 and 2011 (Coffey 2010, 2011), and further ground truthing including consideration of site accessibility. Despite their putative habitat suitability, no evidence of Northern Quoll activity was obtained at the original control sites in the period 2012 and 2015. From 2016 onwards the project specific control sites were replaced with a regional set of control sites comprising Fortescue sites north of Solomon Mine and DPaW Pilbara monitoring sites, all of which are known to support Northern Quoll populations.

[15] From 2016 a set of regional control sites has been adopted in collaboration with DPaW.

Monitoring methods since 2012 have included a combination of cage trapping, motion camera deployment and searches on foot for scats and other evidence of recent quoll activity. In the period 2012 to 2014, the overall trapping effort (control and impact sites) was approximately 4,900 trap-nights at Mainline sites and 5,775 trap-nights at Hamersley line sites. In 2015 the sampling approach was revised in accordance with updates to the Conservation Significant Fauna Management Plan (100-PL-EN-0022). Each site was searched instead for 2 hours over 10 consecutive days and 10 motion cameras were installed for 12 nights; corresponding to overall sampling effort of 720 camera-nights and 120 hours of searching at the Mainline and Hamersley line sites respectively.

In 2016 the sampling effort at the three impact sites carried forward from previous years comprised 10 hours of searches, 20 camera-nights and 200 trap-nights at each site. The sampling approach was amended to be consistent with new regional management guidelines developed by DPaW and more closely integrate with DPaW's Northern Quoll survey program. The progressive rationalisation of sites included in the program over time has been based on previous monitoring site locations and capture data.

4.3.2.2 Results

Along the Mainline, Northern Quolls have been detected at one control site (in 2012) and at four impact sites. Along the Hamersley line, Northern Quolls have been putatively detected at one control site (possible tracks in 2015) and seven impact sites (Figure 5).

In addition, nine opportunistically sampled sites near the Mainline (e.g. where motion cameras installed for other purposes) have produced Northern Quoll records in the 2012 to 2013 period. Similarly, two opportunistically sampled sites near the Hamersley line produced Northern Quoll records in 2015.

Further records of Northern Quolls obtained from motion cameras at culvert locations include (Figure 5):

- Singleton records from three culvert locations along the Mainline in 2014 (near CH65, CH74 and CH213).
- Two years of records (2013 and 2014) at five culvert locations along the Hamersley line in 2013 (two sites near CH199, two sites near CH206 and one site near CH208).
- Singleton records from two culvert locations along the Hamersley line in 2013 (near CH201 and CH210), and seven additional culvert locations along the Hamersley line

in 2014 (one site at CH201, two sites near CH208, two sites near CH212, one at CH213 and one at CH222).

Evidence from the ongoing monitoring program suggests that Northern Quolls use the culverts to cross beneath the rail lines; with Northern Quoll detected at three of 18 culvert monitoring locations where motion cameras were installed along the Mainline; and 13 of 30 culvert monitoring locations where motion cameras were installed along the Hamersley line over the period 2012 to 2014.

Further records of Northern Quoll obtained from motion cameras in rehabilitation areas along the Hamersley line include:

- A singleton record from one site in 2013 (near CH204).
- Singleton records from four different sites in 2014 (all between CH206 and CH207).

This equates to five out of 18 (i.e. 28%) rehabilitation area monitoring sites where Northern Quoll monitoring has been conducted. Note that these rehabilitation areas were selected for monitoring based on their proximity to sites where Northern Quoll have been detected in the period 2013 to 2016. No quolls have been detected in rehabilitation areas along the Mainline (eight sites selected for monitoring in 2015 and three sites in 2016).

Overall the findings from the 2012 to 2016 period indicate that the Northern Quoll occurs in multiple areas along Fortescues heavy rail network. Review of the data indicates that Northern Quolls are persisting in proximity to Fortescue's heavy rail network and utilise historically disturbed areas such as culverts and rehabilitated areas.

4.3.3 Mulgara

4.3.3.1 Sampling methods

Although the Brush-tailed Mulgara was removed from Fortescue's Rail Operations monitoring program in 2016, owing to this species being confirmed as not listed under the EPBC Act, a brief summary of the data collected in the period 2012 to 2015 is provided as follows.

Mulgara monitoring site locations were determined based on a review of historical fauna survey reports for the Mainline (ATA 2007; Bamford 2010; Biota 2004, 2005) and Hamersley line (Coffey 2010, 2011) and reconnaissance surveys in 2013 completed in combination with searches for the Greater Bilby – refer to Section 4.3.1). All sites were targeted to land systems with favourable habitat (i.e. sandy substrates) between Port Hedland and near the junction of the Mainline and Hamersley line (e.g. Macroy, Mallina and Uaroo land systems; refer to Figure 3).

A summary of the number of Brush-tailed Mulgara sampling sites and records in the period 2012 to 2015 is provided in Table 4-5. A summary of the spatial distribution of survey effort and sampling records is provided in Figure 6. For the purposes of the following discussion Mulgara records include animal captures or firm evidence of current Mulgara activity from motion cameras, scats or fresh tracks.

Table 4-5 Brush-tailed Mulgara monitoring – number of sampling locations and records (2012 to 2015)

Site type	Number of locations sampled				Number of locations with records			
	2012	2013	2014	2015	2012	2013	2014	2015
Mainline								
Control	n/a	6	6	6	n/a	1	4	3
Impact	n/a	6	6	6	n/a	3	3	3
Reconnaissance	n/a	3	n/a	n/a	n/a	3	n/a	n/a
Hamersley line[16]								
Control	4	4	4	0	1	1	2	0
Impact	4	4	4	3	3	3	2	1

n/a = no sampling undertaken

All monitoring events occurred in late autumn or winter (May to August). The primary survey method was trapping (Elliot traps), augmented by motion camera stations and searches on foot for secondary evidence of recent mulgara activity. Pitfall trapping was also used in 2013 and 2014. In the period 2012 to 2015, the overall trapping effort (control and impact sites) was approximately 12,600 trap-nights at Mainline sites and 8,820 trap-nights at Hamersley line sites.

[16] Note that no reconnaissance sites were established along the Hamersley line.

4.3.3.2 Results

At the Mainline sites, Brush-tailed Mulgara records include:

- Three control sites (9 km east of CH19, 1 km west of CH23 and 14 km west of CH137) with records in two consecutive years (2014 and 2015);
- Two control sites with records in one year only (3 km west of CH49 in 2013, and 14.5 km east of CH19 in 2014);
- Four impact sites with records from two out of three years in the period 2013 to 2015 (near CH23, CH45, CH121 and CH148);
- One impact site with records in one year only (near CH141 in 2015).

Additional records were also obtained from three other reconnaissance sites assessed in 2013 (near CH118, CH138 and CH175).

At the Hamersley line sites, Brush-tailed Mulgara records include the following locations all within 2 km from the junction with the Mainline (CH177):

- Three consecutive years of records in the period 2012 to 2015 at one control site;
- A single year record at one control site (2014);
- Four consecutive years of records (2012-2015) at one impact site;
- Three consecutive years of records (2012-2014) at one impact site;
- Two consecutive years of records (2012-2013) at one impact site.

The monitoring data includes evidence of an individual moving across the rail line. Overall the findings from the 2012 to 2015 period indicate that Brush-tailed Mulgara populations are persisting in proximity to Fortescue's heavy rail network. This outcome is consistent with those of other mammalian species included in Fortescue's monitoring program.

4.3.4 Conservation significant bird species

4.3.4.1 Sampling methods

Conservation significant bird species either recorded or with the potential to occur in the study area include[17]:

- Grey Falcon (*Falco hypoleucos*) (VU, WC Act)
- Rainbow Bee-eater (*Merops ornatus*) (M, EPBC Act)
- Great Egret (*Ardea alba*) (M, EPBC Act)
- Cattle Egret (*Ardea ibis*) (M, EPBC Act)
- Eastern Great Egret (*Ardea modesta*) (M, EPBC Act)
- Peregrine Falcon (*Falco peregrinus*) (Conservation dependent (Schedule 6) WC Act)
- Wood Sandpiper (*Tringa glareola*) (M, EPBC Act)

Sampling for conservation significant bird species has largely been done opportunistically within Fortescue's overall Rail Operations monitoring program. However, in 2015 and 2016, targeted searches involving two zoologists (2 ha site for 20 minutes) were completed at three impact and three control sites along the Mainline and Hamersley line respectively. A summary of the number of sampling sites in the period 2012 to 2016 is provided in Table 4-6. A summary of the spatial distribution of survey effort and sampling records is provided in Figure 7.

Table 4-6 Conservation significant birds monitoring – number of sampling locations and records[18]

Site type	Number of locations sampled					Number of locations with records				
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Mainline										
Control	0	0	2	7	3	0	0	2	0	0
Impact	0	0	0	6	3	0	0	0	0	0

[17] as identified in Fortescue's Conservation Significant Fauna Management Plan (100-PL-EN-0022)

[18] Note: does not include opportunistic sightings made as part of other monitoring activities for other fauna species.

Site type	Number of locations sampled					Number of locations with records				
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Opportunistic	8	4	4	0	0	6	1	2	1	2
Hamersley line										
Control	0	0	0	4	3	0	0	0	3	0
Impact	0	0	0	3	3	0	0	0	2	0
Opportunistic	2	3	4	0	0	2	3	4	5	4

4.3.4.2 Results

Conservation significant bird records from the study are summarised as follows (Figure 7):

- The Rainbow Bee-eater was recorded at multiple Mainline and Hamersley line sites and in adjacent areas in the 2012 to 2016 period. This species has also been recorded from pre-2012 baseline surveys of the study area (Ecoscape 2016);
- The Grey Falcon was recorded from the Mainline (CH153) in 2012 and the Hamersley line (CH182, CH186 and CH201) in 2014;
- A Peregrine Falcon was sighted near the Hamersley Line (CH208) in 2014;
- An Eastern Great Egret was sighted near the Chinnamon Creek crossing on the Mainline (CH229) in 2015;
- A Wood Sandpiper was sighted south of the junction of the Mainline and Hamersley line (CH189) in 2014;
- During the 2015 targeted surveys, the only records of note were the Rainbow Bee-eater at four of the six Hamersley line locations (two impact and two control sites respectively). No conservation significant bird species were recorded at the Mainline sites.

All conservation significant bird species recorded in the study area are highly mobile and wide ranging. The findings of the monitoring program are consistent with the Fortescue rail network having a negligible effect on the persistence of these species in the study area.

4.4 Mulga Vegetation

4.4.1.1 Sampling methods

Mulga monitoring is targeted to areas where rail infrastructure passes through groved vegetation formations. These have a restricted distribution in the study area, being confined to portions of the Jurrawarrina Land System along the Hamersley line and the Jamindie Land System towards the southern terminus of the Mainline (Figure 8). Monitoring sites were selected on the basis of inferred surface drainage behaviour, vegetation community composition and vegetation condition.

The monitoring methodology was developed by Fortescue in consultation with the DPaW. It is based on transect design oriented perpendicular to the direction of surface sheet flows. The Mainline transects extend 200 m either side of the rail line and the Hamersley line transects extend between 150 m and 500 m either side of the rail line; with the up-gradient portion constituting a 'reference' zone and the down-gradient section an 'impact' zone in each case. Each transect is partitioned into a series of 10 x 10 m quadrats in which the following parameters are measured:

- Population structure and density - The number of living and dead mulga trees in various size/age classes;
- Living grass cover by species as per the Tongway and Hindley (2004) line intercept method;
- Weed cover - % area of plot;
- Litter cover - % area of plot, origin and degree of decomposition/incorporation;
- Erosion – measured against a vertical pole fixture and by visual assessment; and
- Cow dung - faecal units per plot, providing an indication of recent grazing intensity.

Fixed point photographs have also been obtained as part of each monitoring event. Further details of the transect layout and procedures for data collection contained in Mulga Monitoring Methodology (SO-RP-EN-0021; refer to Appendix 4).

Four transects have been established on the Mainline (Figure 8). These have been measured in 2014, 2015 and 2016 (July-September period in each year). Five transects have been established on the Hamersley line, the westernmost of which is wholly a reference transect (Figure 8). These have been measured in 2011, 2013 and 2014 (August-September period in each year).

4.4.1.2 Results

Consistent trends have been observed across all transects (Mainline and Hamersley line sites), with no significant time series change within transects or discernible differences between reference and impact areas. Time series data plots for each of the main monitoring parameters are presented in Appendix 6.

The major findings across all transects are:

- There has been no material change in the number of live or dead mature mulga trees over time. In some instances slight increases in mature tree numbers have been observed, attributable to juvenile trees growing into the mature tree size class.
- Generally there was a reduction in the number of juvenile mulga trees in 2015 and 2016 when compared to earlier sampling phases. It is likely that prolonged hot and dry conditions since mid-2014 have contributing to plant mortality. A secondary factor may be that more established juvenile plants have grown into mature tree size classes.
- Very few seedlings, adult re-sprouts or juvenile re-sprouts have been recorded in any year.
- At Mainline transects - a slight trend of reduced grass cover in 2015 and 2016 when compared to the 2014 sampling phase and greater persistence of highly drought tolerant species (e.g. *Triodia* spp). It is likely that prolonged hot and dry conditions since mid-2014 have contributed to this result. At Hamersley line transects, there was a slight increase in grass species richness and abundance between 2011 and 2014. It is likely that favourable seasonal conditions in the 2012 to 2014 period have contributed to this result.
- Low overall weed burdens, which are relatively stable over time. At Mainline transects, there is a slight trend of reduced weed cover in 2015 and 2016 when compared to the 2014 sampling phase. It is likely that prolonged hot and dry conditions since mid-2014 have contributed to this result. At Hamersley line transects, small numbers of **Bidens bipinnata* and **Malvastrum americanum* were observed in 2014 but not in 2011. Transect 2 includes an exceptional number of **Cenchrus ciliaris* plants relative to the other transects.

- Little to no change in erosion pole height at the Mainline transects (2014 to 2016). Note that a few extreme values (at transects 1 and 3) measured in 2015 were counterbalanced by repeat measurements in 2016; likely indicating that erroneous measurements were made in 2015. At a few transects some localised topsoil loss and accretion was observed, over scales of 10 to 50 meters. The results suggest an absence of high energy overland flow events during the period of monitoring. At the Hamersley line transects, slightly greater changes in erosion pole height were observed between 2011 and 2014, which correlates with relatively higher rainfall received in this period.
- Little to no change in erosion severity over time at the Mainline transects (2014 to 2016), consistent with the erosion pole height measurements. This suggests an absence of high energy overland flow events during the period of monitoring. At the Hamersley Line transects, there is a trend of increased erosion severity in the 2011 to 2014 period at transects 1, 4 and 5; which correlates with relatively higher rainfall received in this period.
- Little to no change in leaf litter over time at the Mainline transects (2014 to 2016). This suggests an absence of high energy overland flow events during the period of monitoring, and also minimal phyllode shedding by mulga trees suggesting that tree productivity over the monitoring period has been modest. At the Hamersley line transects the data suggest a general increase in litter production and varying degrees of localised litter redistribution along the transects in the 2011 to 2014 period. This is consistent with relatively higher rainfall received in this period.

Overall, these data are consistent with the functional behaviour of rain fed vegetation subject to cycles of moisture deficit. No significant differences between reference and impact areas have been identified. There is no evidence to suggest that Fortescue's heavy rail network has affected the health of the mulga vegetation communities during the period of monitoring.

4.6 Riparian vegetation

4.6.1 Survey methods

Fortescue has undertaken fixed photo point monitoring bi-annually at seven major creek crossings along the Mainline since 2008. These are located at East Turner River, Chinnamon Creek, Gillam Creek, Turner River, Coorong Creek, Yule River and Coonarie Creek (Figure 2).

An assessment of change in Normalised Difference Vegetation Index (NDVI) at each of the creek crossing was completed in 2013, based on imagery acquired from fixed wing aircraft in June 2012 and July 2013 respectively (*ecologia* 2014).

Additional structured monitoring was undertaken at the seven major creek crossings along the Mainline in 2015 (MWH 2015), including:

- Analysis of time series change in NDVI imagery acquired for the period June 2014 to June 2015. At each creek crossing five zones were defined according to their distance from the rail infrastructure, as well as the direction of the water flow (upstream vs. downstream):
    - Impact zone – includes direct impacts of rail and road infrastructure with a 15 m buffer.
    - 0 to 100 m zone extending away from the impact zone, further delineated as upstream and downstream respectively.
    - >100 m zone extending from the 0 to 100 m zone to the extent of the analysis area, further delineated as upstream and downstream respectively. The upstream section constitutes the control zone against which other zones are compared.
- A ground validation survey of vegetation health at each location, including visual tree health appraisal in upstream and downstream 50 x 50 m relevés; and
- The establishment of permanent tree health assessment transects at three locations (East Turner River, Turner River and Yule River; refer to Figure 2). These were located in upstream and downstream locations at each site, and comprised a series of 10 m x 10 m quadrats spaced at 50 m intervals across the full width of the main channel and

riparian terrace. Key indicator species of surface and groundwater regimes (*Eucalyptus camaldulensis*, *E. victrix*, and *Melaleuca argentea*) occurred at these transects.

The NDVI analysis was repeated at the seven major creek crossings for the period 2015 to 2016.

4.6.1.1 Results

The major findings are:

- In each creek system, NDVI results spanning the period 2012 to 2016 periods indicate no significant differences between upstream and downstream zones. In the 2012-2013 period, there was a general trend of increasing vegetation density in areas immediately adjacent to the rail line (i.e. within 15 m of the rail and access road infrastructure), which was attributed to the growth of new vegetation on areas previously cleared as part of rail construction and maintenance.
- In general, NDVI signatures and on-ground vegetation health validation measures collected in 2015 were poorly correlated. This may be related to the precision limits of the NDVI imagery, but also fundamental differences in ecosystem attributes being measured (e.g. potentially confounding effects of a transient understorey layer on NDVI pixel metrics).
- In the 2015 permanent tree health assessment transects, vegetation health was relatively good at all sites and no significant differences between upstream downstream locations were observed.
- According the MWH (2015a), the long-term fixed photo point monitoring indicates relatively stable vegetation condition since 2008, in support of the NDVI assessments.

Overall, these findings suggest that riparian vegetation proximal to Fortescue's heavy rail network is in a healthy and stable condition. There is no evidence to suggest that riparian vegetation health has been impacted by the rail infrastructure.

4.8 Surface water

4.8.1.1 Sampling Methods

Prior to 2014, surface water grab samples were collected on an ad hoc basis when stream flows were present. Due to the patchy and inconsistent nature of this data, only very high level conclusions on trends, data patterns and overall surface water details can be made from the information collected to date.

In September/October 2014, Fortescue installed a network of permanent surface water monitoring equipment in drainages and sheetflow areas traversed by Fortescue's heavy rail network (GHD 2015a,b). This included:

1. stormwater water quality samplers;
2. peak level indicators;
3. water level loggers;
4. barometric loggers; and
5. rainfall stations;

Equipment items (1) to (3) are configured in a nested design at locations upstream and downstream of the rail line and at bridge/culvert crossings. This hydrological monitoring network has been designed to collect information on the following aspects of the surface water regime:

- Single and multiple event water quality;
- Continuous water level;
- Single event peak water level; and
- Continuous rainfall.

Operation of the hydrological monitoring network is subject to Fortescue's Rail Surface Water Monitoring Program Monitoring Plan (GHD 2015a). The spatial layout of the monitoring network is provided in Figure 9. The default data collection frequency is quarterly (at the end of January, April, July and October). However, given the ephemeral and erratic nature of flow regimes, the continuous monitoring using automated data logging equipment is augmented with event based monitoring (as per Fortescue's Surface Water Management Plan). The trigger for event based monitoring is an observation of streamflow in designated water courses within the study area.

4.8.1.2 Results

Only a very limited set of water quality data was available for inclusion in this 2016 State of the Environment report, due to a lack of flow events since Fortescue's hydrological monitoring network was installed. Recorded flow events and associated water quality statistics at locations along the Mainline and Hamersley line are summarised in Table 4-7.

The water quality results from Fortescue's surface water monitoring program are typical for ephemeral creek systems of the Pilbara region. In all cases the salinity of water samples was low (i.e. < 3,000 mg/L classified as 'fresh'). Water pH was typically neutral to alkaline, with minor differences between creek systems likely to be attributable to geological variation across catchment areas. In most cases sampled water was highly turbid (>10 NTU), consistent with water deriving from episodic runoff events. Total-N records from 2015 (0.1 to 3.7 mg/L) were consistent with records from pools in the lower Yule River reported by Pinder and Leung (2009), which ranged from 0.3 to 5.9 mg/L. Similarly, Total-P records from 2015 (0.01 to 0.86 mg/L) were similar to values reported by Pinder and Leung (2009), which ranged from 0.01 to 0.49 mg/L. Sulfate concentrations recorded in 2015 (1.0 to 31 mg/L) were also similar to values reported by Pinder and Leung (2009), which ranged from 2.3 to 32.2 mg/L.

Although the time series of water quality observations is limited, the results to date do not suggest any significant change in water quality over time in creek systems traversed by Fortescue's heavy rail network. A comparison of observations from upstream, midstream and downstream locations indicates minimal differences in water quality values between sampling points (refer to Appendix 7). Overall, these data are not suggestive of any material impact on surface water quality from Fortescue's heavy rail network.

Table 4-7 Summary of water quality data from Fortescue's surface water monitoring program

Drainage	Month and year	Water quality parameter ranges (upstream, midstream and downstream locations)						
		EC (µS/cm)	pH	TDS (mg/L)	Turbidity (NTU)	Total-N (mg/L)	Total-P (mg/L)	Sulfate-SO_4 (mg/L)
Chinnamon Creek	Jun-2015	87 – 429	7.26 – 7.57	78 - 244	18.6 – 137	0.8 – 1.2	0.03 – 1.0	1.0 - 29
Coonarie Creek	Jan-2015	163 - 226	7.88 – 8.50	120 - 194	44.5 – 67.2	0.6 – 0.8	0.04	8.0 – 10
	May-2015	262 – 309	7.84 – 8.03	168 – 194	0.9 – 29.3	0.2	0.01 – 0.02	5.0 - 10
	Jun-2015	213 – 230	8.08 – 8.28	132 – 141	0.8 - 1.9	0.1 – 0.2	0.01 – 0.07	3.0 – 4.0
	Jan-2016	69 – 93	8.08 – 8.53	44 – 61	554 - >1000	no data	no data	no data
	Feb-2016	37 – 114	7.34 – 7.49	24 - 75	160 - 819	no data	no data	no data
Coorong Creek	Mar-2015	156 - 231	7.82 – 8.61	238 - 678	1,030 – 3,800	0.9 – 2.8	0.22 – 0.86	3.0 - 17
	May-2015	172	7.63	831	2,150	1.4	0.33	17
	Jun-2015	137	7.31	613	1,040	1.0	0.18	8.0
	Feb-2016	49 – 181	7.06 – 7.43	31 – 118	548 – 4,570	no data	no data	no data
	Jun-2016	85 – 185	7.98 – 8.53	55 – 121	309 - 5,300	no data	no data	no data
Yule River	Mar-2015	65 – 266	6.86 – 7.91	37 - 170	0.7 - 394	0.2 – 3.7	0.01 – 0.45	2.0 - 19
	May-2015	147 – 359	7.68 – 8.07	113 -217	0.7 – 183	0.2 – 1.0	0.02 – 0.11	4.0 - 14
	Jun-2015	89 – 164	6.70 – 7.62	102 – 130	4.7 – 92.6	0.2 – 1.6	0.02 – 0.09	1.0 – 2.0
	Feb-2016	5 – 63	7.15 – 7.33	3 – 44	105 – 387	no data	no data	no data

Drainage	Month and year	Water quality parameter ranges (upstream, midstream and downstream locations)						
		EC (µS/cm)	pH	TDS (mg/L)	Turbidity (NTU)	Total-N (mg/L)	Total-P (mg/L)	Sulfate-SO_4 (mg/L)
East Turner River	Jun-2015	103 – 115	7.51 – 7.53	338 - 398	1,020 – 1,040	1.0	0.17 – 0.22	5.0 – 6.0
HL Stream 1	Jan-2015	91 - 111	7.37 – 7.60	119 - 127	284 - 652	1.1 – 2.5	0.08 – 0.36	2.0 – 4.0
	May-2015	67 - 133	5.19 – 7.55	56 – 75	91.5 – 158	0.9 - 1.4	0.05 – 0.12	1.0 - 31
	Jun-2015	396 – 624	8.19 – 8.39	267 – 349	13.6 – 59.6	0.4 – 0.6	0.02 – 0.06	14 - 25
	Jan-2016	57 – 152	7.74 – 7.92	61 – 99	459 - >1000	no data	no data	no data
HL Stream 2	Jan-2015	34 - 91	6.77 – 7.09	81 - 110	62.7 - 273	0.6 – 1.0	0.05 – 0.14	1.0 – 3.0
	Mar-2015	25 - 37	6.98 – 7.00	75 - 92	549 - 558	2.0 – 2.6	0.34 – 0.49	1.0 – 2.0
	May-2015	129 – 131	7.54 – 7.80	124 - 137	58.3 – 185	0.4 – 1.0	0.03 – 0.12	10
	Jun-2015	31 – 208	7.15 – 7.93	57 – 120	8 – 171	0.2 – 0.5	0.01 -0.07	2.0 - 10
	Feb 2016	81	7.00	53	906	no data	no data	no data
	Mar-2016	33	8.18	56	361	no data	no data	no data
HL Stream 3	Mar-2015	107	7.36	109	635	2.2	0.35	8.0

Note: No flow events and water quality data have been recorded from the Turner River location since monitoring equipment was installed.

4.9 Weeds

4.9.1.1 Survey methods

The weed monitoring methodology implemented by Fortescue, including the spatial location of monitoring points, was developed in consultation with DPaW. The selected monitoring sites include a variety of habitats, representative landforms, vegetation types and vegetation condition within the study area (GG Environmental 2013). The first round of structured biennial monitoring using this methodology was completed along the Hamersley line in 2012, with subsequent monitoring in 2014 and 2016. The Mainline was first monitored in 2014 and then reassessed in 2016.

The monitoring method involves replicated quadrat based weed species cover and density measurements in target areas. Each site comprises three 10m x 10m quadrats placed along a linear transect. Native vegetation condition in each quadrat is also recorded based on the method of EPA and DPaW (2015). Fixed point photographs are also collected. Time series data plots for key weed metrics are presented in Appendix 8.

Prior to 2016 all weed monitoring was completed in late winter. In 2016 the monitoring was completed in autumn (i.e. end of the wet season). Fortescue intends to target future monitoring to the end of the wet season, to improve the efficacy of weed species detection, weed mapping and targeted weed control activities. Fortescue has also commenced systematic weed mapping on a biennial basis following the summer wet season. Data from this weed mapping is used to drive out weed risk mapping and weed control activities.

4.9.1.2 Results

Along the Mainline, 41 sites (12 impact and 29 reference) were established in 2014, 36 of which were reassessed in 2016 (9 impact and 27 reference). Five sites measured in 2014 were not measured in 2016, following the outcome of a review of the weed monitoring program by Fortescue prior to the 2016 monitoring event which identified unnecessary duplication of landform and vegetation types within the program.

Along the Hamersley Line 20 sites (13 impact and 7 reference) have been continuously monitored biennially since 2012.

Weed species occurrences at the Mainline and Hamersley Line sites are summarised in Appendix 8. At the Mainline sites only three weed species have been recorded since the commencement of monitoring. The most significant species is **Cenchrus ciliaris*, recorded at 10 out of 41 sites (i.e. 24%) in 2014 and 9 out of 36 sites (i.e. 25%) in 2016. Other species of note include **Aerva javanica* recorded at 4 sites out of 41 (i.e. 10%) in 2014 and 4 out of 36 sites (i.e. 11%) in 2016, and **Bidens bipinnata* recorded at 3 out of 41 sites (i.e. 7%) in 2014 and 2 out of 36 sites (i.e. 6%) sites in 2016.

At the Hamersley line sites thirteen weed species have been recorded. **Cenchrus ciliaris* was again the most commonly recorded species at 7 out of 20 sites (i.e. 35%) in 2012, 8 out of 20 sites (i.e. 40%) in 2014 and 10 out of 20 sites (i.e. 50%) in 2016. Other species of note include **Malvastrum americanum* recorded at 3 out of 20 sites (i.e. 15%) in 2012, 2 out of 20 sites (i.e. 10%) in 2014 and 4 out of 20 sites (i.e. 20%) in 2016; and **Vachellia farnesiana* recorded at 3 out of 20 sites (i.e. 15%) in 2012, 4 out of 20 sites (i.e. 20%) in 2014 and 4 out of 20 sites (i.e. 20%) in 2016.

In general terms, across all sites weed density and cover has not significantly changed over time. However, **Cenchrus ciliaris* cover increased slightly at seven Hamersley line sites during the 2012 to 2014 period where it was first recorded in 2012 (including 3 impact and 4 reference sites). This species was also newly recorded at two impact sites in 2014 and one additional impact site in 2016 in comparison with 2012. In contrast, at Mainline sites **Cenchrus ciliaris* cover did not materially change in the 2014 to 2016 period and at one impact site (site 20) was not recorded in 2016 despite being recorded in 2014.

Native vegetation condition was recorded at the Mainline and Hamersley line sites in 2014 and 2016[19], with no material change in vegetation condition over this time frame observed. The vegetation condition at all sites ranged from good to excellent.

Overall, weed burdens appear to be stable at most sites and general patterns of weed behaviour are similar in reference and impact sites. It is likely that prolonged hot and dry conditions since mid-2014 have limited the rate of weed species expansion in reference and impact sites, and in some cases contributed to weed species decline. The predominantly 'very good to excellent' condition of native vegetation in all monitoring sites is also likely to have limited weed encroachment over time. When compared against surrounding landscapes, there is no evidence to suggest that Fortescue's heavy rail network has significantly contributed to the introduced and/or spread of weeds.

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[19] As per the method of EPA and DPaW (2015)

4.10 Rehabilitation

During the construction of Fortescue's heavy rail network a variety of temporary disturbance areas were created including borrow pits, overburden stockpiles, access tracks and lay-down areas. As these areas have become operationally redundant, Fortescue has implemented a program of progressive rehabilitation including revegetation with local native species.

On the basis that accurate completion dates of the rail rehabilitation are not available, it has been assumed that rehabilitation along the rail sections was conducted during the same year that construction was completed (i.e. in 2008 for the Mainline and in 2012 for the Hamersley line). Specific completion criteria have not been finalised for the heavy rail network; however consistent with regulatory requirements Fortescue's rehabilitation approach is guided by the following high level criteria:

- Vegetation cover is comparable to the surrounding undisturbed areas;
- Vegetation species is diversity comparable to the surrounding undisturbed areas;
- Surface erosion from water and wind is consistent with surrounding undisturbed areas; and
- Vegetation is stable and resistant to normal environment perturbations (e.g. drought and fire).

A detailed monitoring procedure was produced by Fortescue in early 2014, the Rehabilitation and Revegetation Monitoring Procedure (45-PR-EN-0027), to standardise data collection across its sites (Fortescue 2014a). The key elements of the rehabilitation monitoring program include:

- Land function analysis (LFA) – based on methods described by Tongway and Hindley (2004) including stability, infiltration and nutrient cycling indices;
- Vegetation monitoring (including quadrat based species richness and % cover of major components of the vegetation assemblage); and
- Erosion monitoring.

Monitoring of rehabilitation areas using this procedure was undertaken in late autumn and winter in 2014, 2015 and 2016 at Mainline and Hamersley line sites respectively, and also in adjacent area of undisturbed vegetation (control or 'analogue' sites). Site types were further subdivided on the basis of topography (flat-low slopes <10º; moderate-steep slopes >10º). Time series data plots for key rehabilitation metrics are presented in Appendix 9.

4.10.1.1 Results

A total of 39 sites (including 11 control and 28 rehabilitation areas) were established along the Mainline in 2014. An additional rehabilitation site was added in 2015. A subset of these (including 8 control, 12 rehabilitation areas) were reassessed in 2015 and 2016; with one further rehabilitation area not included in the 2016 program due to inaccessibility. A total of 48 sites (including 13 control, 35 rehabilitation areas) were established along the Hamersley line in 2014. A subset of these (including 10 control, 22 rehabilitation areas) were reassessed in 2015 and 2016. Note that the number of sites across the program was reviewed and reduced in 2015 to improve efficiency (MWH 2015b). Sites with potential rehabilitation issues identified in 2014 were selected as a priority to monitor in 2015. Other sites retained in the program in 2015 were selected to provide good spatial representation along the heavy rail network.

Effective vegetation establishment at the majority of the Mainline rehabilitation sites (up to 8 years old) has been achieved, with species diversity comparable with control sites albeit with some dissimilarity in species composition (MWH 2016). In particular control sites tend to have a considerably greater cover of *Triodia* sp. This is probably a reflection of long term vegetation successional patterns influenced by fire regimes at the control sites.

The Mainline rehabilitation sites display similar LFA and vegetation structural trends to the control sites. A declining trend in some metrics (e.g. infiltration, nutrient cycling and vegetation cover) between 2014 and 2016 across all sites (control and rehabilitation) is consistent with pronounced moisture deficit conditions experienced in the study area during this period. This recent climate sequence provides a good opportunity to evaluate the resilience of vegetation on rehabilitation areas in winter 2017.

The Hamersley line rehabilitation sites (up to 4 years old) display similar LFA and vegetation structural trends to the control sites. In general total perennial cover is lower at the rehabilitation sites, which is probably a reflection of their young age; however on average species richness is higher than the control sites. As with the Mainline sites, a declining trend in some metrics between 2015 and 2016 (e.g. infiltration, nutrient cycling and vegetation cover) across all sites (control and rehabilitation sites) is consistent with pronounced moisture deficit conditions experienced since mid-2014 in the study area.

At the majority of Mainline and Hamersley line sites erosion indices have been stable or reduced in the period 2014 to 2016. This result is consistent with the onset of drier conditions since mid-2014, and is also likely to be related to greater site occupancy by vegetation (i.e. increased surface stability).

The invasive weed **Cenchrus ciliaris* was recorded at 13 Mainline sites (1 control and 12 rehabilitation) and 16 Hamersley line sites (3 control and 13 rehabilitation) in 2014. For the subset of sites measured in 2016, **Cenchrus ciliaris* was only recorded at three Mainline rehabilitation sites. Factors contributing to the decline of this species have not been confirmed, but could be either due to unfavourable climate conditions or Fortescue weed management activities.

Overall, the rehabilitation site monitoring to date indicates that the majority of rehabilitated areas are tracking favourably to meet Fortescue's rehabilitation criteria. A favourable climatic sequence in the early years of vegetation establishment at these sites may be an important factor contributing to this outcome. Prolonged dry conditions experienced since about mid-2014 provide an important test of the resilience of vegetation communities on rehabilitated areas prior to the next monitoring event.

5 Assessment of impacts to environmental factors

5.1 Overview

Fortescue's Rail Operation environmental monitoring program has been formulated to test the overarching hypothesis:

'The Fortescue railway construction and operations are not causing any measurable impacts on the surrounding health of the ecosystem, based on predicted environmental outcomes as detailed in the relevant PER document'

The following sections describe a factor based review of predicted environmental outcomes from the construction and operation of Fortescue's heavy rail infrastructure as detailed in the relevant PER documentation (Fortescue 2004, 2005, 2010, 2011, 2015). Observed factor responses, based on the monitoring program findings presented in Section 4, are reconciled against the predicted environmental outcomes.

5.2 Conservation significant fauna

5.2.1 Greater Bilby

5.2.1.1 Predicted factor response

Predicted impacts to the Greater Bilby and its habitat resulting from the construction and operation of Fortescue's heavy rail network include (Fortescue 2004, 2005, 2010):

- Direct disturbance of burrowing and foraging habitat; and
- Indirect disturbance of habitat through:
    - changes to surface hydrology;
    - increased risk of erosion;
    - increased potential for the introduction and spread of weeds;
    - increased fire frequency; and
    - habitat fragmentation - restriction of fauna movement.

The anticipated outcomes of implementing the project in accordance with approved environment management commitments were:

- Impacts on Greater Bilby populations are expected to be localised and not significant;

- No unacceptable impacts on the biological diversity of the Project area;
- No unacceptable impacts on fauna populations; and
- The Project will not threaten the conservation status of any significant fauna habitats.

5.2.1.2 Observed factor response

Greater Bilby populations are persisting in areas close to Fortescue's heavy rail network and also proximal to BHP Billiton's rail line and the Great Northern Highway, within an approximately 50 km long section of rail crossing the Macroy Land System (Figure 4). Three factors are postulated to explain the persistence of Greater Bilby in this area:

1. Favourable physiographic setting (i.e. habitat) for bilbies adjacent to the rail infrastructure footprint, including deep sandy substrates and productive vegetation in drainage tracts. The drainages may also function as animal movement and dispersal corridors.
2. Related to (1) the majority of the habitat zone where bilby records have been obtained has not experienced wildfires for 10 or more years (Figure 10). The major watercourses traversing this area are likely to be functioning as natural firebreaks. Examination of fire history mapping since 2006, recently made available at the North Australia and Rangelands Fire Information (NAFI) online database (http://www.firenorth.org.au/nafi3), supports this assessment (Figure 10). Furthermore, it appears that rail and road infrastructure including the Great Northern Highway, Fortescue's Mainline and BHP Billiton's rail line may also be functioning as firebreaks, thereby helping to protect Greater Bilby habitat.
3. Distance from the coast, providing a buffer from fox populations. The fox is recognised as the primary threat to Greater Bilby persistence on mainland Australia (Abbott 2001; Cramer et al. 2016a), and a single animal is capable of wiping out a resident Bilby population. In the Pilbara, foxes are mostly confined to the cooler and more humid coastal fringe.

5.2.1.3 Conclusion

The conservation significant fauna monitoring completed to date supports the overarching hypothesis. With portions of the Macroy Land System favoured by bilbies, land disturbance has been limited to a relatively narrow linear zone. Suitable habitat for the Greater Bilby has been maintained in areas adjacent to the zone of direct disturbance (i.e. not degraded by hydrological change, weed invasion, erosion etc.).

This assessment suggests that Fortescue's Mainline may be helping to protect Bilby habitat by functioning as a firebreak in combination with natural drainages and other linear infrastructure (neighbouring rail lines). However this functionality cannot be assured in the future. Consistent with adaptive management principles, a proactive approach to fire management for Greater Bilby conservation in the subject area is warranted.

5.2.2 Northern Quoll

Predicted impacts to the Northern Quoll and its habitat resulting from the construction and operation of Fortescue's heavy rail network include (Fortescue 2004, 2005, 2010):

- Direct disturbance to habitat (foraging, nesting/denning habitat);
- Death of individuals from vehicle/locomotive strikes; and
- Indirect disturbance of habitat through:
    - changes to surface hydrology;
    - increased risk of erosion;
    - changed fire regimes (increased fire frequency);
    - habitat fragmentation - restriction of fauna movement; and
    - increased potential for the introduction and spread of weeds.

The anticipated outcomes of implementing the project in accordance with approved environment management commitments were:

- Impacts on Northern Quoll populations are expected to be localised and not significant;
- No unacceptable impacts on the biological diversity of the Project area;
- No unacceptable impacts on fauna populations, and
- The Project will not threaten the conservation status of any significant fauna habitats.

5.2.2.1 Observed factor response

The ongoing presence of the Northern Quoll has been detected in proximity to Fortescue's heavy rail network since the commencement of monitoring. Although the data is insufficient for robust statistical interpretation, Northern Quoll activity has persisted along large sections of the rail line. Northern Quolls have also been detected on motion cameras using the culverts and moving through rehabilitated areas. The findings suggest that the rail line does not pose a significant barrier to Northern Quoll movement across the landscape, nor does it appear to have had a negative impact on populations interacting with Fortescue's heavy rail network.

5.2.2.2 Conclusion

The conservation significant fauna monitoring completed to date supports the overarching hypothesis. Disturbance to Northern Quoll habitat has been limited to a narrow linear zone associated with the physical rail infrastructure. Fortescue's Mainline may be helping to maintain Northern Quoll foraging habitat by functioning as a landscape scale firebreak.

5.2.3 Conservation significant birds

5.2.3.1 Predicted factor response

Predicted impacts to conservation significant birds and their habitat resulting from the development of Fortescue's heavy rail network include (Fortescue 2004, 2005, 2010):

- Direct disturbance of habitat; and
- Indirect disturbance of habitat through:
  - changes to surface hydrology;
  - potential introduction and/ or spread of weeds; and
  - changed fire regimes (increased fire frequency).

The anticipated outcomes of implementing the project in accordance with approved environment management commitments were:

- No unacceptable impacts on the biological diversity of the Project area;
- No unacceptable impacts on fauna populations; and
- The Project will not threaten the conservation status of any significant fauna habitats.

5.2.3.2 Observed factor response

All conservation significant bird species recorded in the study area are highly mobile and range across relatively large landscape areas. There is no evidence to suggest that important habitat for these species, such as roosting and breeding habitat, has been significantly affected by the construction and operation of the heavy rail network. Targeted and opportunistic sightings of species of interest during the implementation of the Rail Operations monitoring program suggest that these species are persisting in landscapes proximal to Fortescue's heavy rail network.

5.2.3.3 Conclusion

The findings of the conservation significant bird monitoring program are consistent with the overarching hypothesis.

5.3 Mulga vegetation communities

5.3.1 Predicted factor response

The predicted impacts to mulga vegetation communities resulting from the development of Fortescue's heavy rail network include (Fortescue 2004, 2005, 2010):

- Direct disturbance where the rail corridor crosses mulga vegetation communities; and
- Indirect disturbance through:
  - changes to surface hydrology;
  - introduction and/ or spread of weeds;
  - erosion; and
  - increased susceptibility to fires.

The anticipated outcomes of implementing the project in accordance with approved environment management commitments were:

- Surface water quality or natural flow characteristics are unlikely to be significantly affected;
- The final project design will take into consideration the location of significant vegetation and where practicable avoid these areas (e.g. railway alignment and borrow pits);

- No unacceptable impacts on the biological diversity of the Project area;
- No unacceptable impacts on mulga woodlands within areas proposed for future conservation (i.e. pastoral lease excision);
- The Project will not threaten the conservation status of significant vegetation communities; and
- The Project will not threaten the conservation status of significant flora present in the Project area.

5.3.2 Observed factor response

The intersection of Fortescue's heavy rail network with mulga vegetation communities is geographically restricted to portions of the Jurrawarrina and Jamindie land systems. Monitoring has been targeted to these areas, using the Mulga Monitoring Methodology (SO-RP-EN-0021) developed in consultation with DPaW.

Observations since 2011 at the Hamersley line intersections and 2014 at the Mainline intersections indicate:

- No material change in the health status of mulga trees;
- Evidence of mulga recruitment (development of juvenile plants into larger trees);
- Understory composition that is responsive to climatic conditions;
- Minimal weed encroachment;
- Minimal erosion; and
- Minimal impacts from wildfires.

5.3.3 Conclusion

The monitoring of mulga vegetation communities completed to date supports the overarching hypothesis.

5.4 Riparian vegetation

5.4.1 Predicted factor response

The predicted impacts to the riparian vegetation communities resulting from the development of Fortescue's heavy rail network include (Fortescue 2004, 2005, 2010):

- Direct disturbance to riparian vegetation; and
- Potential upstream and downstream impacts on vegetation condition due to changes in water flow and/or quality.

The anticipated outcomes of implementing the project in accordance with approved environment management commitments were:

- No unacceptable disturbance to riparian vegetation; and
- No unacceptable impacts on the biological diversity of the Project area.

5.4.2 Observed factor response

Riparian vegetation at major creek crossings along the Mainline has been monitored since 2008 (fixed point photographs), with more detailed NDVI and on-ground assessments completed in the period 2014 to 2016. Overall, this vegetation is in a healthy and stable condition.

5.4.3 Conclusion

The findings of riparian vegetation monitoring completed to date support the overarching hypothesis.

5.5 Surface water

5.5.1 Predicted factor response

The predicted impacts to the surface water resulting from the development of Fortescue's heavy rail network include (Fortescue 2004, 2005, 2010):

- Alteration of natural drainage patterns with potential to cause:
    - scouring;
    - erosion and siltation of the drainage channels;
    - inundation of upstream areas; and
    - introduction of sediment to surface water sheet flow.

The anticipated outcomes of implementing the project in accordance with approved environment management commitments were:

- No adverse downstream surface water impacts, particularly in sheet flow zones; and
- No adverse impacts on surface water quality downstream of the Project.

5.5.2 Observed factor response

Fortescue has established an extensive hydrological monitoring network encompassing major drainages and sheetflow zones intersected by the heavy rail network (installed in Sept/Oct 2014). This provides a good basis for collecting information to characterise the hydrological regimes of these areas. To date a lack of flow events has limited the collection of hydrological data from the major drainages intersecting Fortescue's heavy rail line. However the available water quality data collected in 2015 and 2016 are consistent with records from Pilbara watercourses more generally, including pools in the lower Yule River sampled by Pinder and Leung (2009), and suggest that water quality has not been significantly affected by the heavy rail network.

With respect to potential impacts on vegetation arising from altered natural drainage patterns, the mulga and riparian vegetation monitoring programs indicate that indirect impacts caused by modifications to the surface water regime have been insignificant (refer to the discussion of monitoring results in Section 4).

5.5.3 Conclusion

Fortescue has established a comprehensive network of surface water monitoring equipment at locations where the heavy rail infrastructure crosses the major drainages of the study area. Owing to prolonged dry conditions since about mid-2014 limited surface flow and water quality data has been collected to date. In combination with vegetation monitoring data, there is no evidence to suggest increased erosion, sedimentation and flooding has occurred in these areas. Overall the findings are consistent with the overarching hypothesis.

5.6 Weeds

5.6.1 Predicted factor response

The predicted impacts of weeds resulting from the development of Fortescue's heavy rail network include (Fortescue 2004, 2005, 2010):

- Potential introduction or spread of weeds during construction or operation of the railway; and
- Degradation of native vegetation by weeds (e.g. caused by increased fire frequency, completion for site resources).

The anticipated outcomes of implementing the project in accordance with approved environment management commitments were:

- No unacceptable impacts on the biological diversity of the Project area.

5.6.2 Observed factor response

Weed monitoring is being implemented on a biennial basis at multiple locations along the rail network selected in consultation with DPaW. Observations since 2012 in the Hamersley line sites and 2014 at the Mainline sites indicate:

- Minimal weed encroachment and spread in overall terms; however **Cenchrus ciliaris* cover has increased at several Hamersley line reference and impact sites where it was first recorded in 2012.
- No material change in native vegetation condition, which ranges from good to excellent across the Mainline and the Hamersley line sites; and
- Similar patterns of weed behaviour in reference and impact sites, in particular with respect to responsiveness to climatic conditions. It is likely that prolonged dry conditions since mid-2014 have limited the rate of weed species expansion in reference and impact areas, and in some cases contributed to weed species decline.

5.6.3 Conclusion

There is no evidence to suggest that Fortescue's heavy rail network has materially contributed to the introduction and spread of weeds. The overarching hypothesis is supported.

5.7 Rehabilitation

5.7.1 Predicted factor response

The predicted impacts of rehabilitation resulting from the development of Fortescue's heavy rail network include (Fortescue 2004, 2005, 2010):

- Vegetation clearing and revegetation will be undertaken progressively throughout the life of the Project with all disturbed areas revegetated on closure of the Project.

The anticipated outcomes of implementing the project in accordance with approved environment management commitments were:

- Re-establishment of safe and stable, revegetated landforms that resemble the pre-mining landscape as close as practicable; and
- Any remaining depressions will be free-draining where practicable and stable.

5.7.2 Observed factor response

Progressive rehabilitation of borrow pits, laydown areas and other temporary disturbance zones associated with Fortescue's heavy rail network commenced in 2008 along the Mainline, and in 2012 along the Hamersley line. Fortescue has developed a detailed Rehabilitation and Revegetation Monitoring Procedure (45-PR-EN-0027) which has been implemented at Mainline and Hamersley line sites since 2014.

Overall, vegetation establishment on rehabilitation areas has been successful. Favourable climatic conditions in the early years of plant establishment may have contributed to this result. Landscape function, vegetation density and cover and erosion metrics from rehabilitation areas compare favourably with natural analogue sites; taking into account the age and landscape context of these areas. The monitoring results indicate that the majority of rehabilitated areas are tracking favourably to meet Fortescue's broad rehabilitation goals. Specific completion criteria for these areas remain to be developed.

Drought conditions experienced in 2016 are anticipated to provide an important test of the resilience of vegetation communities on rehabilitated areas prior to the next monitoring event.

5.7.3 Conclusion

On the basis of a favourable rehabilitation trajectory at the majority of the Mainline and Hamersley line rehabilitation areas the overarching hypothesis is supported.

6 Overall findings and recommendations

This report provides a synthesis of Mainline and Hamersley line environmental monitoring data provided by Fortescue for the period 2011 to 2016, in addition to historical studies dating from 2005. The monitoring program has included:

- Comprehensive spatial coverage of the study area including impact and reference sites,
- Frequent measurements (typically annually or biennially), and
- Consultation with regulatory agencies regarding the design of the monitoring program (in particular DPaW).

The monitoring program is considered to provide a sufficient basis for detecting change and time series trends in the environmental factors targeted by the program.

The major findings include:

- Populations of Greater Bilby, Northern Quoll and conservation significant bird species are persisting in proximity to Fortescue's heavy rail network;
- In combination with natural drainages, it is possible that the rail line is helping to protect conservation significant fauna habitat (in particular the Greater Bilby) by functioning as a firebreak;
- The rail line does not appear to be affecting the ability of Northern Quolls to move across the landscape. Similar findings were made with the Brush-tailed Mulgara, which was monitored over the period 2012 to 2015 prior to this species being confirmed as not listed under the EPBC Act;
- The condition of mulga vegetation communities has not materially changed during the period of monitoring. These communities have persisted in relatively good health with minimal weed encroachment and acceptable land surface stability. Time series change in understorey species composition and cover is consistent with the functional behaviour of rain-fed vegetation subject to cycles of moisture deficit;
- The condition of riparian vegetation proximal to Fortescue's heavy rail network has not materially changed during the period of monitoring. These communities are healthy and the structural integrity of the overstorey has been maintained;

- In 2014 Fortescue established an extensive hydrological monitoring network including major drainages and sheetflow areas traversed by the heavy rail network. Only a limited set of water quality data was available for inclusion in this 2016 State of the Environment report; however this data indicates that water quality is consistent with that of ephemeral creek systems of the Pilbara more generally. In combination with vegetation monitoring data, there is no evidence to suggest that Fortescue's heavy rail network has affected water quality or contributed to erosion, sedimentation and/or flooding near drainage crossing points or in sheetflow areas;
- Native vegetation proximal to the heavy rail network and in surrounding areas is predominantly in good to excellent condition. Only a limited number of weed species have been recorded in a subset of weed monitoring sites, and generally weed burdens have been stable during the period of monitoring. In some cases weed burdens have reduced, which may be attributable in part to prolonged dry conditions since mid-2014. When compared against surrounding landscapes, there is no evidence to suggest that Fortescue's heavy rail network has contributed to the introduction and/or spread of weeds during the monitoring period; and
- Rehabilitation areas progressively rehabilitated (since 2008 along the Mainline and since 2012 along the Hamersley Line) exhibit broadly similar landscape function, vegetation density/cover and land surface stability indices relative to adjacent 'analogue' areas. The results suggest a generally favourable rehabilitation trajectory. Vegetation establishment on rehabilitation areas may have benefited from the relatively wet period between 2012 and 2014. A decline in some LFA and vegetation cover indices since 2014 at control and rehabilitation site respectively correlates with prolonged dry conditions since about mid-2014.

Key recommendations for applying the findings of the assessment to future monitoring and adaptive environmental management more generally include:

- Develop a Greater Bilby conservation Fire Management Plan for the approximately 50 km portion of the Macroy Land system where populations are persisting adjacent to Fortescue's Mainline.
- Undertake a risk assessment of the potential for Fortescue's Mainline to provide a vector for feral predator dispersal inland from the coastal plain; for example by contributing to more persistent drinking water availability. The potential for fox dispersal inland is of particular interest, given the potentially catastrophic impact of

this species on Greater Bilby populations. Update the Conservation Significant Fauna Management Plan (100-PL-EN-0022) based on the findings of this risk assessment.

- Maintain timely, ongoing targeted monitoring of known Greater Bilby populations. Continue to align with DPaW Greater Bilby monitoring and research activities (e.g. genetic analysis of populations; regional scale meta-analysis) where this is consistent with the Rail Operations monitoring program objectives;
- Continue to align with DPaW Northern Quoll monitoring and research activities (e.g. genetic analysis of populations; regional scale meta-analysis) where this is consistent with the Rail Operations monitoring program objectives;
- Incorporate individual Mulga tree stem diameter measurements into the Mulga monitoring program and utilise this with ongoing photograph monitoring of individual trees. This will enable long term growth responses to environmental variables (in particular water availability) to be evaluated;
- Continue riparian vegetation monitoring using NDVI methods, complemented by periodic ground truthing to assist with results interpretation. It is recommended that the frequency of on-ground monitoring is aligned with Fortescue's mulga monitoring methodology as per the *Significant Flora and Vegetation Management Plan* (45-PL-EN-0017). Include assessment of erosion in riparian areas as part of on-ground assessment, to complement surface water flow and water quality data sets;
- Continue to monitor surface water as per Fortescue's Surface Water Management Plan (100-PL-EN-1015);
- Continue to monitor weeds on a biennial basis as per Fortescue's Weed Management Plan (100-PL-EN-1017)(Appendix 4);
- Finalise rehabilitation completion criteria for Fortescue's heavy rail network, and review and update the Rehabilitation and Revegetation Monitoring Procedure (45-PR-EN-0027) to provide an efficient basis for confirming when these criteria have been achieved. It is anticipated that this task will involve consultation with regulatory agencies and relevant land managers/custodians; and

- Improve data collation and management practices across all programs. As part of this review, a number of inconsistencies in plot identifiers were identified between monitoring events. Establish a generic site ID coding system for environmental datasets; for example using a standard alphanumeric coding system that identifies site attributes including the year that the site was established. Suggested elements to include in the coding system are tabulated as follows:

	Fauna	**Mulga vegetation**	**Riparian vegetation**	**Weeds**	**Rehabilitation**
Rail section	ML = Mainline; HL = Hamersley line				
Site type	F	M	R	W	X
Sub type	bilby = b quoll = q cons. sig. birds = z				
Impact or Reference site	I or R				
Year established	AA = 2012; AB = 2013; AC = 2014; AD= 2015; AE = 2016 …etc				
Site number	Whole numbers in consecutive order				
Site sub-reference (if required)	e.g. sub-sites a, b, c … etc				

Under this system:

- ML-Fb-I-AC-14 = Greater Bilby monitoring impact site number 14, established on the Mainline in 2014.
- HL-M-R-AA-30b = Mulga monitoring reference site number 30 (on transect b), established on the Hamersley line in 2012.

- In connection with improved data collation, use simple visual tools, building on those developed as part of this study (refer to Appendices 6 - 9) to aid in data interpretation and inform the selection of quantitative methods for future data analysis.

7 Conclusion

Fortescue has established a broad ranging environmental monitoring program for evaluating the impact of its heavy rail network on the surrounding environment. The program addresses the following environmental factors:

- Conservation significant fauna,
- Mulga vegetation communities,
- Riparian vegetation communities,
- Surface water,
- Weeds, and
- Rehabilitation of disturbed areas.

Overall, the findings of the monitoring program indicate that Fortescue's heavy rail network is not causing any significant impacts to general ecosystem health in surrounding areas. Conservation significant fauna (i.e. Greater Bilby, Northern Quoll and Conservation Significant Birds) are persisting in proximity to the heavy rail network. There is no evidence of significant indirect impacts to habitat used by these species; conversely the rail line may be contributing to the protection of habitat by providing a landscape scale firebreak. There is no evidence to suggest that the rail line is impeding fauna movement within the landscape.

In broad terms the native vegetation in the landscapes surrounding the rail line has remained in good to excellent condition. There is no evidence to suggest that the health and integrity of mulga and riparian vegetation has been impacted by the heavy rail network. A number of weed species have been documented to occur in the study area, however there is no evidence to suggest that weed burdens have significantly increased as a consequence of the construction and operation of the heavy rail infrastructure. Climatic drivers appear to have had the greatest influence on vegetation dynamics across the study area.

Due to the paucity of flows in ephemeral drainages intersected by the heavy rail network, only limited surface water monitoring data has been collected to date. However, the available water quality data suggests that no significant impact on surface water quality arising from the construction and operation of the heavy rail network have occurred.

Native vegetation has successfully been re-established in disturbed areas that have been rehabilitated. The majority of rehabilitated areas are on a favourable trajectory for meeting targets for vegetation structure and function.

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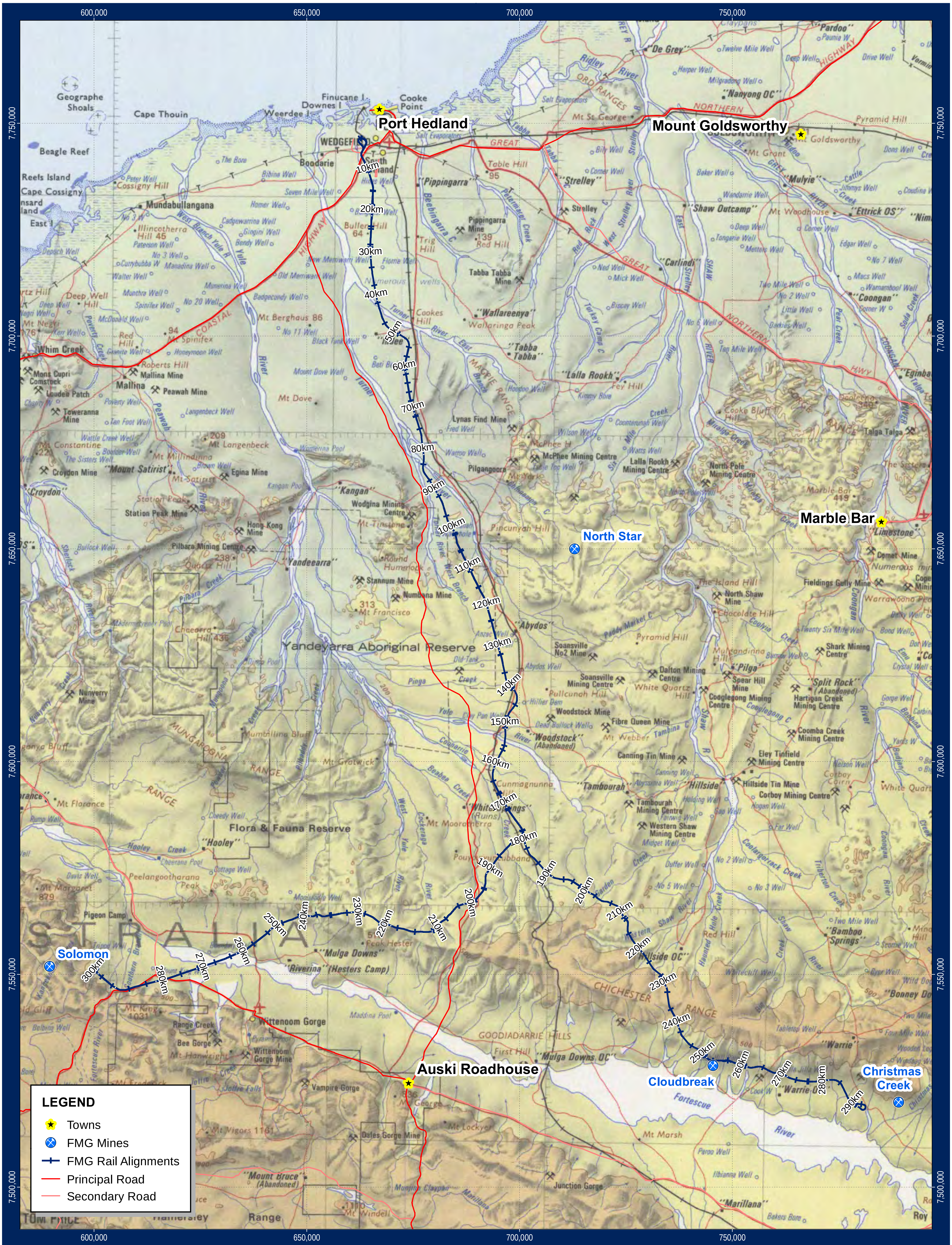
Figures



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Date: 1/02/2017
Size: A3P
Revision: 0
Confidentiality: 0

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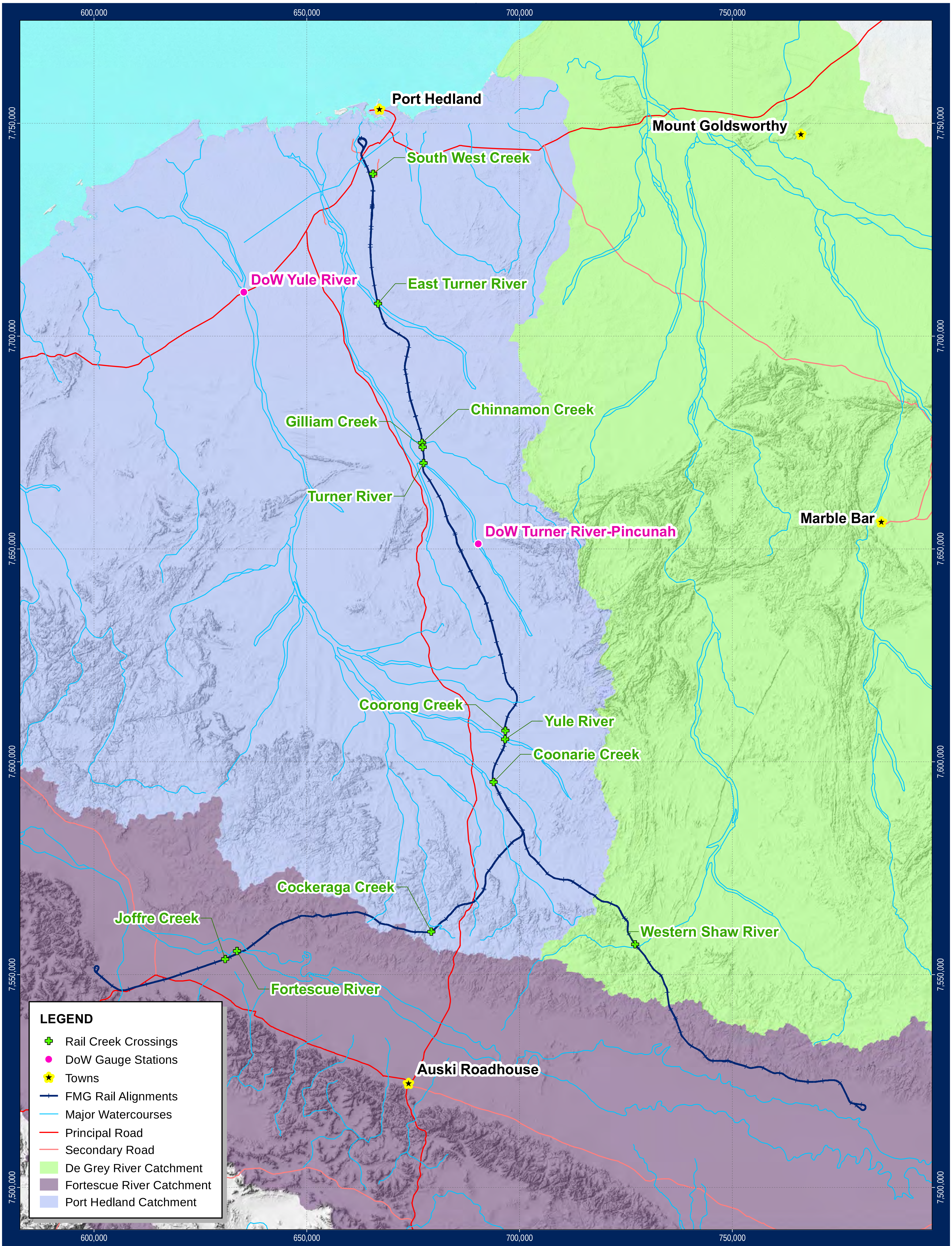
Fig 1: Fortescue Rail Operations

Fortescue Metals Group Ltd
The New Force in Iron Ore



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Date: 31/01/2017
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Fig 2: Rail - Hydrological Setting

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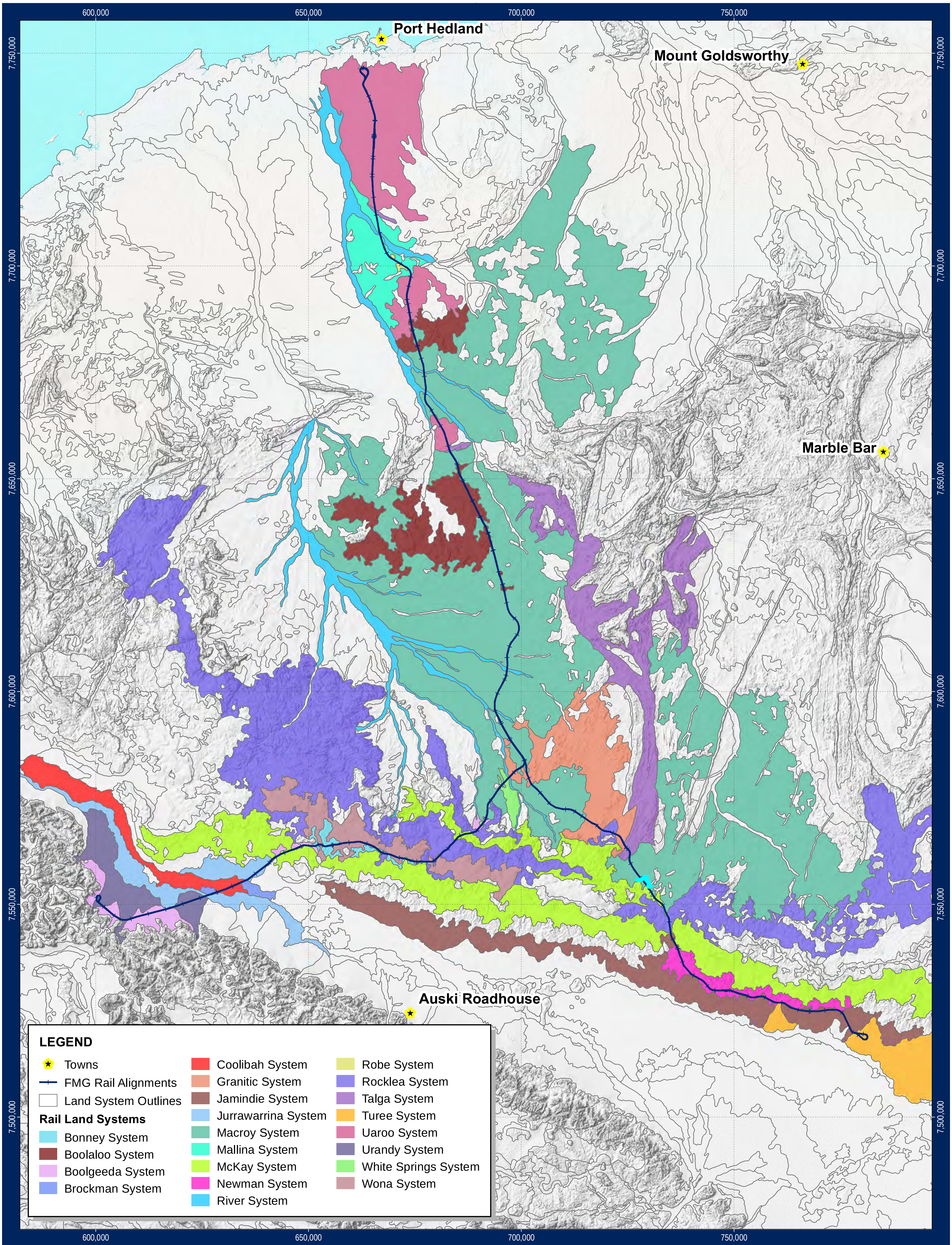

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Land Systems, DoA.
DEM, Geoscience Aus.

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Revised By: scostello
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Date: 1/02/2017
Size: A3P
Revision: 0
Confidentiality: 0

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Fig 3: Rail - Land Systems

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The New Force in Iron Ore

Data Sources:
Towns, Landgate.
Basemap, Geoscience Aus.

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Kilometres

Requested By: D. Huxtable
Drawn By: S. Costello
Revised By: scostello
Approved By: P. Mastalir
Scale: 1:800,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: R_MP_EN_0146.008_r0

Date: 3/02/2017
Size: A3P
Revision: 0
Confidentiality: 0

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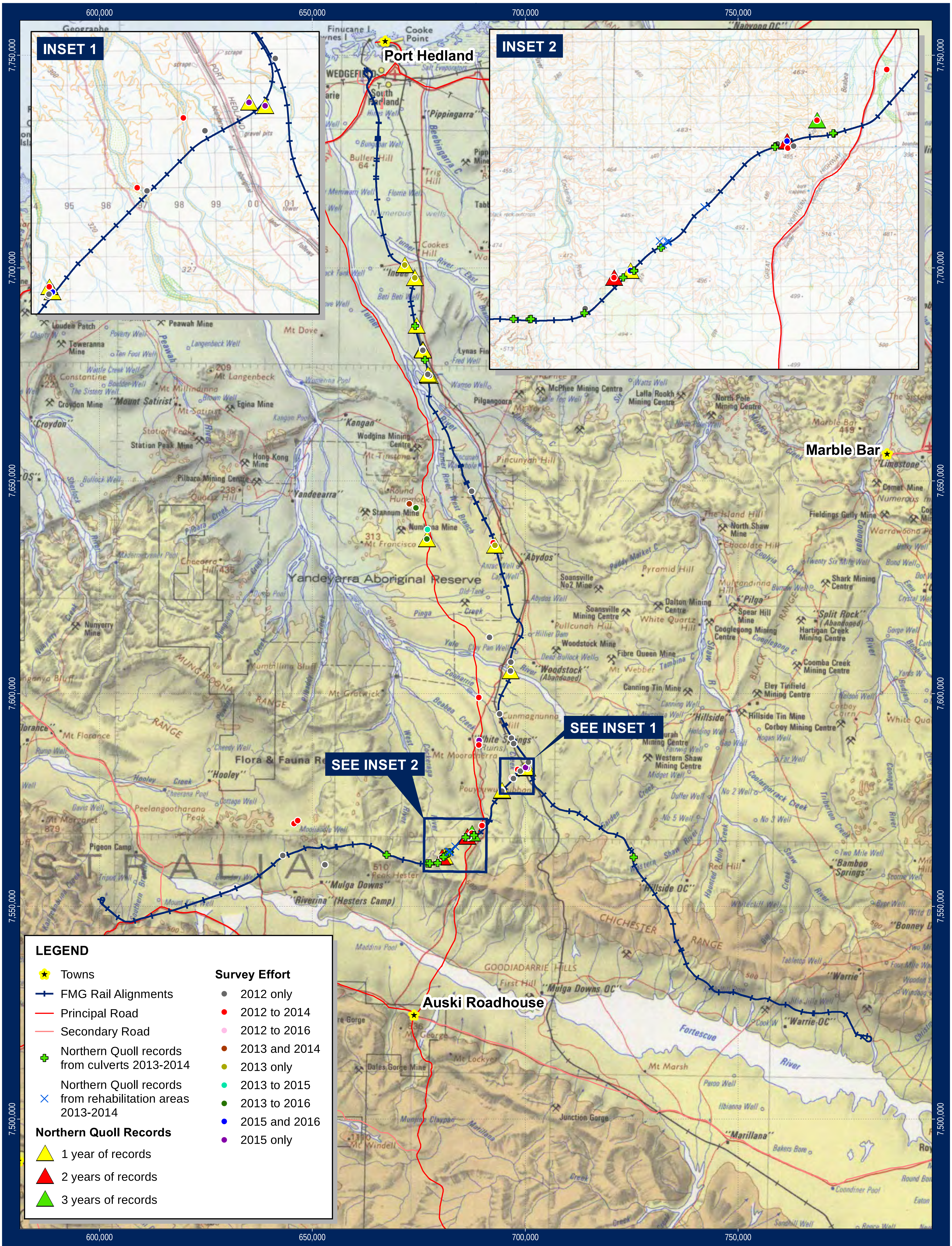
Fig 4: Greater Bilby Records

Fortescue Metals Group Ltd
The New Force in Iron Ore



Data Sources:
Towns, Landgate.
Basemap, Geoscience Aus.

N

0 10 20 30 40 50
Kilometres

Requested By: D. Huxtable
Drawn By: S. Costello
Revised By: scostello
Approved By: P. Mastalir
Scale: 1:800,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: R_MP_EN_0146.009_r1

Date: 7/03/2017
Size: A3P
Revision: 1
Confidentiality: 0

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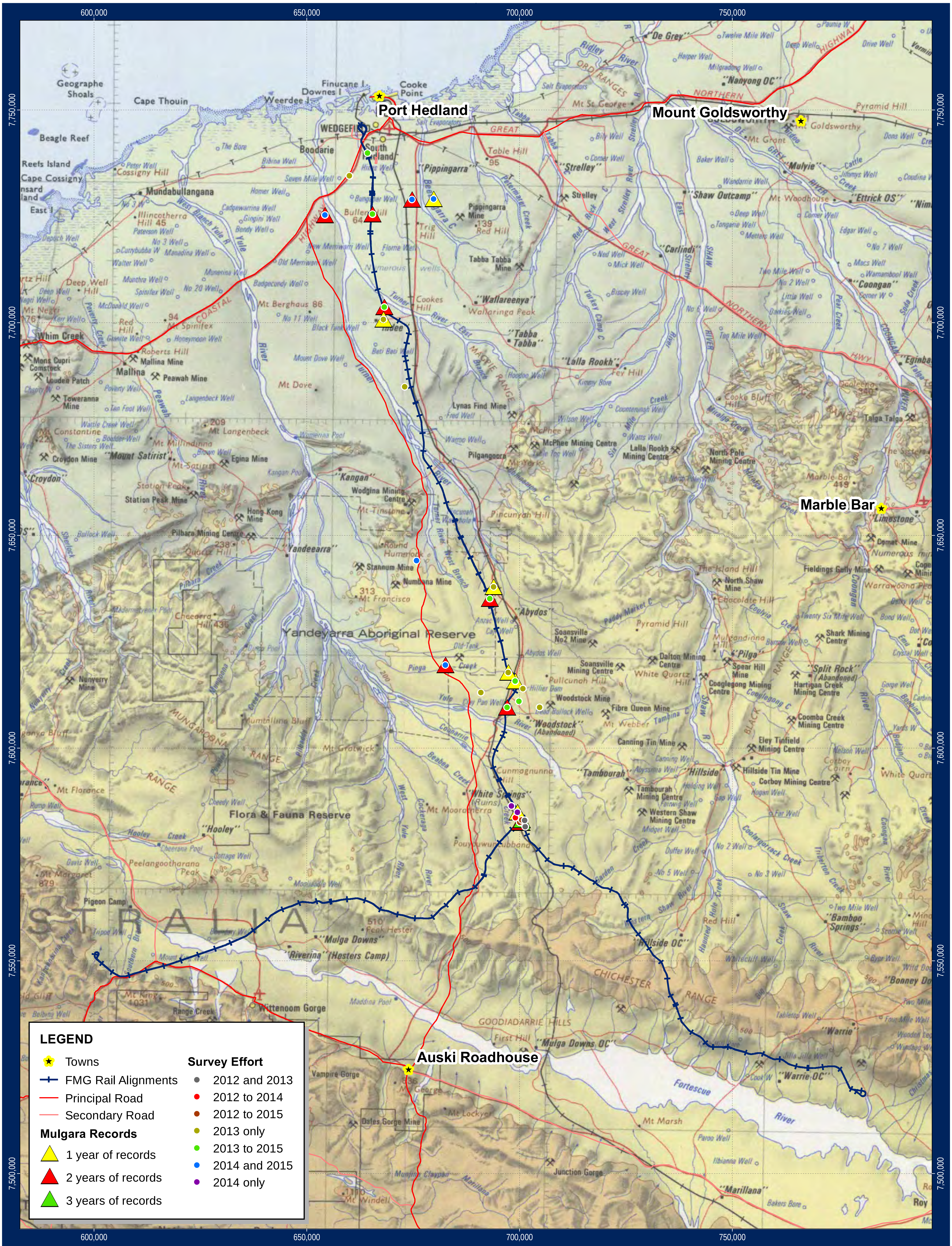
Fig 5: Northern Quoll Records

Fortescue Metals Group Ltd
The New Force in Iron Ore



Data Sources:
Towns, Landgate.
Basemap, Geoscience Aus.

N

0 10 20 30 40 50
Kilometres

Requested By: D. Huxtable
Drawn By: S. Costello
Revised By: scostello
Approved By: P. Mastalir
Scale: 1:800,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: R_MP_EN_0146.010_r0

Date: 3/02/2017
Size: A3P
Revision: 0
Confidentiality: 0

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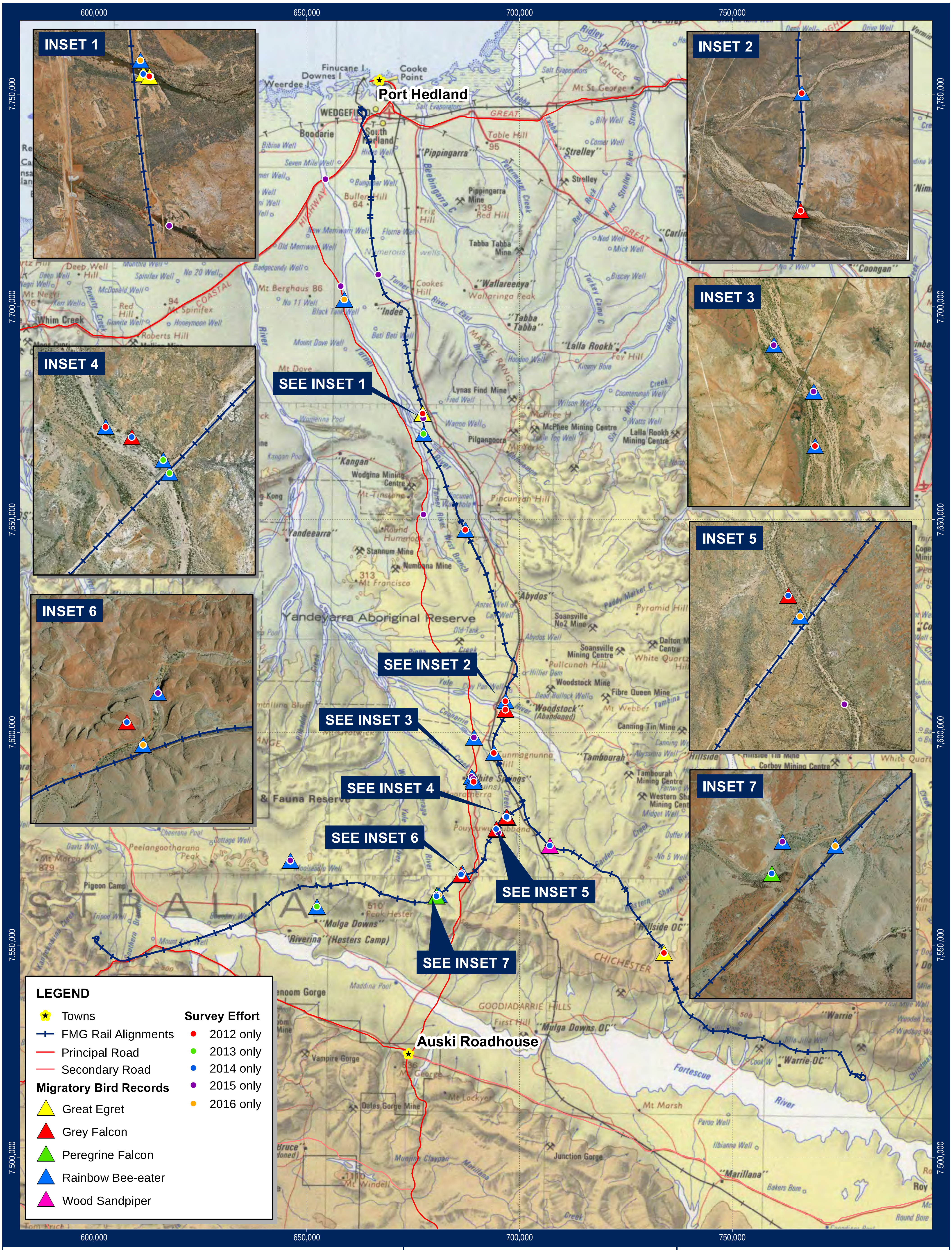
Fig 6: Brush-tailed Mulgara Records

Fortescue Metals Group Ltd
The New Force in Iron Ore



Data Sources:
Towns, Landgate.
Basemap, Geoscience Aus.

N

0 10 20 30 40 50
Kilometres

Requested By: D. Huxtable
Drawn By: S. Costello
Revised By: scostello
Approved By: P. Mastalir
Scale: 1:800,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: R_MP_EN_0146.011_r2

Date: 7/03/2017
Size: A3P
Revision: 2
Confidentiality: 0

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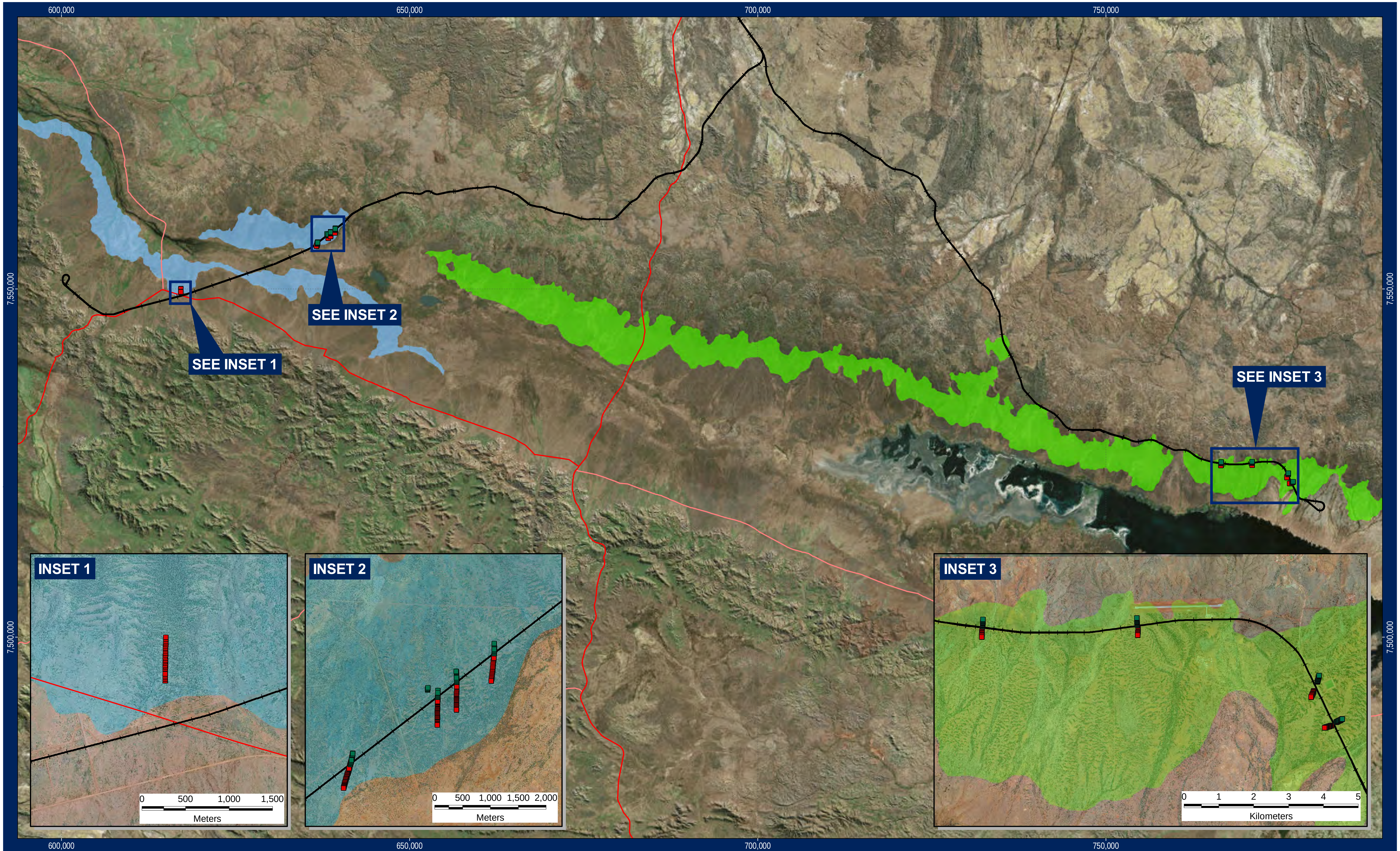
Fig 7: Conservation Significant Bird Species Records

Fortescue Metals Group Ltd
The New Force in Iron Ore



LEGEND

- Mulga - Impact Site
- Reference
- FMG Rail Alignments
- Principal Road
- Secondary Road
- Jamindie Land System
- Jurrawarrina Land System

Data Sources:
Aerial Imagery: ESRI, FMG.
Land Systems, DoA.

N

0 5 10 15 20 25
Kilometres

Requested By: D. Huxtable
Drawn By: S. Costello
Revised By: scostello
Approved By: P. Mastalir
Scale: 1:500,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: R_MP_EN_0146.004_r0

Date: 1/02/2017
Size: A3L
Revision: 0
Confidentiality: 0

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Fig 8: Mulga Vegetation Monitoring Locations

Fortescue Metals Group Ltd
The New Force in Iron Ore

Data Sources:
Towns, Roads, Landgate.
Basemap, Geoscience Aus.

N

0 10 20 30 40 50

Kilometres

Requested By: D. Huxtable
Drawn By: S. Costello
Revised By: scostello
Approved By: P. Mastalir
Scale: 1:800,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: R_MP_EN_0146.005_r0

Date: 1/02/2017
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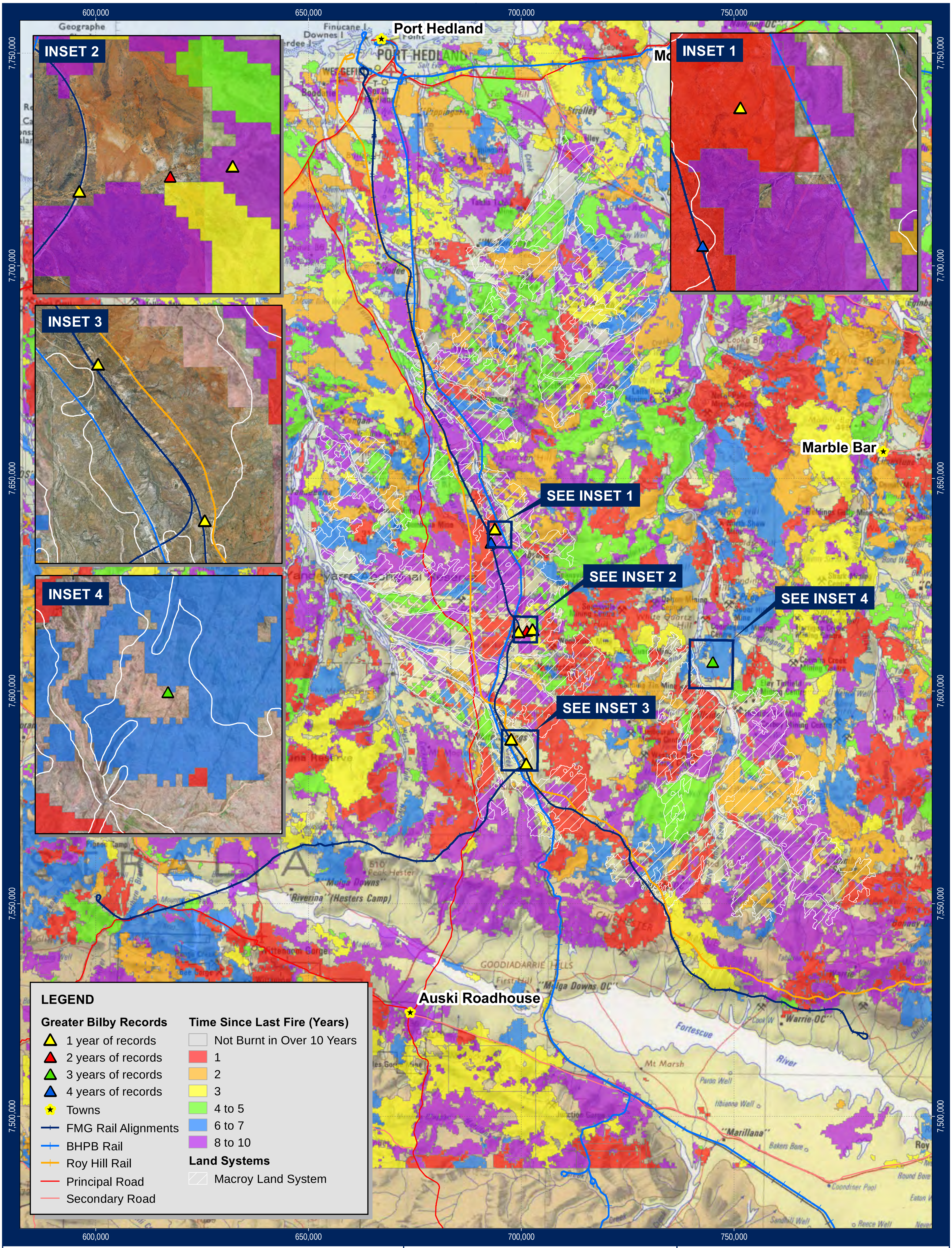
Fig 9: Rail Hydrological Monitoring

Fortescue Metals Group Ltd
The New Force in Iron Ore



Data Sources:
Towns, Roads, Landgate.
Land Systems, DoA.
Fire history, NAFI.
Basemap, Geoscience Aus.

N

0 10 20 30 40 50
Kilometres

Requested By: D. Huxtable
Drawn By: S. Costello
Revised By: scostello
Approved By: P. Mastalir
Scale: 1:800,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: R_MP_EN_0146.006_r1

Date: 6/02/2017
Size: A3P
Revision: 1
Confidentiality: 0

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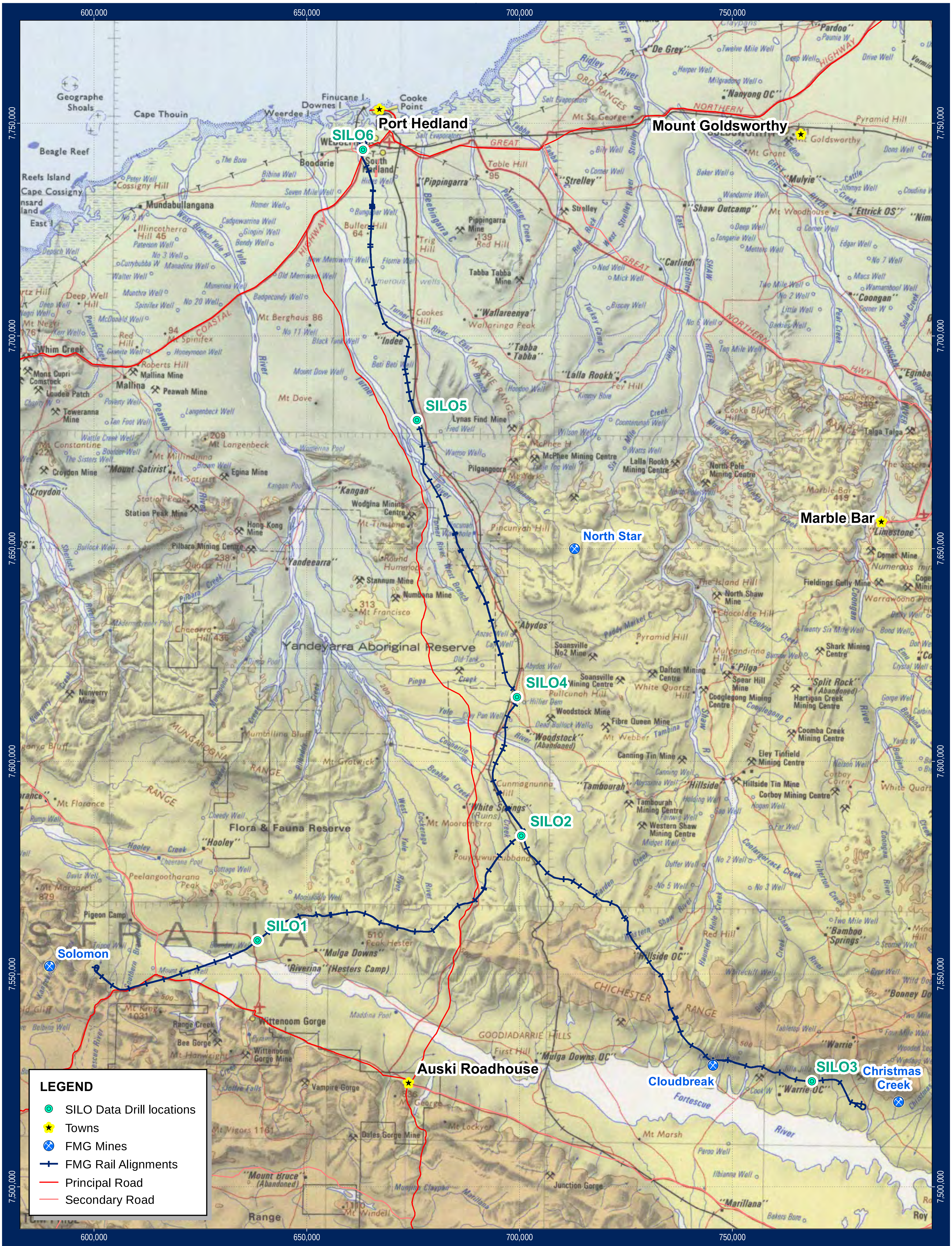
Fig 10: Bilby Records and Landscape Fire History

Fortescue Metals Group Ltd
The New Force in Iron Ore

Appendix 1 SILO Data Drill climate records from selected locations along Fortescue's heavy rail network



Data Sources:
Towns, Landgate.
Basemap, Geoscience Aus.

N

0 10 20 30 40 50

Kilometres

Requested By: D. Huxtable
Drawn By: S. Costello
Revised By: scostello
Approved By: P. Mastalir
Scale: 1:800,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: R_MP_EN_0146.007_r0

Date: 1/02/2017
Size: A3P
Revision: 0
Confidentiality: 0

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Figure A: Fortescue Rail Operations SILO Locations

Fortescue Metals Group Ltd
The New Force in Iron Ore

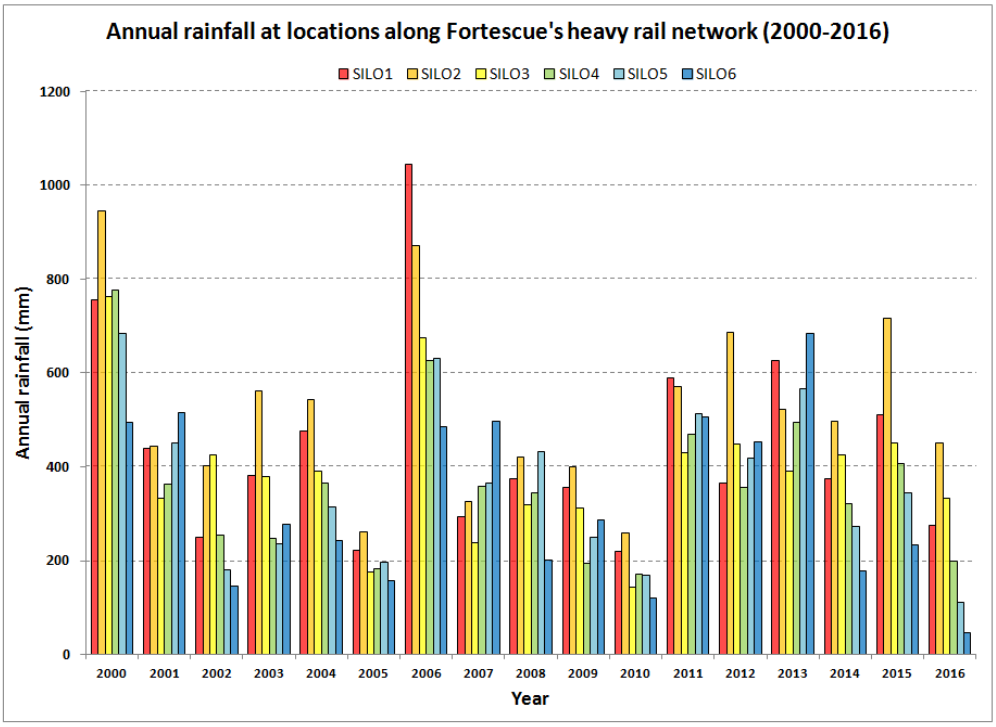


Figure B – Annual rainfall patterns since 2000

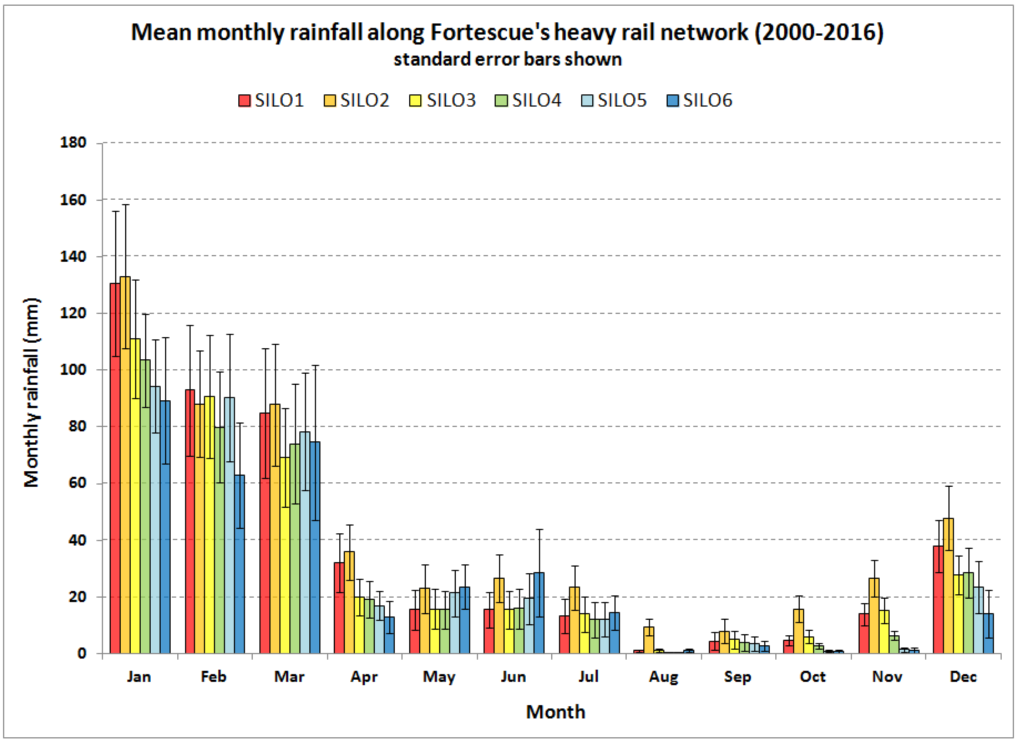


Figure C – Mean monthly rainfall since 2000

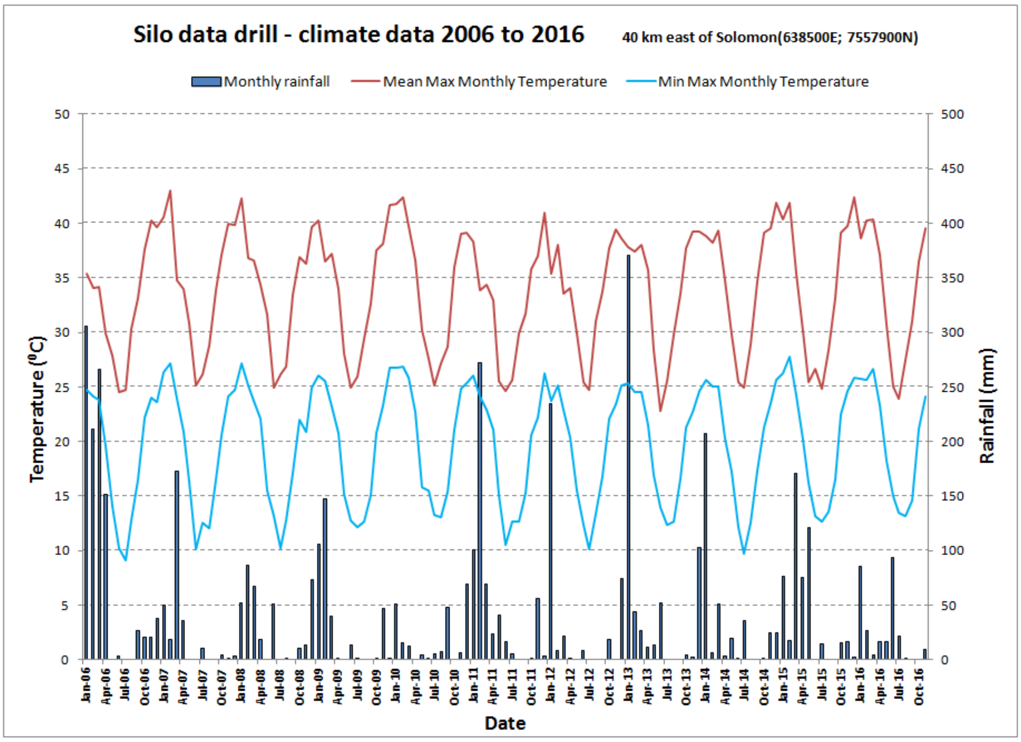


Figure D - SILO 1

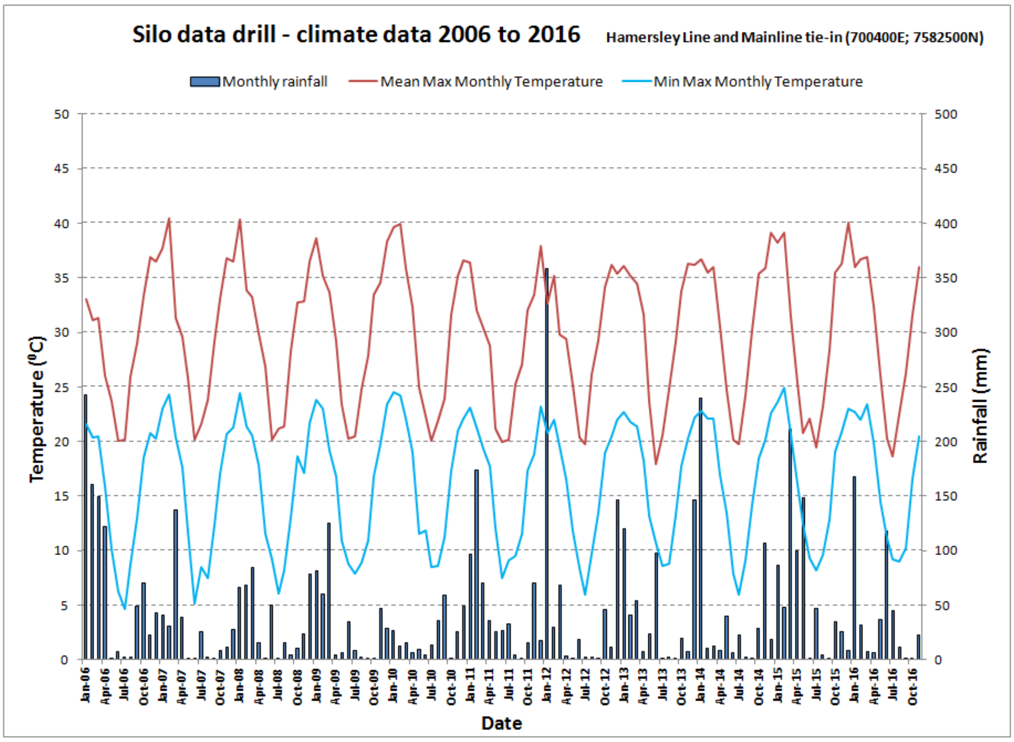


Figure E - SILO 2

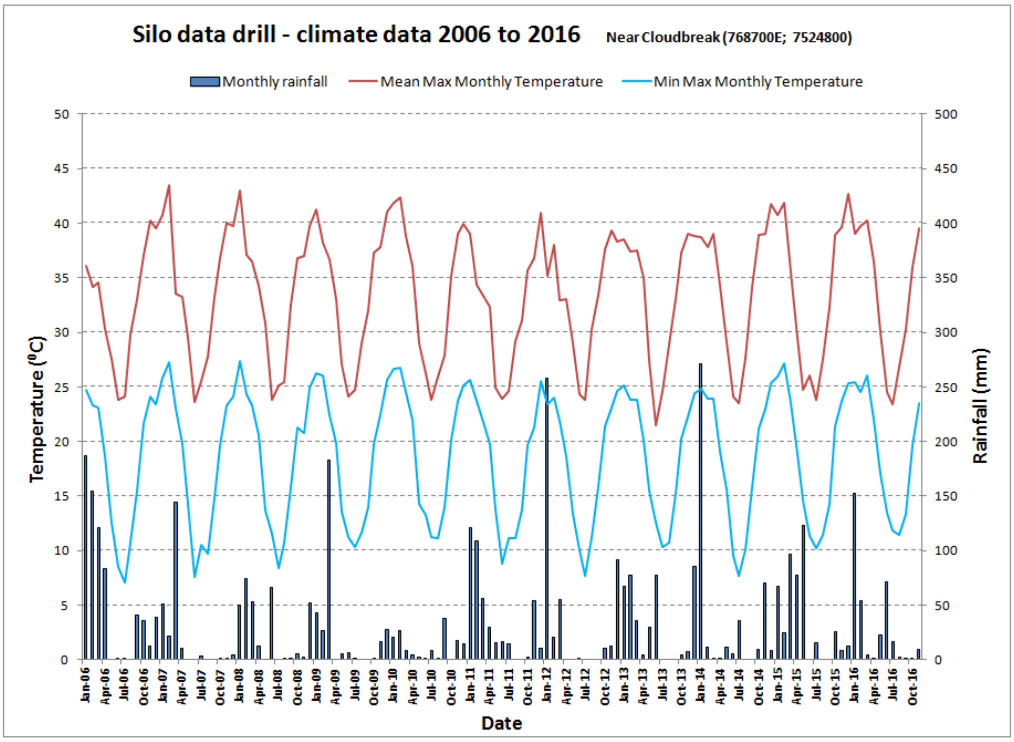


Figure F – SILO 3

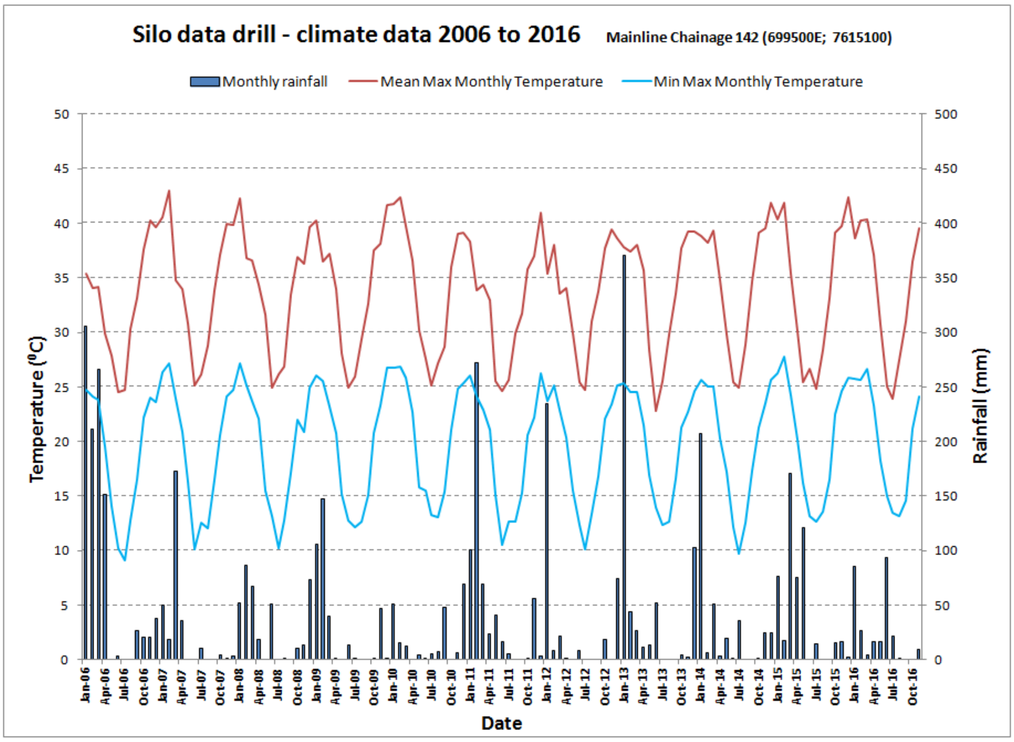


Figure G – SILO 4

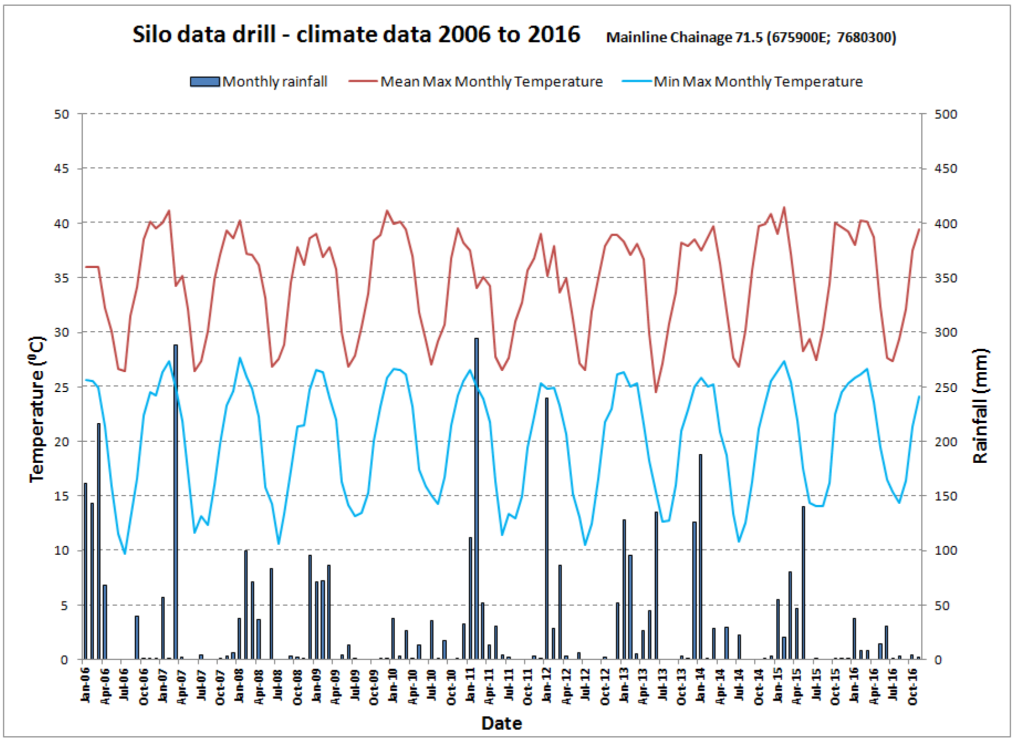


Figure H – SILO 5

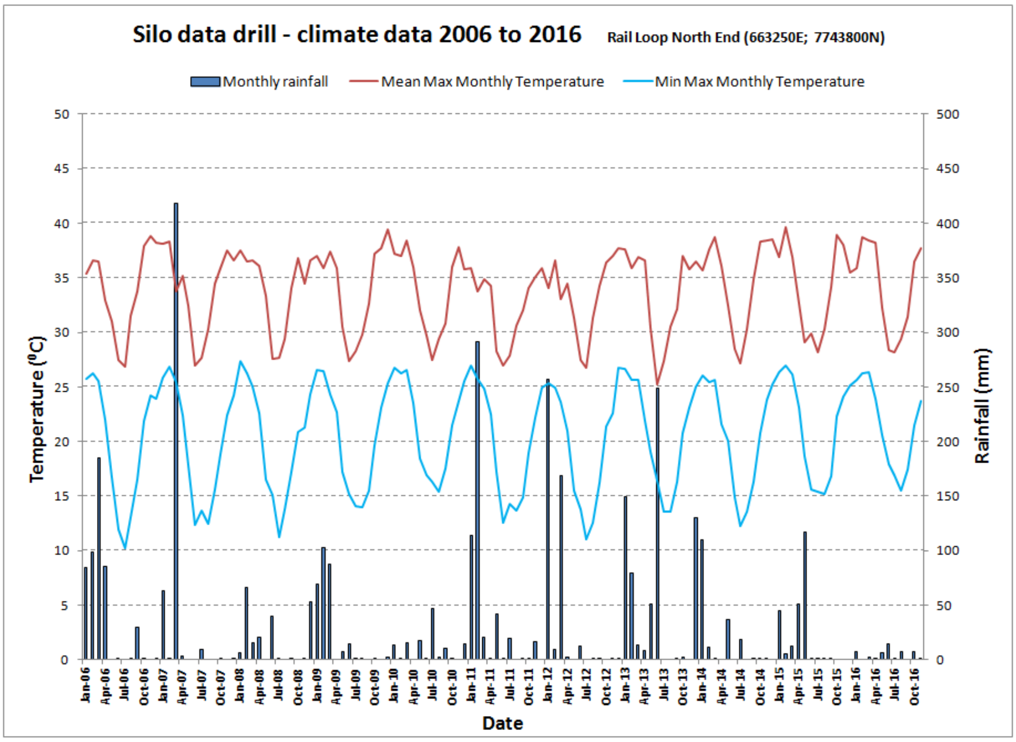


Figure I – SILO 6

Appendix 2 Stream gauge station records Turner River and Yule River

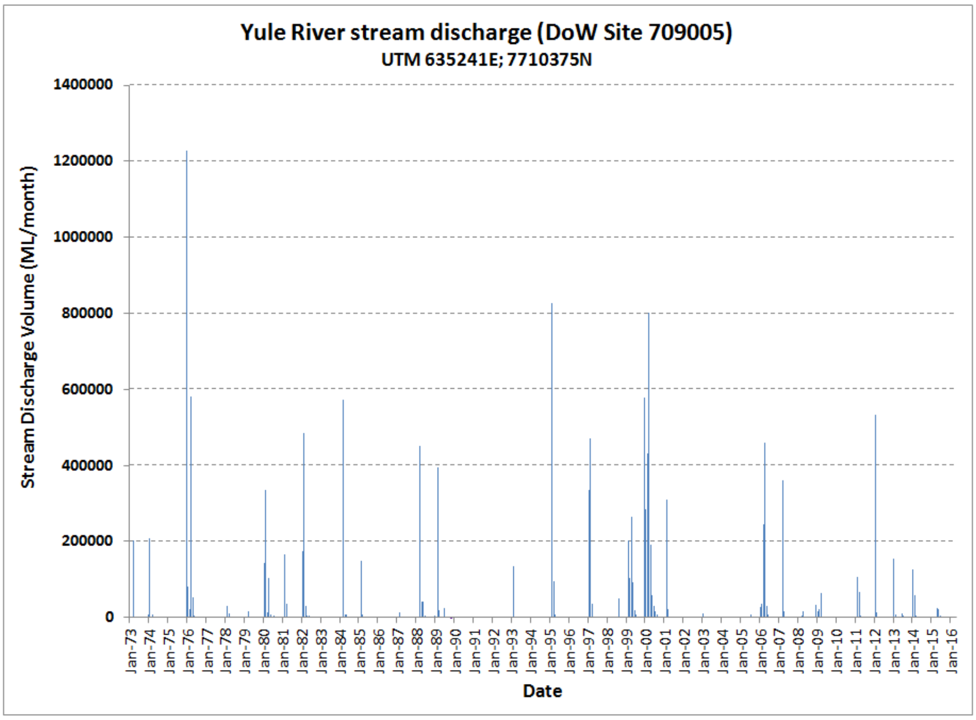


Figure A Yule River (128 km downstream from Fortescue Mainline rail crossing)

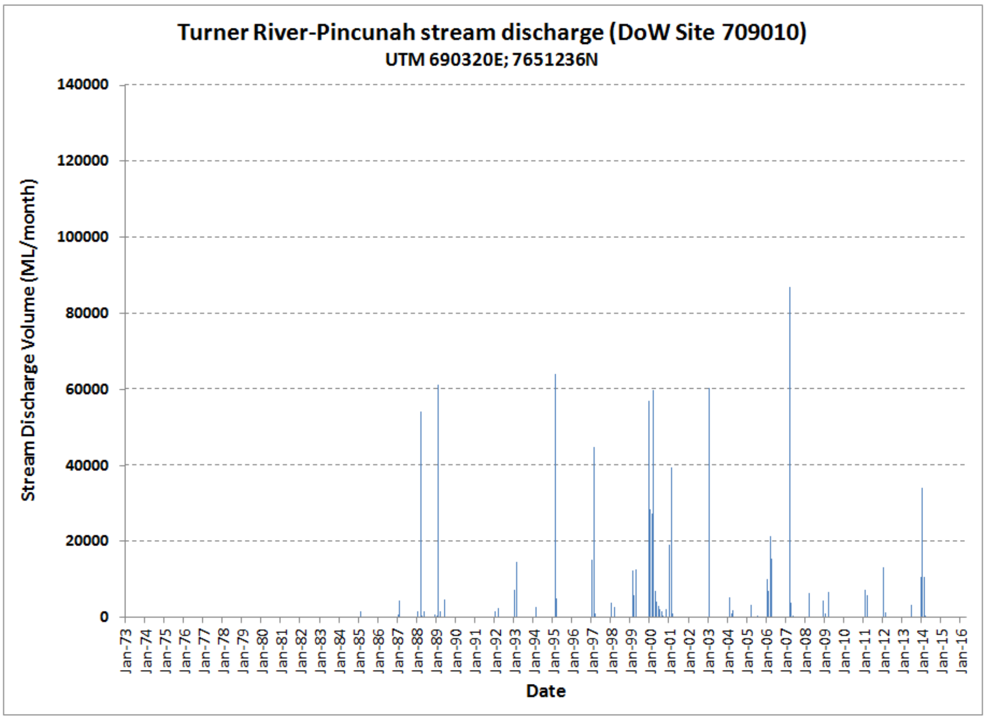


Figure B Turner River (23 km upstream from Fortescue Mainline rail crossing)[20]

[20] Note: No data at Turner River gauge station prior to 1987

Appendix 3 Land systems intersected by Fortescue's heavy rail network (source: van Vreeswyk et al. 2004; area intersections MWH 2016)

Notes:

- The following table excludes intersections with a total area of less than 5 hectares.
- Land systems are approximately ordered from north to south (mainline) and east to west (Hamersley line)

<table>
<tr><th>Land system</th><th>Description</th><th>Vulnerability to indirect impacts from linear infrastructure</th><th>Mainline corridor intersection (ha)</th><th>Hamersley line corridor intersection (ha)</th></tr>
<tr><td colspan="5">Mainline (to Hamersley line tie-in)</td></tr>
<tr><td>Uaroo</td><td>Broad sandy plains near the coast supporting shrubby hard and soft spinifex grasslands.
Depositional surfaces of low relief, with little organised through drainage. Red and loamy sandy earths of moderate depth, less commonly with calcrete at shallow depth.</td><td rowspan="3">The major vegetation types are unexceptional and regionally well represented. The vegetation predominantly subsists on rainfall and locally redistributed runoff.</td><td>2,773</td><td>N/A</td></tr>
<tr><td>Talga</td><td>Hills and ridges of greenstone and chert and stony plains supporting hard and soft spinifex grasslands.
Erosional surfaces, hill tracts and ridges with rocky basement exposures. Moderately spaced tributary and strike aligned drainage floors and channels. Shallow calcareous soils.</td><td>157</td><td>N/A</td></tr>
<tr><td>Mallina</td><td>Sandy surfaced alluvial plains supporting soft spinifex (and occasionally hard spinifex) grasslands.
Depositional surfaces; level sandy surfaced plains with occasional patches of small claypans, and occasional stony plains and isolated low hills. Drainage patterns restricted to rare, non-tributary through channels with narrow terraces. Soils are mainly deep sands and loams.</td><td>823</td><td>N/A</td></tr>
<tr><td>River</td><td>Active floodplains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands. Relatively deep, sandy textured alluvial sediments.</td><td>Riparian vegetation is geographically restricted and has elevated conservation significance. Riparian ecosystems are reliant on flooding regimes and less commonly shallow groundwater.</td><td>118</td><td>N/A</td></tr>
<tr><td>Boolaloo</td><td>Granite, domes and tor fields and sandy plains with shrubby spinifex grasslands. Erosional surfaces of moderate relief. Widely spaced tributary drainage patterns of narrow drainage floors and channels. Generally skeletal or shallow sandy soils.</td><td>The major vegetation types are unexceptional and regionally well represented. The vegetation predominantly subsists on rainfall and locally redistributed runoff.
Rocky outcrops may provide refuge habitat for fauna.</td><td>471</td><td>N/A</td></tr>
<tr><td>Macroy</td><td>Stony plains and occasional tor fields based on granite supporting hard and soft spinifex grasslands. Gently undulating erosional surfaces, with closely spaced tributary drainage lines becoming wider downslope. Shallow sandy soils overlying granite with pockets of deeper sandplain country.</td><td>The major vegetation types are unexceptional and regionally well represented. The vegetation predominantly subsists on rainfall and locally redistributed runoff.
Rocky outcrops and deeper sandplains may provide refuge habitat for fauna.</td><td>3,682</td><td>N/A</td></tr>
<tr><td colspan="5">Mainline (East-West line to Christmas Creek)</td></tr>
<tr><td>Granitic</td><td>Rugged granitic hills supporting shrubby hard and soft spinifex grasslands. Erosional surfaces including hill tracts and domes on granitic rocks with rough crests, rocky hill slopes and restricted lower stony plains. Narrow, widely spaced tributary drainage floors and channels.</td><td>The major vegetation types are unexceptional and regionally well represented. The vegetation predominantly subsists on rainfall</td><td>264</td><td>N/A</td></tr>
</table>

Land system	Description	Vulnerability to indirect impacts from linear infrastructure	Mainline corridor intersection (ha)	Hamersley line corridor intersection (ha)
		and locally redistributed runoff. Rocky outcrops may provide refuge habitat for fauna.		
Macroy	See above			
Rocklea	Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands. Erosional surfaces of high relief including hills, ridges and plateaux remnants. Tributary drainage patterns grade into broader floors and channels downslope. Soils are generally shallow with abundant basalt cobbles.	The major vegetation types are unexceptional and regionally well represented. The vegetation predominantly subsists on rainfall and locally redistributed runoff. Rocky outcrops and breakaways may provide refuge habitat for fauna.	141	N/A
Talga	See above			
Robe	Low limonite mesa and buttes supporting soft spinifex (and occasionally hard spinifex) grasslands. Erosional surfaces formed by partial dissection of old Tertiary surfaces. Closely to moderately spaced narrow tributary drainage floors. Soils are generally shallow and gravelly.	The major vegetation types are unexceptional and regionally well represented. The vegetation predominantly subsists on rainfall and locally redistributed runoff.	107	N/A
McKay	Hills, ridges, plateau remnants and breakaways of meta-sedimentary and sedimentary rocks supporting hard spinifex grasslands. Erosional surfaces with moderately spaced tributary drainage patterns incised in narrow valleys in upper parts, becoming broader and more widely spaced downstream. Soils are mainly shallow and stony.	The major vegetation types are unexceptional and regionally well represented. The vegetation predominantly subsists on rainfall and locally redistributed runoff.	68	N/A
Jamindie	Depositional surfaces including non-saline plains with hardpan at shallow depth, stony upper plains and low rises on hardpan or rock. Very widely spaced tributary drainage tracts and channels. Minor stony gilgai plains, sandy banks and low rides and hills. Shallow loamy soils (often stony/gravelly) are predominant	The vegetation, including groved mulga shrublands/woodlands occasionally with a spinifex understorey, has elevated conservation significance. Vegetation water requirements may include redistributed surface water. Major floods are likely to replenish deep soil water stores infrequently.	525	N/A
Newman	Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands. Erosional surfaces, characterised by skeletal soils (with abundant pebbles, cobbles and stones) and frequent rock outcropping. Soils are shallow and stony.	The major vegetation types are unexceptional and regionally well represented. The vegetation predominantly subsists on rainfall and locally redistributed runoff.	525	N/A
Turee	Stony alluvial plains supporting tussock grasslands and grassy shrublands. Mosaic depositional surfaces of low relief (hardpan, stony and gilgai plains) inter-dispersed with few drainage channels. Localised sheet flow can occur. Soils include various earths, loams and clays often with abundant surface cobbles.	Vegetation water requirements may include localised surface water distribution. Major floods are likely to replenish deep soil water stores infrequently.	127	N/A
Hamersley Line				
Macroy	See above		N/A	704
Granitic	See above		N/A	94
River	Active floodplains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands. Relatively deep alluvial sediments (mixed texture classes).	Riparian vegetation is geographically restricted and has elevated conservation significance. Riparian ecosystems are reliant on flooding regimes and less commonly shallow groundwater.	N/A	43

Land system	Description	Vulnerability to indirect impacts from linear infrastructure	Mainline corridor intersection (ha)	Hamersley line corridor intersection (ha)
White Springs	Residual plains supporting tussock grasslands and hard spinifex grasslands. Mostly depositional surfaces of low relief, with a mixture of stony and non-stony mantled plains. Drainage is largely internal and localised. Generally medium to heavy textured soils.	The stony plains support mainly spinifex grasslands, whilst the cracking clays support tussock grasslands. Vegetation water requirements may include localised surface water distribution. Major floods are likely to replenish deep soil water stores infrequently.	N/A	200
Boolgeeda	Stony lower slopes and plains below hill systems, supporting hard and soft Spinifex grasslands and less frequently Mulga shrublands. Quaternary colluvium parent materials. Closely spaced dendritic and sub-parallel drainage lines. Predominantly depositional surfaces characterised by red loamy soils of shallow to moderate depth.	The major vegetation types are unexceptional and regionally well represented. The vegetation predominantly subsists on rainfall and locally redistributed runoff.	N/A	2,404
Rocklea	Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands. Erosional surfaces of moderate to high relief. Tributary drainage patterns grade into broader floors and channels downslope. Soils are generally shallow with abundant basalt cobbles.	The major vegetation types are unexceptional and regionally well represented. The vegetation predominantly subsists on rainfall and locally redistributed runoff.	N/A	710
McKay	See above			993
Wona	Basalt upland gilgai plains supporting tussock grasslands and minor hard spinifex grasslands. Mainly erosional surfaces including uplands and subdued plateaux with gently sloping stony gilgai plains, minor hills and benched slopes. Sparse patterns of incised drainage with narrow drainage and steep, stony slopes. Soils are predominantly cracking and non-cracking clays.	Some of the tussock grassland communities have elevated conservation significance (Four plant assemblages of the Wona Land System Priority Ecological Community). The vegetation predominantly subsists on rainfall and locally redistributed runoff.	N/A	1,272
Bonney	Erosional surfaces including low hills, undulating rises and gently undulating stony plains supporting soft spinifex grasslands. Widely spaced drainage patterns of narrow drainage floors with minor channels. Soils are shallow and stony, with a mix of non-cracking clays, calcareous loamy earths and red loamy earths on rises and plains.	The major vegetation types are unexceptional and regionally well represented. The vegetation predominantly subsists on rainfall and locally redistributed runoff.	N/A	595
Jurrawarrina	Depositional surfaces derived from Quaternary alluvium and colluvium. Plains receiving overland sheetflow characterised by banded Mulga vegetation; and broad drainage tracts with or without defined channels. Soils are a mixture of red/brown clays, loams, earths and duplex types.	The vegetation, including groved mulga shrublands/woodlands, has elevated conservation significance. Vegetation water requirements may include redistributed surface water. Major floods are likely to replenish deep soil water stores infrequently.	N/A	710
Coolibah	Flood plains with weakly gilgaied clay soils supporting *E. victrix* woodlands (sometimes also with mulga) with a tussock grass understorey. Broad plains with shallow, meandering and anastomosing central channels. Soils include deep red/brown clays and loams.	*E. victrix* woodlands are geographically restricted and have elevated conservation significance. Vegetation water requirements include redistributed surface water. Major floods are likely to replenish deep soil water stores infrequently.	N/A	326
Hooley	Alluvial clay plains supporting a mosaic of snakewood shrublands, hummock and tussock grasslands. Flat depositional surfaces of clayey and stony alluvium. Mostly sluggish internal drainage with occasional better formed, through flow drainage tracts. Soils a mixture of cracking and non-cracking clays.	The stony plains support mainly spinifex grasslands, whilst the cracking clays support tussock grassland and scattered woodlands of mulga and snakewood.	N/A	503

Land system	Description	Vulnerability to indirect impacts from linear infrastructure	Mainline corridor intersection (ha)	Hamersley line corridor intersection (ha)
		Vegetation water requirements may include redistributed surface water. Major floods are likely to replenish deep soil water stores infrequently.		
Urandy	Stony plains, alluvial plains and drainage lines supporting shrubby soft spinifex grasslands with an overstorey of scattered *Acacia* small trees and shrubs (various species). Depositional surfaces of low relief. Plains and fans of sandy alluvium with widely spaced through going or sub-parallel distributor creek lines and channels. Soil types mainly include red loamy earths, with some red shallow sandy duplex soils.	The major vegetation types are unexceptional and regionally well represented. The vegetation predominantly subsists on rainfall and locally redistributed runoff.	N/A	757
Newman	See above		N/A	38

Appendix 4 Environmental Management Plans (EMPs) applicable to Fortescue's heavy rail infrastructure

Environmental factor/aspect	Ministerial Statement and Condition	Relevant EMP	EMP requirements
Hydrological Processes and Inland Waters Environmental Quality	MS690 Condition 8	Surface Water Management Plan (100-PL-EN-1015)	The Surface Water Management Plan shall: • establish existing surface flow regimes; and • identify significant surface water dependent ecological systems which may be impacted by changes to surface water regimes; and shall set out measures for: • controlling excessive turbidity caused by erosion directly related to railway infrastructure; • minimising the potential for contaminants to enter waterways; • maintaining the integrity of flow paths and water quantities to protect surface water dependent ecological systems; and • monitoring and reporting of any changes in surface water flow regimes caused by implementation of the proposal, and impacts on surface water dependent ecological systems.
Hydrological Processes and Inland Waters Environmental Quality	MS707 Condition 11 & MS1033 Condition 12	Surface Water Management Plan (100-PL-EN-1015)	Environmental objective (MS1033): minimise direct and indirect impacts on flora, vegetation and fauna from activities associated with the management of surface water, including, but not limited to, modifications to surface water drainage. The Surface Water Management Plan shall detail: • the alignment of the transport corridor and the components within it; • locations of infrastructure and resources (e.g. roads, conveyors, borrow pits, groundwater bores, communications facilities); • the design considerations and management measures used for borrow pits; • the specifications and locations of altered surface drainage mitigation measures such as levees and spreader ditches; and • any ongoing monitoring and management measures adopted to minimise the impacts described above.
Hydrological Processes and Inland Waters Environmental Quality	MS862 Condition 10	Surface Water Management Plan (100-PL-EN-1015)	Environmental objective: ensure that changes to surface water flows related to the construction of the railway do not adversely affect any significant vegetation community, including Mulga. To verify that the requirements of the condition are met the proponent shall: • identify any areas of significant vegetation potentially impacted by changes to surface water flows related to the proposal in consultation with the Department of Environment and Conservation[21]; • undertake baseline monitoring of areas of significant vegetation; • determine trigger levels for surface water flows, vegetation community health and vegetation cover in consultation with the Department of Environment and Conservation; • design and locate environmental culverts and other surface water control features in consultation with the Department of Environment and Conservation; • monitor surface water flows, including in the vicinity of significant vegetation; and • monitor the health and cover of significant vegetation to be retained in the proposal area and in adjacent areas. Monitoring is to be carried out according to a method and schedule determined to the satisfaction of the Chief Executive Officer of the Office of the Environmental Protection Authority prior to the commencement of construction of the railway, and is to be carried out until such time as the Chief Executive Officer of the Office of the Environmental Protection Authority determines on advice from the Department of Environment and Conservation that monitoring actions may cease.
Flora and vegetation	MS707 Condition 6	Significant Flora and Vegetation Management Plan (45-PL-EN-0017)	Environmental objective (MS1033): minimise impacts to Mulga vegetation communities This Plan shall address (MS707):

[21] Now the Department of Parks and Wildlife (DPaW)

Environmental factor/aspect	Ministerial Statement and Condition	Relevant EMP	EMP requirements
	& MS1033 Condition13		1. the results of further targeted flora and vegetation surveys where surveys have not been completed or where the result of previous surveys cannot be extrapolated prior to ground-disturbing activities to provide further information on the conservation and baseline values status of each of the species and/or communities within the project area; 2. the ongoing management, monitoring and reporting of impacts on vegetation communities, including Declared Rare Flora and Priority flora species, Mulga and restricted plant communities, within the project area; 3. any regeneration or revegetation strategies which are required for species and/or communities referred to in item 1 above, including completion criteria to be met following the survey for species and/or communities impacted by the project; 4. any management or mitigation actions required to address any failure to achieve regeneration completion criteria arising from item 3 above; and 5. any further investigations into the regeneration and seed ecology of affected species or communities in order to determine appropriate regeneration methodologies, if completion criteria are not being achieved. This Plan shall address (MS1033) potential impacts on conservation significant flora and vegetation health including from, but not limited to, changes to surface flows and weeds.
Terrestrial Fauna	MS690 Condition 7	Conservation Significant Fauna Management Plan (100-PL-EN-0022)	The Fauna Management Plan shall set out measures for: 1. Follow-up surveys and delineation of significant fauna populations; 2. Identifying suitable relocation sites and relocation techniques or other means of ensuring the· ongoing appropriate protection; and 3. Monitoring and reporting the success of relocation or other agreed means of appropriate protection employed.
Terrestrial Fauna	MS 862 Condition 12	Conservation Significant Fauna Management Plan (100-PL-EN-0022)	The Fauna Management Plan shall include, but is not limited to, the following: • management strategies to minimise impacts to the Pilbara Leaf-nosed Bat; • management strategies for minimisation of impacts to Northern Quoll and Mulgara, developed in consultation with the Department of Environment and Conservation; • management strategies for minimisation of impacts to habitat associated with the Northern Quoll; • measures to protect a range of fauna habitat types, including creek bed and rocky habitats; and • detailed monitoring procedures to determine the effectiveness of management strategies.
Terrestrial Fauna	EPBC 2010/5513) Applicable to additional rail infrastructure along the existing rail line between the Herb Elliot Port and Cloudbreak mine site	Conservation Significant Fauna Management Plan (100-PL-EN-0022)	Implementation of the Conservation Significant Fauna Management Plan must address: • Measures to minimise mortality to EPBC listed threatened fauna species • Measures to protect EPBC listed threatened fauna habitat • Measures to rehabilitate areas disturbed during construction that are not required for ongoing operations. • Design details of culverts in EPBC listed habitat areas that will allow fauna to traverse the rail. • A fauna monitoring program to: ○ collect baseline population data prior to commencement of construction followed by ongoing surveys and monitoring within areas of suitable EPBC listed species habitat where EPBC Act species have been recorded. ○ measure the success of management measures to inform adaptive management approach. ○ determine the usage and success of culverts.
Terrestrial Fauna	EPBC 2010/5567) Applicable to the Solomon Iron Ore Project including the Hamersley rail line	Conservation Significant Fauna Management Plan (100-PL-EN-0022)	Implementation of the Conservation Significant Fauna Management Plan must address: • Measures to minimise mortality to EPBC listed threatened fauna species • Measures to protect EPBC listed threatened fauna habitat, including Northern Quoll and the Pilbara Leaf-nosed Bat • Measures to rehabilitate areas disturbed during construction that are not required for ongoing operations.

Environmental factor/aspect	Ministerial Statement and Condition	Relevant EMP	EMP requirements
			• Design details of culverts in EPBC listed habitat areas that will allow fauna to traverse the rail. • A fauna monitoring program to: o collect baseline population data prior to commencement of construction followed by ongoing surveys and monitoring within areas of suitable EPBC listed species habitat where EPBC Act species have been recorded. o measure the success of management measures to inform adaptive management approach. o determine the usage and success of culverts.
Weeds	MS690 Condition 10	Weed Management Plan (100-PL-EN-1017)	The Weed Management Plan shall set out measures for: • identifying target weeds, having regard for weed species outside the corridor; • weed control during construction and operation; • hygiene and wash-down for all plant and equipment; and • monitoring the success of weed control.
Weeds	MS1033 Condition 13	Weed Management Plan (100-PL-EN-1017)	Weed management addressing potential impacts on conservation significant flora and vegetation health is linked to Significant Flora and Vegetation Management Plan (45-PL-EN-0017).
Weeds	MS 862 Condition 8	Weed Management Plan (100-PL-EN-1017)	The proponent shall ensure that: • Prior to commencement of ground disturbing activities reference sites on nearby land which will not be impacted during implementation of the proposal are chosen in consultation with the Office of the Environmental Protection Authority, on advice from the Department of Environment and Conservation and a baseline survey undertaken; • Prior to commencement of ground disturbing activities, impact sites within the proposal area are chosen in consultation with the Office of the Environmental Protection Authority, on advice from the Department of Environment and Conservation, and a baseline survey undertaken; • No new species of weeds (including both declared weeds and environmental weeds) are introduced into the proposal area as a result of the implementation of the proposal; • The cover of weeds (including both declared weeds and environmental weeds) within the proposal area does not exceed that existing on reference sites determined in accordance with condition 8-1(1); • The reference sites and impact sites are to be monitored every two years after commencement of ground disturbing activities to determine whether changes in weed cover and type are as a result of project implementation or broader regional changes.
Rehabilitation	MS690 Condition 9	Rehabilitation and Revegetation Management Plan (100-PL-EN-0023)	The Rail Corridor Rehabilitation Plan shall set out measures for: • identification of disturbed areas not required for ongoing operations; • topsoil management; • borrow pit management; • weed management during operations; • restoration of fauna habitat areas lost or modified during construction activities, fauna habitat reconstruction, and rehabilitation of disturbed areas (including rehabilitation of mulga communities); • the derivation of completion criteria; • monitoring the success of rehabilitation against completion criteria; • maintenance of rehabilitation; and • progressive surveying of total area rehabilitated.

Environmental factor/aspect	Ministerial Statement and Condition	Relevant EMP	EMP requirements
Rehabilitation	MS707 & MS1033	Rehabilitation and Revegetation Management Plan (100-PL-EN-0023)	Environmental objective (MS1033): ensure that the proposal is decommissioned and rehabilitated consistent with the requirements of the TPI Agreement Act[22]. MS707 Rehabilitation is carried out in a coordinated, progressive manner. The EMP should address the rehabilitation of all disturbed mine and infrastructure corridor areas to a standard suitable for the agreed end land use(s), with local flora species appropriate for the area.
Rehabilitation	MS862 Condition 9	Rehabilitation and Revegetation Management Plan (100-PL-EN-0023)	The proponent shall undertake progressive rehabilitation, beginning within 12 months of the commencement of ground-disturbing activities and continuing until the following outcomes are achieved: 1. The waste material landforms and tailings storage facility shall be non-polluting and shall be constructed so that their stability, surface drainage, resistance to erosion and ability to support local native vegetation are similar to undisturbed natural analogue landforms as demonstrated by Ecosystem Function Analysis or other methodology acceptable to regulatory agencies. 2. The waste material landforms, tailings storage facility and other areas disturbed through implementation of the proposal, shall be progressively rehabilitated with vegetation composed of native plant species of local provenance (defined as seed material collected within a suitable maximum distance of the proposal area as agreed by regulatory agencies. 3. The percentage cover and species diversity of living self sustaining native vegetation in all rehabilitation areas shall be comparable to that of undisturbed natural analogue sites as demonstrated by Ecosystem Function Analysis or other methodology acceptable to regulatory agencies.

[22] Section 32 of the TPI Agreement Act describes conditions for returning the land in the Railway Corridor to a condition as near as possible to the condition that land was in prior to the grant of authority to implement the Railway Corridor.

Appendix 5 Monitoring reports reviewed for the purposes of the 2016 State of the Environment – Rail Operations report

Environmental factor	Reports reviewed	Rail section	Years of Monitoring Data					
			2011	2012	2013	2014	2015	2016
Fauna – Greater Bilby, Mulgara, Northern Quoll, Migratory birds	Ecoscape 2017, Conservation Significant Fauna Monitoring 2016/2017, January 2017, 100-RP-EN-9641 Ecoscape 2016, Conservation Significant Fauna Monitoring Summary Memorandum (winter), October 2016, 100-EN-0673 Ecoscape 2016, Conservation Significant Fauna Monitoring 2015/2016: Operations, Fortescue Metals Group, 100-RP-EN-9626 Ecologia 2015, Conservation Significant Fauna Monitoring Annual Report 2014/15, August 2015 , R-RP-EN-1082 Ecologia 2015, Conservation Significant Fauna Monitoring 2013/14, February 2015, R-RP-EN-1053 Ecologia 2015, Hamersley Rail Line Conservation Significant Fauna Monitoring 2014, January 2015 , R-RP-EN-1064 Ecologia 2014, Solomon Rail - Conservation Significant Fauna Monitoring 2013, August 2014, R-AS-EN-0012 Ecologia 2014, Conservation Significant Fauna Monitoring, July 2014, R-AS-EN-0008 Ecologia 2013, Conservation Significant Fauna Monitoring, October 2013, SS-AS-EN-0001	Mainline and Hamersley line	No data	Hamersley -mulgara and northern quoll Mainline- Bilby, mulgara, northern quoll	Hamersley -mulgara and northern quoll Mainline- Bilby, mulgara, northern quoll	Hamersley -mulgara and northern quoll Mainline- Bilby, mulgara, northern quoll	Hamersley - northern quoll, mulgara, migratory birds and rehabilitation sites and culvert monitoring Mainline -northern quoll, greater bilby, mulgara, migratory birds and rehabilitation sites and culvert monitoring	Hamersley - northern quoll, migratory birds and rehabilitation sites and culvert monitoring Mainline -northern quoll, greater bilby, migratory birds and rehabilitation sites and culvert monitoring
Fauna- Northern Quoll, Mulgara, Migratory birds	FMG 2016b, Quarterly Significant Native Species Register 02/02/2016 45-RG-EN-0001	No data	No data	Sightings of EPBC Act listed species	Sightings of EPBC Act listed species	Sightings of EPBC Act listed species	Sightings of EPBC Act listed species	Sightings of EPBC Act listed species
Surface water	GHD 2016, Fortescue Rail Surface Water Monitoring Program Installation report, R-RP-EN-1078	Mainline and Hamersley line	No data	No data	No data	2014 equipment installation dates	No data	No data

Environmental factor	Reports reviewed	Rail section	Years of Monitoring Data					
			2011	2012	2013	2014	2015	2016
	Rail surface water monitoring data, Excel spreadsheet (data provided by Fortescue Water Team)	Hamersley line and Mainline	No data	No data	No data	No data	Incomplete data set for EC, pH, TDS, NTU, TN, TP, SO4	Incomplete data set for EC, pH, TDS, NTU, TN, TP, SO4
Vegetation - Mulga	Syrinx 2012, Solomon Rail Project Mulga Monitoring – Baseline Survey, Syrinx 2012 Baseline Mulga Monitoring FMG Ecologia 2015, Fortescue Metals Group Limited, Mulga Monitoring 2014, Hamersley Line, R-RP-EN-1062	Hamersley	Transects Photographs Condition assessment	No data	Transects Photographs Condition assessment	Transects Photographs Condition assessment	No data	No data
	ecologia (2014) 'baseline' Mainline Mulga monitoring event (R-RPEN-1065) Ecoscape 2015, 2015 Mainline rail Mulga monitoring, R-RP-EN-1085 Ecoscape 2016, 2016 Vegetation Health Monitoring Program, December 2016, 100-RP-EN-9652	Mainline	No data	No data	No data	Transects Photographs Condition assessment	Transects Photographs Condition assessment	Transects Photographs Condition assessment
Mulga- ants as bioindicators	Ecologia 2015b, Fortescue Metals Group Limited, Ant Community Monitoring 2014, Hamersley Rail, R-RP-EN-1069	Hamersley	Pitfall traps	No data	Pitfall traps	Pitfall traps	No data	No data
Vegetation - Riparian	*ecologia* Environment 2014, *Mainline rail – riparian vegetation health monitoring (multi-spectral)*, R-AS-EN-0011, Report prepared for Fortescue Metals Group Limited, February 2014 MWH 2015, Mainline Riparian Vegetation Assessment, Prepared for Fortescue Metals Group August 2015, R-AS-EN0017 Ecoscape 2016, 2016 Vegetation Health Monitoring Program, December 2016, 100-RP-EN-9652	Mainline	No data	NDVI	NDVI	Photographs NDVI	Photographs NDVI Transects	Photographs NDVI

Environmental factor	Reports reviewed	Rail section	Years of Monitoring Data					
			2011	2012	2013	2014	2015	2016
Vegetation - Rehabilitation	MWH 2016, Rehabilitation Monitoring 2016, FORT_LF_16001_Rehab_Monitoring_2016Draftv1.0 FMG 2015, Rehabilitation Monitoring 2015 Fortescue Operations, 100-RP-EN-9624 FMG 2014, Rehabilitation Monitoring 2014 – Rail, R_RP_EN_1058	Mainline and Hamersley line	No data	No data	No data	LFA Vegetation	LFA Vegetation	LFA Vegetation
Weeds	GG Environmental 2013, Weed Monitoring Baseline Survey for the Solomon Iron Ore Project, SO-00000-AS-EN-0001	Hamersley Line	No data	Monitoring quadrats	Monitoring quadrats	No data	No data	N/A
	Ecoscape 2015, Weed Monitoring: Main Line Rail 2014, R-RP-EN-1067	Mainline	No data	No data	No data	Monitoring quadrats	No data	N/A
	Ecoscape 2016b, Weed Monitoring: Operations, Fortescue Metals Group Limited, 100_RP-EN-9368_draft	Mainline and Hamersley line	No data	Hamersley only – Monitoring quadrats	No data	Monitoring quadrats	No data	Monitoring quadrats (Note: program consolidated across whole of Fortescue Pilbara operations in 2016)

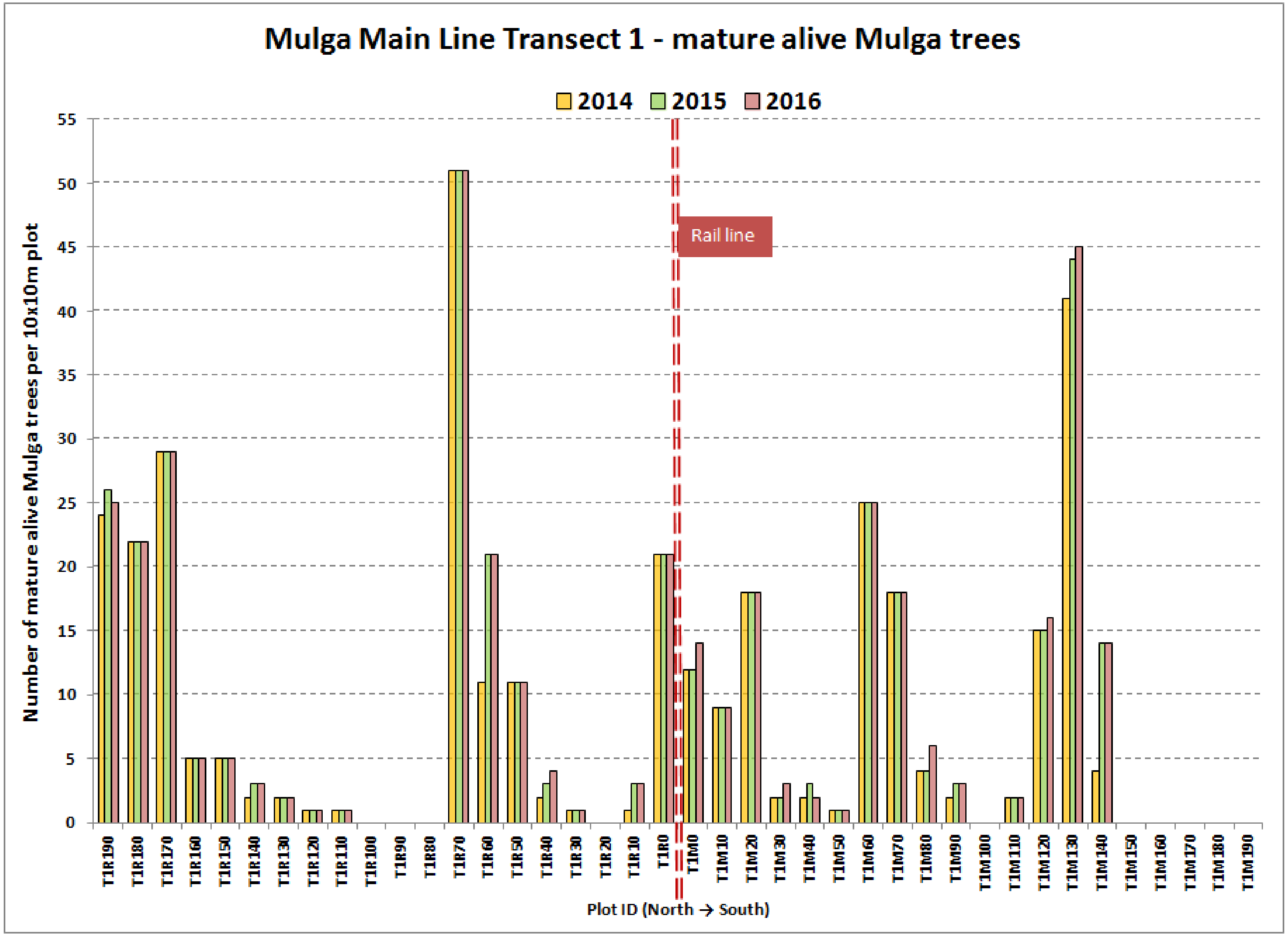
Appendix 6 Mulga monitoring - Time series data plots for each of the main monitoring parameters

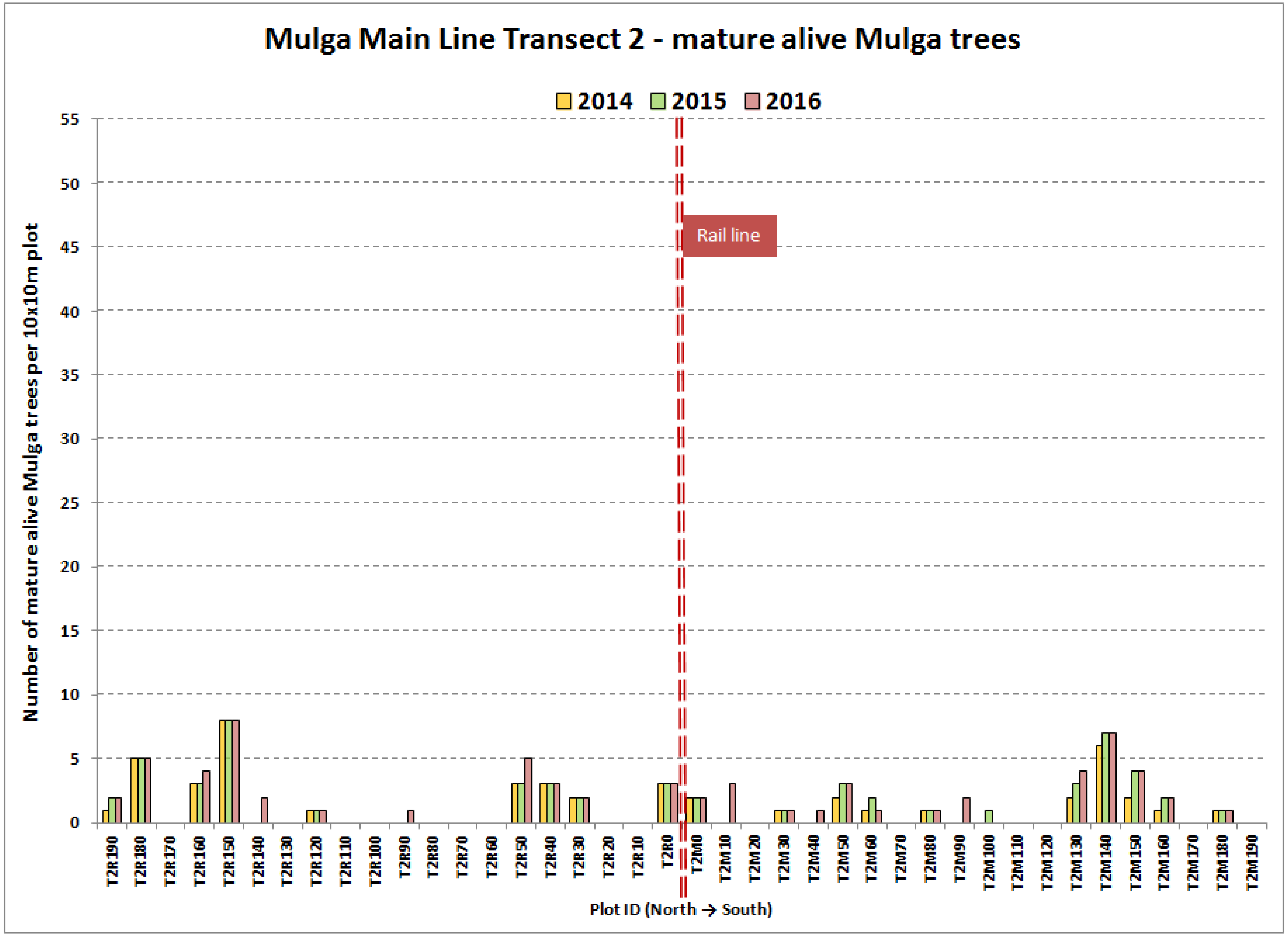
Figure List:

Mainline - Mulga population structure and density data summary for the period 2014 to 2016. Reproduced from Ecoscape (2016); Fortescue ref. 100-RP-EN-9652

Table 37: Summary of Mulga individuals recorded in 2014, 2015 and 2016

	Year	Main					Reference				
		T1M	T2M	T3M	T4M	Total	T1R	T2R	T3R	T4R	Total
Mature alive	2014	155	19	91	38	303	189	29	42	23	283
	2015	170	24	95	38	327	204	29	42	22	297
	2016	176	32	93	39	340	205	36	43	22	306
Juvenile alive	2014	30	25	47	19	121	41	15	21	8	85
	2015	25	23	46	18	112	46	15	23	7	91
	2016	21	15	40	15	91	43	11	21	9	84
Seedlings alive	2014	0	0	0	0	0	0	0	1	0	1
	2015	0	0	0	0	0	0	0	1	0	1
	2016	0	0	0	0	0	0	0	1	0	1
Mature re-sprouts	2014	4	0	0	2	6	6	0	0	0	6
	2015	3	0	0	2	5	6	0	0	0	6
	2016	1	0	0	2	3	6	0	0	0	6
Juvenile re-sprout	2014	0	0	0	0	0	0	0	0	0	0
	2015	0	0	0	0	0	0	0	0	0	0
	2016	0	0	0	0	0	0	0	0	0	0
Combined alive	2014	189	44	138	59	430	236	44	64	31	375
	2015	198	47	141	58	444	256	44	66	29	395
	2016	198	47	133	56	434	254	47	65	31	397
Mature dead	2014	19	22	26	23	90	16	13	7	11	47
	2015	19	22	26	24	91	16	13	8	10	47
	2016	22	22	29	23	96	16	13	9	9	47
Juvenile dead	2014	0	10	8	11	29	2	4	0	6	12
	2015	0	10	10	11	31	2	4	0	6	12
	2016	3	10	14	13	40	5	4	0	1	10
Seedling dead	2014	0	0	0	0	0	0	0	0	0	0
	2015	0	0	0	0	0	0	0	0	0	0
	2016	0	0	0	0	0	0	0	0	0	0
Combined dead	2014	208	76	172	93	549	254	61	71	48	434
	2015	217	79	177	93	566	274	61	74	45	454
	2016	223	79	176	92	570	275	64	74	41	454


Mulga Main Line Transect 1 - mature alive Mulga trees
2014
2015
2016
Number of mature alive Mulga trees per 10x10m plot
Rail line
Plot ID (North → South)
T1R190
T1R180
T1R170
T1R160
T1R150
T1R140
T1R130
T1R120
T1R110
T1R100
T1R90
T1R80
T1R70
T1R60
T1R50
T1R40
T1R30
T1R20
T1R10
T1R0
T1M0
T1M10
T1M20
T1M30
T1M40
T1M50
T1M60
T1M70
T1M80
T1M90
T1M100
T1M110
T1M120
T1M130
T1M140
T1M150
T1M160
T1M170
T1M180
T1M190


Mulga Main Line Transect 2 - mature alive Mulga trees
2014
2015
2016
Number of mature alive Mulga trees per 10x10m plot
Rail line
Plot ID (North → South)
T2R190
T2R180
T2R170
T2R160
T2R150
T2R140
T2R130
T2R120
T2R110
T2R100
T2R90
T2R80
T2R70
T2R60
T2R50
T2R40
T2R30
T2R20
T2R10
T2R0
T2M0
T2M10
T2M20
T2M30
T2M40
T2M50
T2M60
T2M70
T2M80
T2M90
T2M100
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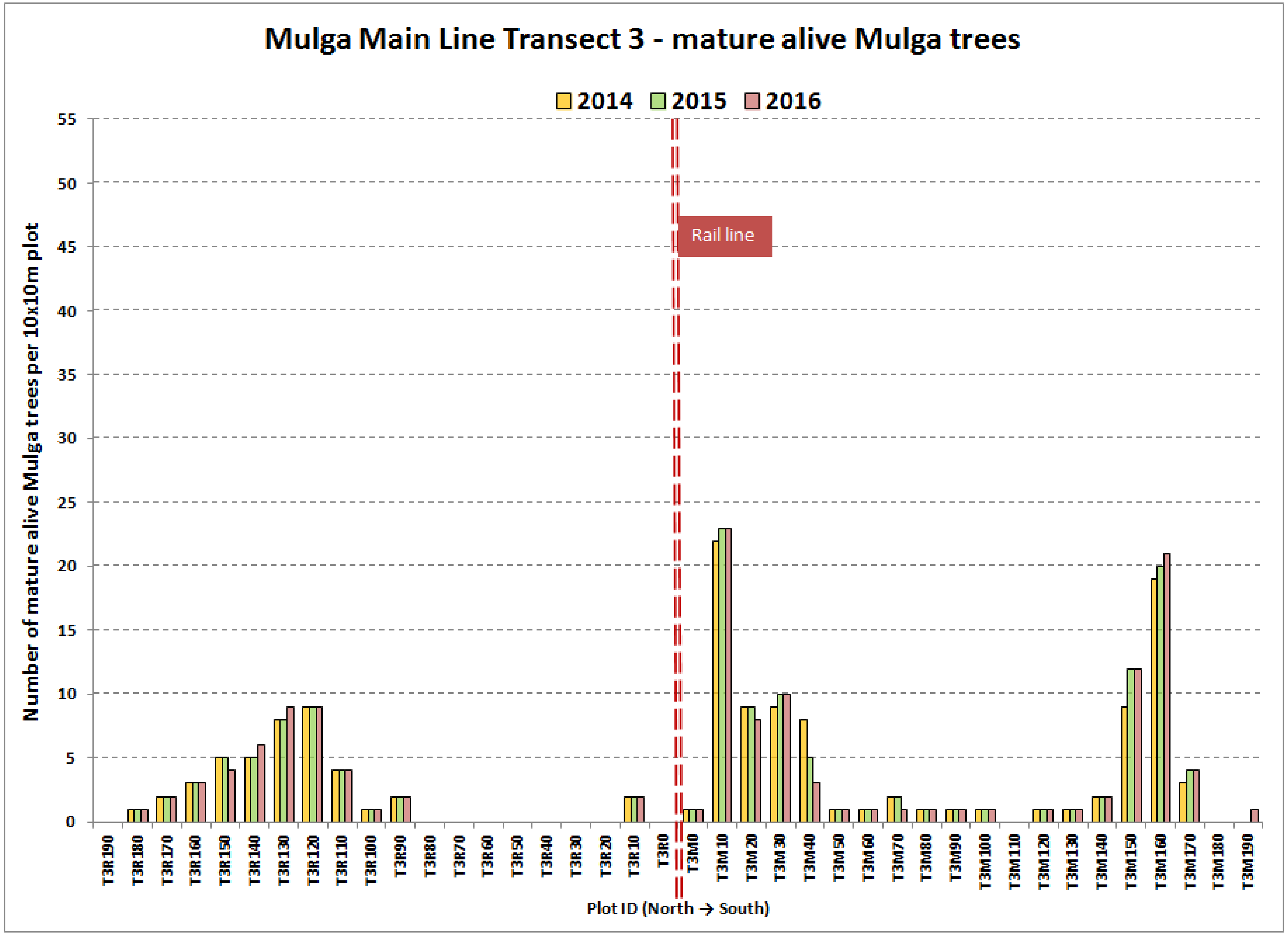
T2M120
T2M130
T2M140
T2M150
T2M160
T2M170
T2M180
T2M190



Mulga Main Line Transect 3 - mature alive Mulga trees
2014
2015
2016
Rail line
Number of mature alive Mulga trees per 10x10m plot
Plot ID (North → South)
0
5
10
15
20
25
30
35
40
45
50
55
T3R190
T3R180
T3R170
T3R160
T3R150
T3R140
T3R130
T3R120
T3R110
T3R100
T3R90
T3R80
T3R70
T3R60
T3R50
T3R40
T3R30
T3R20
T3R10
T3R0
T3M0
T3M10
T3M20
T3M30
T3M40
T3M50
T3M60
T3M70
T3M80
T3M90
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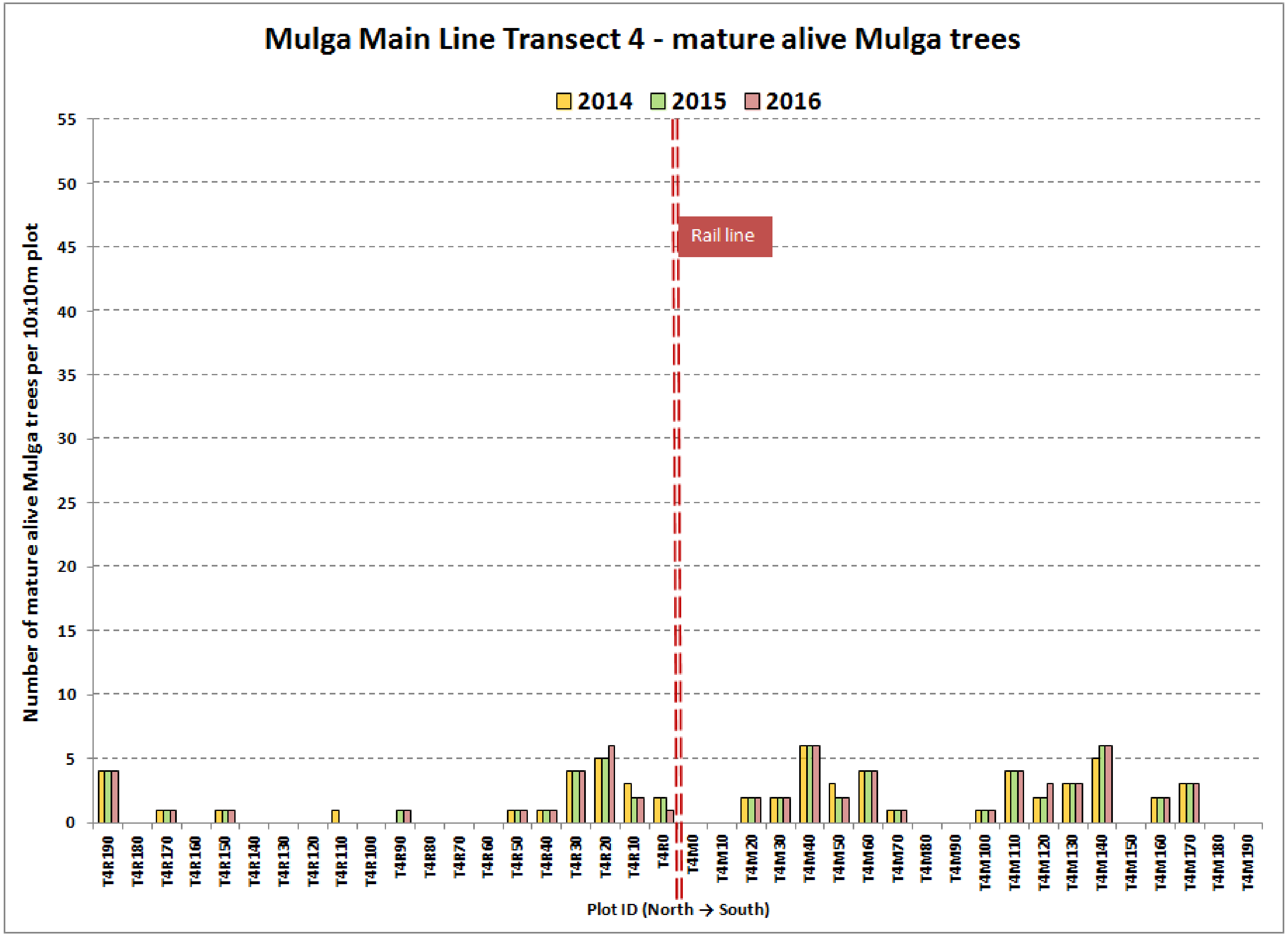
T3M180
T3M190


Mulga Main Line Transect 4 - mature alive Mulga trees
2014
2015
2016
Rail line
Number of mature alive Mulga trees per 10x10m plot
0
5
10
15
20
25
30
35
40
45
50
55
T4R190
T4R180
T4R170
T4R160
T4R150
T4R140
T4R130
T4R120
T4R110
T4R100
T4R90
T4R80
T4R70
T4R60
T4R50
T4R40
T4R30
T4R20
T4R10
T4R0
T4M0
T4M10
T4M20
T4M30
T4M40
T4M50
T4M60
T4M70
T4M80
T4M90
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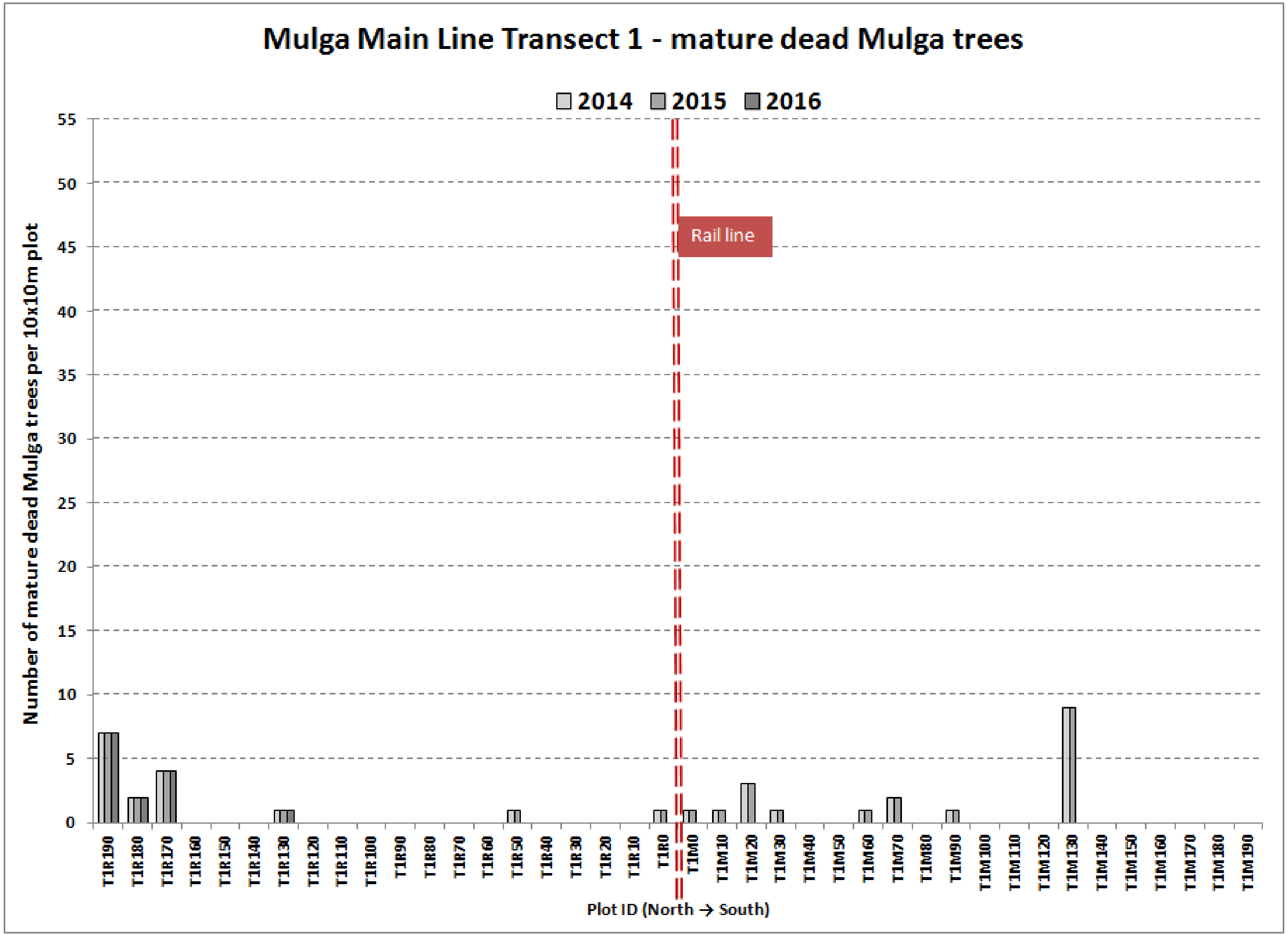
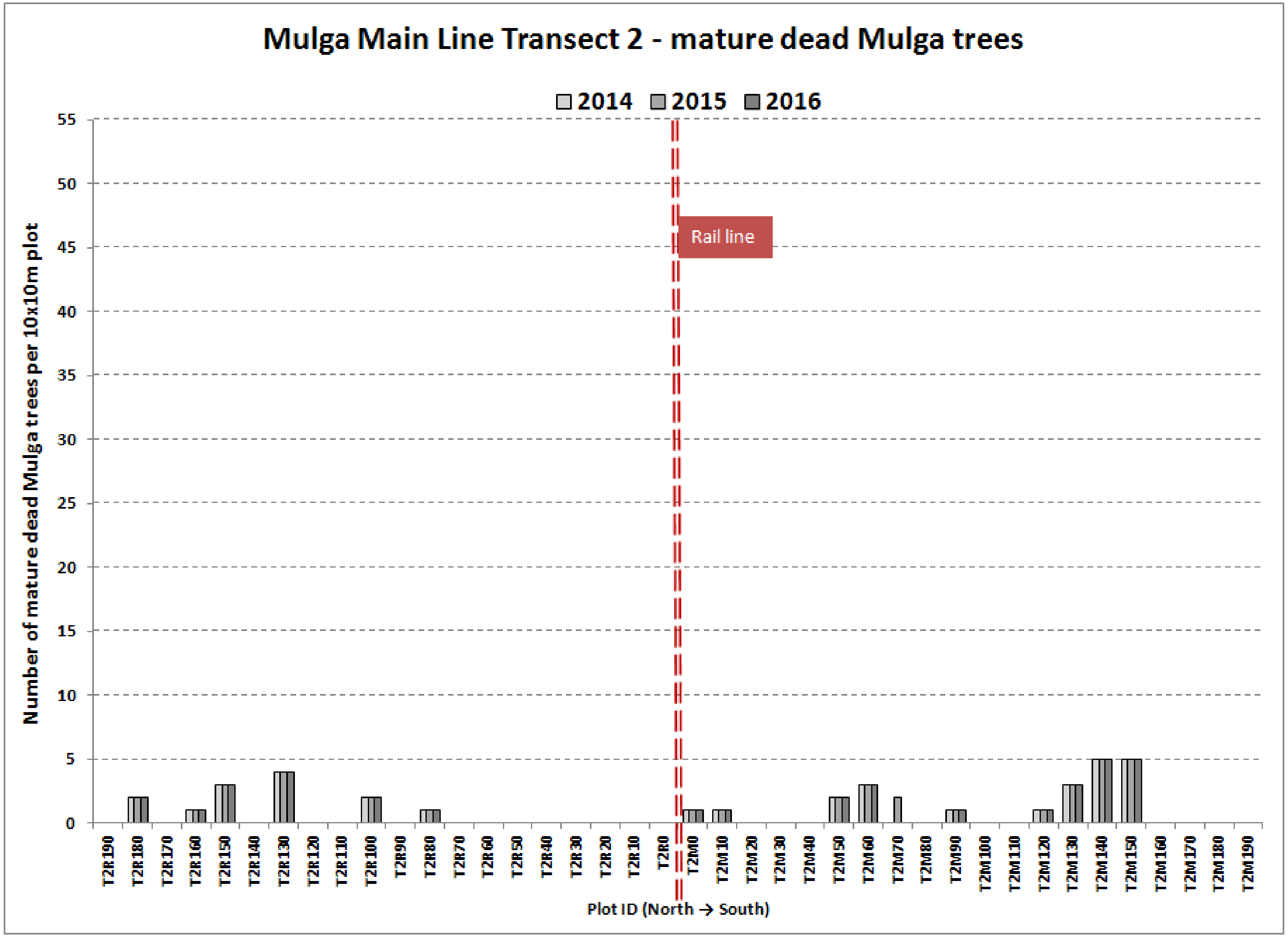
T4M190
Plot ID (North → South)



Mulga Main Line Transect 1 - mature dead Mulga trees
2014
2015
2016
Number of mature dead Mulga trees per 10x10m plot
Rail line
Plot ID (North → South)


Mulga Main Line Transect 2 - mature dead Mulga trees
2014
2015
2016
Number of mature dead Mulga trees per 10x10m plot
0
5
10
15
20
25
30
35
40
45
50
55
Rail line
T2R190
T2R180
T2R170
T2R160
T2R150
T2R140
T2R130
T2R120
T2R110
T2R100
T2R90
T2R80
T2R70
T2R60
T2R50
T2R40
T2R30
T2R20
T2R10
T2R0
T2M0
T2M10
T2M20
T2M30
T2M40
T2M50
T2M60
T2M70
T2M80
T2M90
T2M100
T2M110
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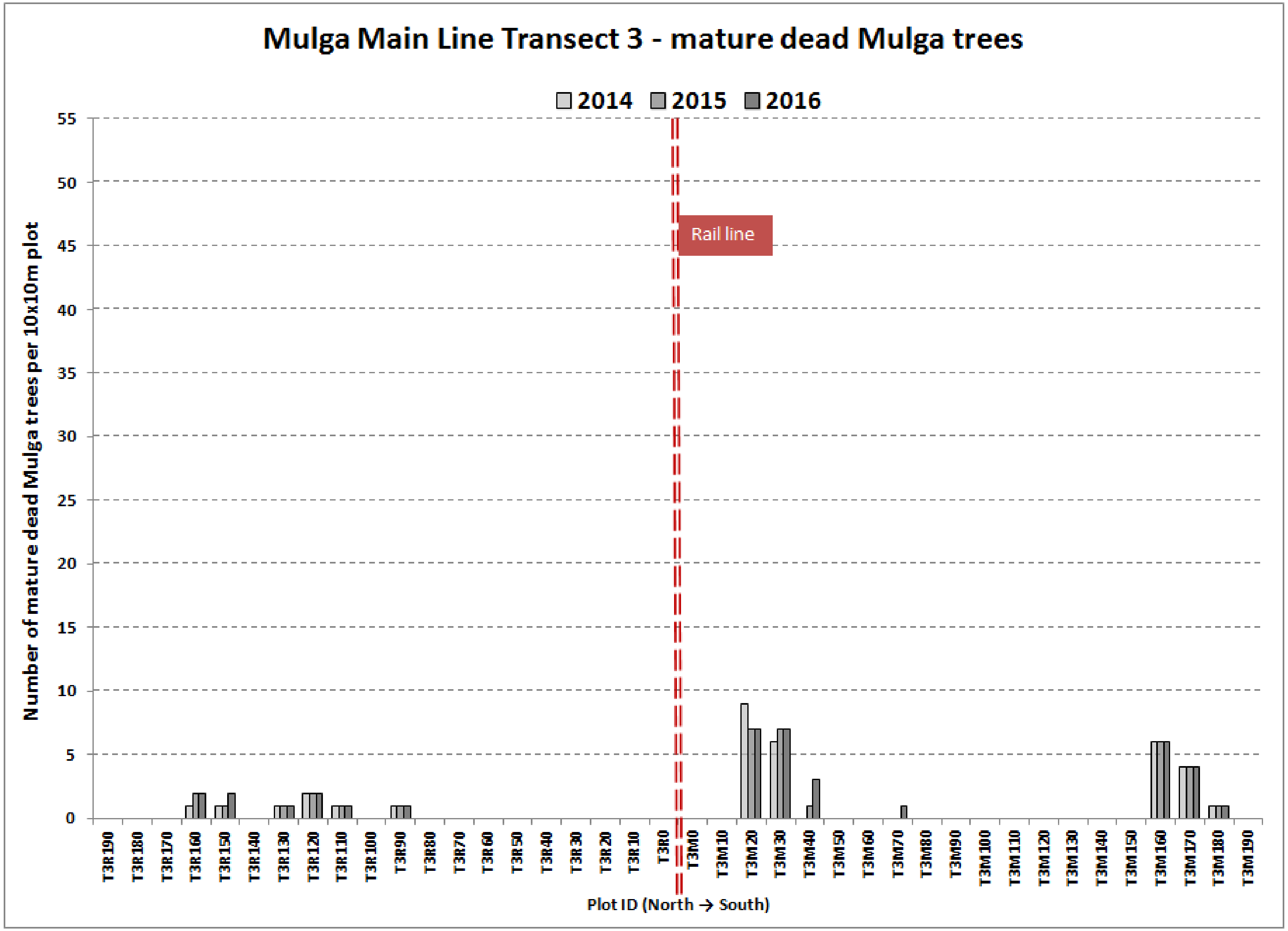
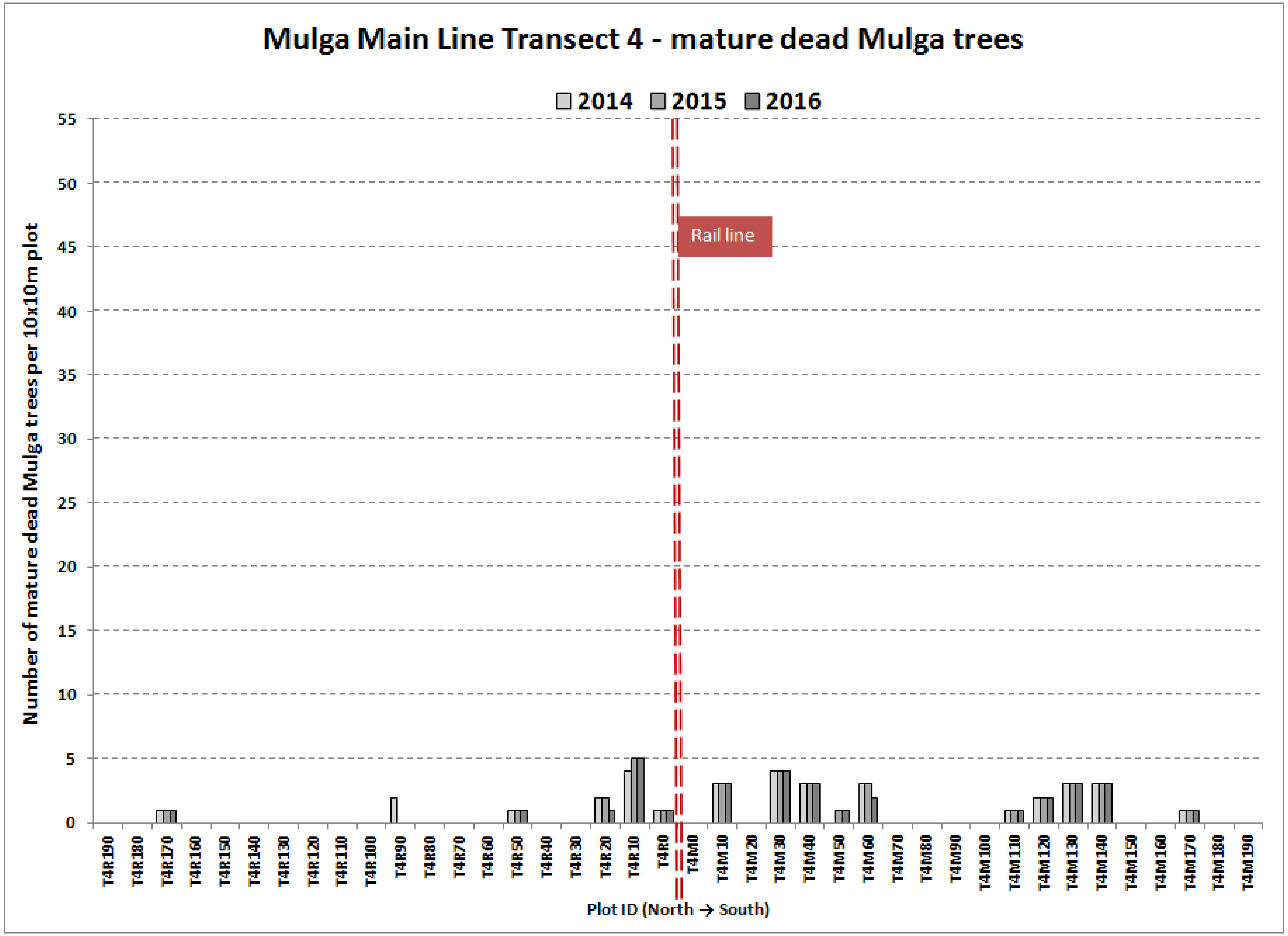
T2M140
T2M150
T2M160
T2M170
T2M180
T2M190
Plot ID (North → South)



Mulga Main Line Transect 3 - mature dead Mulga trees
2014
2015
2016
Number of mature dead Mulga trees per 10x10m plot
Rail line
Plot ID (North → South)



Mulga Main Line Transect 4 - mature dead Mulga trees
2014
2015
2016
Rail line
Number of mature dead Mulga trees per 10x10m plot
Plot ID (North → South)
0
5
10
15
20
25
30
35
40
45
50
55
T4R190
T4R180
T4R170
T4R160
T4R150
T4R140
T4R130
T4R120
T4R110
T4R100
T4R90
T4R80
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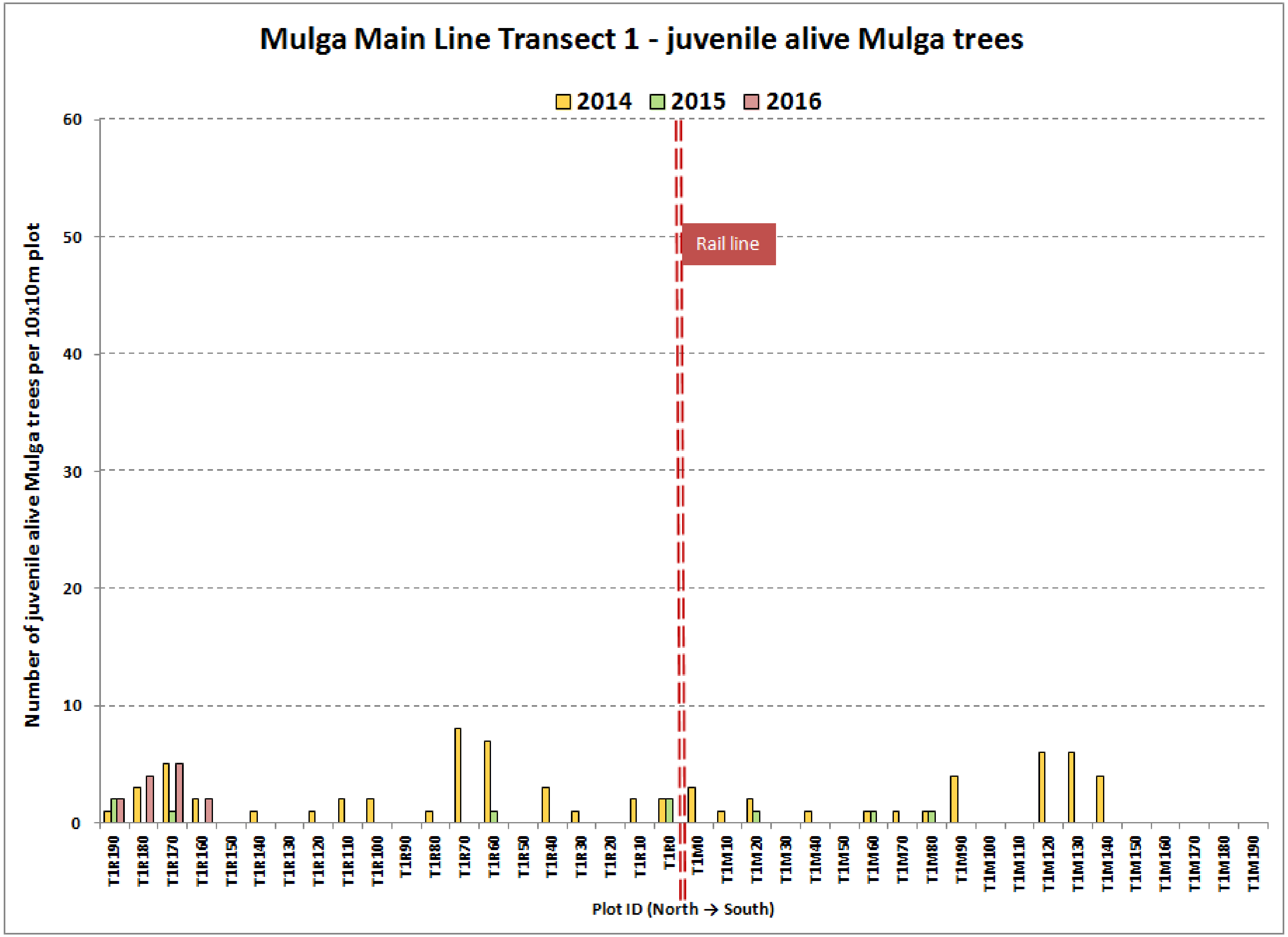
T4M190


Mulga Main Line Transect 1 - juvenile alive Mulga trees
2014
2015
2016
Number of juvenile alive Mulga trees per 10x10m plot
60
50
40
30
20
10
0
Rail line
T1R190
T1R180
T1R170
T1R160
T1R150
T1R140
T1R130
T1R120
T1R110
T1R100
T1R90
T1R80
T1R70
T1R60
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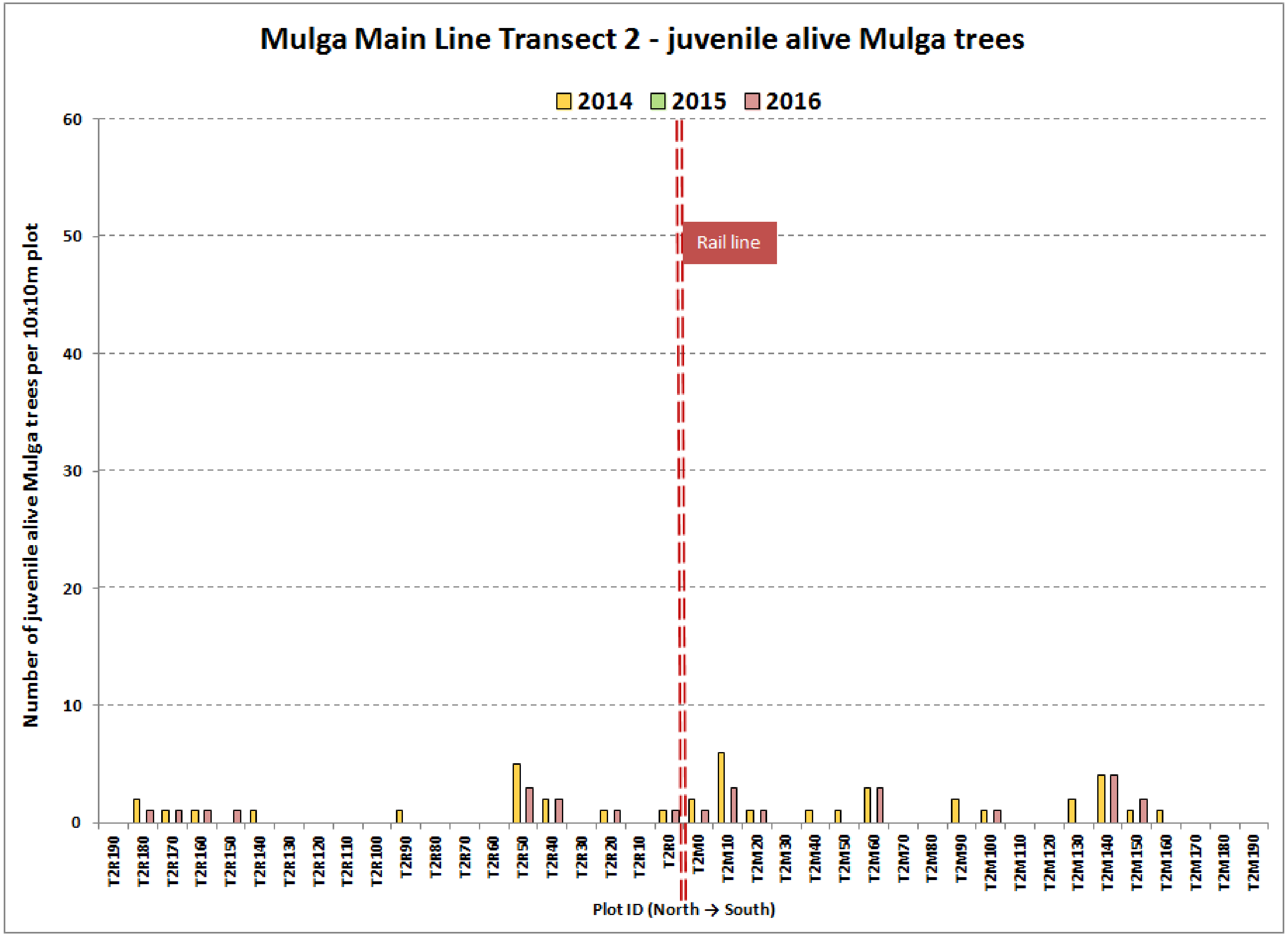
T1M190
Plot ID (North → South)


Mulga Main Line Transect 2 - juvenile alive Mulga trees
2014
2015
2016
Rail line
Number of juvenile alive Mulga trees per 10x10m plot
Plot ID (North → South)
0
10
20
30
40
50
60
T2R190
T2R180
T2R170
T2R160
T2R150
T2R140
T2R130
T2R120
T2R110
T2R100
T2R90
T2R80
T2R70
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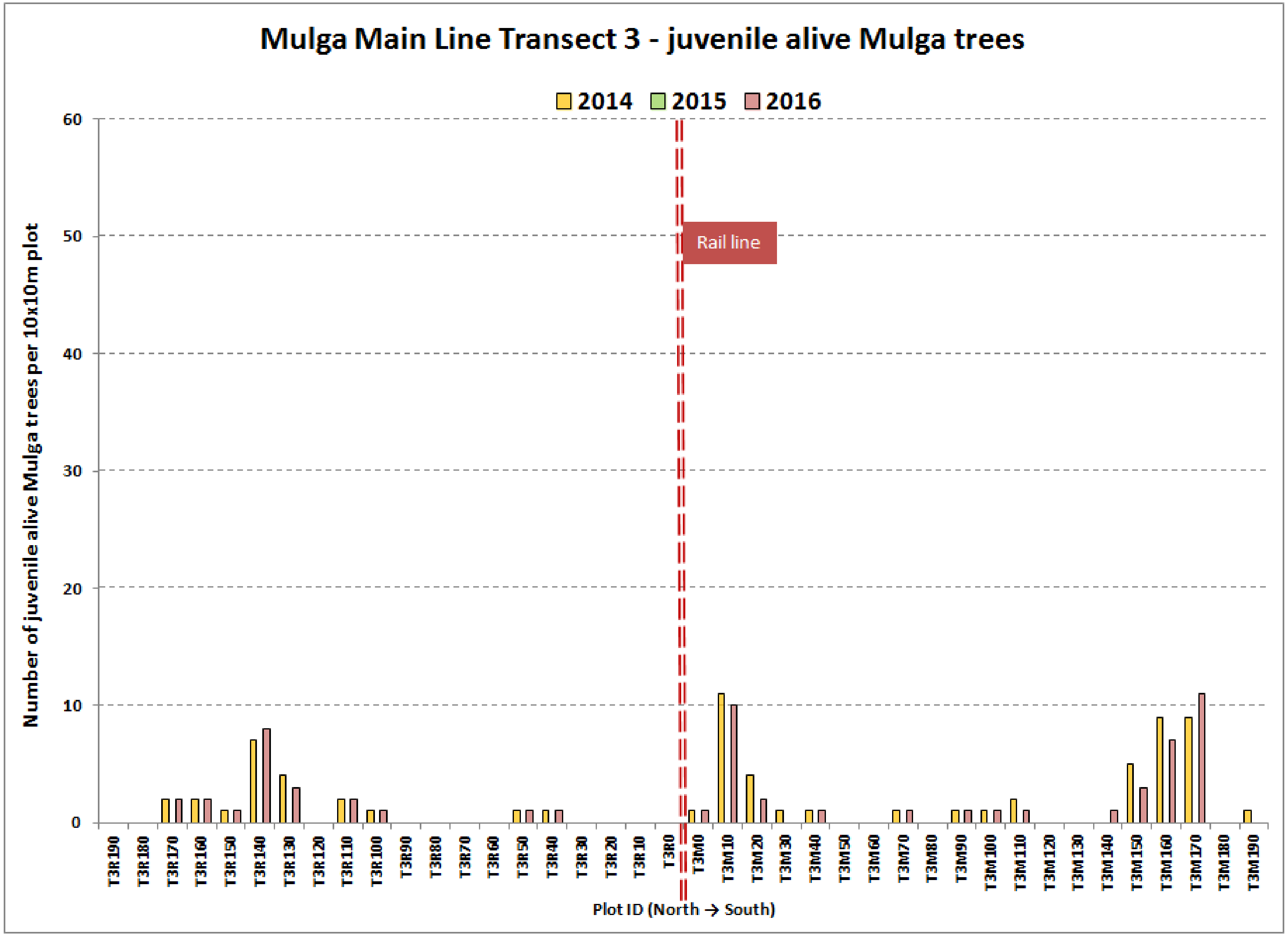
T2M180
T2M190



Mulga Main Line Transect 3 - juvenile alive Mulga trees
2014
2015
2016
Number of juvenile alive Mulga trees per 10x10m plot
60
50
40
30
20
10
0
Rail line
T3R190
T3R180
T3R170
T3R160
T3R150
T3R140
T3R130
T3R120
T3R110
T3R100
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T3M110
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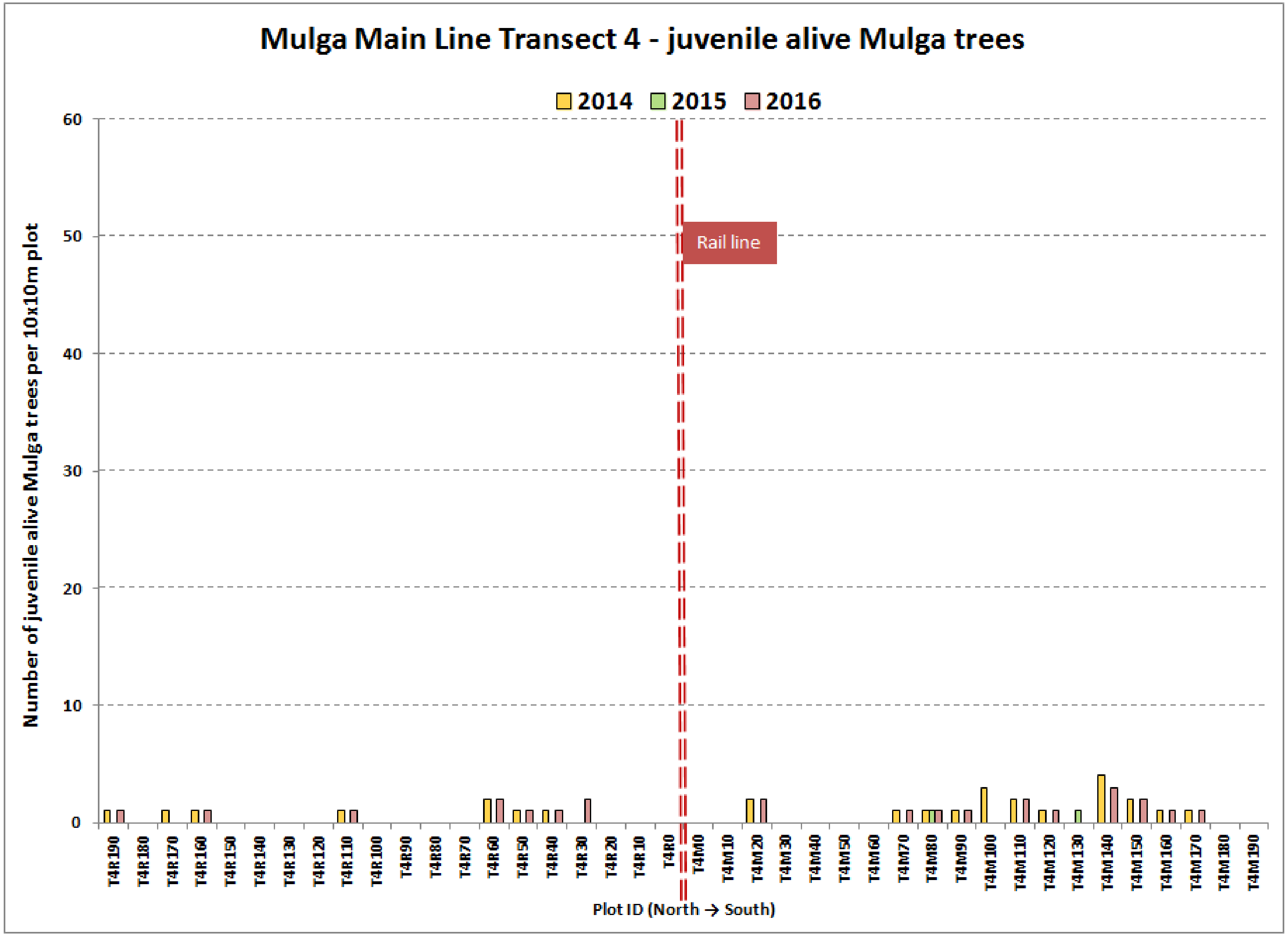
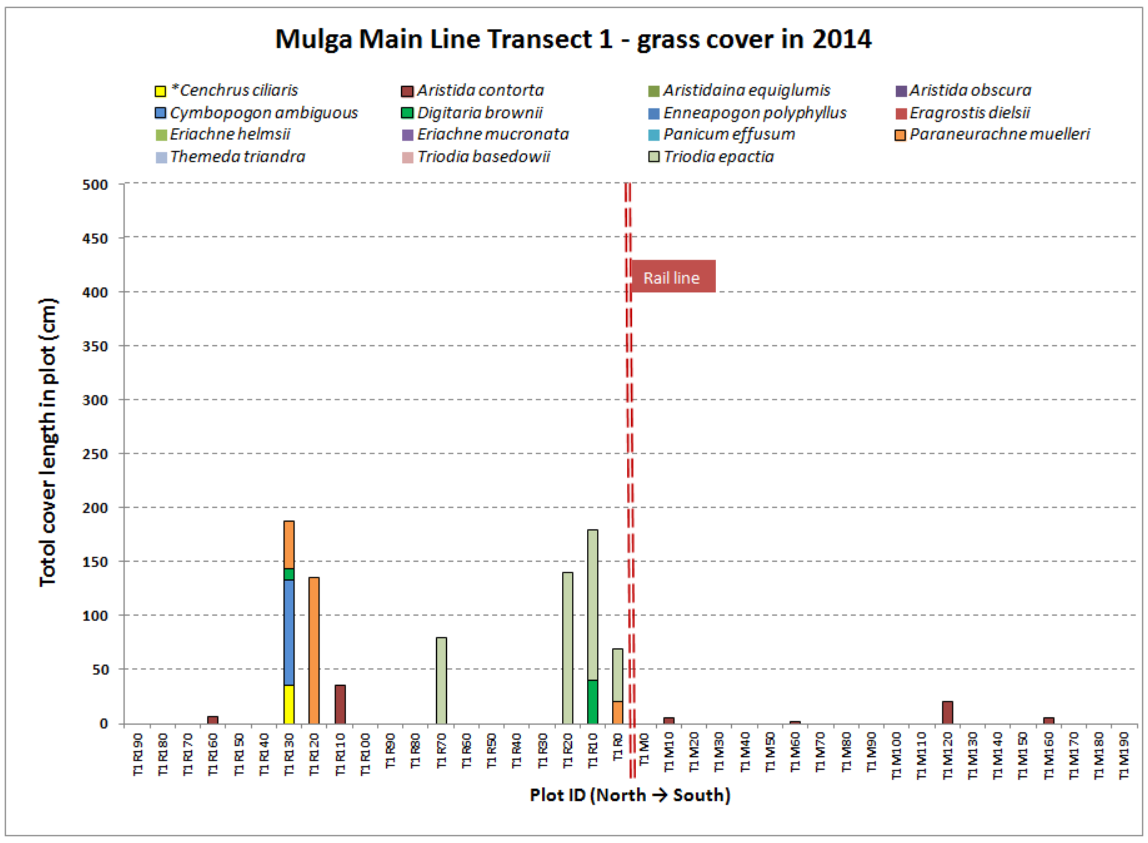
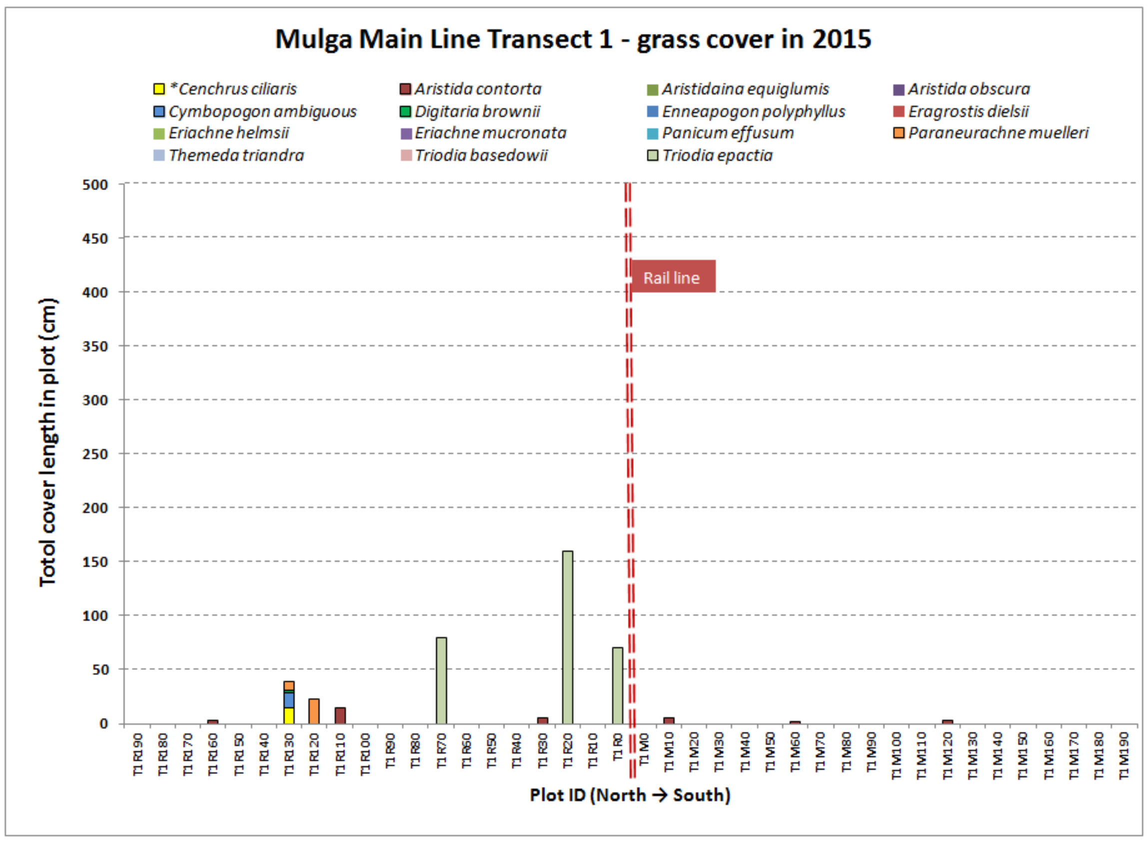
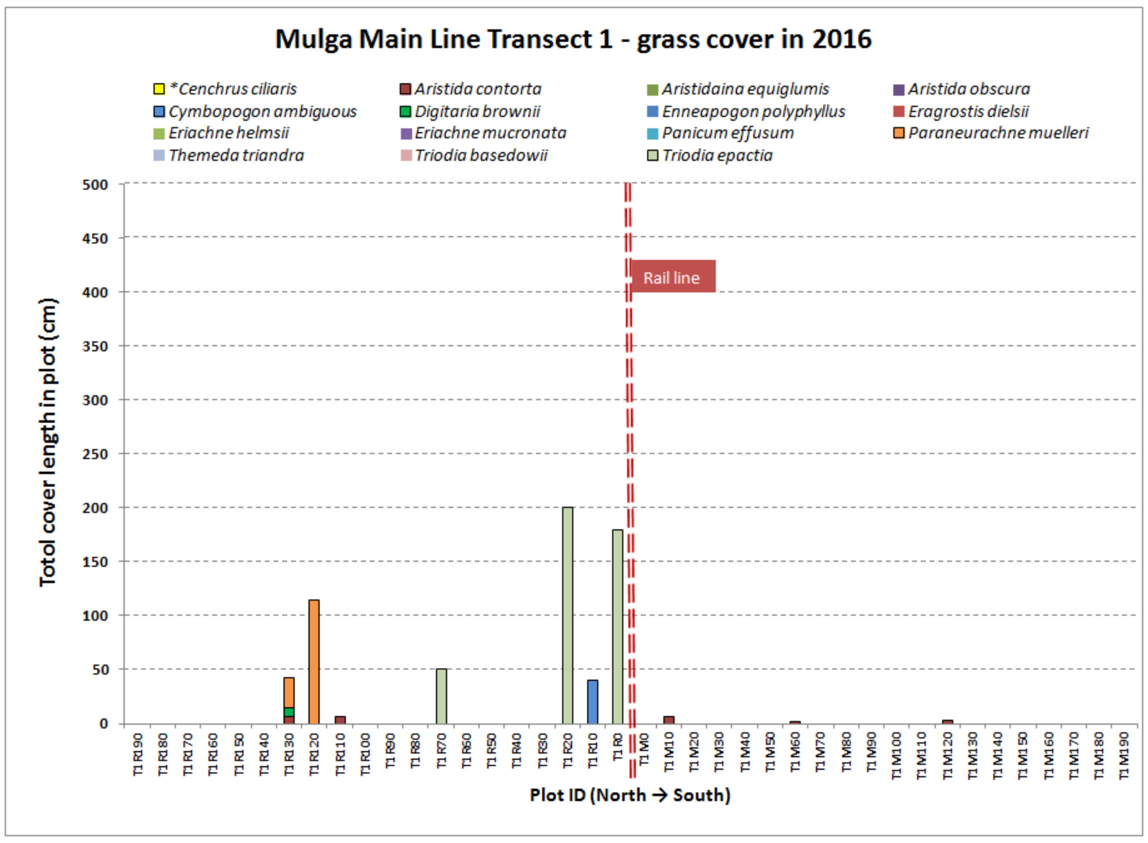
T3M190
Plot ID (North → South)

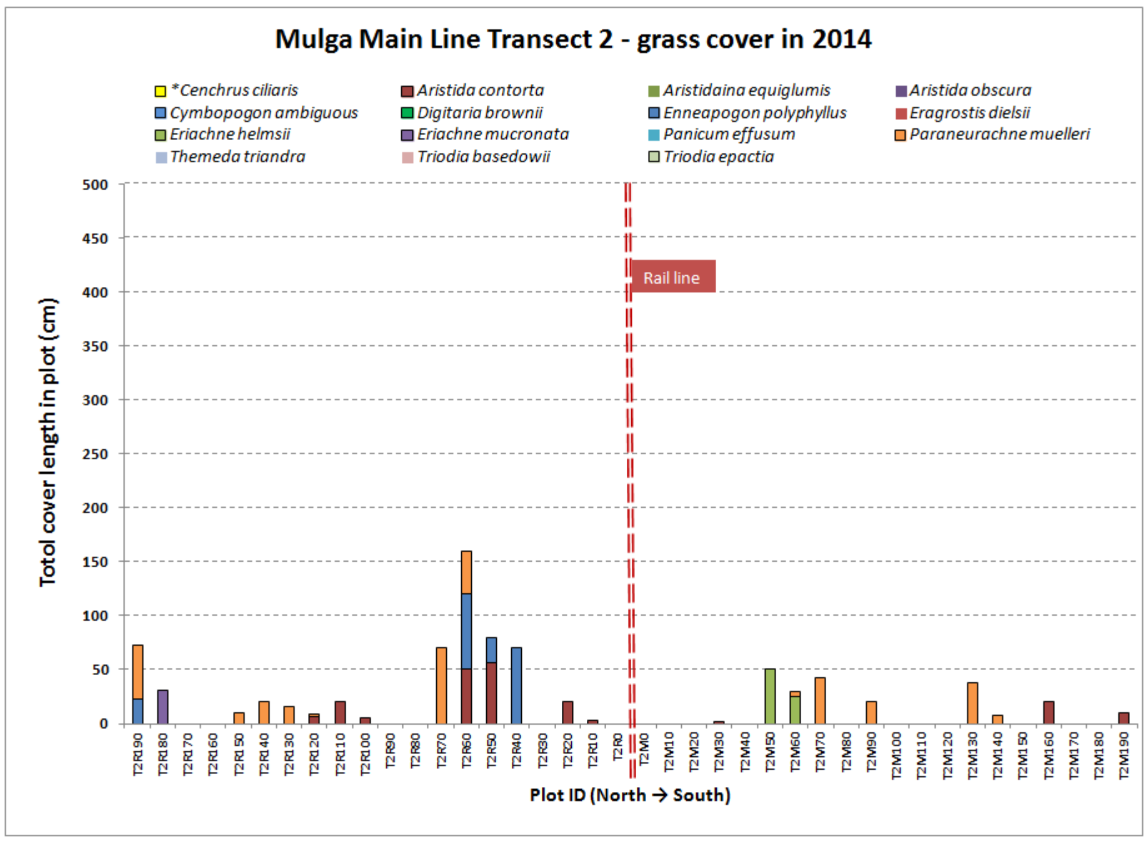


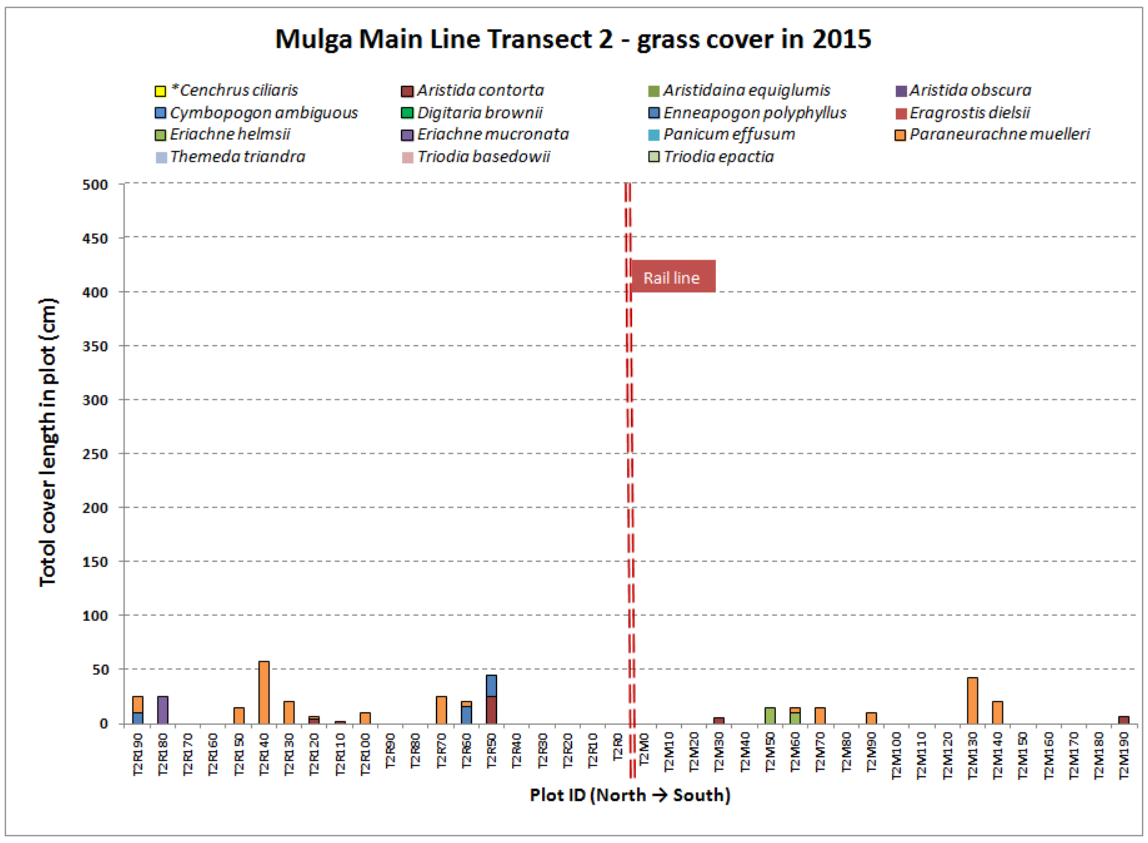
Mulga Main Line Transect 4 - juvenile alive Mulga trees
2014
2015
2016
Rail line
Number of juvenile alive Mulga trees per 10x10m plot
60
50
40
30
20
10
0
T4R190
T4R180
T4R170
T4R160
T4R150
T4R140
T4R130
T4R120
T4R110
T4R100
T4R90
T4R80
T4R70
T4R60
T4R50
T4R40
T4R30
T4R20
T4R10
T4R0
T4M0
T4M10
T4M20
T4M30
T4M40
T4M50
T4M60
T4M70
T4M80
T4M90
T4M100
T4M110
T4M120
T4M130
T4M140
T4M150
T4M160
T4M170
T4M180
T4M190
Plot ID (North → South)

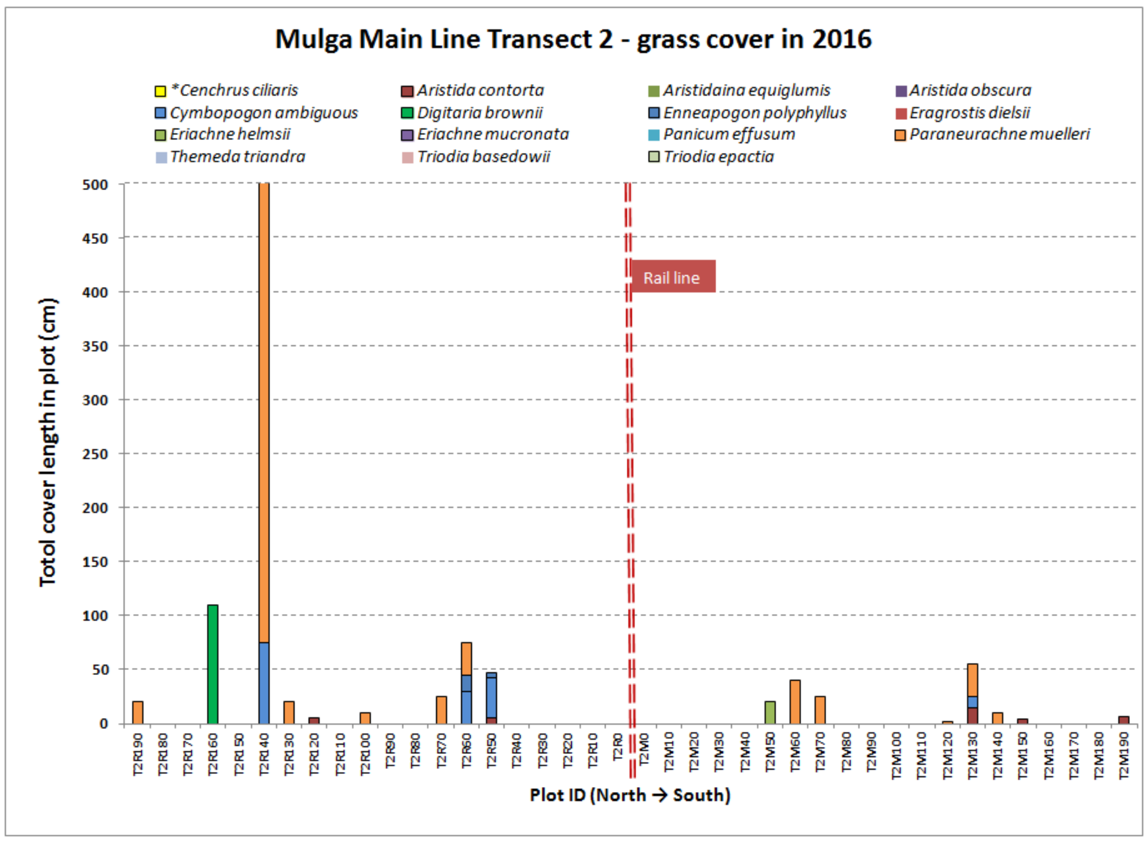

Mulga Main Line Transect 1 - grass cover in 2014
*Cenchrus ciliaris
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Cymbopogon ambiguous
Digitaria brownii
Enneapogon polyphyllus
Eragrostis dielsii
Eriachne helmsii
Eriachne mucronata
Panicum effusum
Paraneurachne muelleri
Themeda triandra
Triodia basedowii
Triodia epactia
Totol cover length in plot (cm)
0
50
100
150
200
250
300
350
400
450
500
Rail line
Plot ID (North → South)

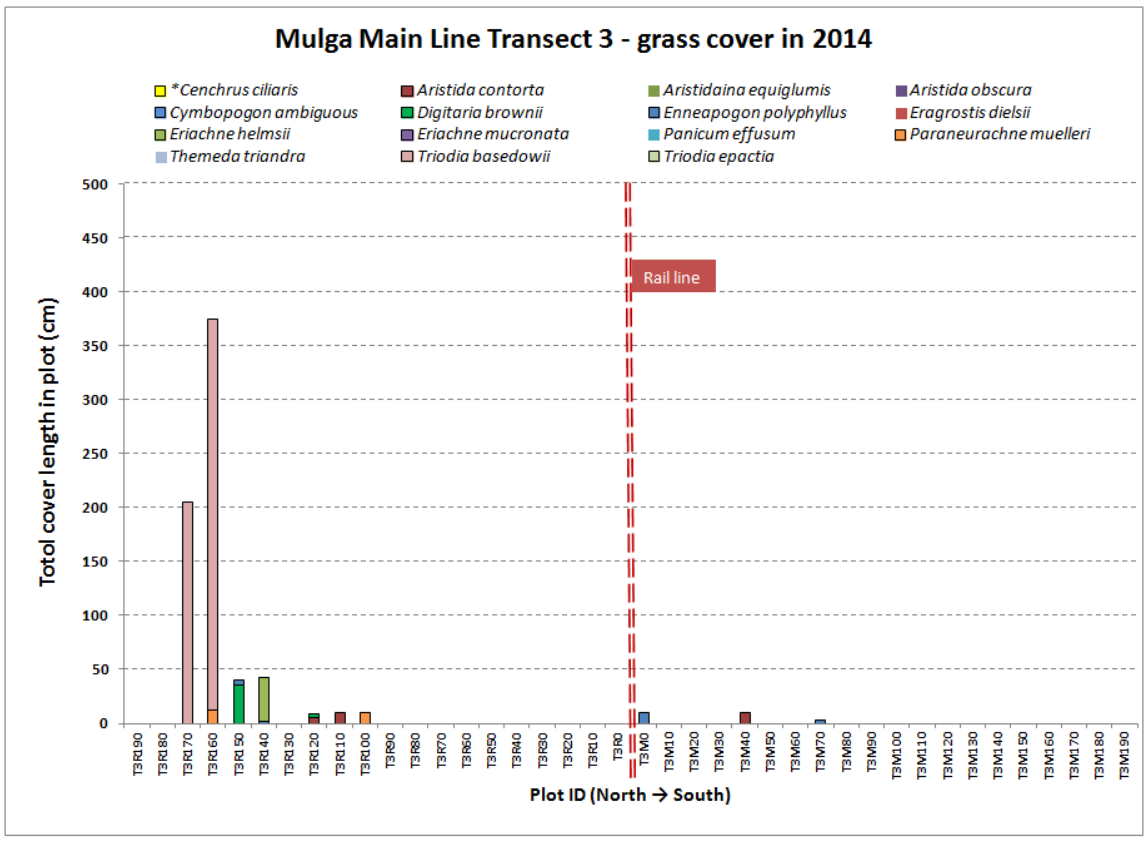

Mulga Main Line Transect 1 - grass cover in 2015
*Cenchrus ciliaris
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Cymbopogon ambiguous
Digitaria brownii
Enneapogon polyphyllus
Eragrostis dielsii
Eriachne helmsii
Eriachne mucronata
Panicum effusum
Paraneurachne muelleri
Themeda triandra
Triodia basedowii
Triodia epactia
Totol cover length in plot (cm)
0
50
100
150
200
250
300
350
400
450
500
Rail line
Plot ID (North → South)

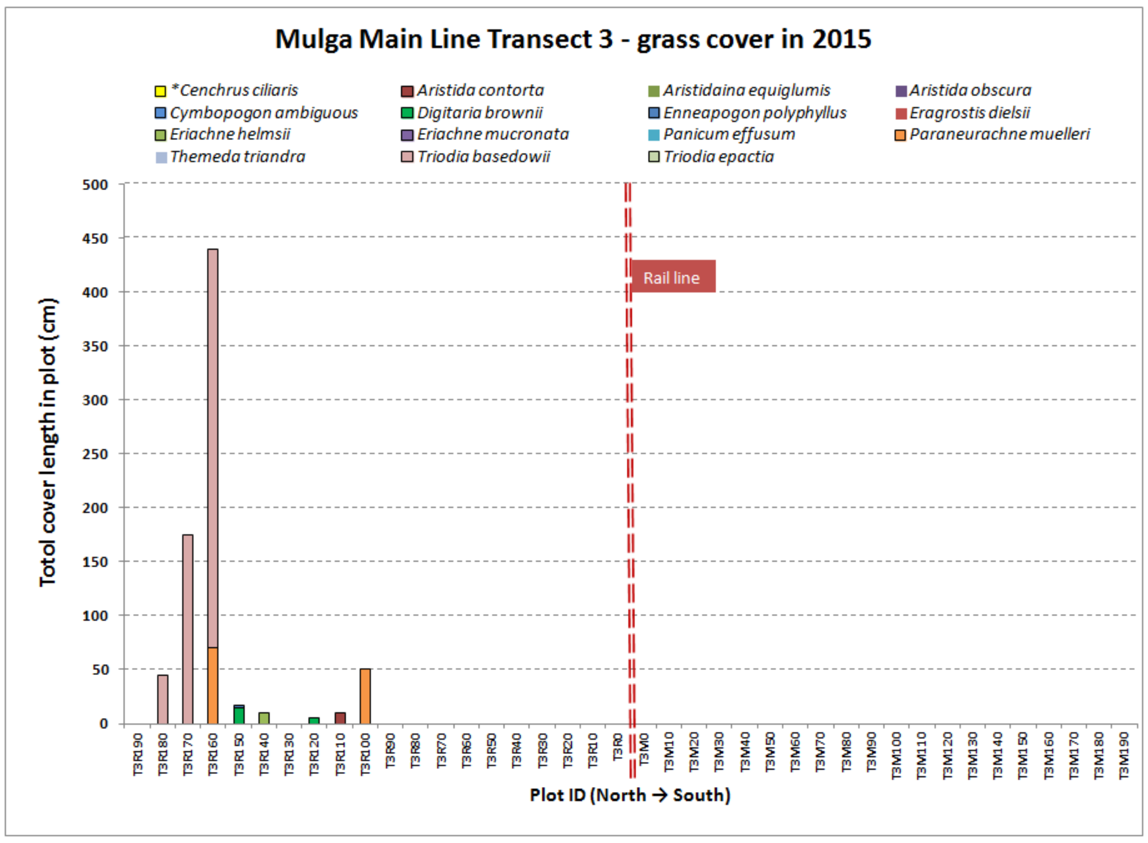

Mulga Main Line Transect 1 - grass cover in 2016
*Cenchrus ciliaris
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Cymbopogon ambiguous
Digitaria brownii
Enneapogon polyphyllus
Eragrostis dielsii
Eriachne helmsii
Eriachne mucronata
Panicum effusum
Paraneurachne muelleri
Themeda triandra
Triodia basedowii
Triodia epactia
Totol cover length in plot (cm)
0
50
100
150
200
250
300
350
400
450
500
Rail line
Plot ID (North → South)

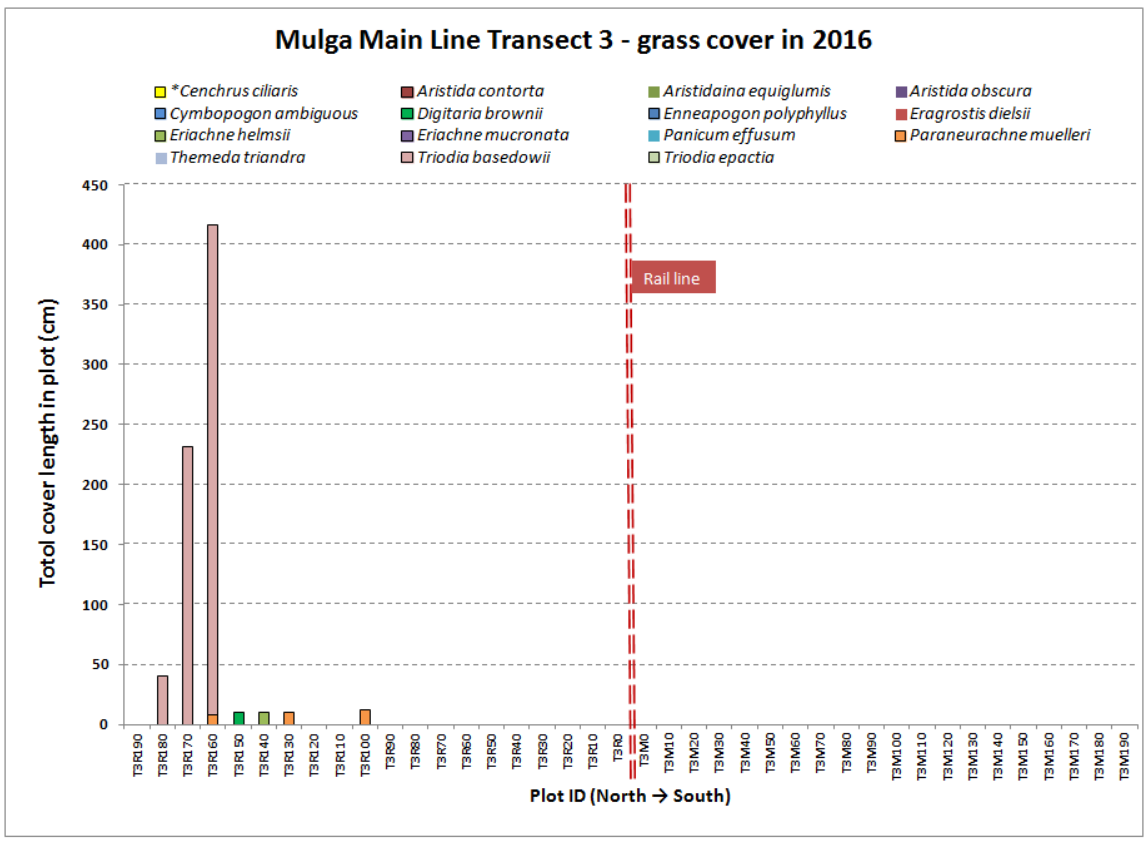

Mulga Main Line Transect 2 - grass cover in 2014
*Cenchrus ciliaris
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Cymbopogon ambiguous
Digitaria brownii
Enneapogon polyphyllus
Eragrostis dielsii
Eriachne helmsii
Eriachne mucronata
Panicum effusum
Paraneurachne muelleri
Themeda triandra
Triodia basedowii
Triodia epactia
Totol cover length in plot (cm)
Rail line
Plot ID (North → South)

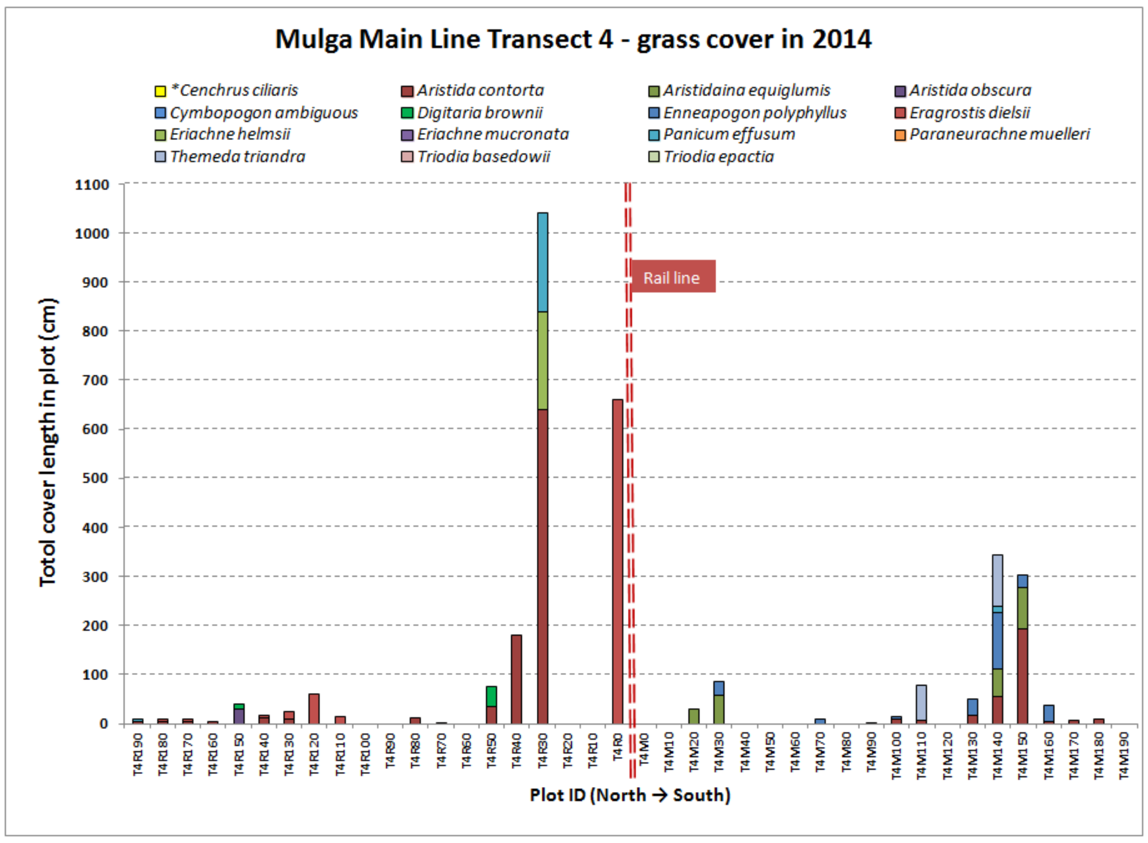

Mulga Main Line Transect 2 - grass cover in 2015
*Cenchrus ciliaris
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Cymbopogon ambiguous
Digitaria brownii
Enneapogon polyphyllus
Eragrostis dielsii
Eriachne helmsii
Eriachne mucronata
Panicum effusum
Paraneurachne muelleri
Themeda triandra
Triodia basedowii
Triodia epactia
Totol cover length in plot (cm)
Rail line
Plot ID (North → South)

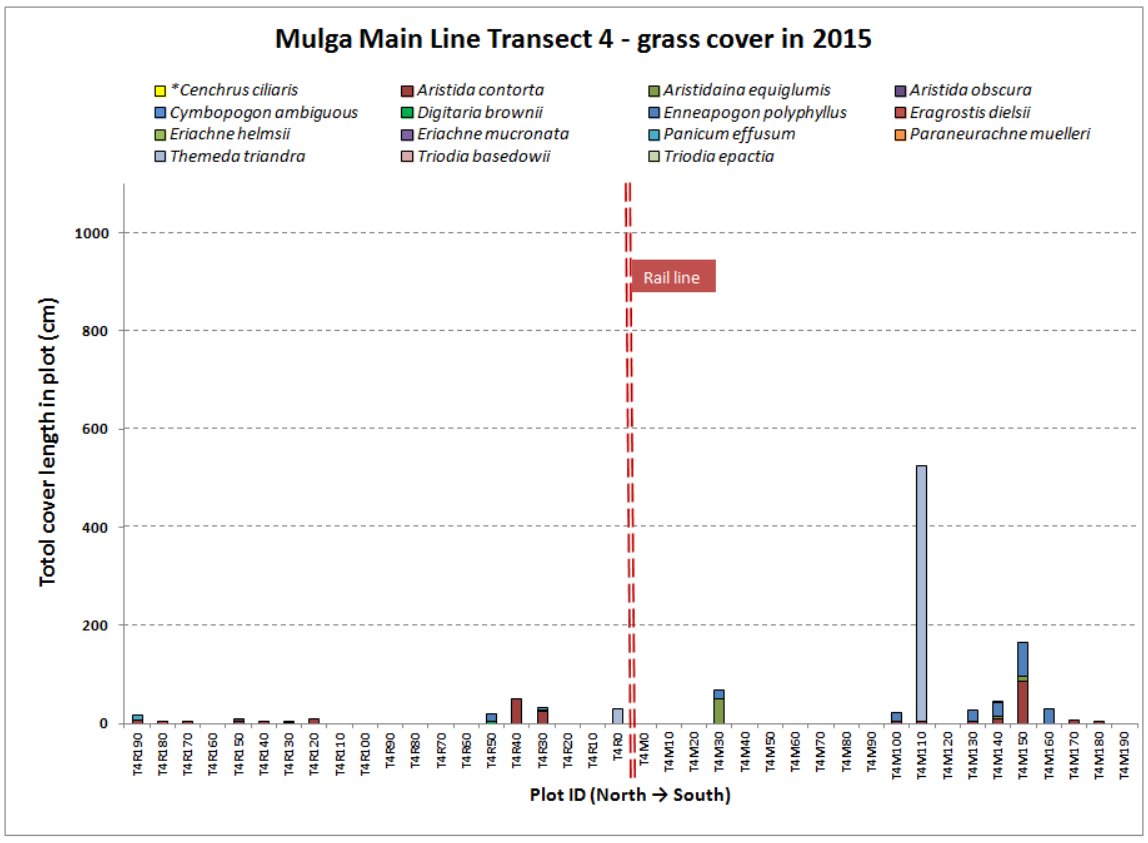

Mulga Main Line Transect 2 - grass cover in 2016
*Cenchrus ciliaris
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Cymbopogon ambiguous
Digitaria brownii
Enneapogon polyphyllus
Eragrostis dielsii
Eriachne helmsii
Eriachne mucronata
Panicum effusum
Paraneurachne muelleri
Themeda triandra
Triodia basedowii
Triodia epactia
Totol cover length in plot (cm)
Rail line
Plot ID (North → South)

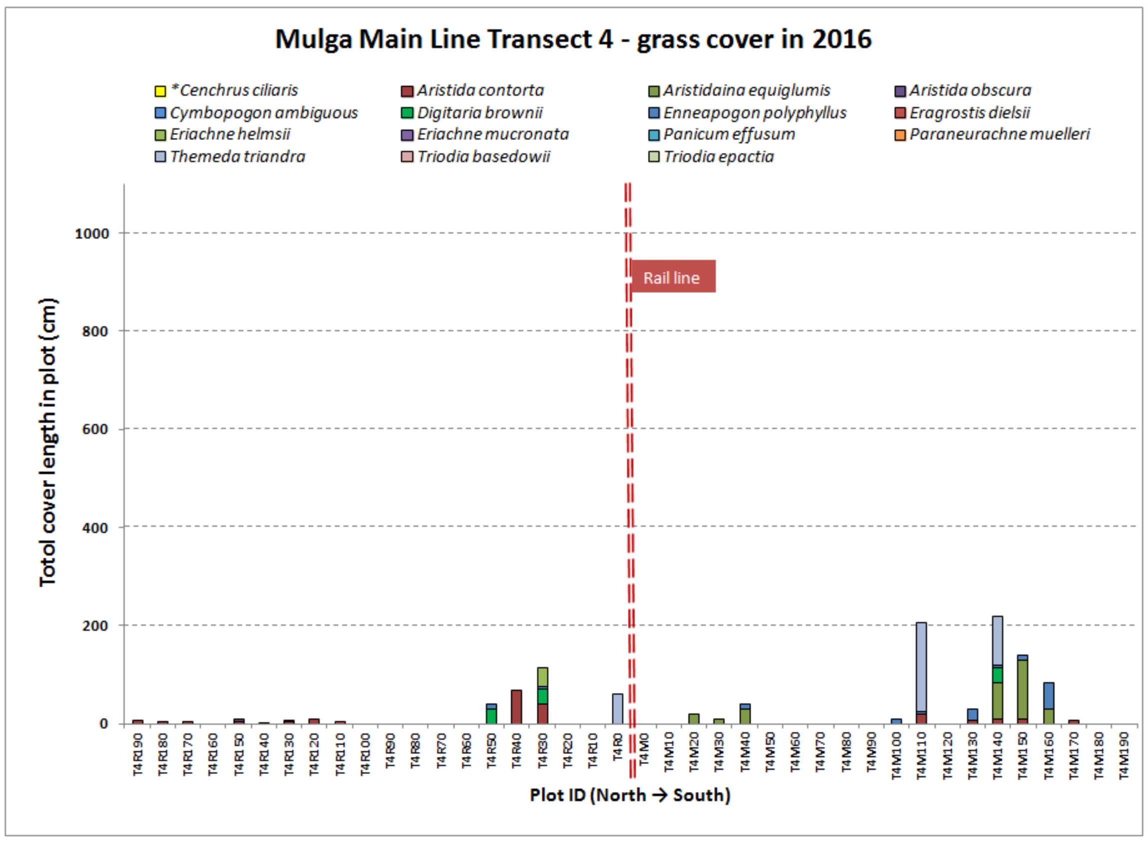

Mulga Main Line Transect 3 - grass cover in 2014
*Cenchrus ciliaris
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Cymbopogon ambiguous
Digitaria brownii
Enneapogon polyphyllus
Eragrostis dielsii
Eriachne helmsii
Eriachne mucronata
Panicum effusum
Paraneurachne muelleri
Themeda triandra
Triodia basedowii
Triodia epactia
Totol cover length in plot (cm)
Rail line
Plot ID (North → South)

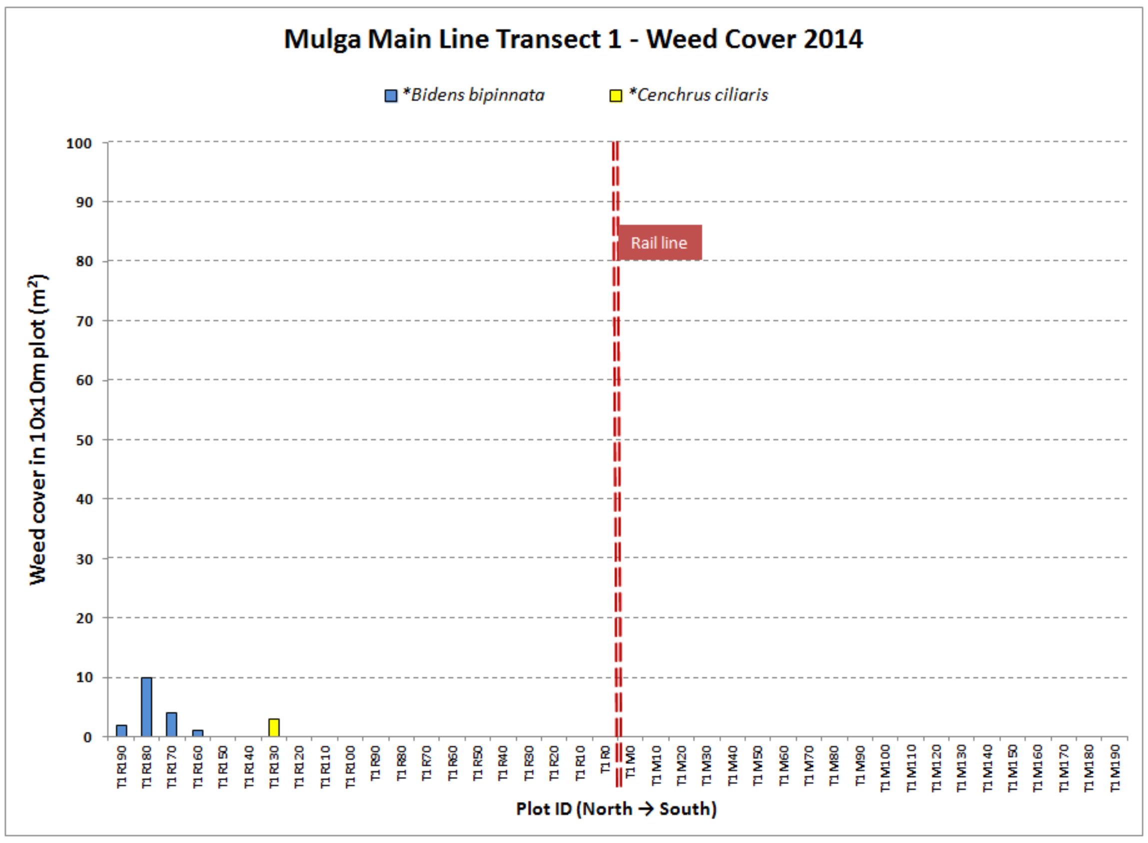

Mulga Main Line Transect 3 - grass cover in 2015
*Cenchrus ciliaris
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Cymbopogon ambiguous
Digitaria brownii
Enneapogon polyphyllus
Eragrostis dielsii
Eriachne helmsii
Eriachne mucronata
Panicum effusum
Paraneurachne muelleri
Themeda triandra
Triodia basedowii
Triodia epactia
Totol cover length in plot (cm)
Rail line
Plot ID (North → South)

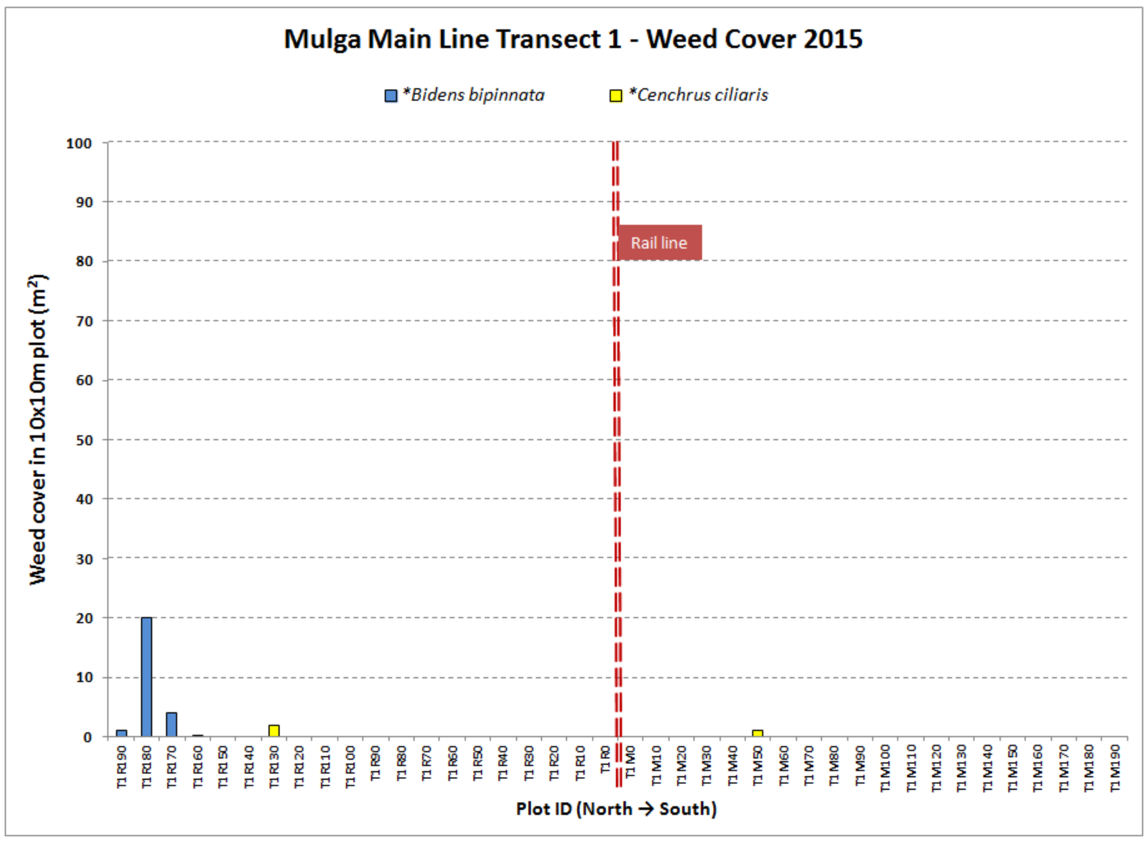

Mulga Main Line Transect 3 - grass cover in 2016
*Cenchrus ciliaris
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Cymbopogon ambiguous
Digitaria brownii
Enneapogon polyphyllus
Eragrostis dielsii
Eriachne helmsii
Eriachne mucronata
Panicum effusum
Paraneurachne muelleri
Themeda triandra
Triodia basedowii
Triodia epactia
Totol cover length in plot (cm)
Rail line
Plot ID (North → South)

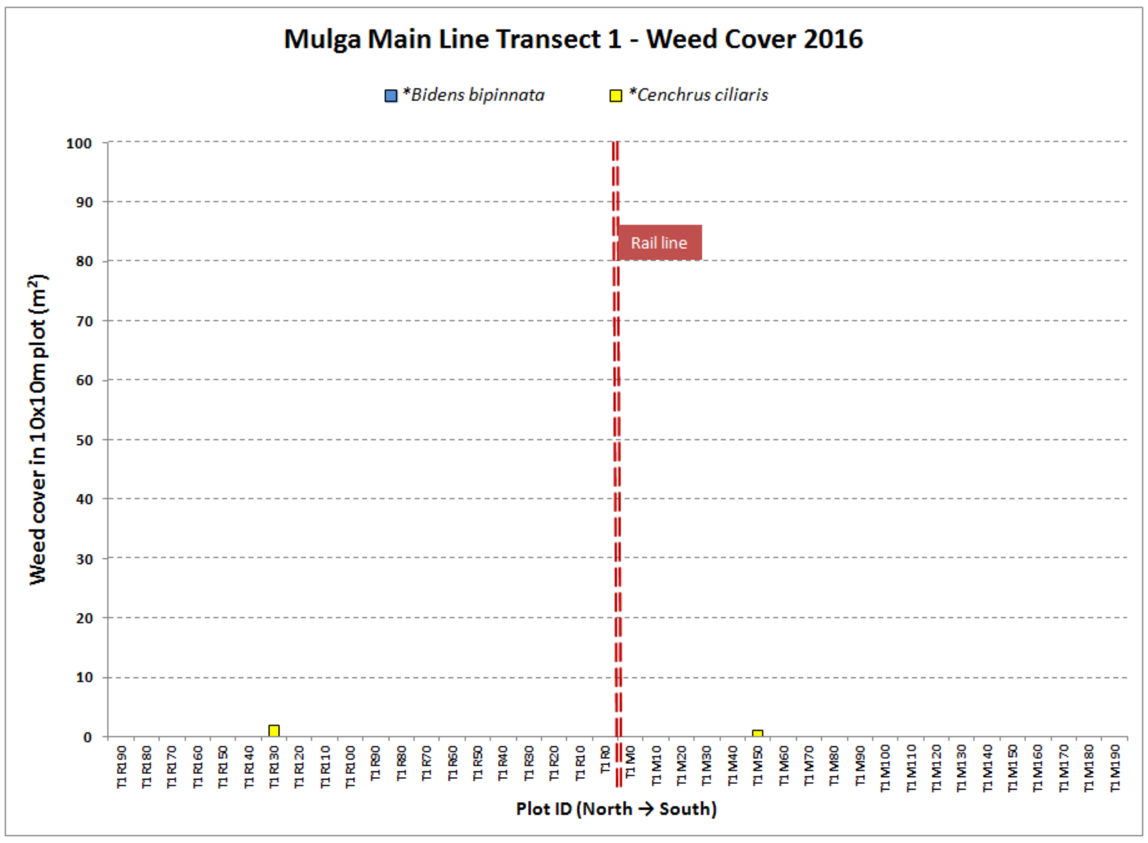

Mulga Main Line Transect 4 - grass cover in 2014
*Cenchrus ciliaris
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Cymbopogon ambiguous
Digitaria brownii
Enneapogon polyphyllus
Eragrostis dielsii
Eriachne helmsii
Eriachne mucronata
Panicum effusum
Paraneurachne muelleri
Themeda triandra
Triodia basedowii
Triodia epactia
Rail line
Totol cover length in plot (cm)
Plot ID (North → South)

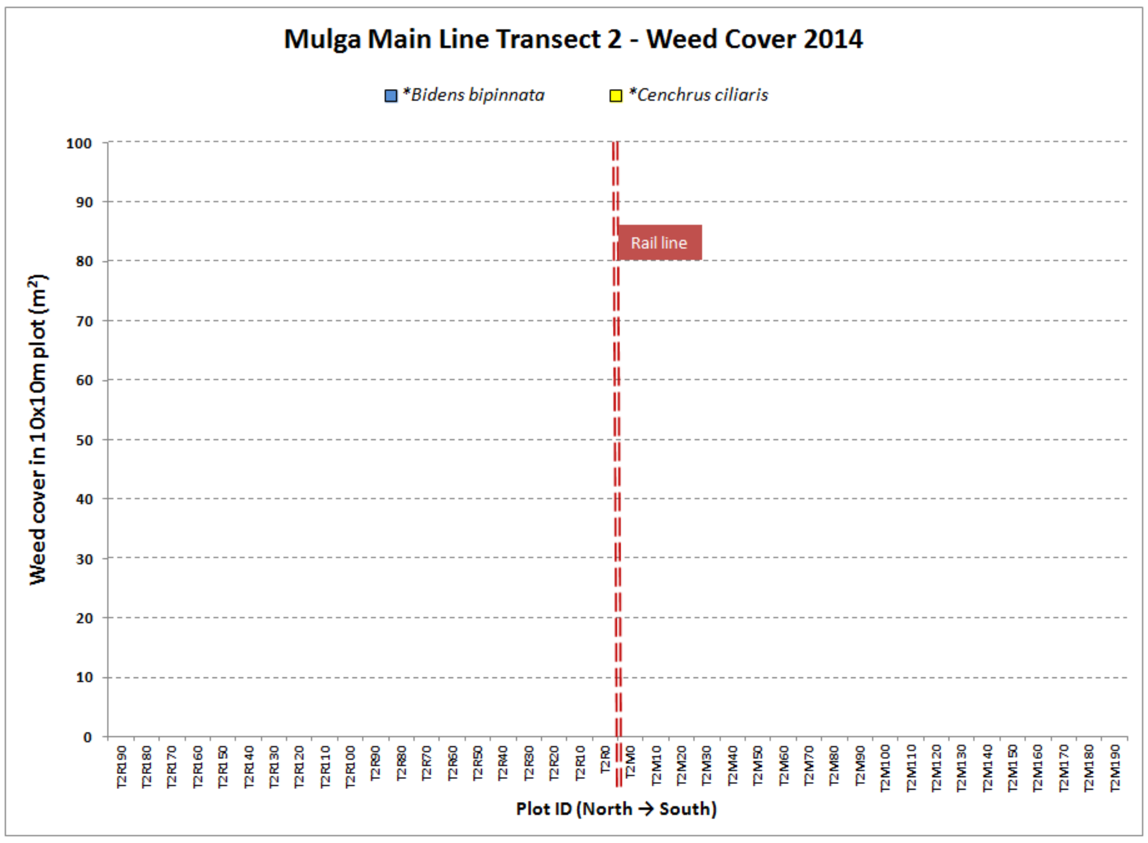

Mulga Main Line Transect 4 - grass cover in 2015
*Cenchrus ciliaris
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Cymbopogon ambiguous
Digitaria brownii
Enneapogon polyphyllus
Eragrostis dielsii
Eriachne helmsii
Eriachne mucronata
Panicum effusum
Paraneurachne muelleri
Themeda triandra
Triodia basedowii
Triodia epactia
Rail line
Totol cover length in plot (cm)
Plot ID (North → South)

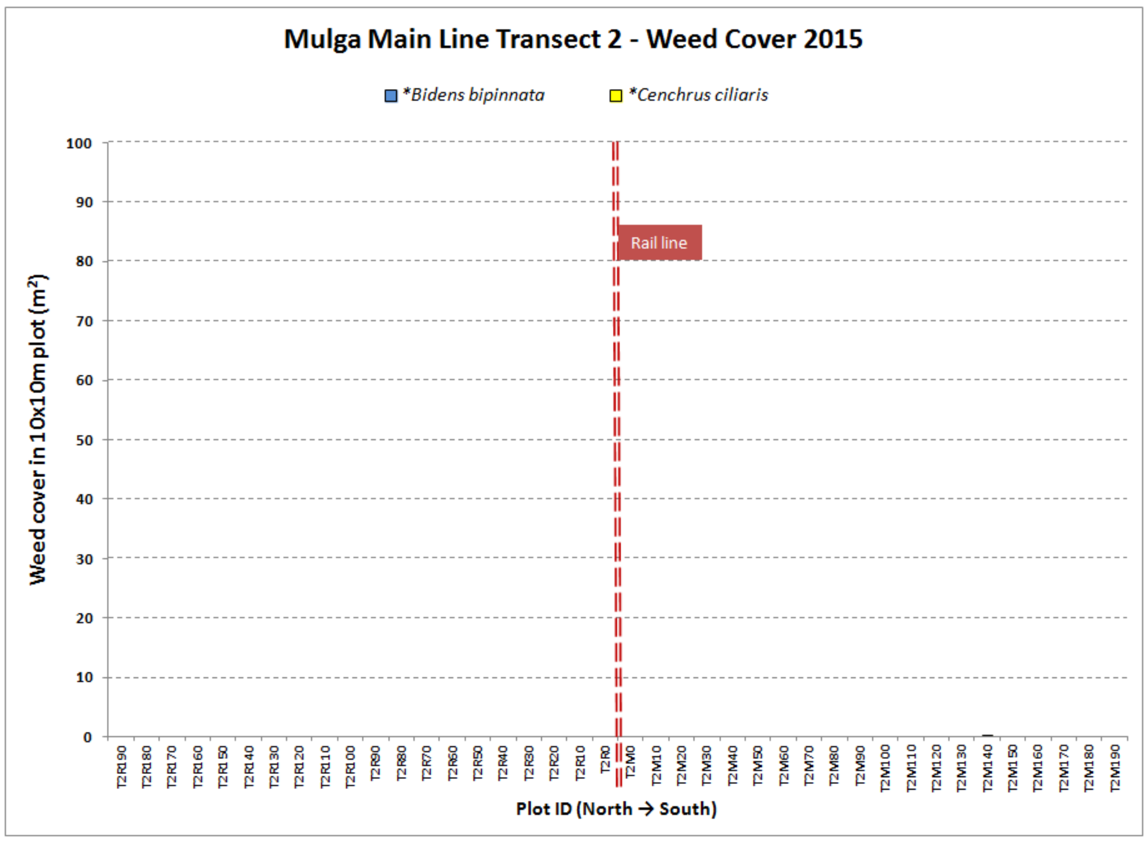

Mulga Main Line Transect 4 - grass cover in 2016
*Cenchrus ciliaris
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Cymbopogon ambiguous
Digitaria brownii
Enneapogon polyphyllus
Eragrostis dielsii
Eriachne helmsii
Eriachne mucronata
Panicum effusum
Paraneurachne muelleri
Themeda triandra
Triodia basedowii
Triodia epactia
Rail line
Totol cover length in plot (cm)
Plot ID (North → South)

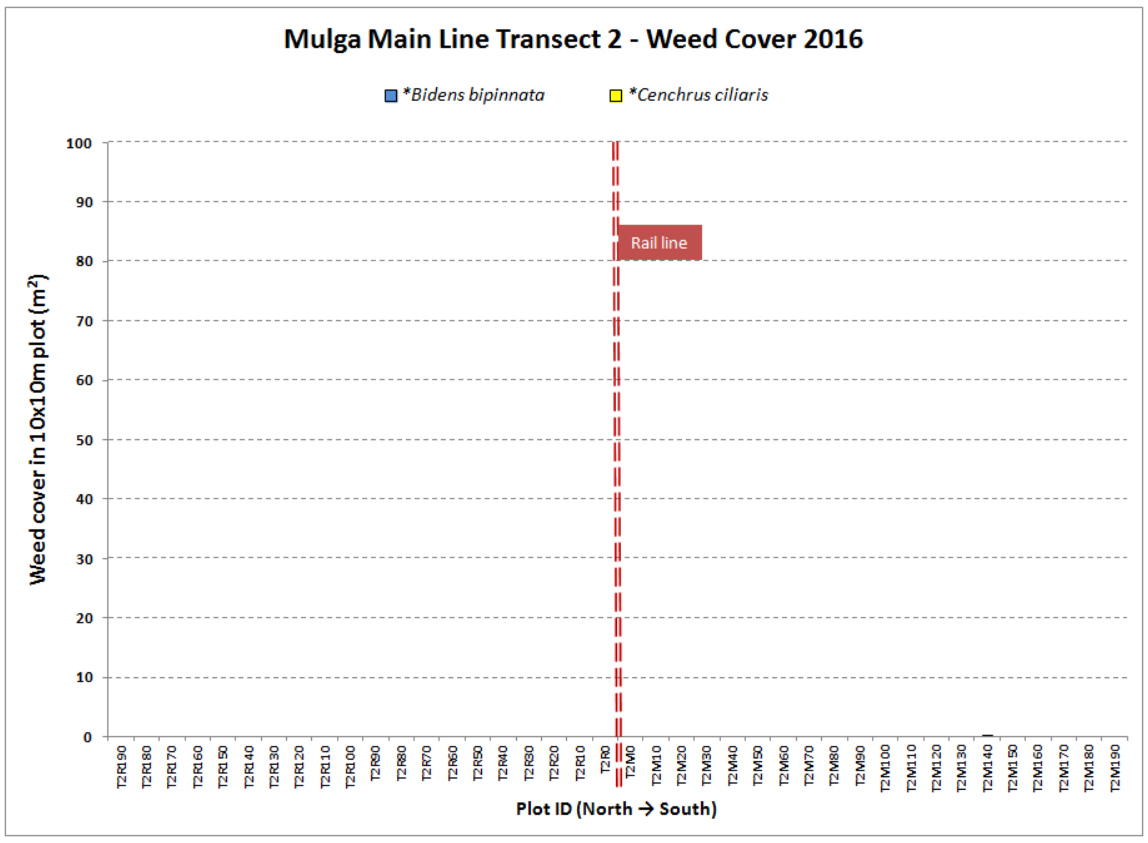

Mulga Main Line Transect 1 - Weed Cover 2014
*Bidens bipinnata
*Cenchrus ciliaris
Rail line
Weed cover in 10x10m plot (m²)
Plot ID (North → South)

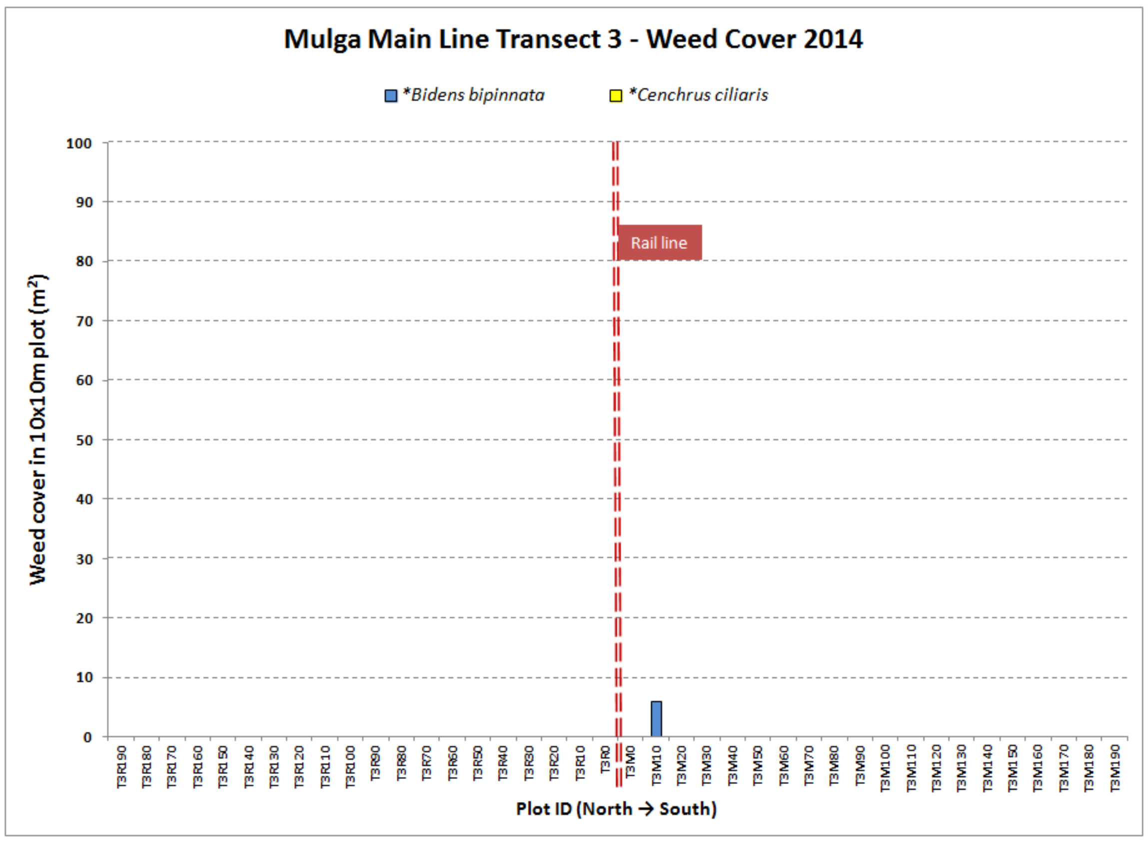

Mulga Main Line Transect 1 - Weed Cover 2015
*Bidens bipinnata
*Cenchrus ciliaris
Rail line
Weed cover in 10x10m plot (m²)
Plot ID (North → South)

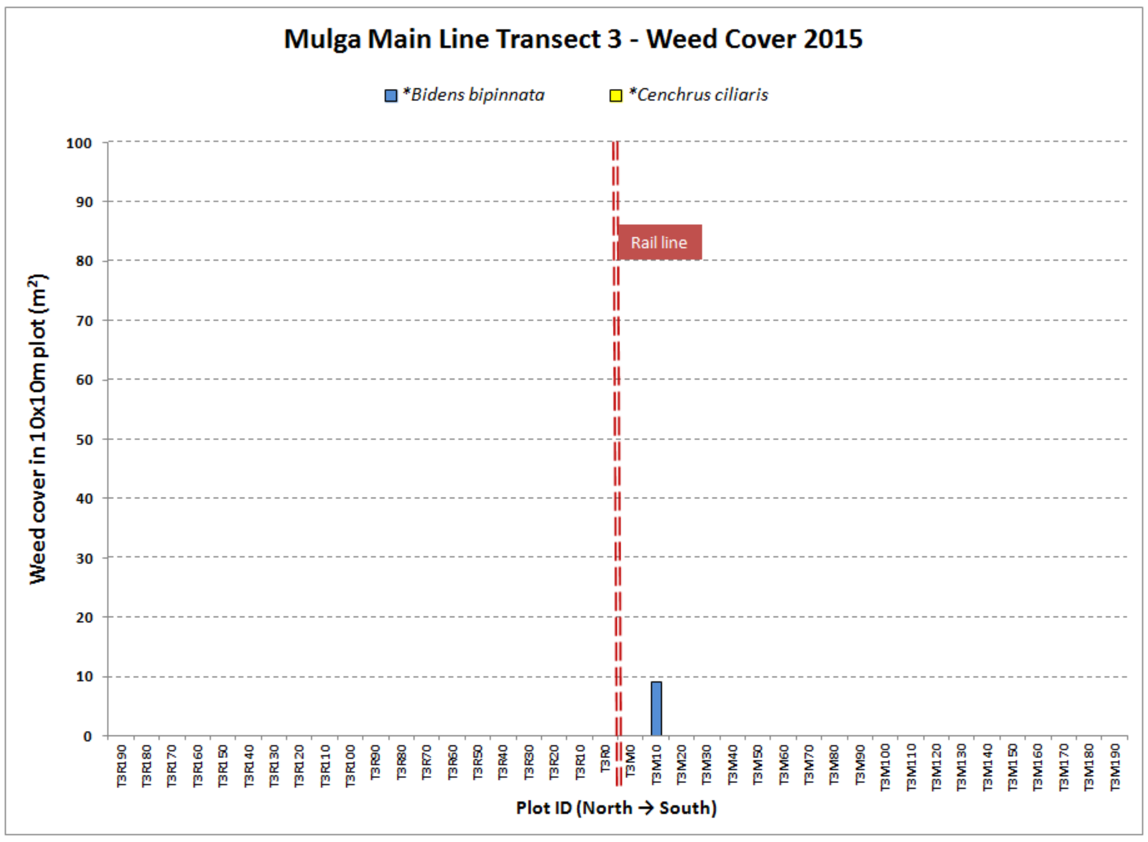

Mulga Main Line Transect 1 - Weed Cover 2016
*Bidens bipinnata
*Cenchrus ciliaris
Rail line
Weed cover in 10x10m plot (m²)
Plot ID (North → South)

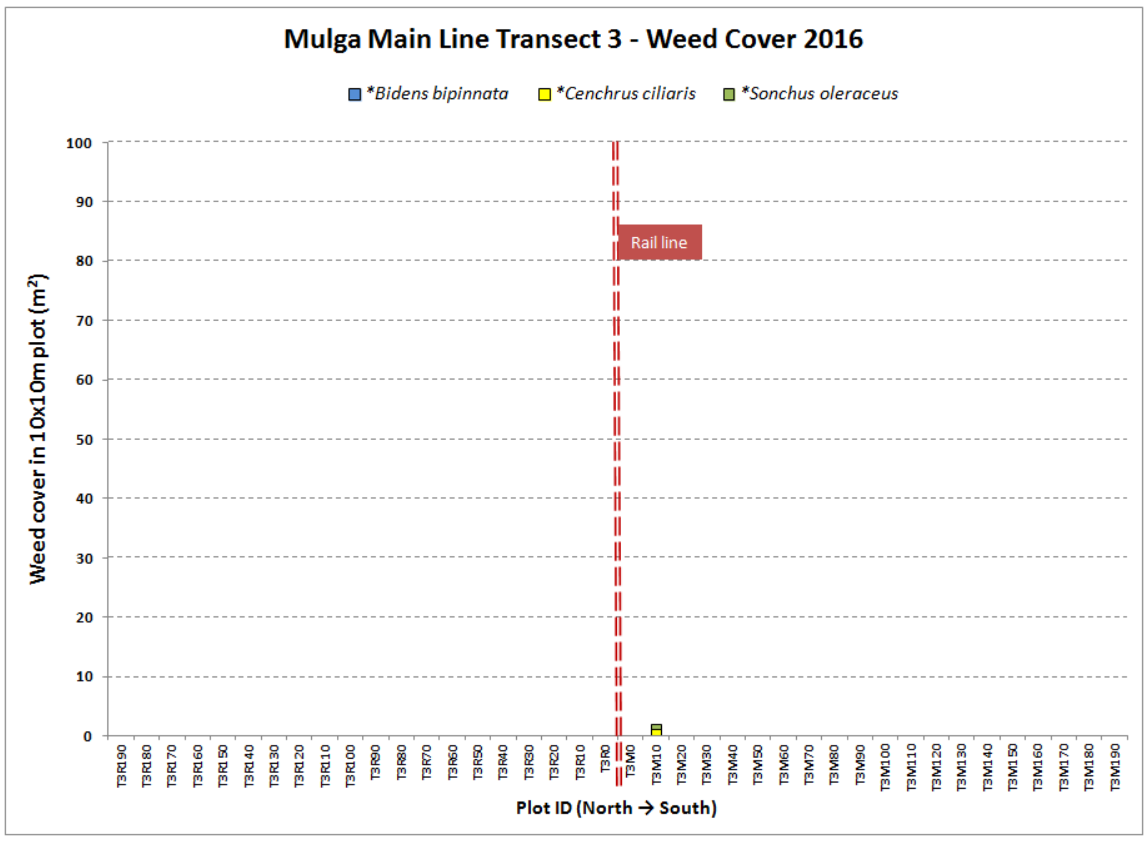

Mulga Main Line Transect 2 - Weed Cover 2014
*Bidens bipinnata
*Cenchrus ciliaris
Weed cover in 10x10m plot (m²)
Rail line
Plot ID (North → South)

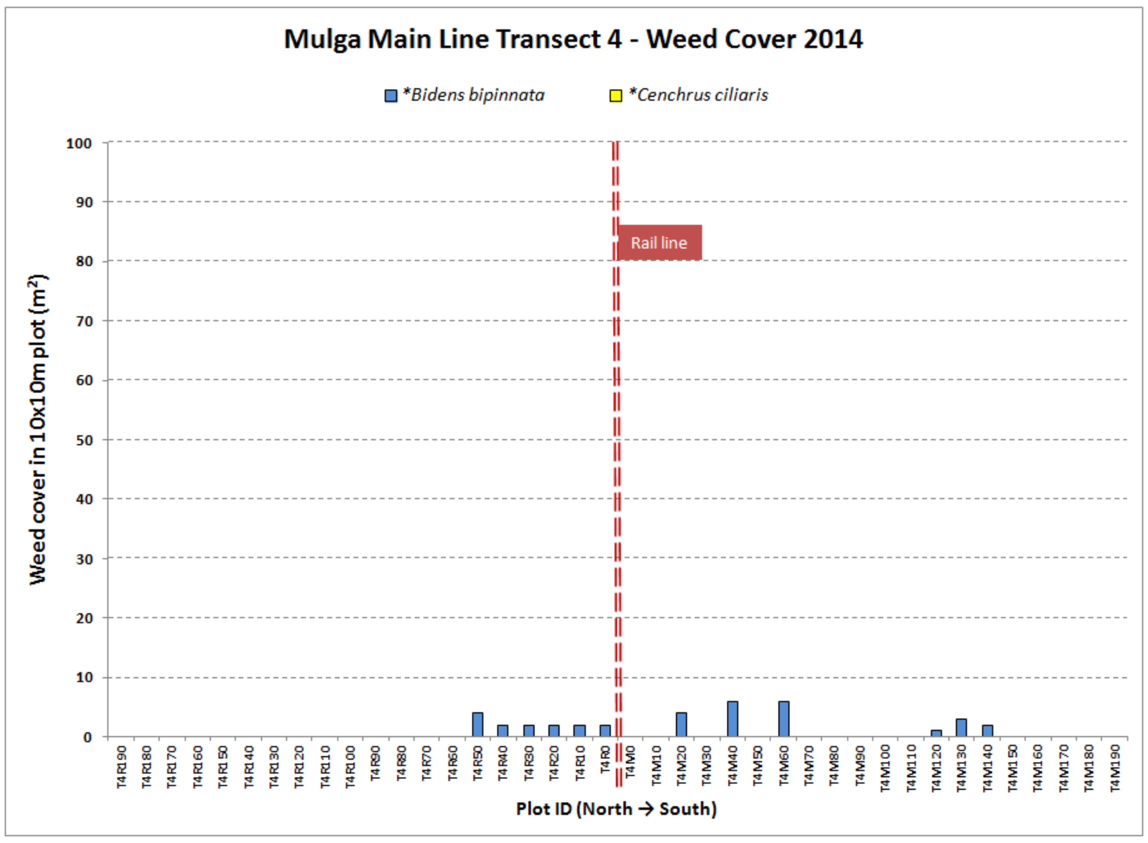

Mulga Main Line Transect 2 - Weed Cover 2015
*Bidens bipinnata
*Cenchrus ciliaris
Weed cover in 10x10m plot (m²)
Rail line
Plot ID (North → South)

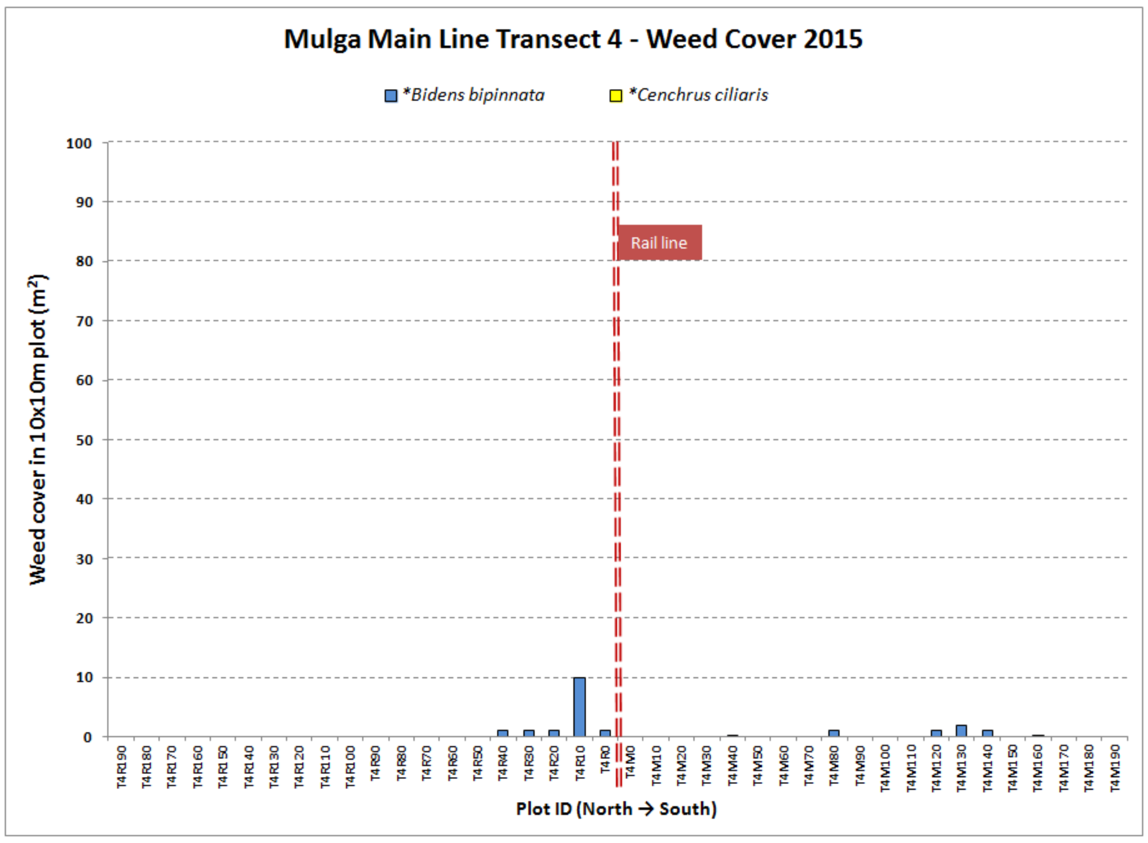

Mulga Main Line Transect 2 - Weed Cover 2016
*Bidens bipinnata
*Cenchrus ciliaris
Weed cover in 10x10m plot (m²)
Rail line
Plot ID (North → South)

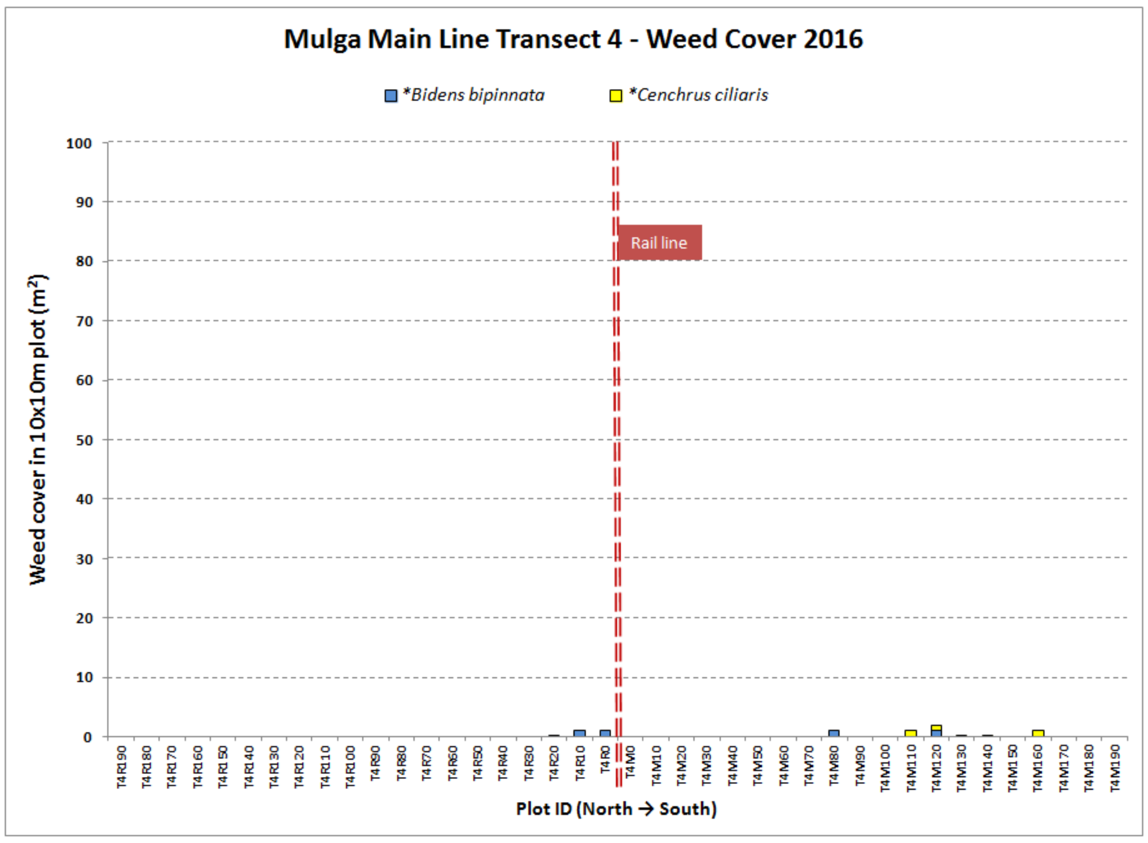

Mulga Main Line Transect 3 - Weed Cover 2014
*Bidens bipinnata
*Cenchrus ciliaris
Weed cover in 10x10m plot (m²)
Rail line
Plot ID (North → South)

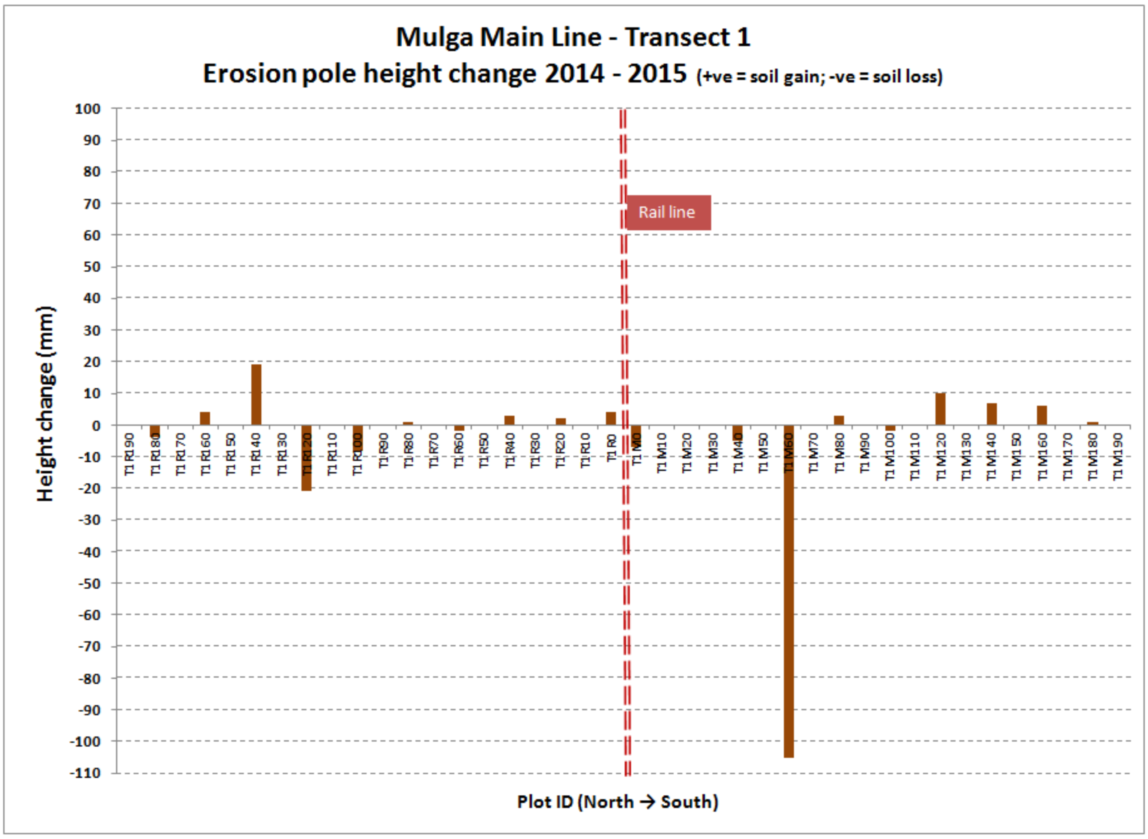

Mulga Main Line Transect 3 - Weed Cover 2015
*Bidens bipinnata
*Cenchrus ciliaris
Weed cover in 10x10m plot (m²)
Rail line
Plot ID (North → South)

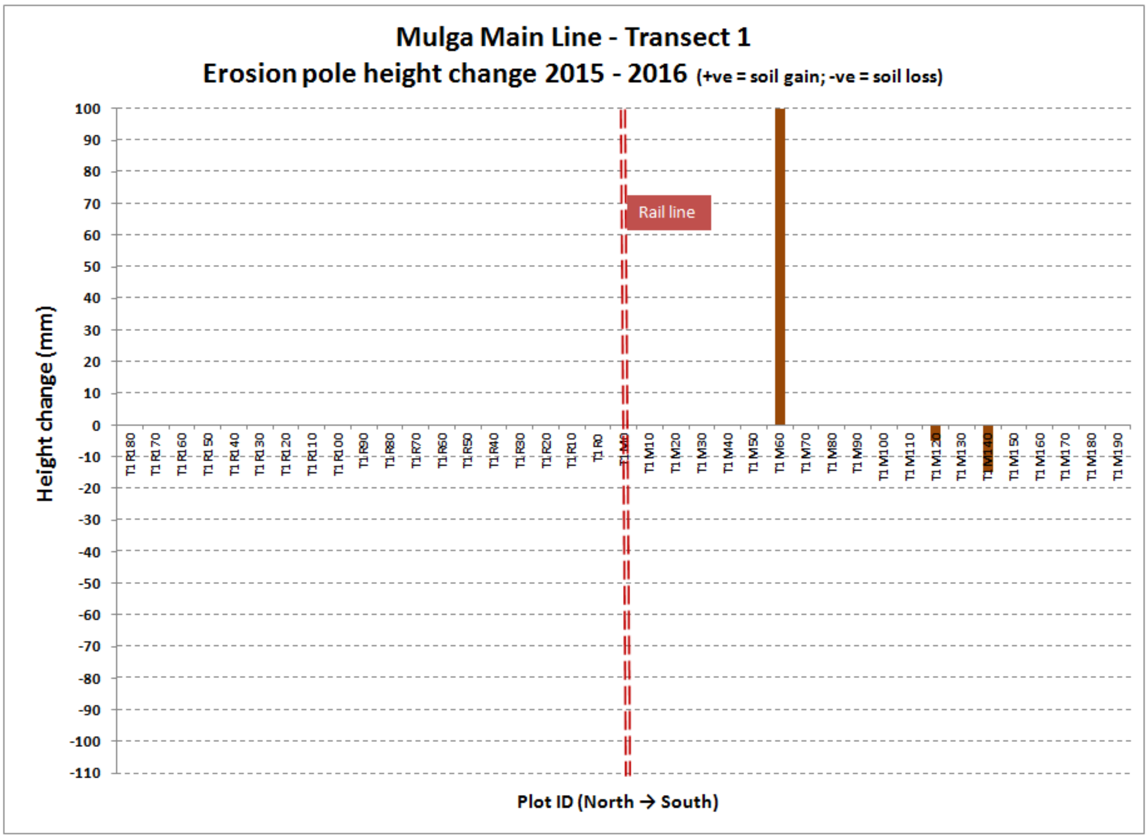

Mulga Main Line Transect 3 - Weed Cover 2016
*Bidens bipinnata
*Cenchrus ciliaris
*Sonchus oleraceus
Weed cover in 10x10m plot (m²)
Rail line
Plot ID (North → South)

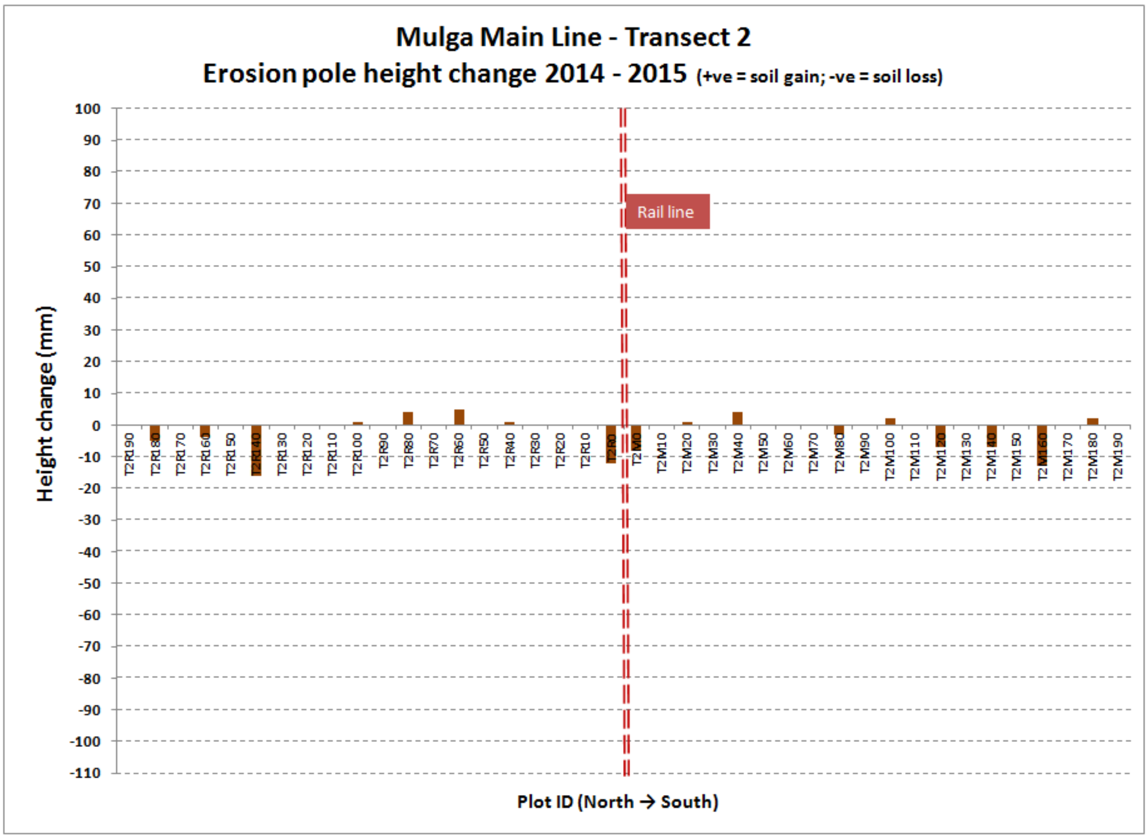

Mulga Main Line Transect 4 - Weed Cover 2014
*Bidens bipinnata
*Cenchrus ciliaris
Rail line
Weed cover in 10x10m plot (m²)
100
90
80
70
60
50
40
30
20
10
0
T4R190
T4R180
T4R170
T4R160
T4R150
T4R140
T4R130
T4R120
T4R110
T4R100
T4R90
T4R80
T4R70
T4R60
T4R50
T4R40
T4R30
T4R20
T4R10
T4R0
T4M0
T4M10
T4M20
T4M30
T4M40
T4M50
T4M60
T4M70
T4M80
T4M90
T4M100
T4M110
T4M120
T4M130
T4M140
T4M150
T4M160
T4M170
T4M180
T4M190
Plot ID (North → South)

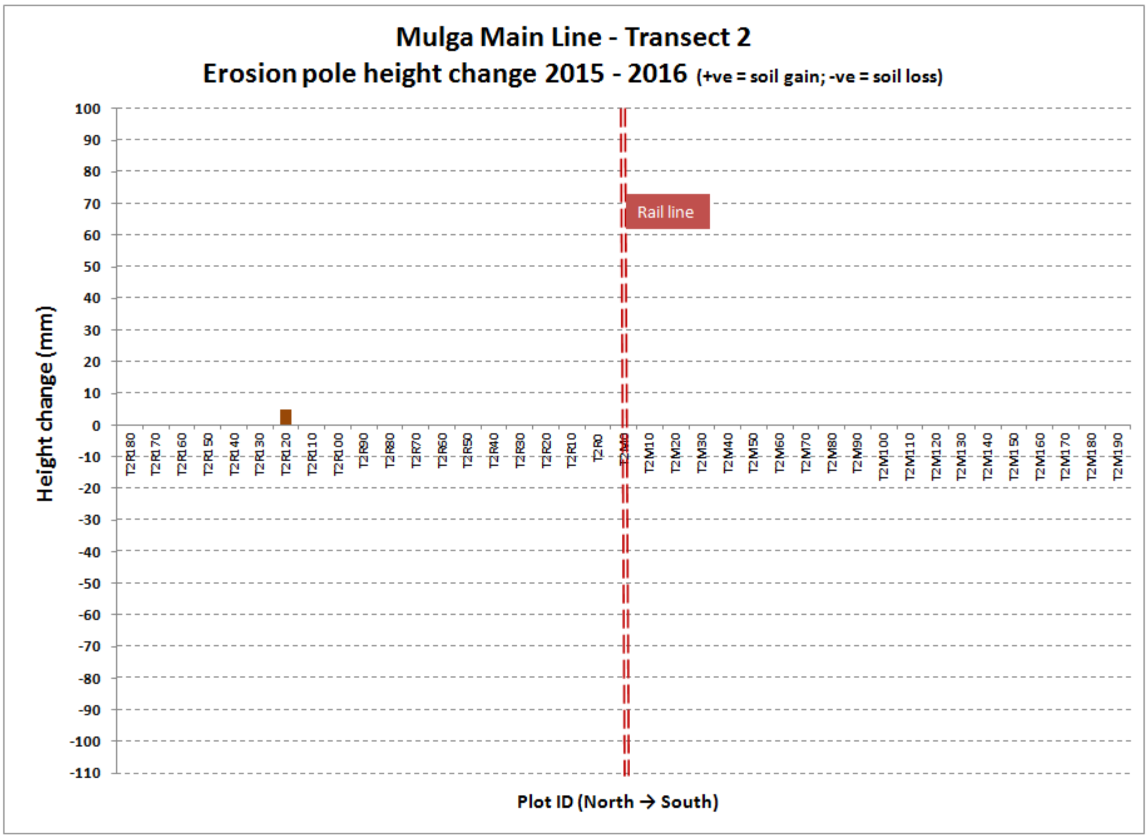

Mulga Main Line Transect 4 - Weed Cover 2015
*Bidens bipinnata
*Cenchrus ciliaris
Rail line
Weed cover in 10x10m plot (m²)
100
90
80
70
60
50
40
30
20
10
0
T4R190
T4R180
T4R170
T4R160
T4R150
T4R140
T4R130
T4R120
T4R110
T4R100
T4R90
T4R80
T4R70
T4R60
T4R50
T4R40
T4R30
T4R20
T4R10
T4R0
T4M0
T4M10
T4M20
T4M30
T4M40
T4M50
T4M60
T4M70
T4M80
T4M90
T4M100
T4M110
T4M120
T4M130
T4M140
T4M150
T4M160
T4M170
T4M180
T4M190
Plot ID (North → South)

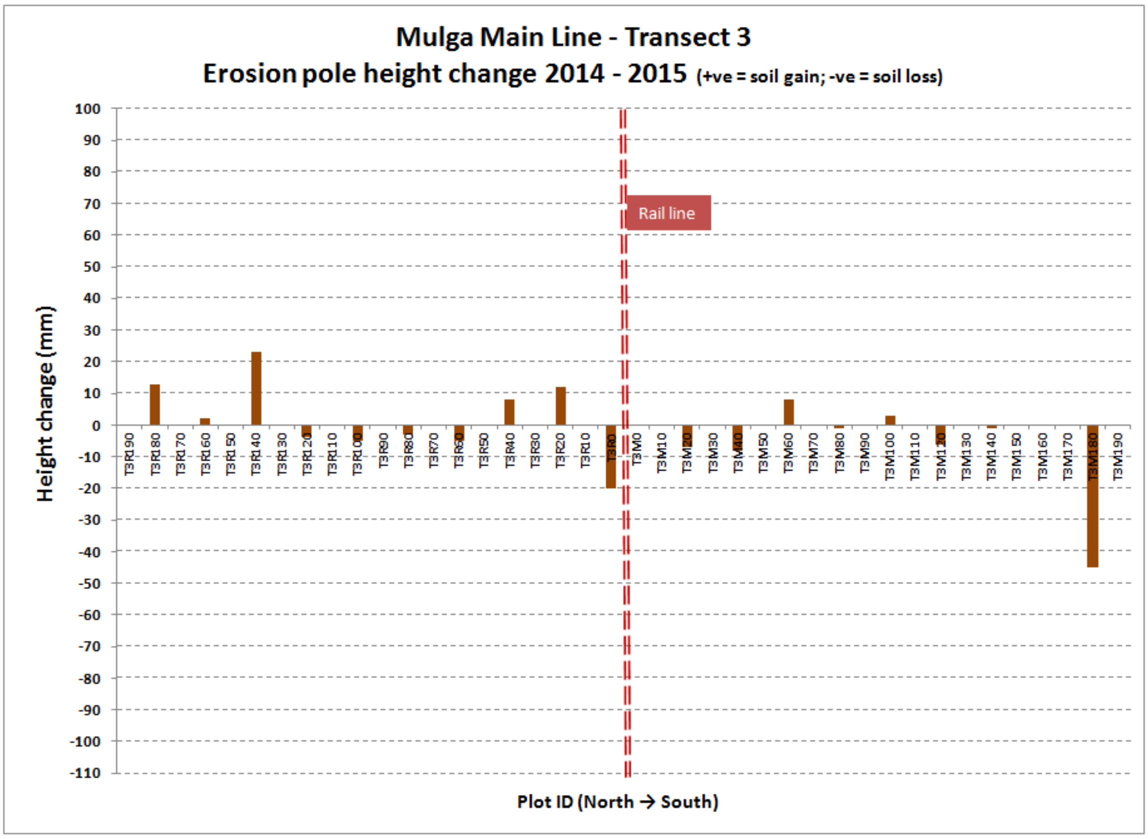

Mulga Main Line Transect 4 - Weed Cover 2016
*Bidens bipinnata
*Cenchrus ciliaris
Rail line
Weed cover in 10x10m plot (m²)
100
90
80
70
60
50
40
30
20
10
0
T4R190
T4R180
T4R170
T4R160
T4R150
T4R140
T4R130
T4R120
T4R110
T4R100
T4R90
T4R80
T4R70
T4R60
T4R50
T4R40
T4R30
T4R20
T4R10
T4R0
T4M0
T4M10
T4M20
T4M30
T4M40
T4M50
T4M60
T4M70
T4M80
T4M90
T4M100
T4M110
T4M120
T4M130
T4M140
T4M150
T4M160
T4M170
T4M180
T4M190
Plot ID (North → South)

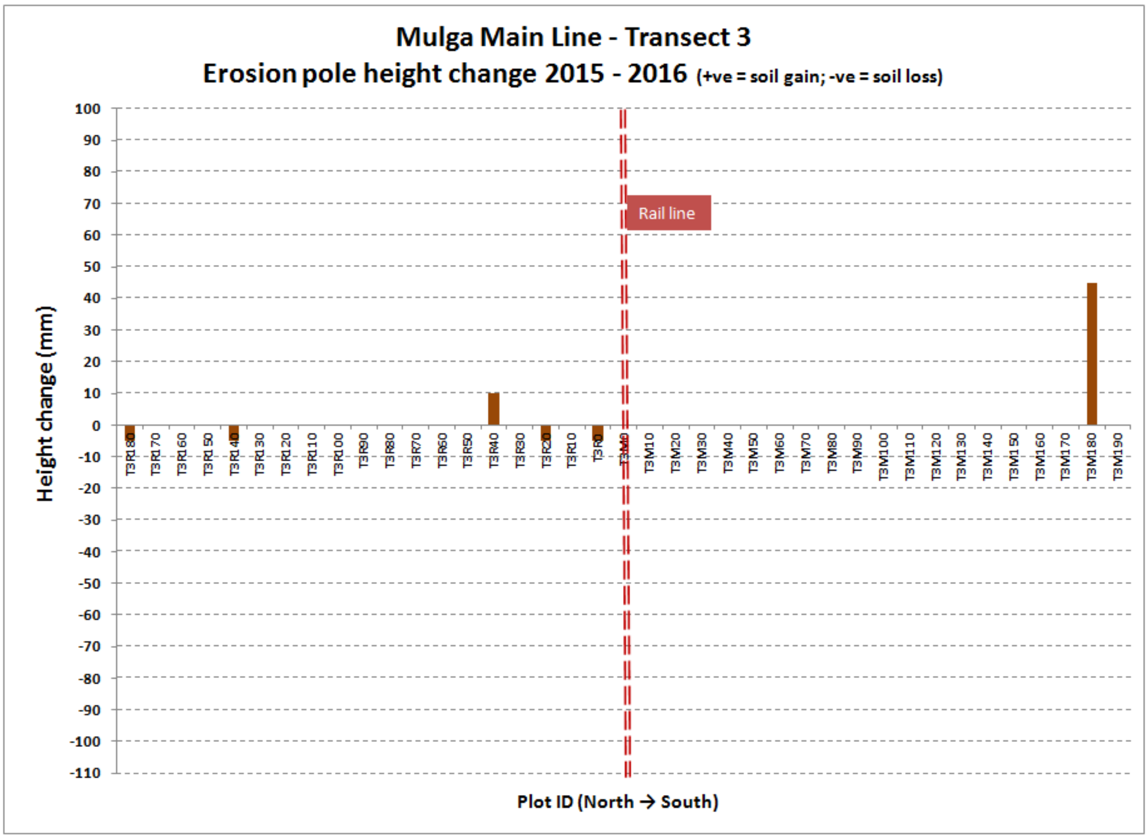

Mulga Main Line - Transect 1
Erosion pole height change 2014 - 2015 (+ve = soil gain; -ve = soil loss)
Height change (mm)
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
Rail line
T1 R190
T1 R180
T1 R170
T1 R160
T1 R150
T1 R140
T1 R130
T1 R120
T1 R110
T1 R100
T1 R90
T1 R80
T1 R70
T1 R60
T1 R50
T1 R40
T1 R30
T1 R20
T1 R10
T1 R0
T1 M0
T1 M10
T1 M20
T1 M30
T1 M40
T1 M50
T1 M60
T1 M70
T1 M80
T1 M90
T1 M100
T1 M110
T1 M120
T1 M130
T1 M140
T1 M150
T1 M160
T1 M170
T1 M180
T1 M190
Plot ID (North → South)

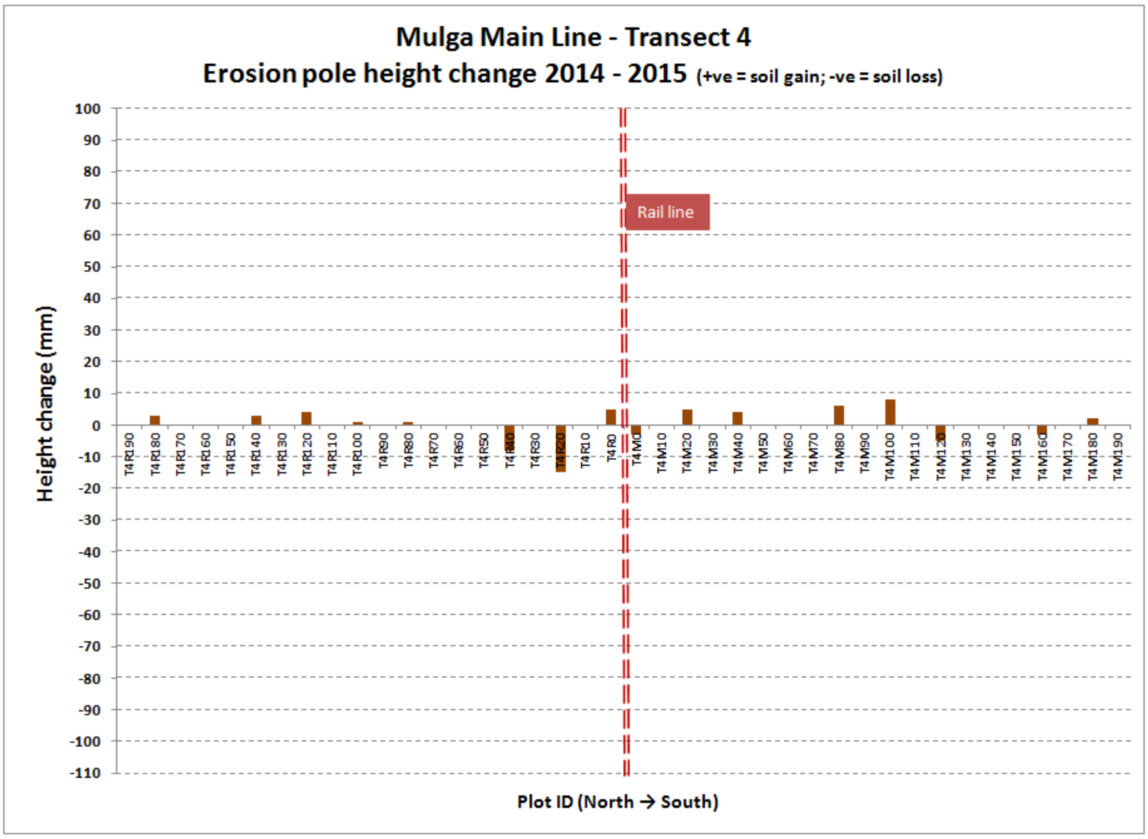

Mulga Main Line - Transect 1
Erosion pole height change 2015 - 2016 (+ve = soil gain; -ve = soil loss)
Height change (mm)
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
Rail line
T1 R180
T1 R170
T1 R160
T1 R150
T1 R140
T1 R130
T1 R120
T1 R110
T1 R100
T1 R90
T1 R80
T1 R70
T1 R60
T1 R50
T1 R40
T1 R30
T1 R20
T1 R10
T1 R0
T1 M0
T1 M10
T1 M20
T1 M30
T1 M40
T1 M50
T1 M60
T1 M70
T1 M80
T1 M90
T1 M100
T1 M110
T1 M120
T1 M130
T1 M140
T1 M150
T1 M160
T1 M170
T1 M180
T1 M190
Plot ID (North → South)

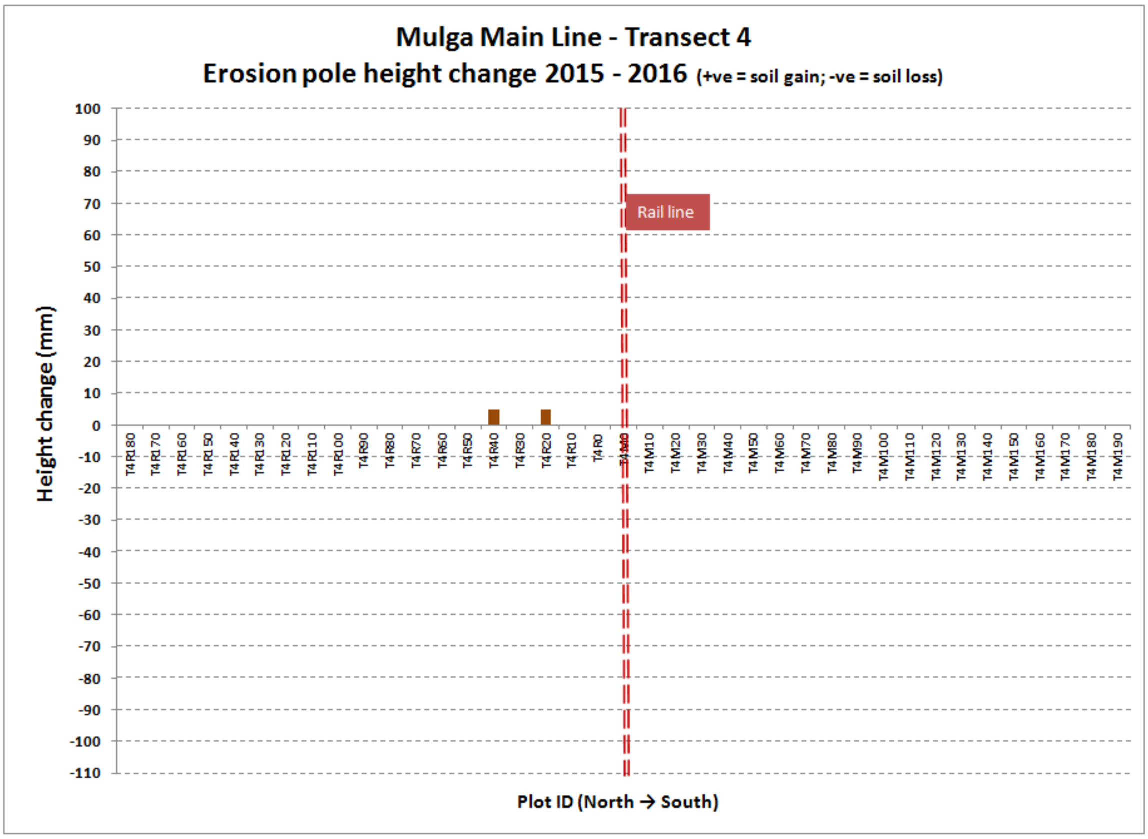

Mulga Main Line - Transect 2
Erosion pole height change 2014 - 2015 (+ve = soil gain; -ve = soil loss)
Height change (mm)
Rail line
Plot ID (North → South)

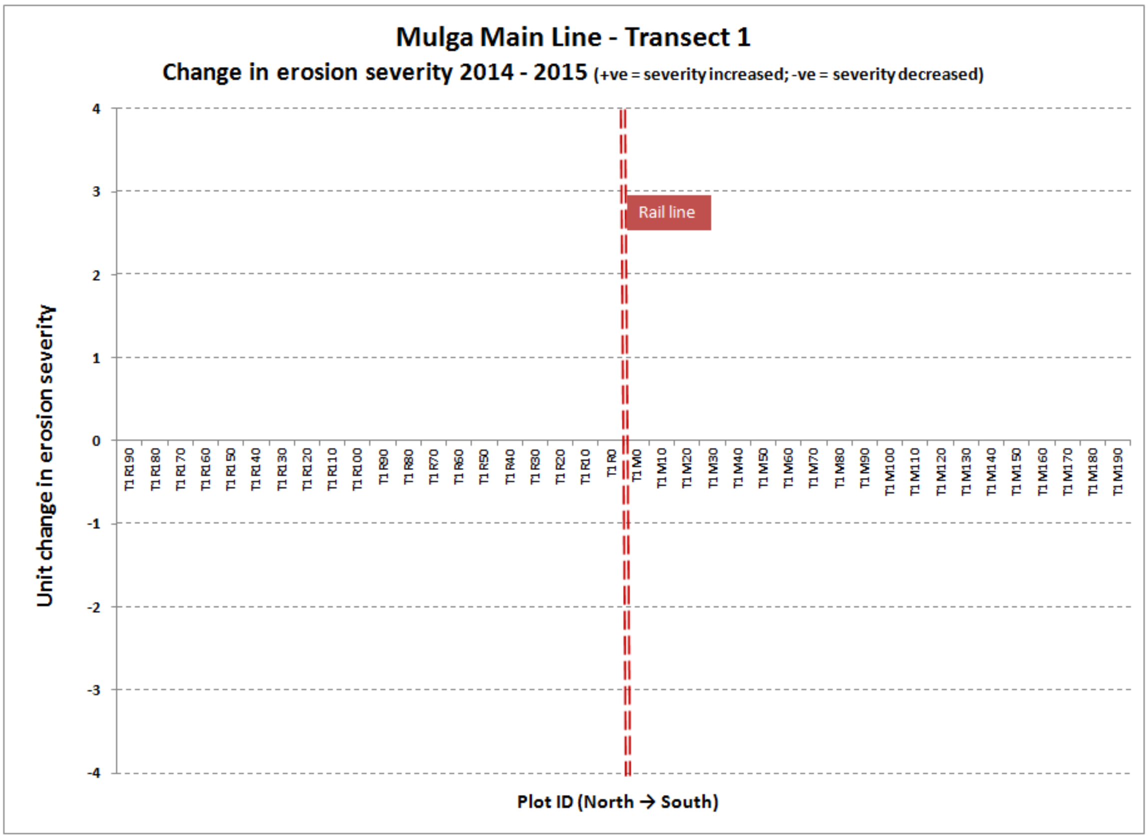

Mulga Main Line - Transect 2
Erosion pole height change 2015 - 2016 (+ve = soil gain; -ve = soil loss)
Height change (mm)
Rail line
Plot ID (North → South)

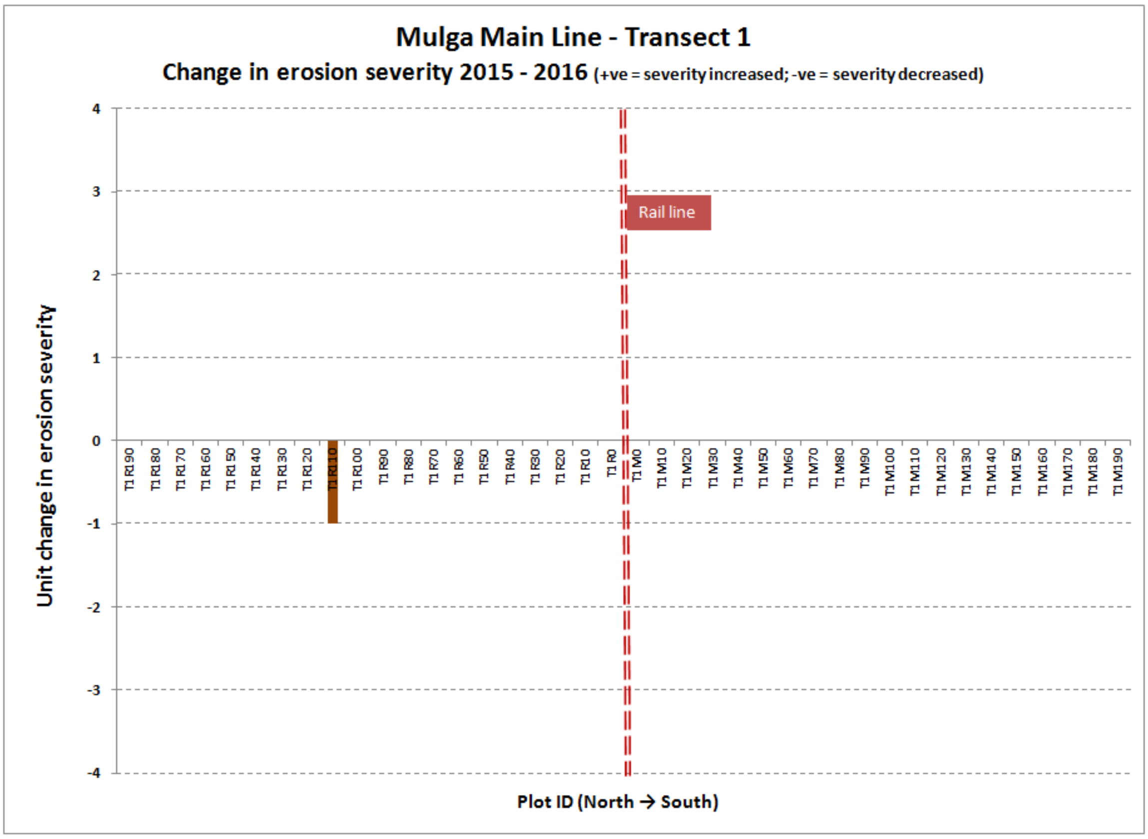

Mulga Main Line - Transect 3
Erosion pole height change 2014 - 2015 (+ve = soil gain; -ve = soil loss)
Height change (mm)
Rail line
Plot ID (North → South)

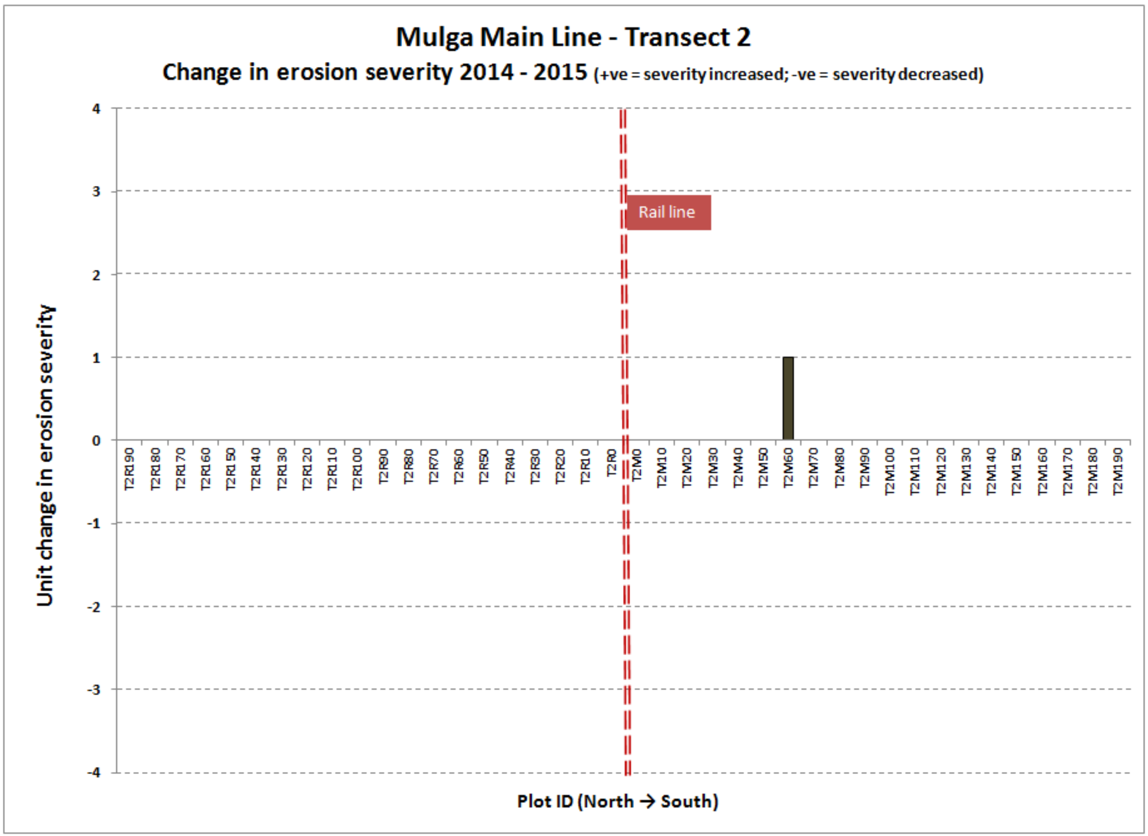

Mulga Main Line - Transect 3
Erosion pole height change 2015 - 2016 (+ve = soil gain; -ve = soil loss)
Height change (mm)
Rail line
Plot ID (North → South)


Mulga Main Line - Transect 4
Erosion pole height change 2014 - 2015 (+ve = soil gain; -ve = soil loss)
Height change (mm)
Rail line
Plot ID (North → South)

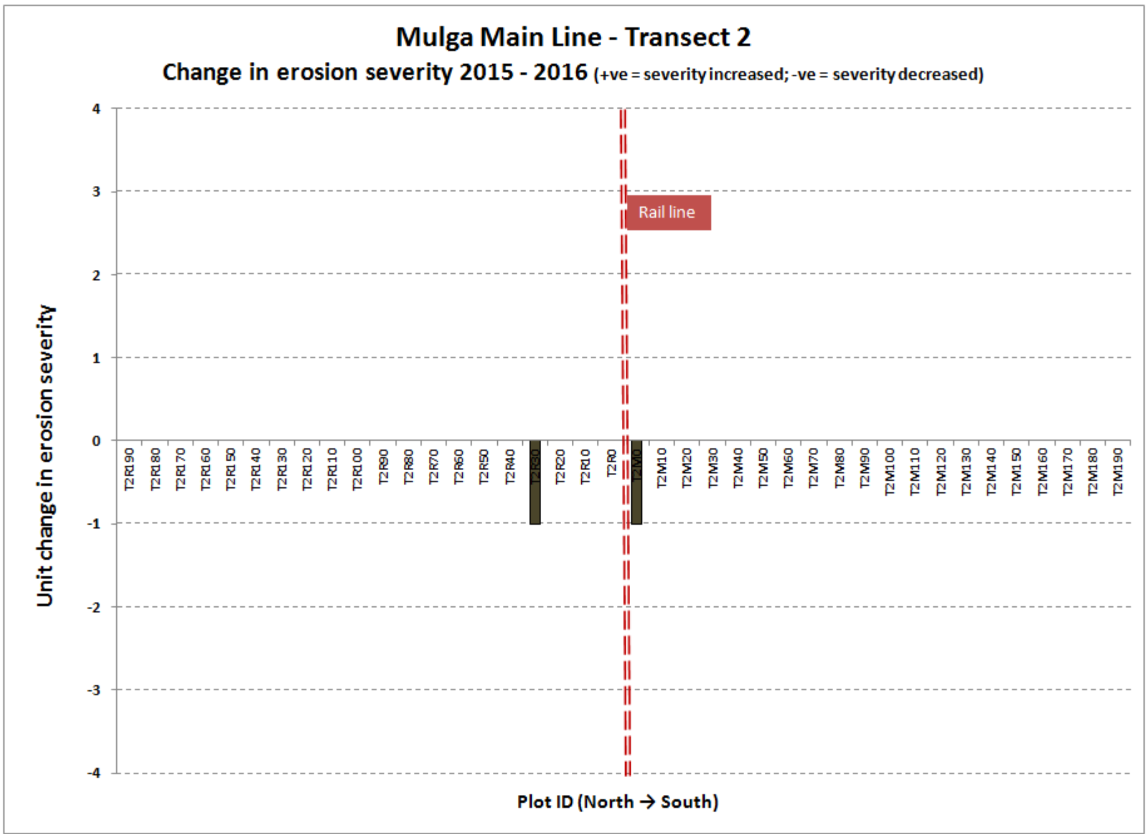

Mulga Main Line - Transect 4
Erosion pole height change 2015 - 2016 (+ve = soil gain; -ve = soil loss)
Height change (mm)
Rail line
Plot ID (North → South)


Mulga Main Line - Transect 1
Change in erosion severity 2014 - 2015 (+ve = severity increased; -ve = severity decreased)
Unit change in erosion severity
4
3
2
1
0
-1
-2
-3
-4
Rail line
T1 R190
T1 R180
T1 R170
T1 R160
T1 R150
T1 R140
T1 R130
T1 R120
T1 R110
T1 R100
T1 R90
T1 R80
T1 R70
T1 R60
T1 R50
T1 R40
T1 R30
T1 R20
T1 R10
T1 R0
T1 M0
T1 M10
T1 M20
T1 M30
T1 M40
T1 M50
T1 M60
T1 M70
T1 M80
T1 M90
T1 M100
T1 M110
T1 M120
T1 M130
T1 M140
T1 M150
T1 M160
T1 M170
T1 M180
T1 M190
Plot ID (North → South)

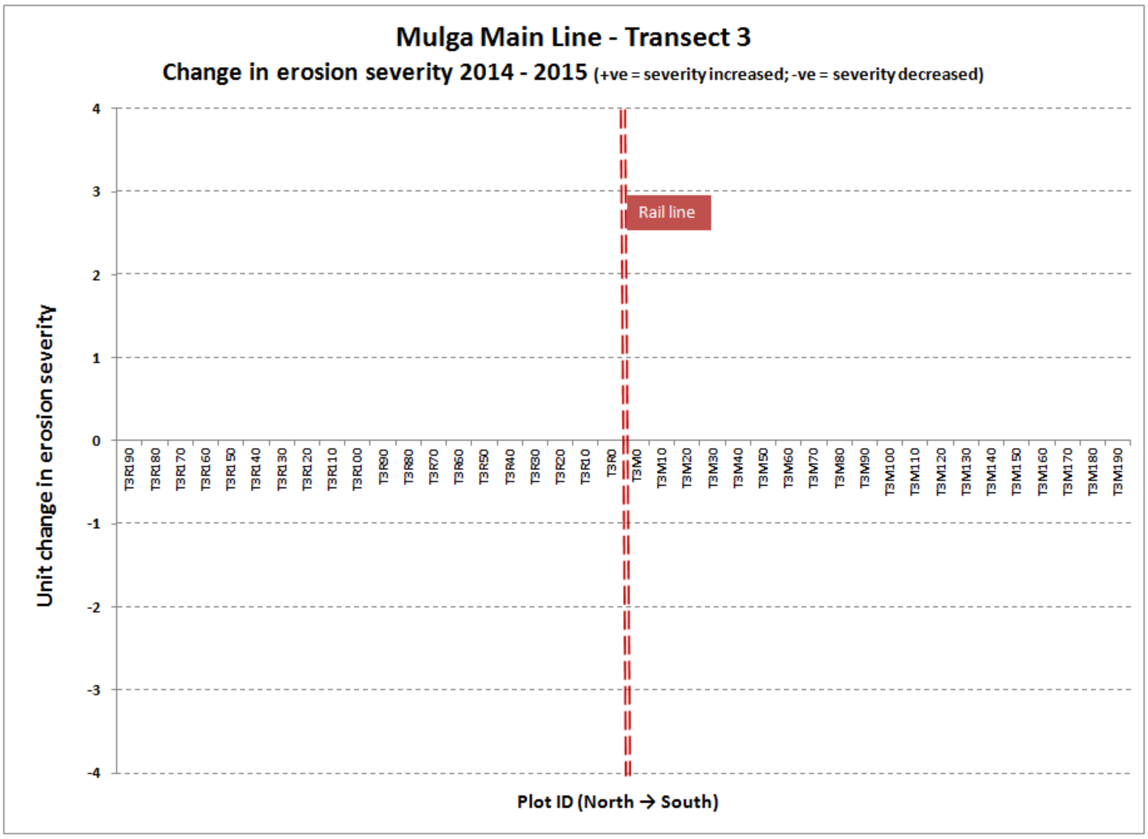

Mulga Main Line - Transect 1
Change in erosion severity 2015 - 2016 (+ve = severity increased; -ve = severity decreased)
Unit change in erosion severity
4
3
2
1
0
-1
-2
-3
-4
Rail line
T1 R190
T1 R180
T1 R170
T1 R160
T1 R150
T1 R140
T1 R130
T1 R120
T1 R110
T1 R100
T1 R90
T1 R80
T1 R70
T1 R60
T1 R50
T1 R40
T1 R30
T1 R20
T1 R10
T1 R0
T1 M0
T1 M10
T1 M20
T1 M30
T1 M40
T1 M50
T1 M60
T1 M70
T1 M80
T1 M90
T1 M100
T1 M110
T1 M120
T1 M130
T1 M140
T1 M150
T1 M160
T1 M170
T1 M180
T1 M190
Plot ID (North → South)

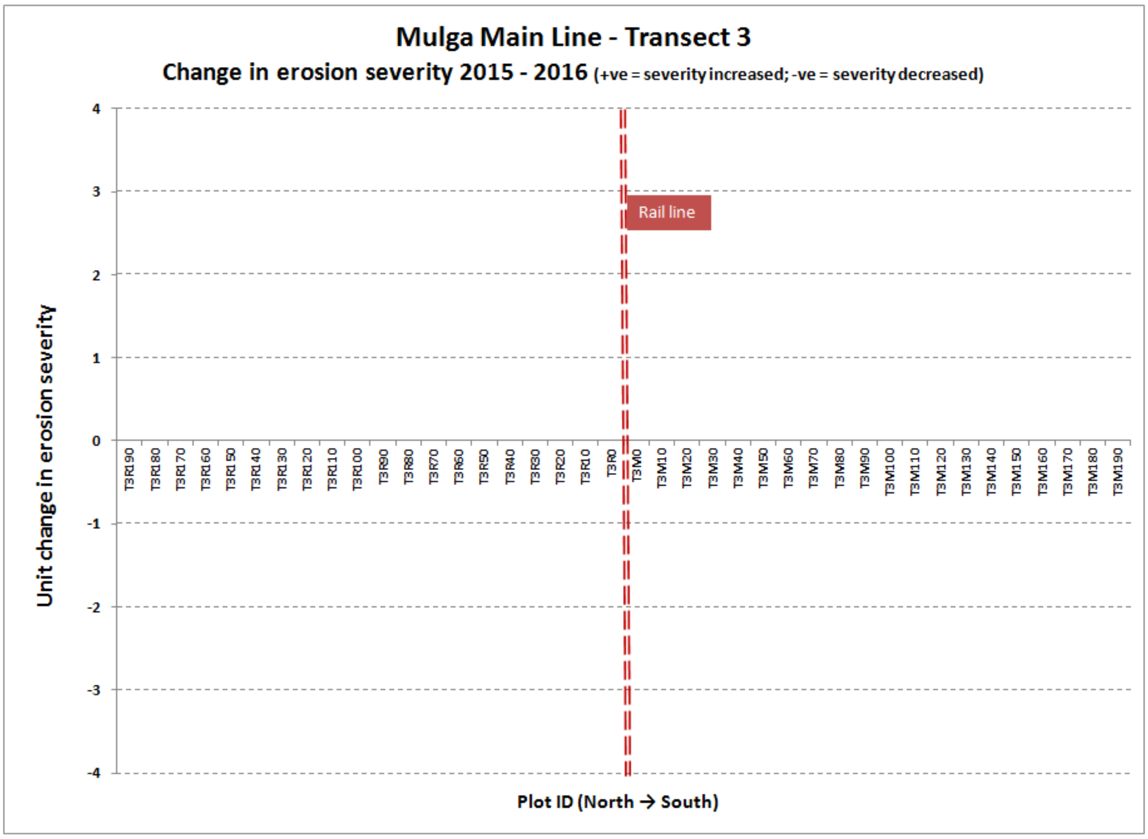


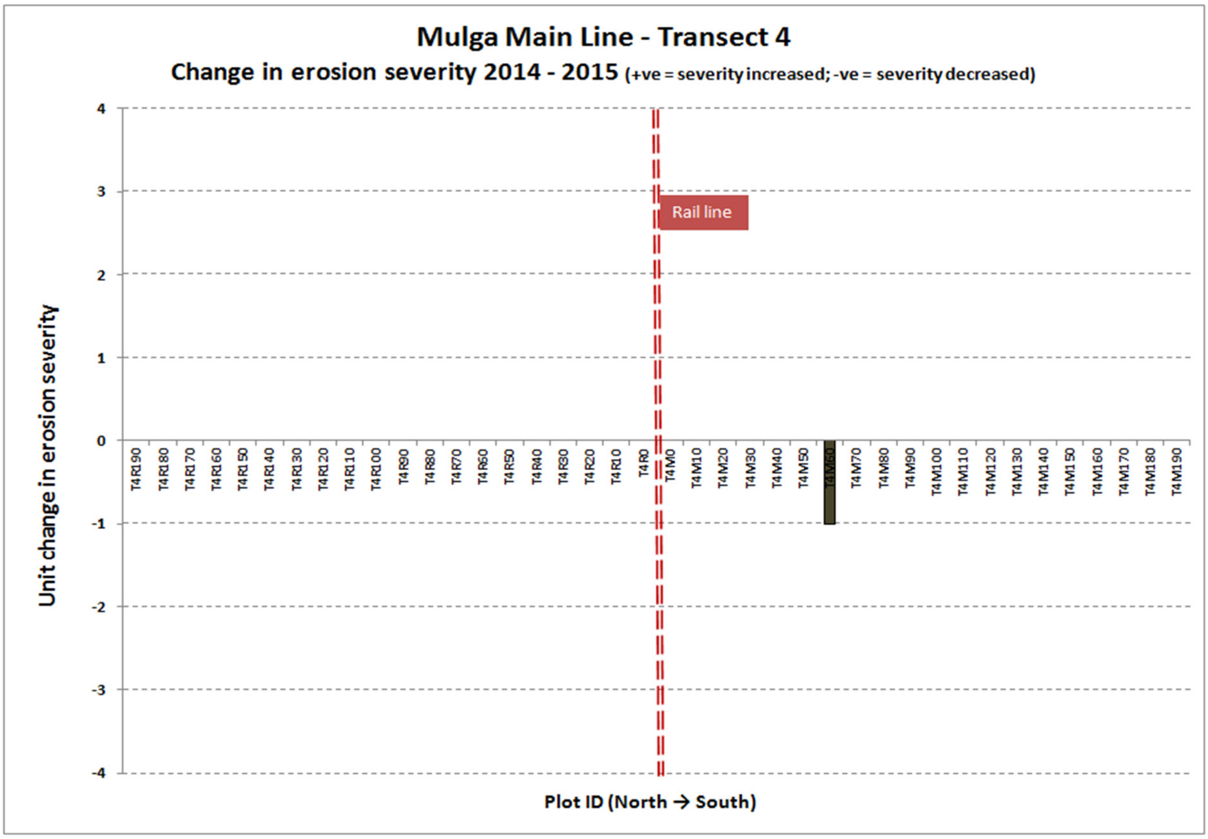
Mulga Main Line - Transect 2
Change in erosion severity 2014 - 2015 (+ve = severity increased; -ve = severity decreased)
Unit change in erosion severity
Rail line
4
3
2
1
0
-1
-2
-3
-4
T2R190 T2R180 T2R170 T2R160 T2R150 T2R140 T2R130 T2R120 T2R110 T2R100 T2R90 T2R80 T2R70 T2R60 T2R50 T2R40 T2R30 T2R20 T2R10 T2R0 T2M0 T2M10 T2M20 T2M30 T2M40 T2M50 T2M60 T2M70 T2M80 T2M90 T2M100 T2M110 T2M120 T2M130 T2M140 T2M150 T2M160 T2M170 T2M180 T2M190
Plot ID (North → South)

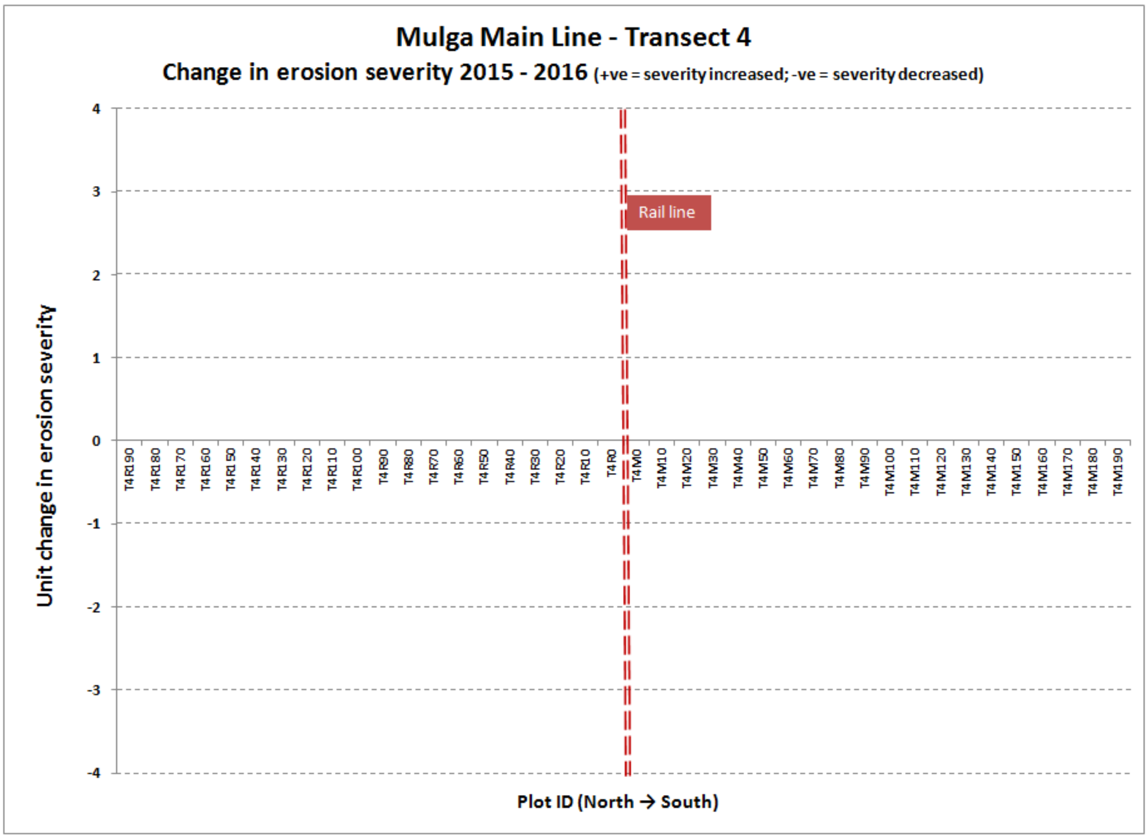


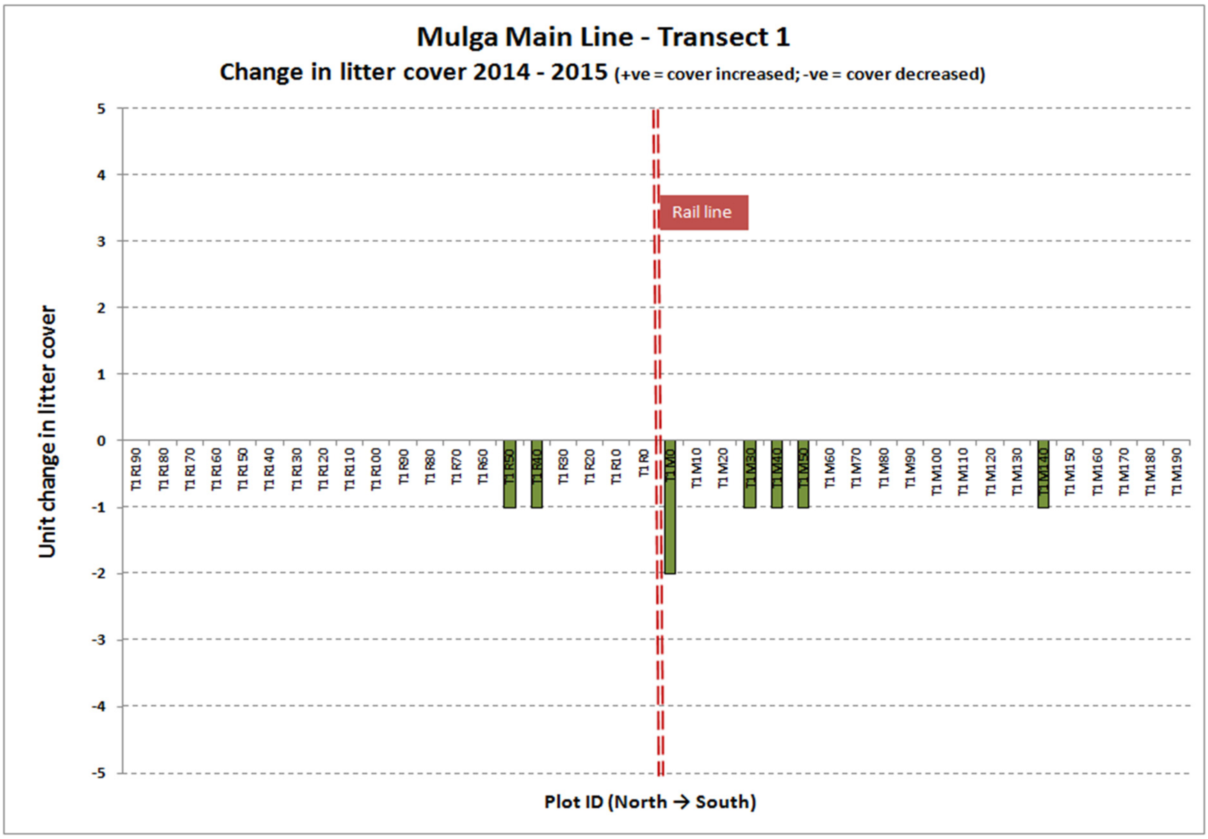
Mulga Main Line - Transect 2
Change in erosion severity 2015 - 2016 (+ve = severity increased; -ve = severity decreased)
Unit change in erosion severity
Rail line
4
3
2
1
0
-1
-2
-3
-4
T2R190 T2R180 T2R170 T2R160 T2R150 T2R140 T2R130 T2R120 T2R110 T2R100 T2R90 T2R80 T2R70 T2R60 T2R50 T2R40 T2R30 T2R20 T2R10 T2R0 T2M0 T2M10 T2M20 T2M30 T2M40 T2M50 T2M60 T2M70 T2M80 T2M90 T2M100 T2M110 T2M120 T2M130 T2M140 T2M150 T2M160 T2M170 T2M180 T2M190
Plot ID (North → South)

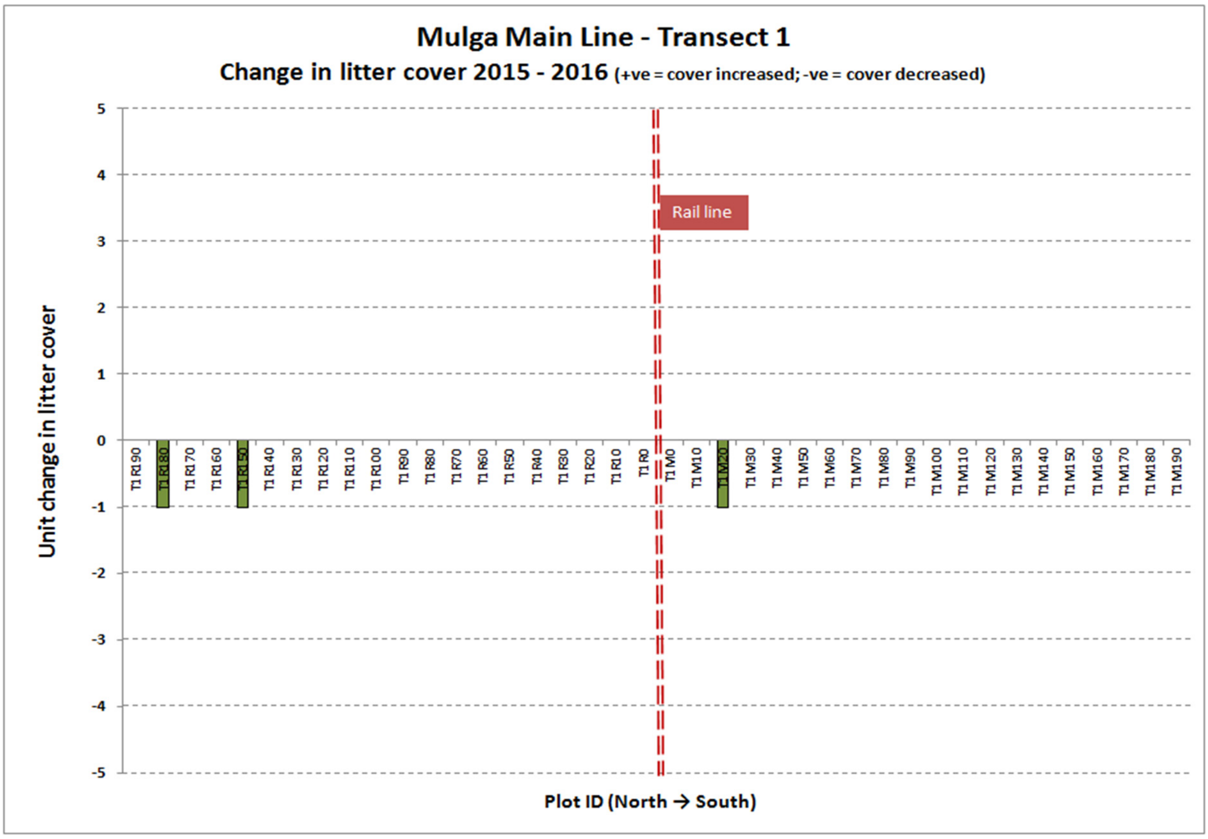

Mulga Main Line - Transect 3
Change in erosion severity 2014 - 2015 (+ve = severity increased; -ve = severity decreased)
Unit change in erosion severity
Rail line
Plot ID (North → South)

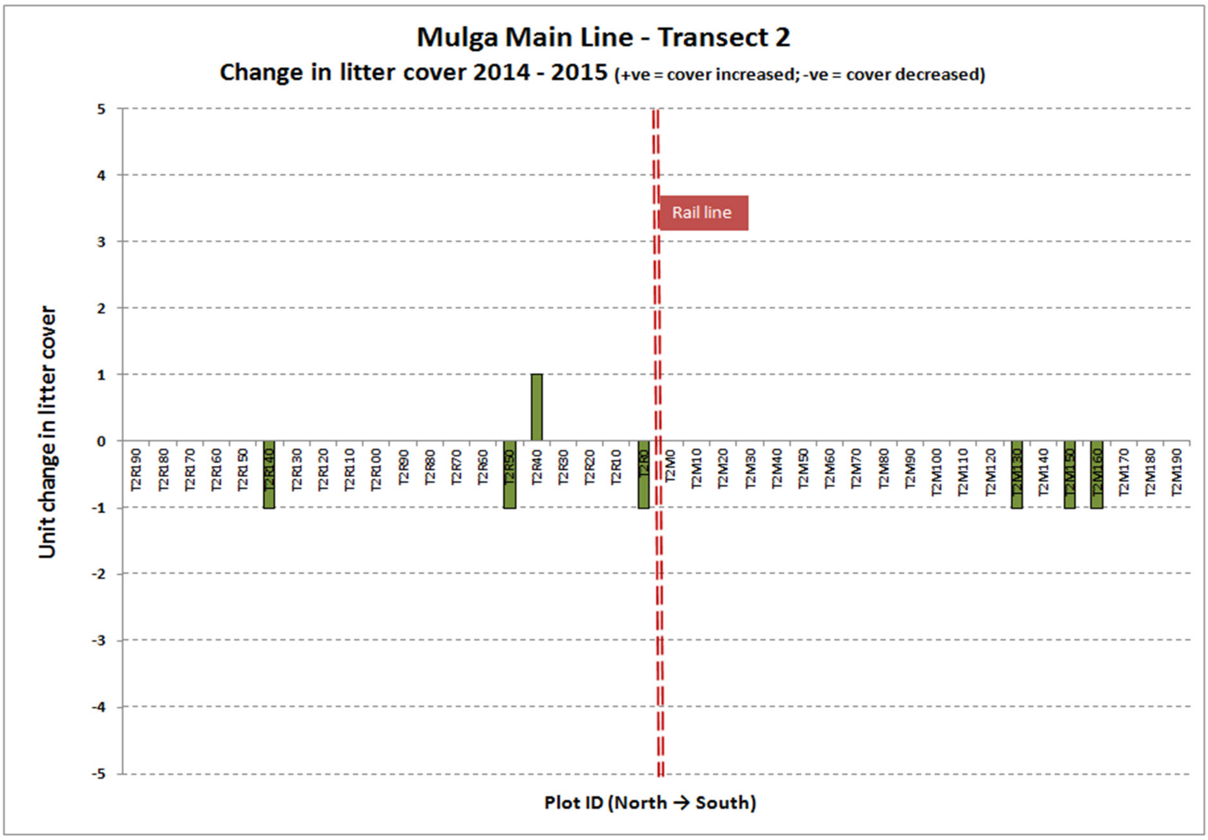

Mulga Main Line - Transect 3
Change in erosion severity 2015 - 2016 (+ve = severity increased; -ve = severity decreased)
Unit change in erosion severity
Rail line
Plot ID (North → South)

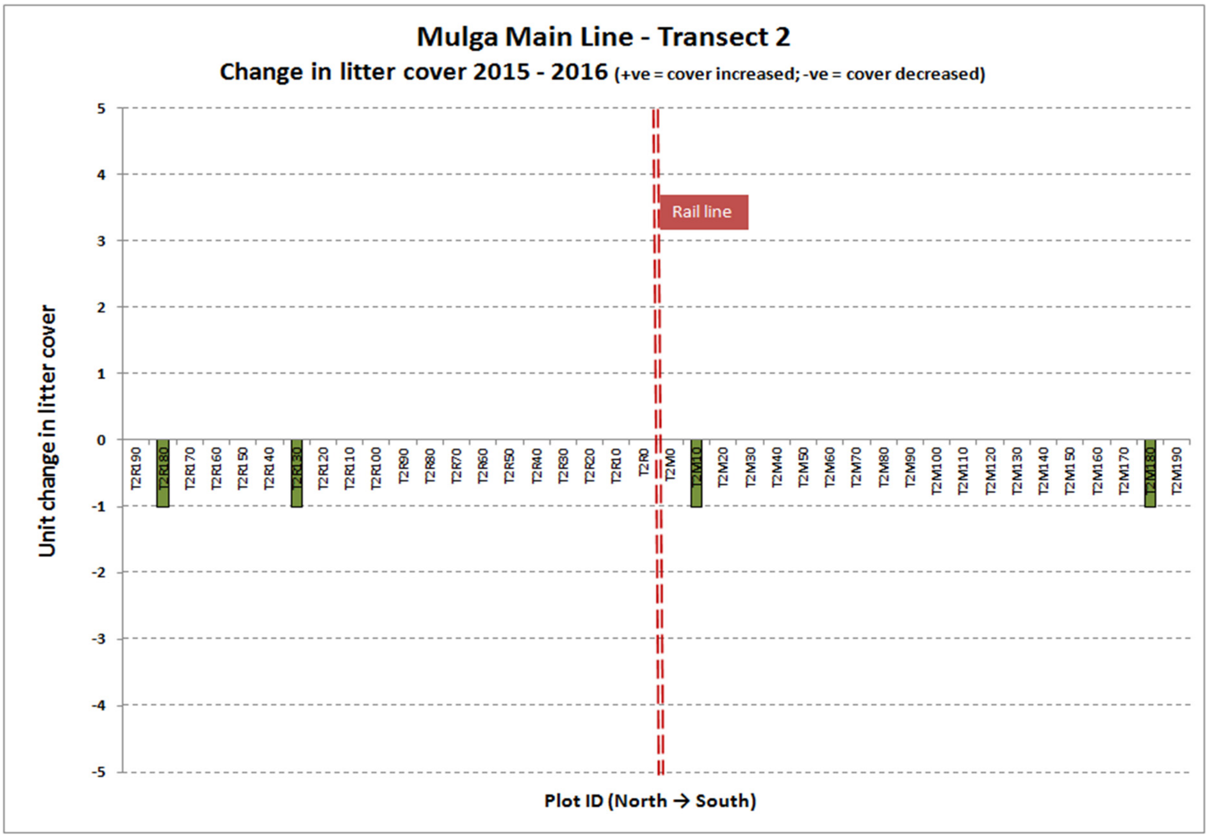

Mulga Main Line - Transect 4
Change in erosion severity 2014 - 2015 (+ve = severity increased; -ve = severity decreased)
Unit change in erosion severity
Rail line
Plot ID (North → South)

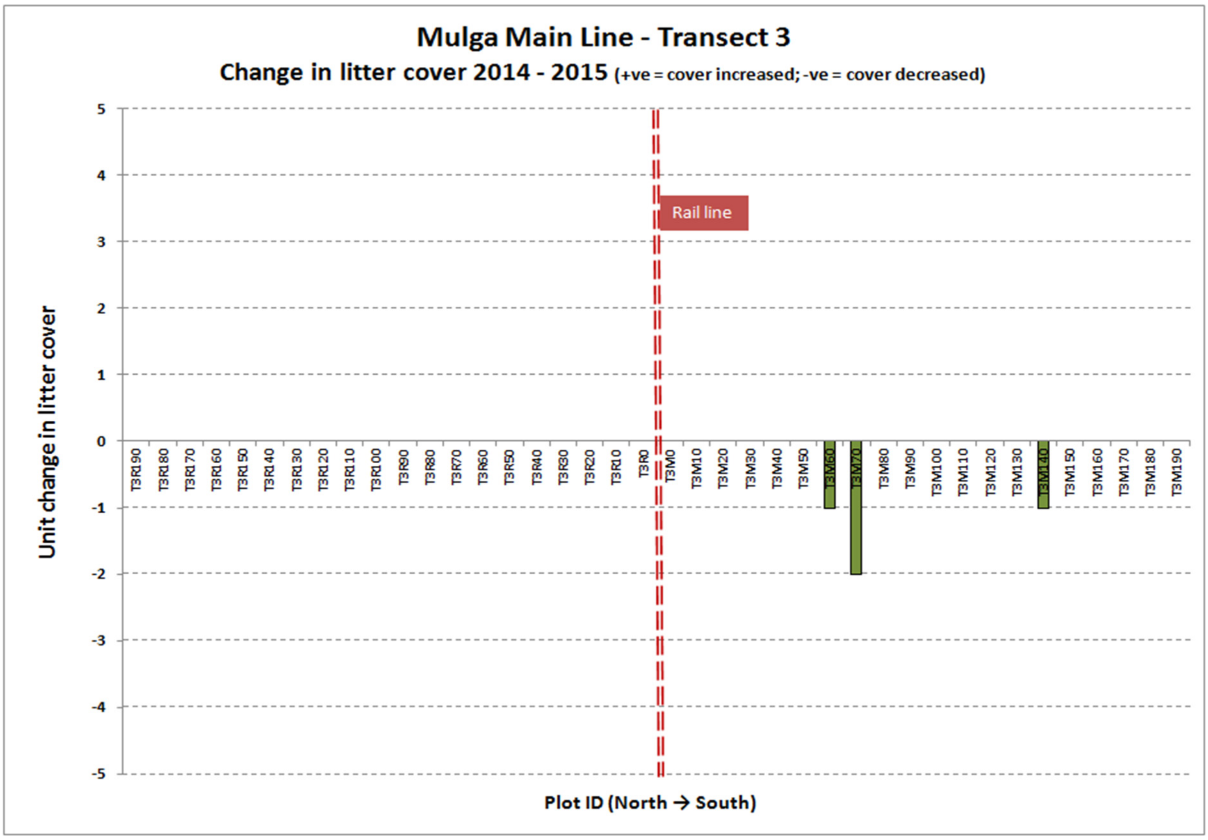

Mulga Main Line - Transect 4
Change in erosion severity 2015 - 2016 (+ve = severity increased; -ve = severity decreased)
Unit change in erosion severity
Rail line
Plot ID (North → South)


Mulga Main Line - Transect 1
Change in litter cover 2014 - 2015 (+ve = cover increased; -ve = cover decreased)
Unit change in litter cover
Rail line
Plot ID (North → South)

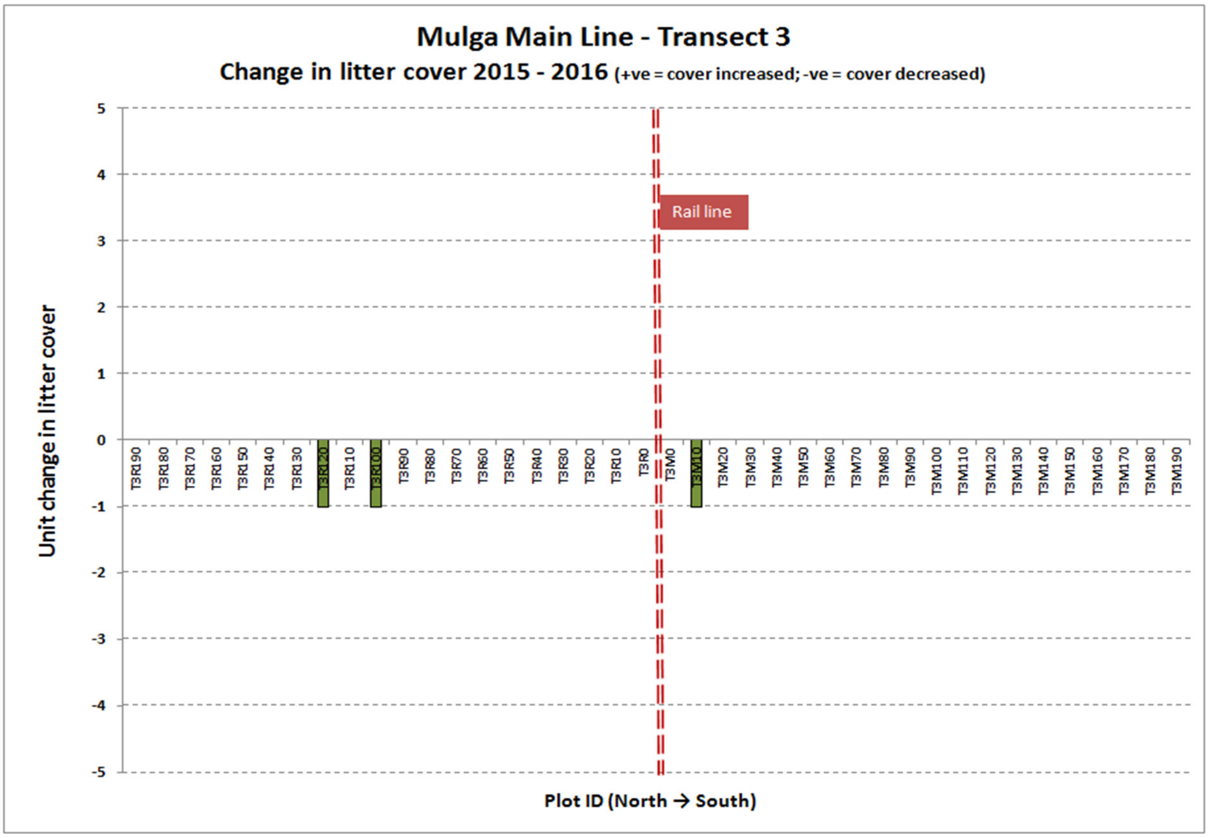

Mulga Main Line - Transect 1
Change in litter cover 2015 - 2016 (+ve = cover increased; -ve = cover decreased)
Unit change in litter cover
Rail line
Plot ID (North → South)


Mulga Main Line - Transect 2
Change in litter cover 2014 - 2015 (+ve = cover increased; -ve = cover decreased)
Unit change in litter cover
Rail line
Plot ID (North → South)

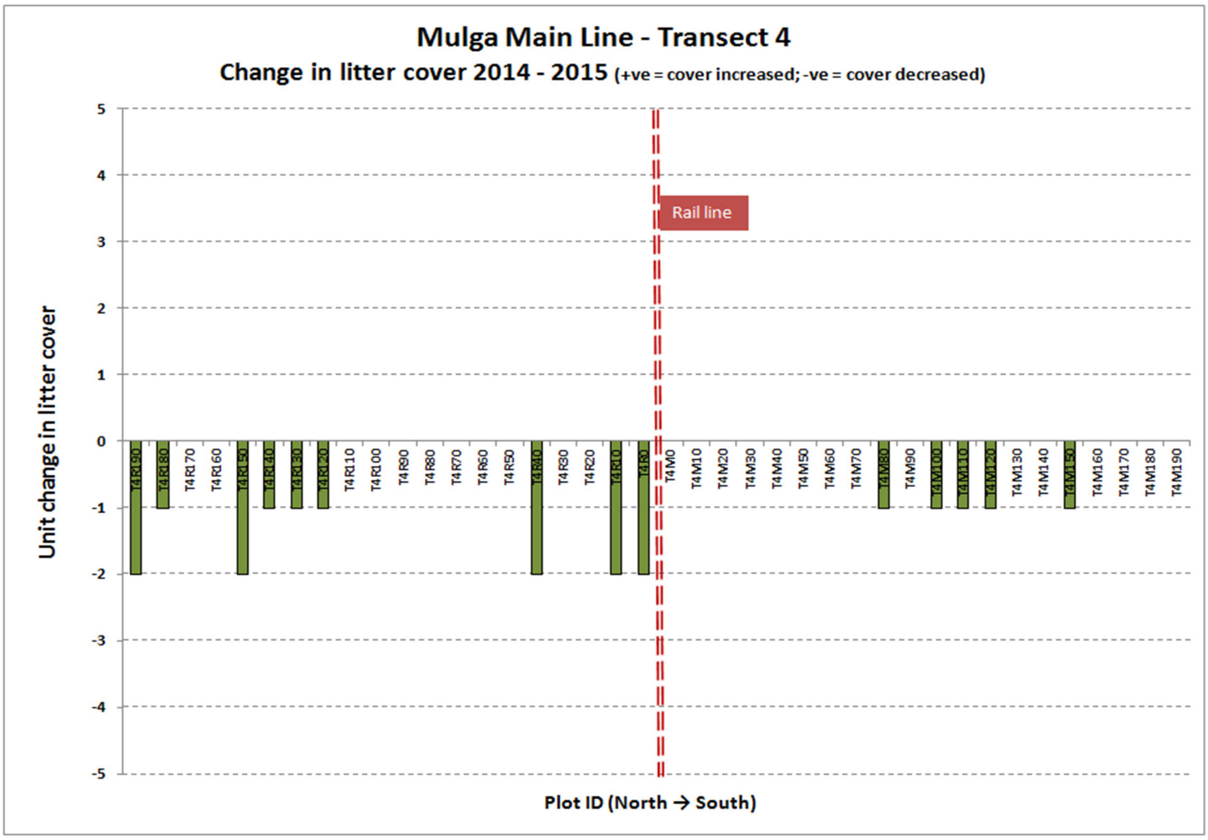

Mulga Main Line - Transect 2
Change in litter cover 2015 - 2016 (+ve = cover increased; -ve = cover decreased)
Unit change in litter cover
Rail line
Plot ID (North → South)

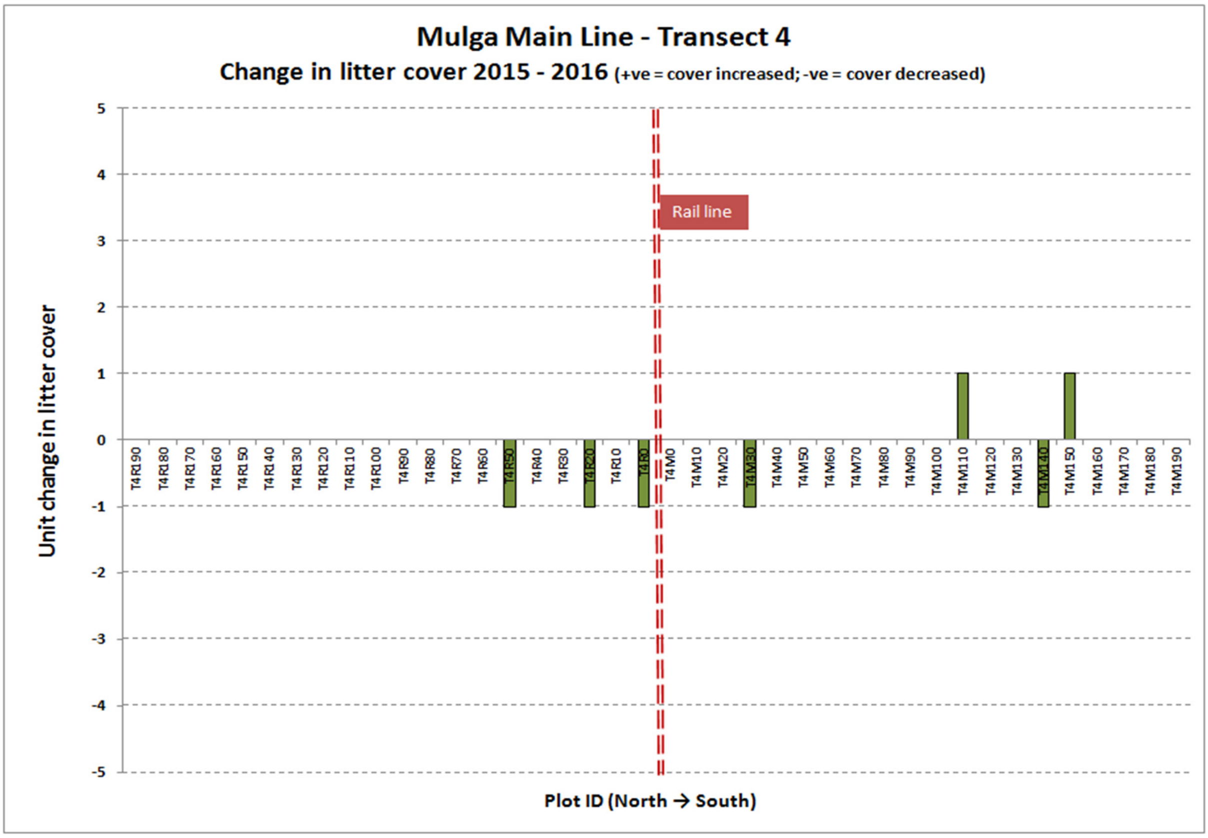


Mulga Main Line - Transect 3
Change in litter cover 2014 - 2015 (+ve = cover increased; -ve = cover decreased)
Rail line
Unit change in litter cover
5
4
3
2
1
0
-1
-2
-3
-4
-5
T3R190 T3R180 T3R170 T3R160 T3R150 T3R140 T3R130 T3R120 T3R110 T3R100 T3R90 T3R80 T3R70 T3R60 T3R50 T3R40 T3R30 T3R20 T3R10 T3R0 T3M0 T3M10 T3M20 T3M30 T3M40 T3M50 T3M60 T3M70 T3M80 T3M90 T3M100 T3M110 T3M120 T3M130 T3M140 T3M150 T3M160 T3M170 T3M180 T3M190
Plot ID (North → South)



Mulga Main Line - Transect 3
Change in litter cover 2015 - 2016 (+ve = cover increased; -ve = cover decreased)
Rail line
Unit change in litter cover
5
4
3
2
1
0
-1
-2
-3
-4
-5
T3R190 T3R180 T3R170 T3R160 T3R150 T3R140 T3R130 T3R120 T3R110 T3R100 T3R90 T3R80 T3R70 T3R60 T3R50 T3R40 T3R30 T3R20 T3R10 T3R0 T3M0 T3M10 T3M20 T3M30 T3M40 T3M50 T3M60 T3M70 T3M80 T3M90 T3M100 T3M110 T3M120 T3M130 T3M140 T3M150 T3M160 T3M170 T3M180 T3M190
Plot ID (North → South)


Mulga Main Line - Transect 4
Change in litter cover 2014 - 2015 (+ve = cover increased; -ve = cover decreased)
Unit change in litter cover
Rail line
Plot ID (North → South)

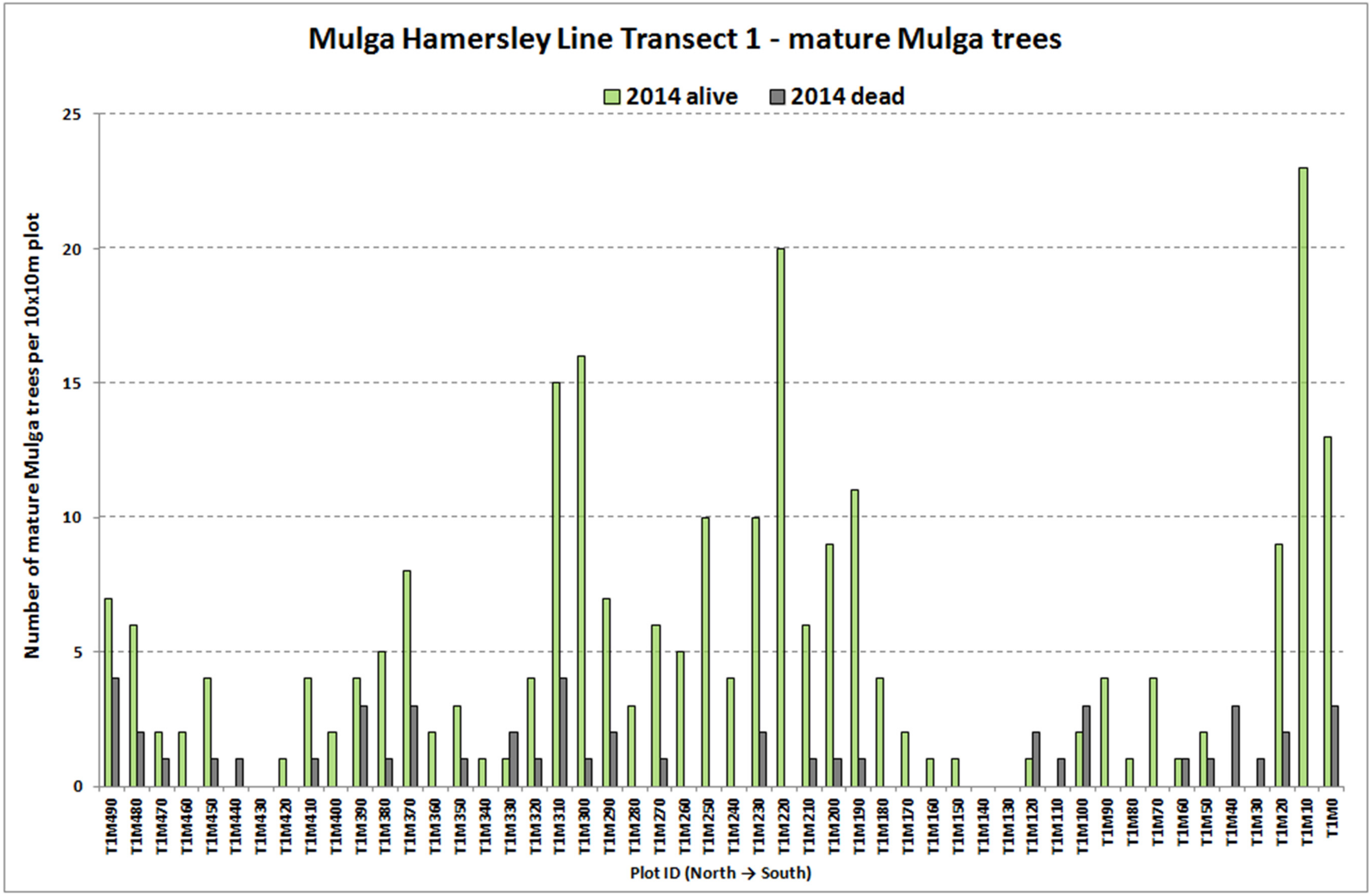

Mulga Main Line - Transect 4
Change in litter cover 2015 - 2016 (+ve = cover increased; -ve = cover decreased)
Unit change in litter cover
Rail line
Plot ID (North → South)

Hamersley Line - Mulga population structure and density data summary for the period 2011 to 2014.

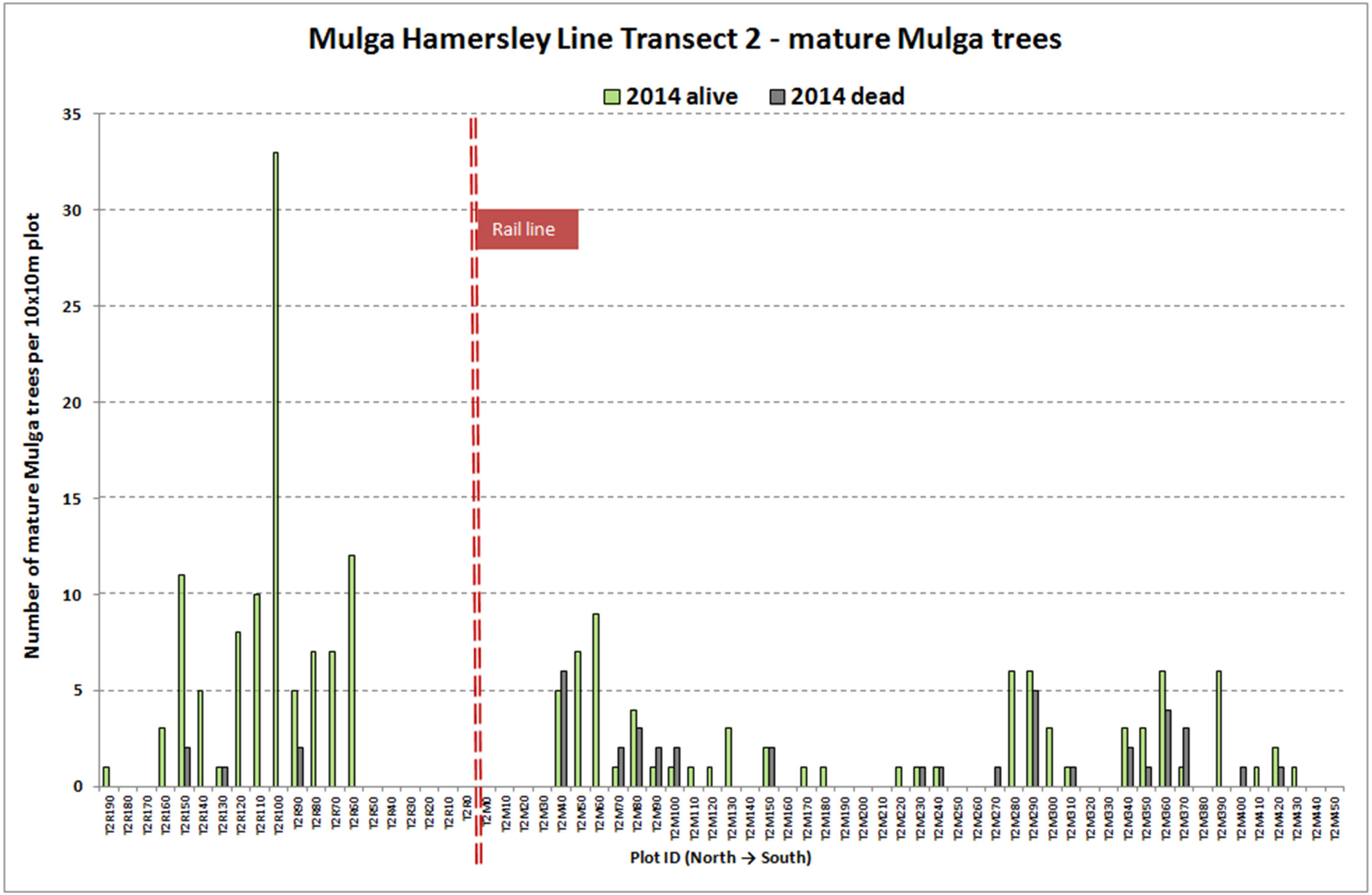
Reproduced from Ecologia (2015); Fortescue ref. R-RP-EN-1062

Table 3.1 – Number of Mulga individuals

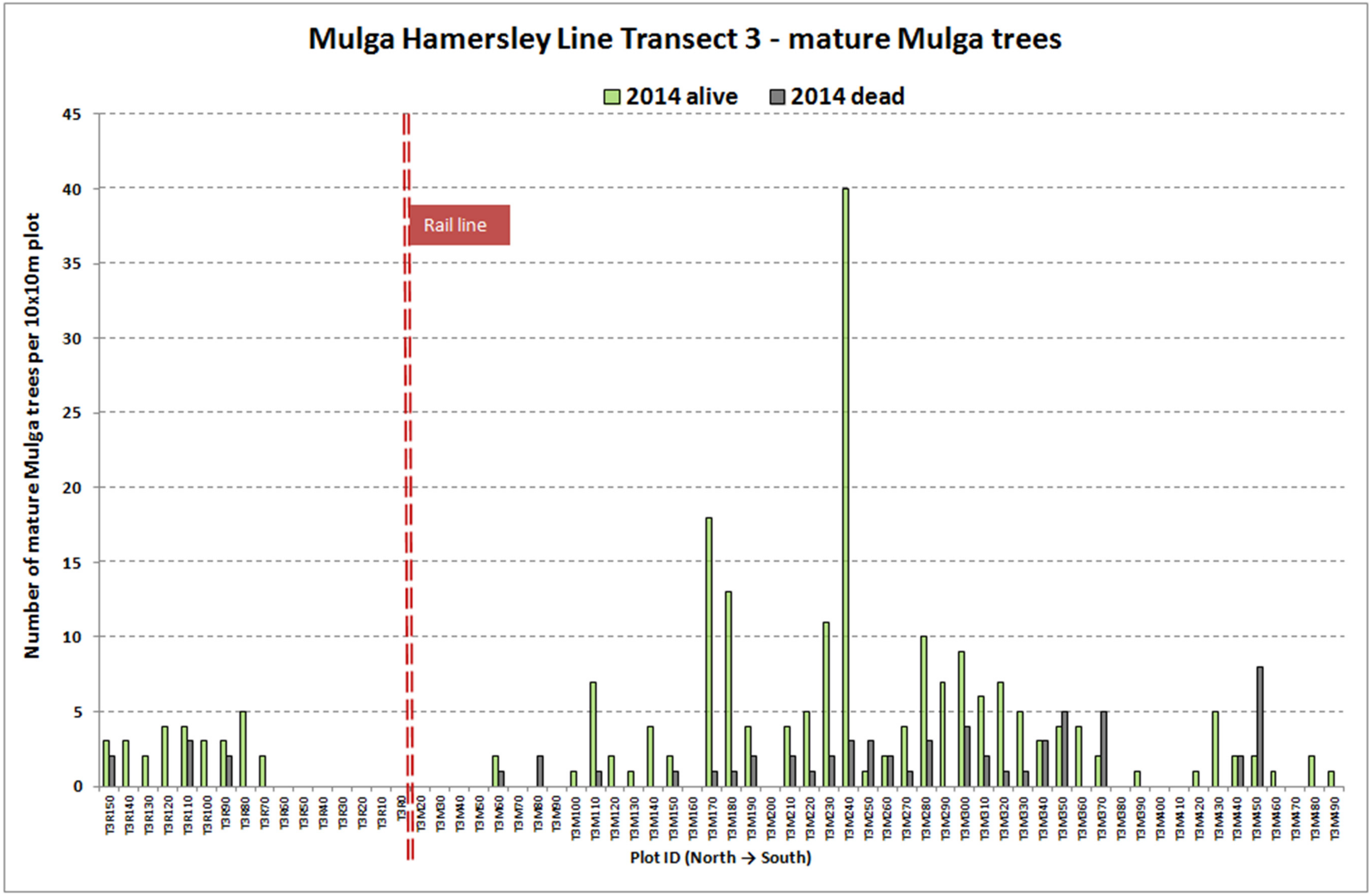
Transect		Main						Reference					Combined total
		T1	T2	T3	T4	T5	Main Total	T2	T3	T4	T5	Reference total	
Mature alive (>2 m)	2011	145	74	90	149	75	533	80	18	27	17	142	675
	2013	209	75	160	201	102	747	66	31	40	17	154	901
	2014	246	79	193	237	122	877	103	17	38	36	194	1,071
Juvenile alive	2011	260	46	357	282	178	1,123	151	31	31	479	692	1,815
	2013	156	31	234	222	122	765	82	45	21	341	489	1,254
	2014	112	42	184	175	131	644	59	26	19	149	253	897
Seedlings alive (<0.1 m)	2011	2	0	7	0	5	14	0	3	0	19	22	36
	2013	43	0	5	1	9	58	0	1	1	3	5	63
	2014	16	0	8	3	0	27	0	0	0	1	1	28
Adult Resprouts alive	2011	17	0	0	0	1	18	1	0	0	0	1	19
	2013	7	0	0	0	0	7	1	0	0	0	1	8
	2014	20	0	3	1	2	26	0	0	0	0	0	26
Juvenile Resprouts alive	2011	15	8	3	0	7	33	0	0	0	5	5	38
	2013	2	0	0	0	1	3	0	1	0	0	1	4
	2014	7	2	0	0	3	12	0	0	0	7	7	19
Combined alive	2011	439	128	457	431	266	1,721	232	52	58	520	862	2,583
	2013	417	106	399	424	234	1,580	149	78	62	361	650	2,230
	2014	401	123	388	416	258	1,586	162	43	57	193	455	2,041
Mature dead (>2 m)	2011	62	43	79	38	38	260	10	6	8	4	28	288
	2013	50	27	52	49	42	220	8	5	9	7	29	249
	2014	51	38	57	43	40	229	5	5	6	6	22	251
Juvenile dead	2011	17	10	4	19	30	80	6	8	3	1	18	98
	2013	9	11	40	26	214	300	1	2	12	1	16	316
	2014	4	1	5	2	38	50	1	3	0	3	7	57
Seedlings dead (<0.1 m)	2011	0	0	0	0	0	0	0	0	0	0	0	0
	2013	0	0	0	0	0	0	0	0	0	0	0	0
	2014	0	0	0	0	1	1	0	0	0	1	1	2
Combined dead	2011	79	53	83	57	68	340	16	14	11	5	46	386
	2013	59	38	92	75	256	520	9	7	21	8	45	565
	2014	55	39	62	45	79	280	6	8	6	10	30	310



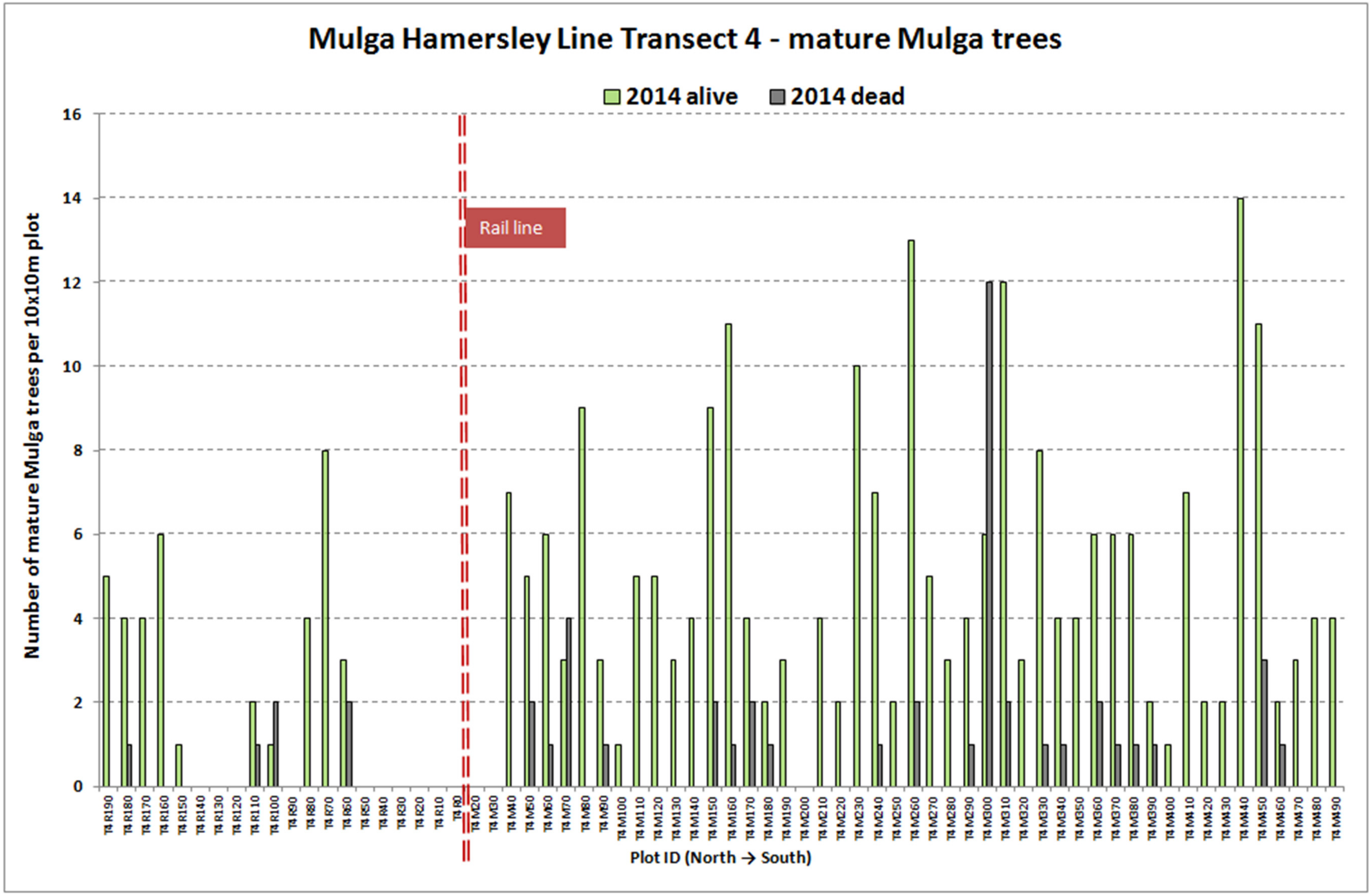
Note: Raw data for 2011 and 2013 was not available for figure production



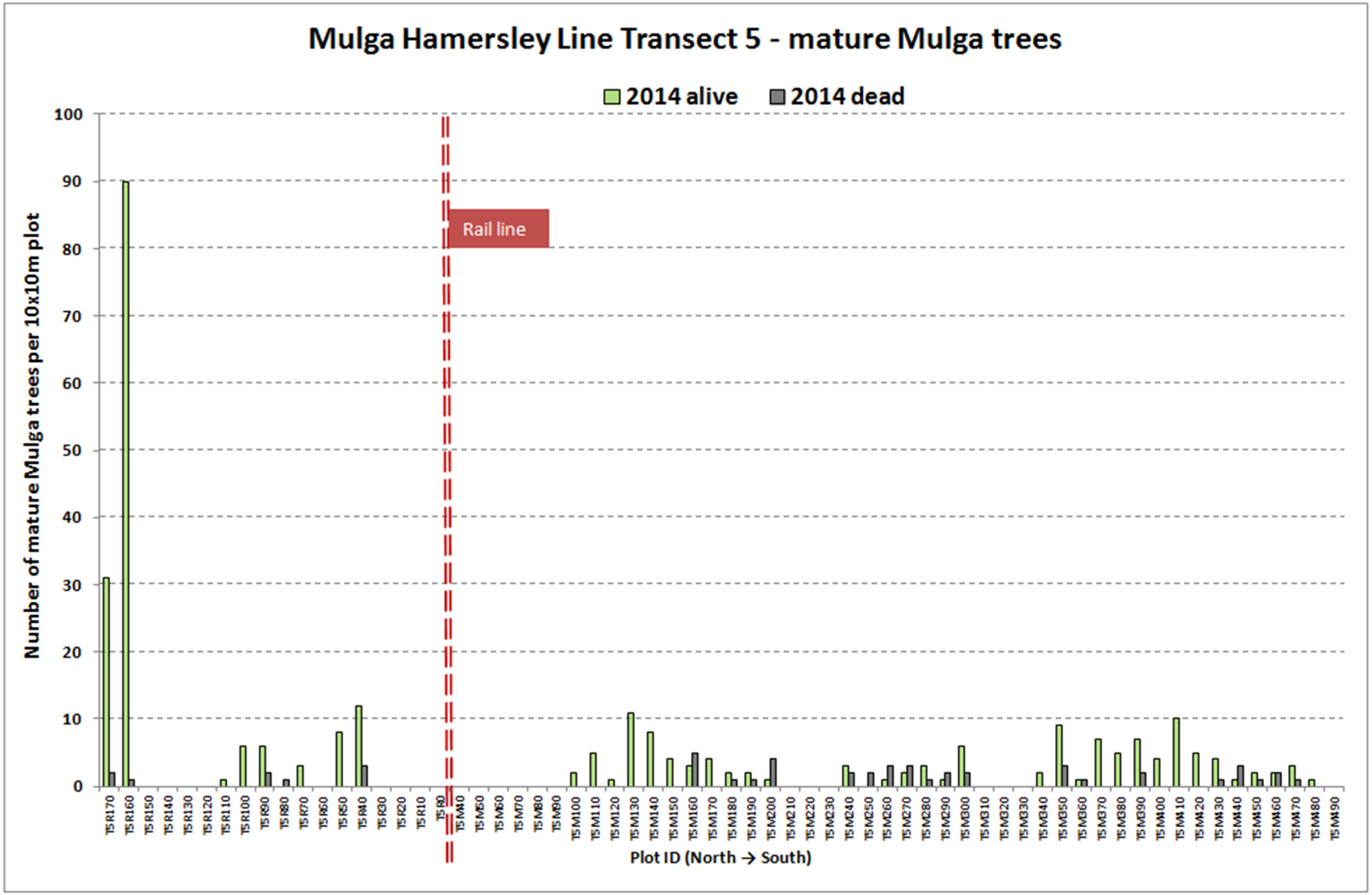
Note: Raw data for 2011 and 2013 was not available for figure production



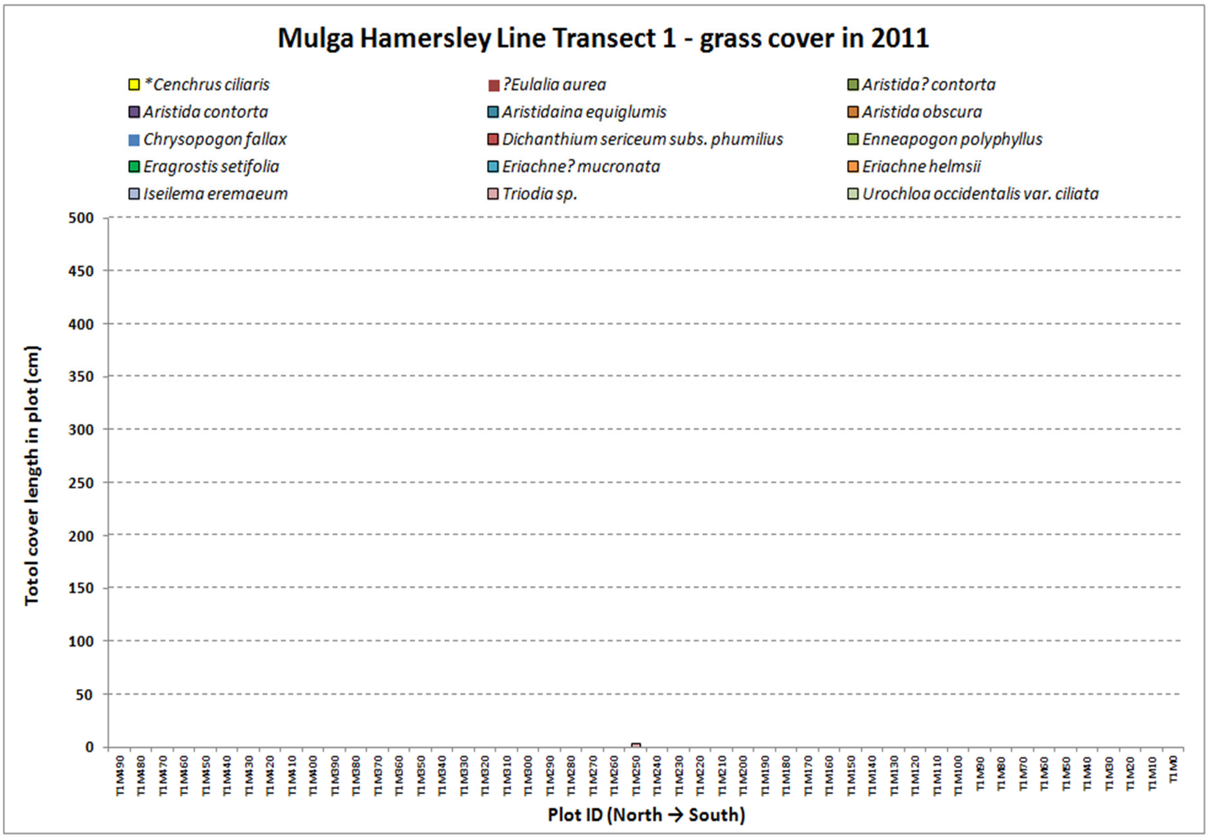
Note: Raw data for 2011 and 2013 was not available for figure production

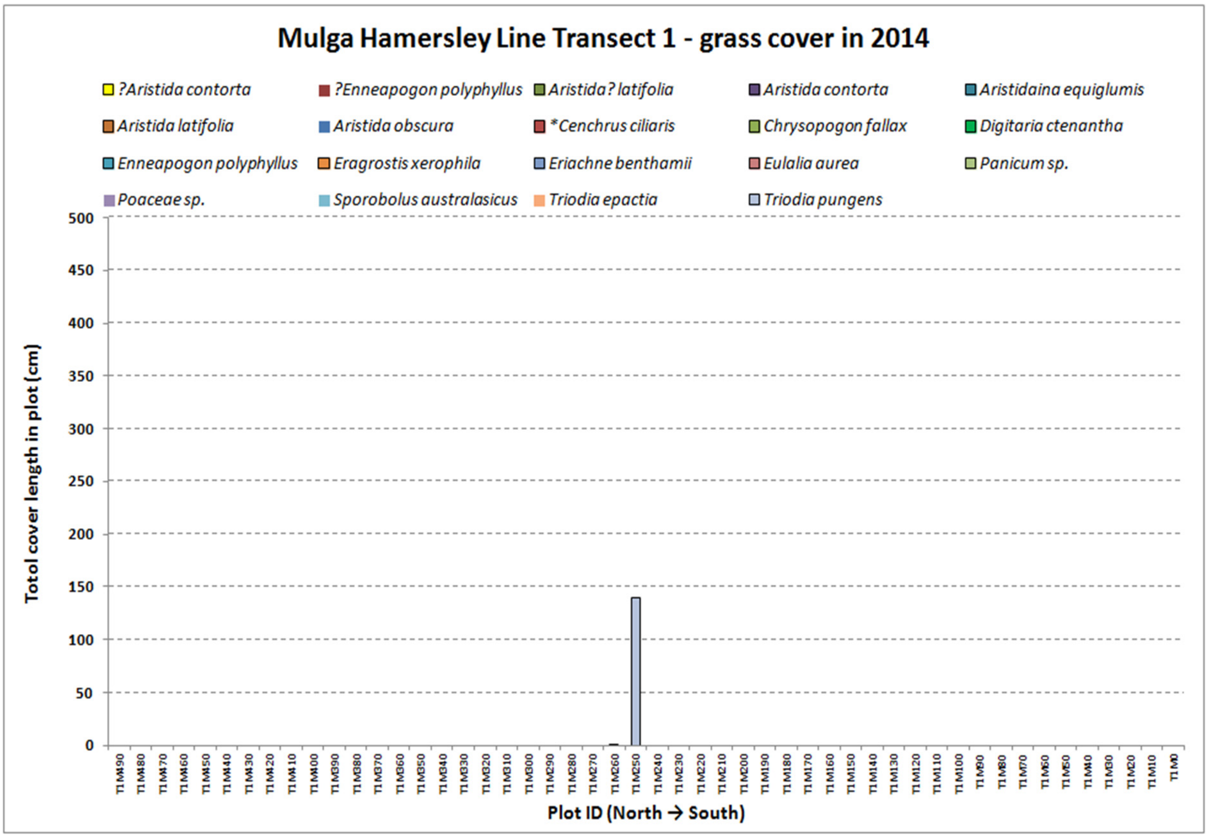


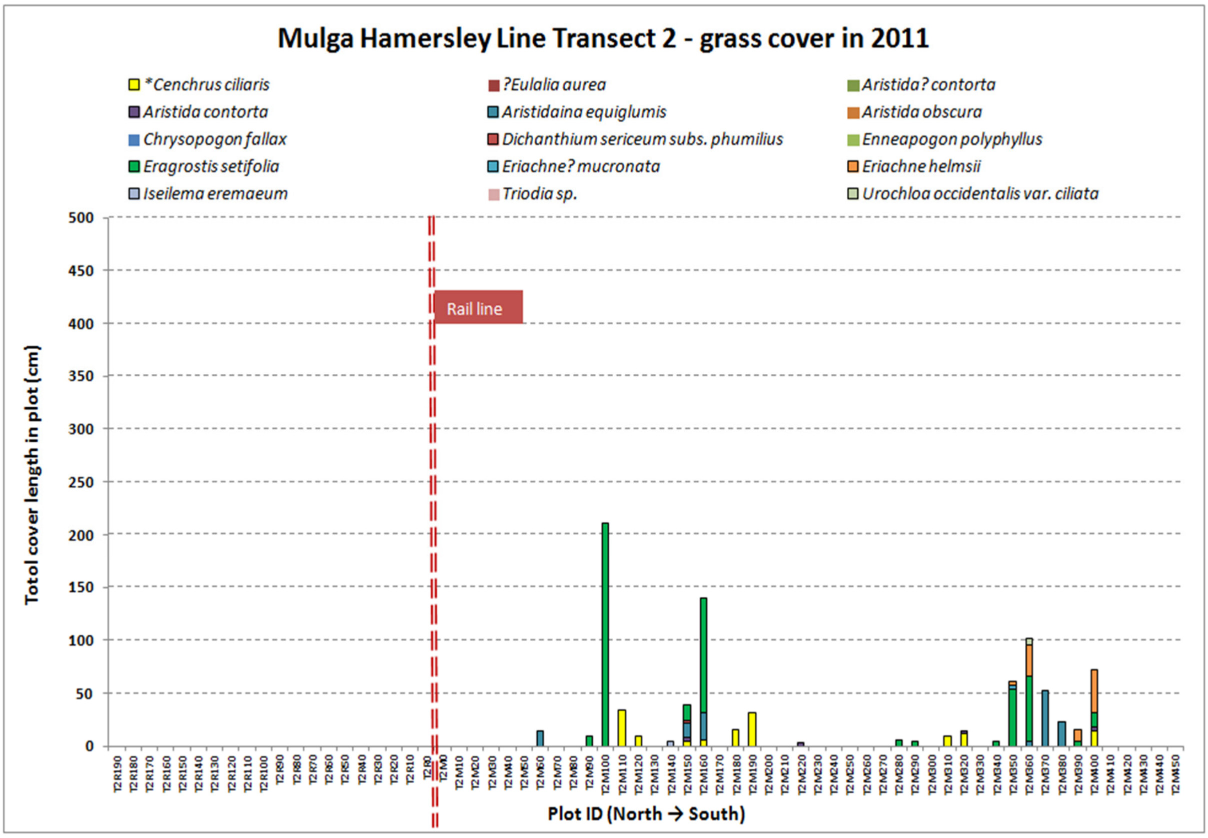
Note: Raw data for 2011 and 2013 was not available for figure production

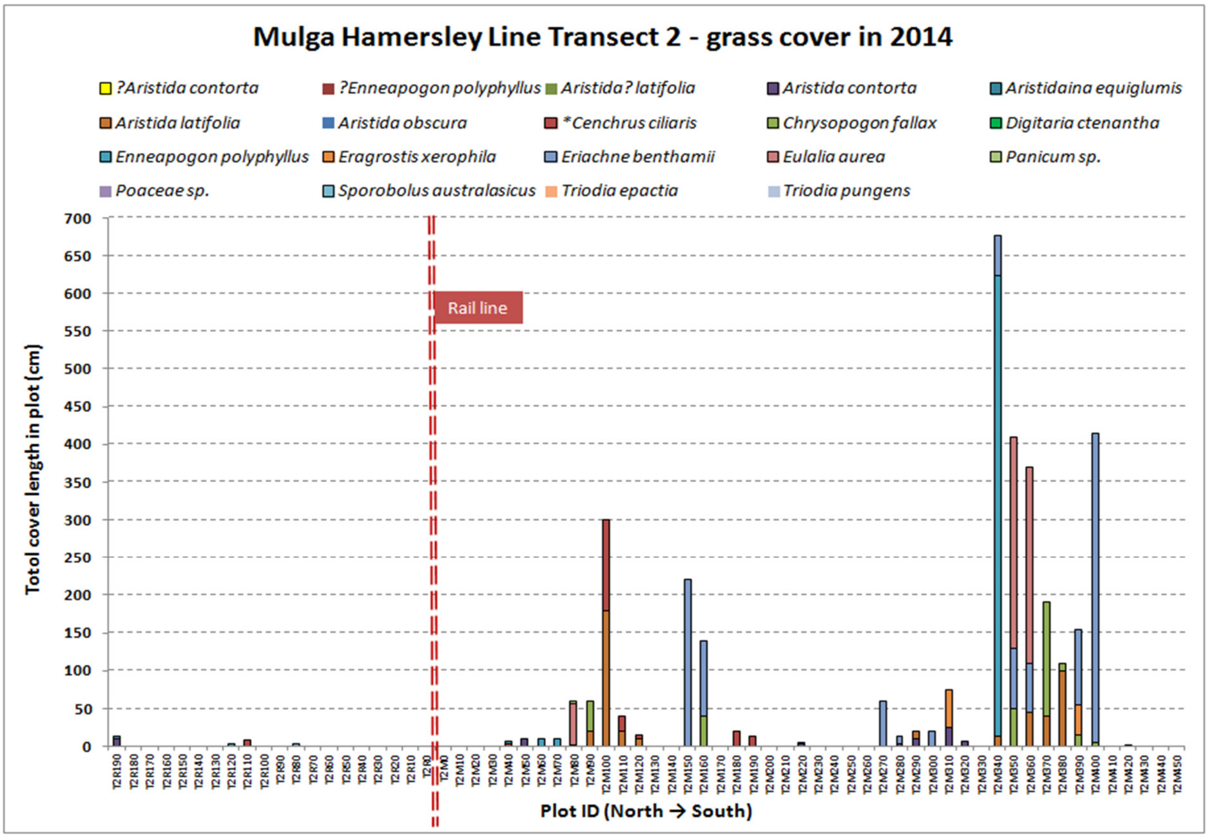


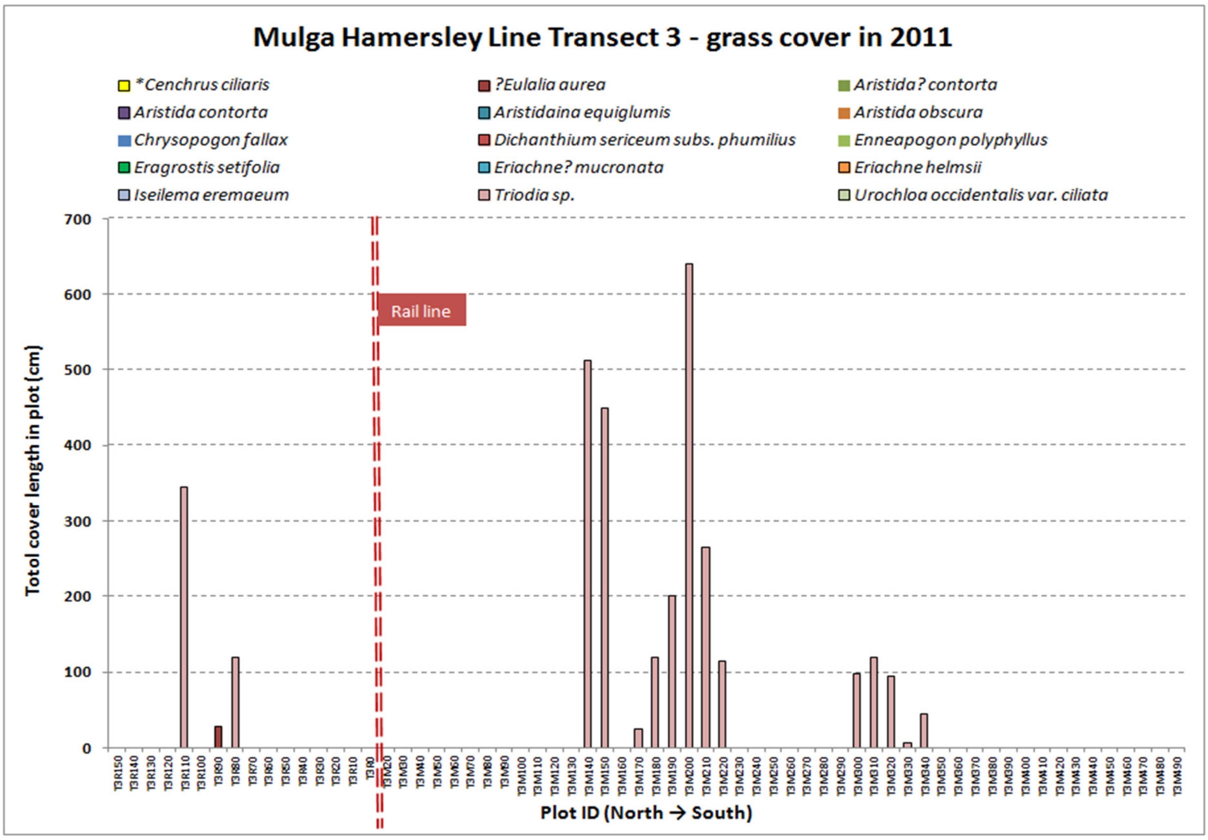
Note: Raw data for 2011 and 2013 was not available for figure production

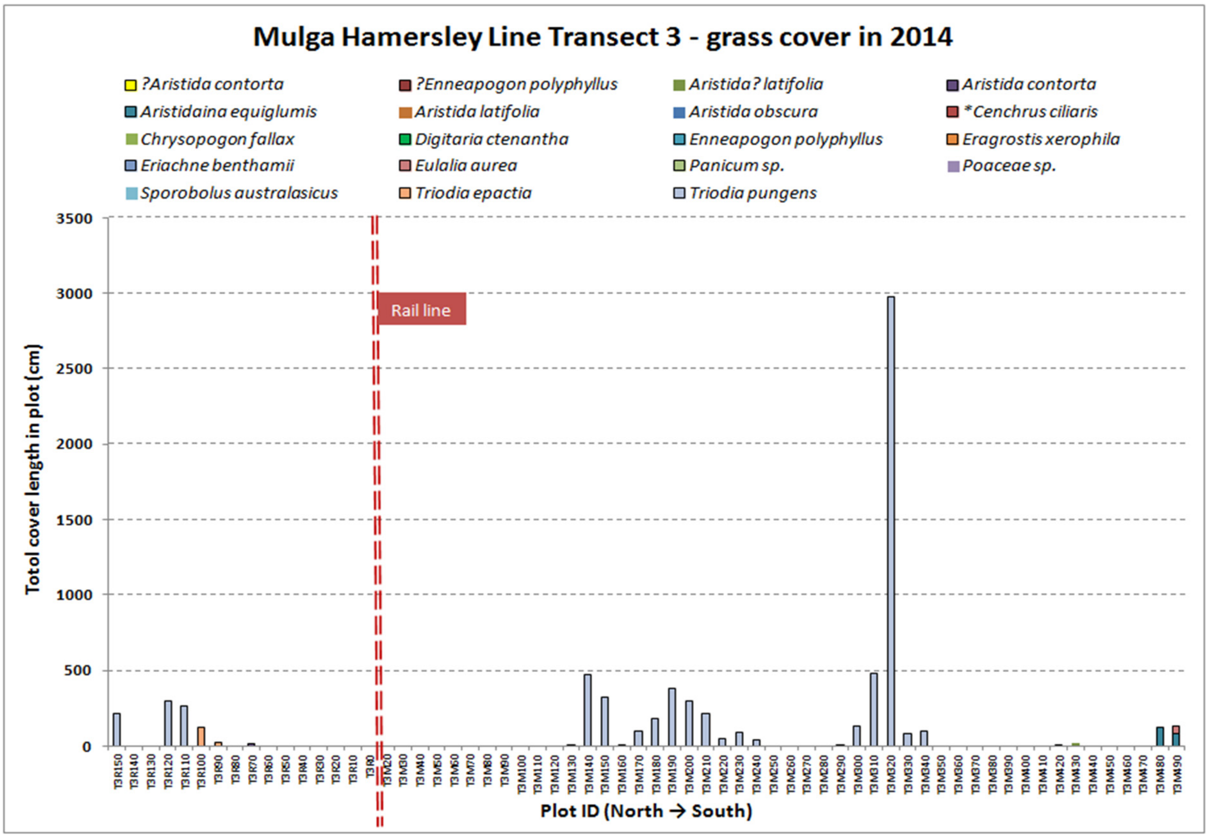

Mulga Hamersley Line Transect 1 - grass cover in 2011
*Cenchrus ciliaris
?Eulalia aurea
Aristida ? contorta
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Chrysopogon fallax
Dichanthium sericeum subs. phumilius
Enneapogon polyphyllus
Eragrostis setifolia
Eriachne ? mucronata
Eriachne helmsii
Iseilema eremaeum
Triodia sp.
Urochloa occidentalis var. ciliata
Totol cover length in plot (cm)
Plot ID (North → South)

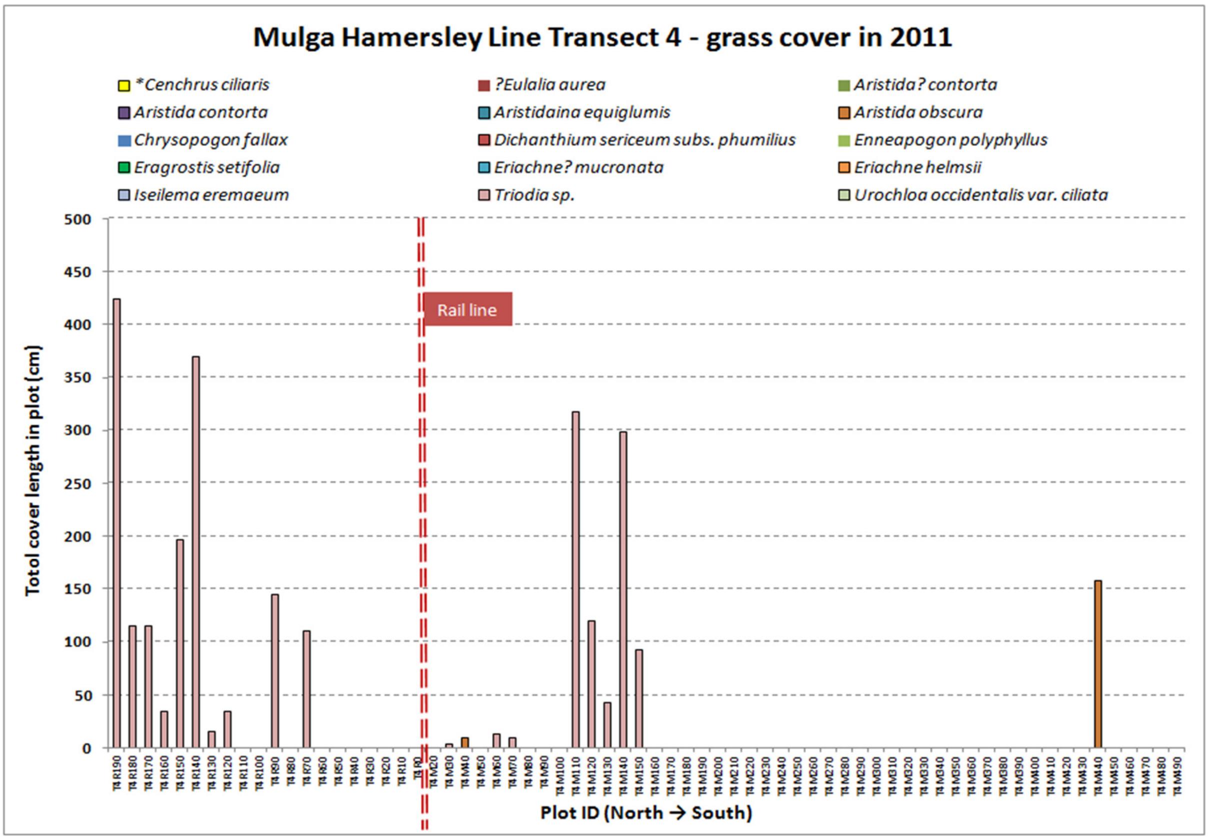

Mulga Hamersley Line Transect 1 - grass cover in 2014
?Aristida contorta
?Enneapogon polyphyllus
Aristida ? latifolia
Aristida contorta
Aristidaina equiglumis
Aristida latifolia
Aristida obscura
*Cenchrus ciliaris
Chrysopogon fallax
Digitaria ctenantha
Enneapogon polyphyllus
Eragrostis xerophila
Eriachne benthamii
Eulalia aurea
Panicum sp.
Poaceae sp.
Sporobolus australasicus
Triodia epactia
Triodia pungens
Totol cover length in plot (cm)
Plot ID (North → South)

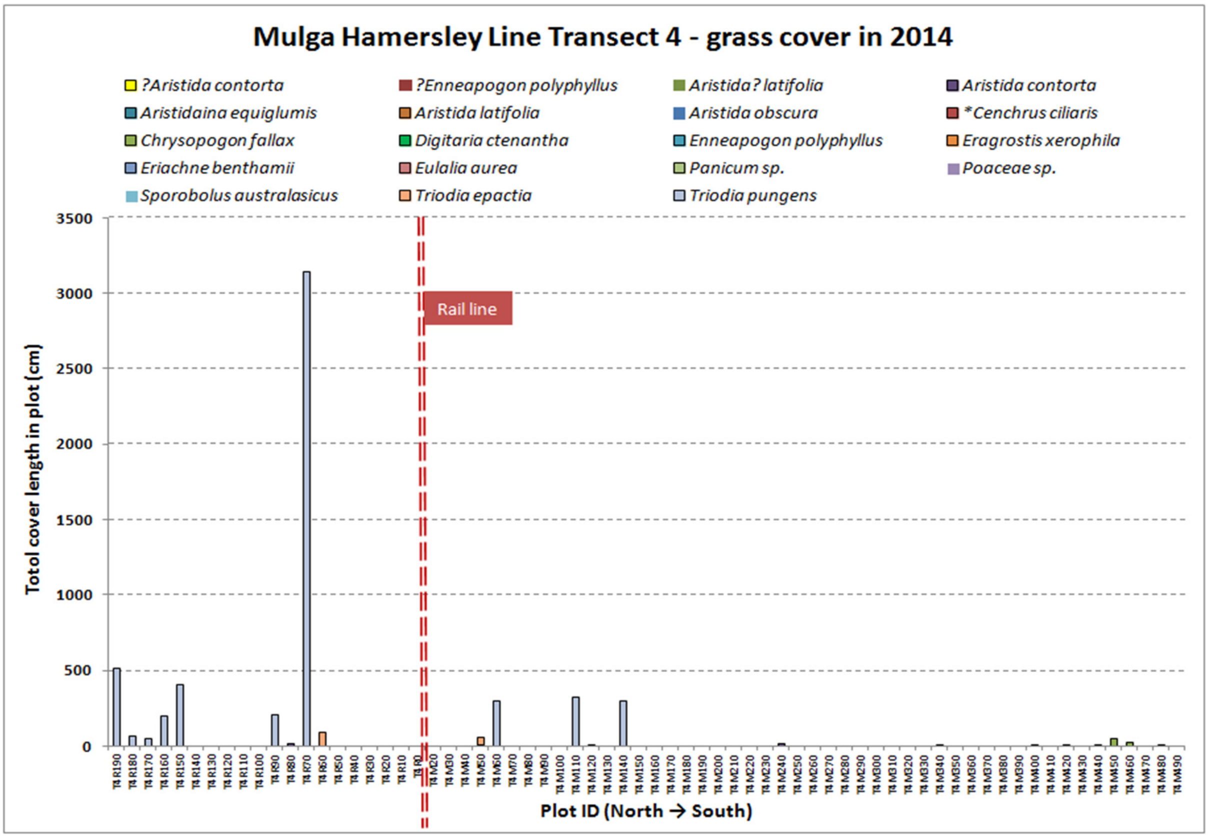

Mulga Hamersley Line Transect 2 - grass cover in 2011
*Cenchrus ciliaris
?Eulalia aurea
Aristida? contorta
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Chrysopogon fallax
Dichanthium sericeum subs. phumilius
Enneapogon polyphyllus
Eragrostis setifolia
Eriachne? mucronata
Eriachne helmsii
Iseilema eremaeum
Triodia sp.
Urochloa occidentalis var. ciliata
Rail line
Totol cover length in plot (cm)
Plot ID (North → South)

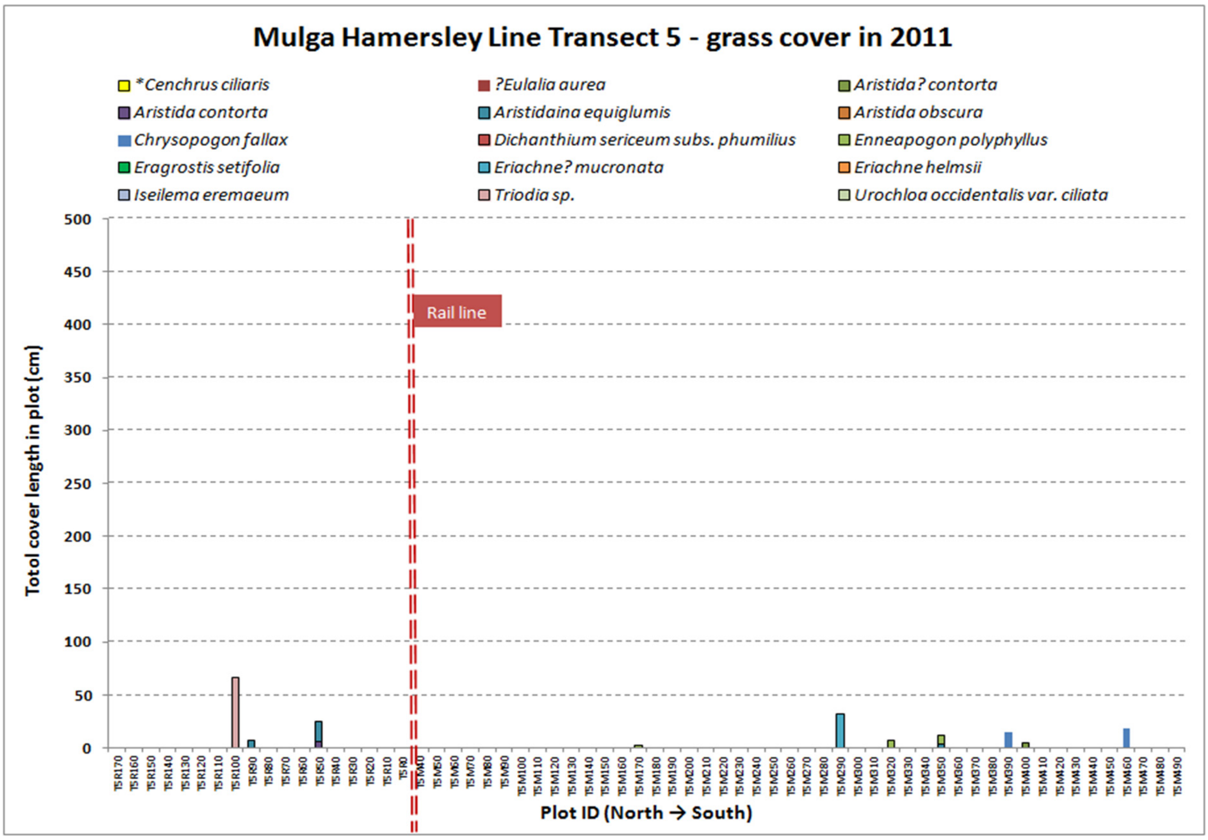

Mulga Hamersley Line Transect 2 - grass cover in 2014
?Aristida contorta
?Enneapogon polyphyllus
Aristida? latifolia
Aristida contorta
Aristidaina equiglumis
Aristida latifolia
Aristida obscura
*Cenchrus ciliaris
Chrysopogon fallax
Digitaria ctenantha
Enneapogon polyphyllus
Eragrostis xerophila
Eriachne benthamii
Eulalia aurea
Panicum sp.
Poaceae sp.
Sporobolus australasicus
Triodia epactia
Triodia pungens
Rail line
Totol cover length in plot (cm)
Plot ID (North → South)

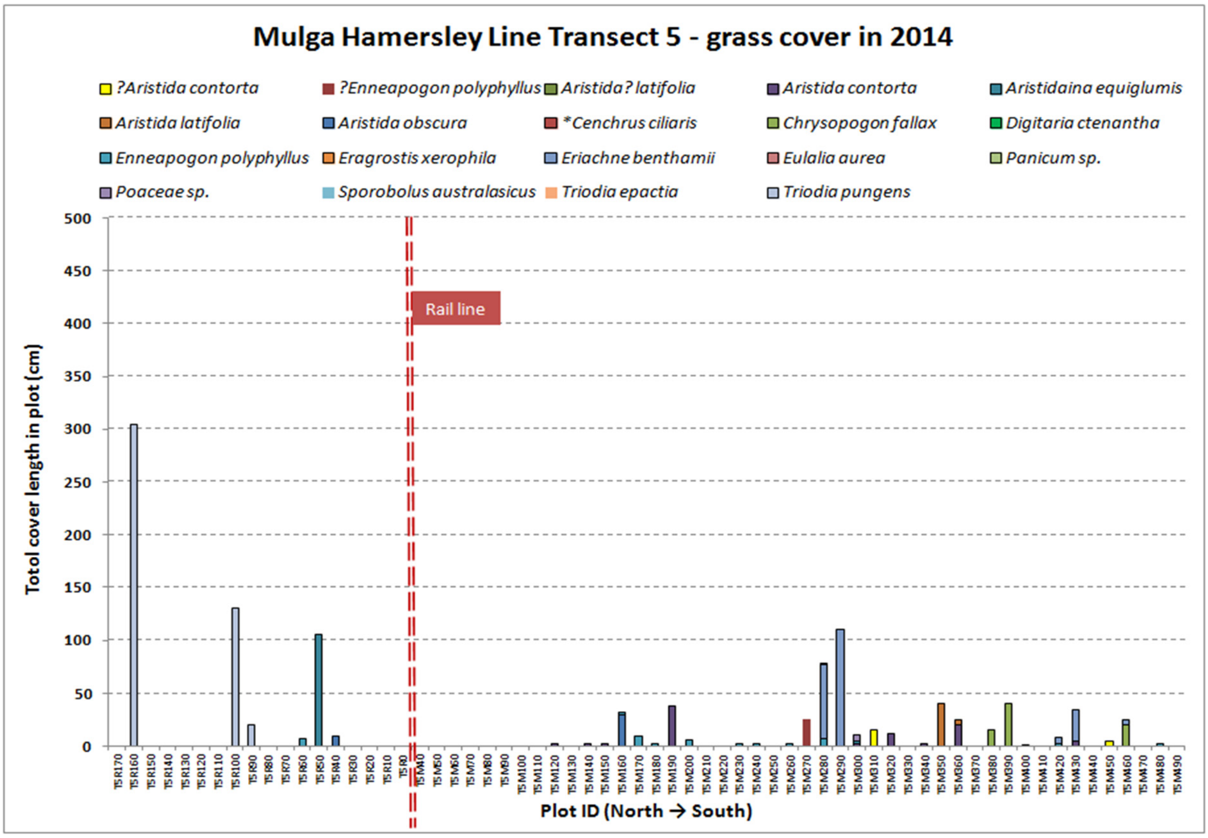

Mulga Hamersley Line Transect 3 - grass cover in 2011
*Cenchrus ciliaris
?Eulalia aurea
Aristida? contorta
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Chrysopogon fallax
Dichanthium sericeum subs. phumilius
Enneapogon polyphyllus
Eragrostis setifolia
Eriachne? mucronata
Eriachne helmsii
Iseilema eremaeum
Triodia sp.
Urochloa occidentalis var. ciliata
Totol cover length in plot (cm)
700
600
500
400
300
200
100
0
Rail line
Plot ID (North → South)

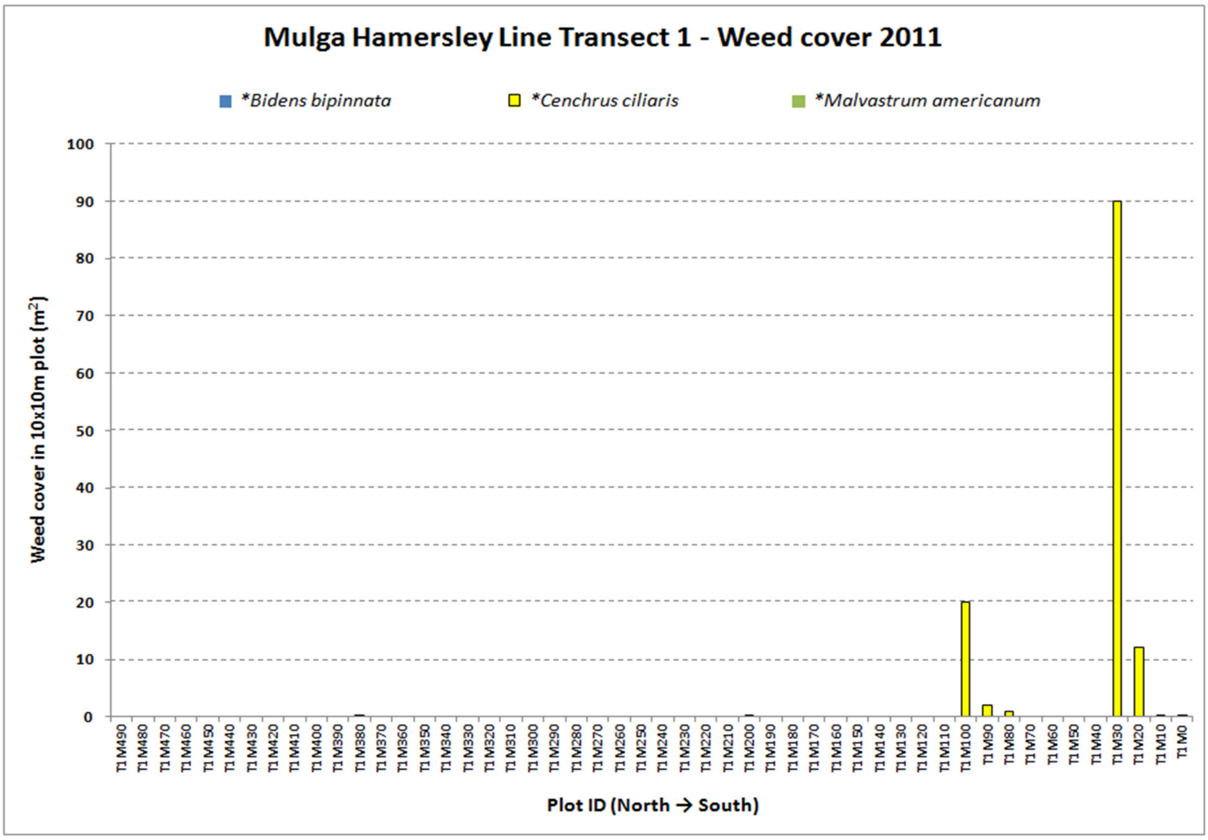

Mulga Hamersley Line Transect 3 - grass cover in 2014
?Aristida contorta
?Enneapogon polyphyllus
Aristida? latifolia
Aristida contorta
Aristidaina equiglumis
Aristida latifolia
Aristida obscura
*Cenchrus ciliaris
Chrysopogon fallax
Digitaria ctenantha
Enneapogon polyphyllus
Eragrostis xerophila
Eriachne benthamii
Eulalia aurea
Panicum sp.
Poaceae sp.
Sporobolus australasicus
Triodia epactia
Triodia pungens
Totol cover length in plot (cm)
3500
3000
2500
2000
1500
1000
500
0
Rail line
Plot ID (North → South)


Mulga Hamersley Line Transect 4 - grass cover in 2011
*Cenchrus ciliaris
?Eulalia aurea
Aristida? contorta
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Chrysopogon fallax
Dichanthium sericeum subs. phumilius
Enneapogon polyphyllus
Eragrostis setifolia
Eriachne? mucronata
Eriachne helmsii
Iseilema eremaeum
Triodia sp.
Urochloa occidentalis var. ciliata
Rail line
Totol cover length in plot (cm)
Plot ID (North → South)

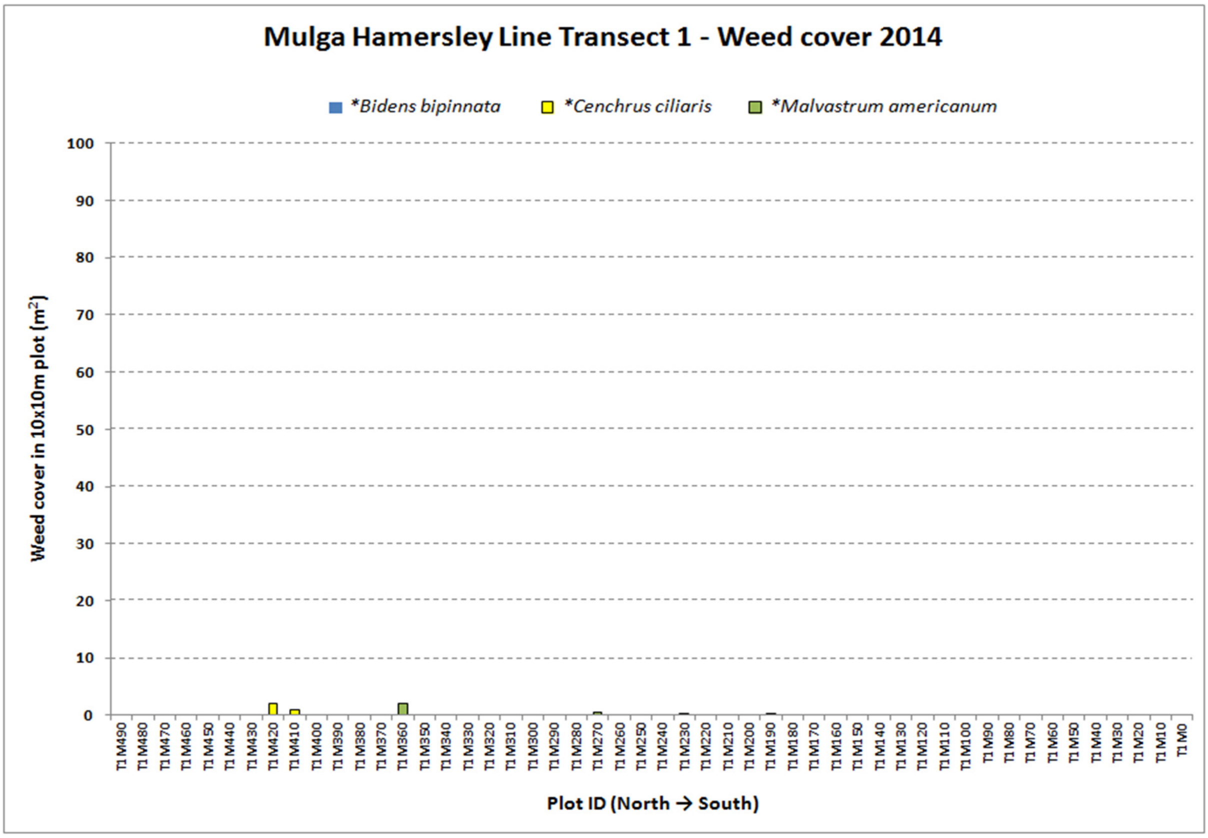

Mulga Hamersley Line Transect 4 - grass cover in 2014
?Aristida contorta
?Enneapogon polyphyllus
Aristida? latifolia
Aristida contorta
Aristidaina equiglumis
Aristida latifolia
Aristida obscura
*Cenchrus ciliaris
Chrysopogon fallax
Digitaria ctenantha
Enneapogon polyphyllus
Eragrostis xerophila
Eriachne benthamii
Eulalia aurea
Panicum sp.
Poaceae sp.
Sporobolus australasicus
Triodia epactia
Triodia pungens
Rail line
Totol cover length in plot (cm)
Plot ID (North → South)


Mulga Hamersley Line Transect 5 - grass cover in 2011
*Cenchrus ciliaris
?Eulalia aurea
Aristida? contorta
Aristida contorta
Aristidaina equiglumis
Aristida obscura
Chrysopogon fallax
Dichanthium sericeum subs. phumilius
Enneapogon polyphyllus
Eragrostis setifolia
Eriachne? mucronata
Eriachne helmsii
Iseilema eremaeum
Triodia sp.
Urochloa occidentalis var. ciliata
Rail line
Totol cover length in plot (cm)
Plot ID (North → South)

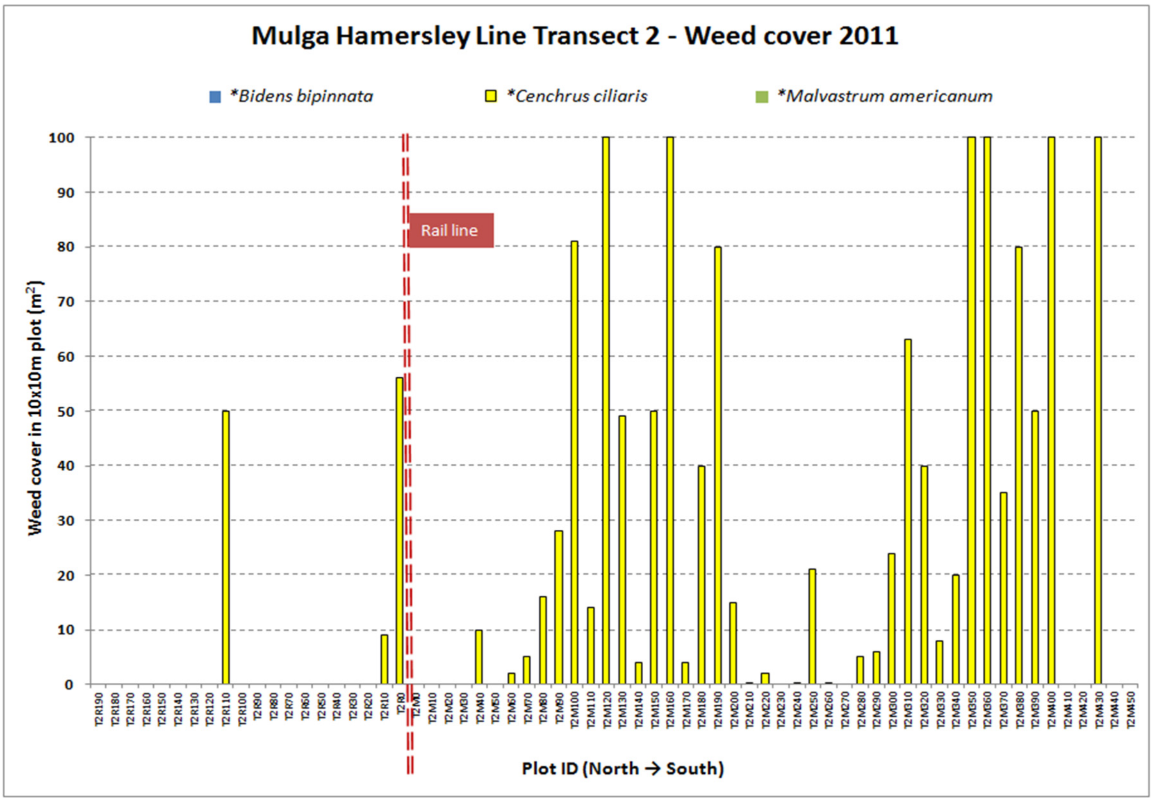

Mulga Hamersley Line Transect 5 - grass cover in 2014
?Aristida contorta
?Enneapogon polyphyllus
Aristida? latifolia
Aristida contorta
Aristidaina equiglumis
Aristida latifolia
Aristida obscura
*Cenchrus ciliaris
Chrysopogon fallax
Digitaria ctenantha
Enneapogon polyphyllus
Eragrostis xerophila
Eriachne benthamii
Eulalia aurea
Panicum sp.
Poaceae sp.
Sporobolus australasicus
Triodia epactia
Triodia pungens
Rail line
Totol cover length in plot (cm)
Plot ID (North → South)

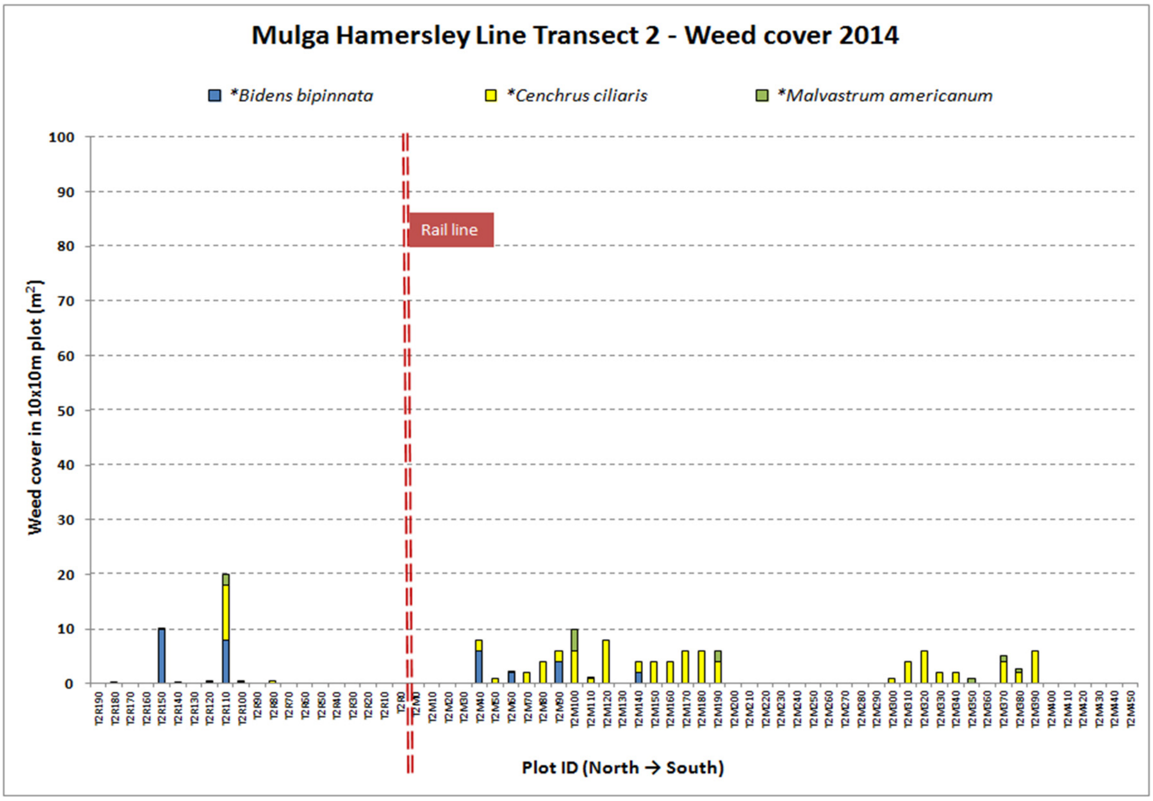


Mulga Hamersley Line Transect 1 - Weed cover 2011
*Bidens bipinnata
*Cenchrus ciliaris
*Malvastrum americanum
Weed cover in 10x10m plot (m2)
Plot ID (North → South)

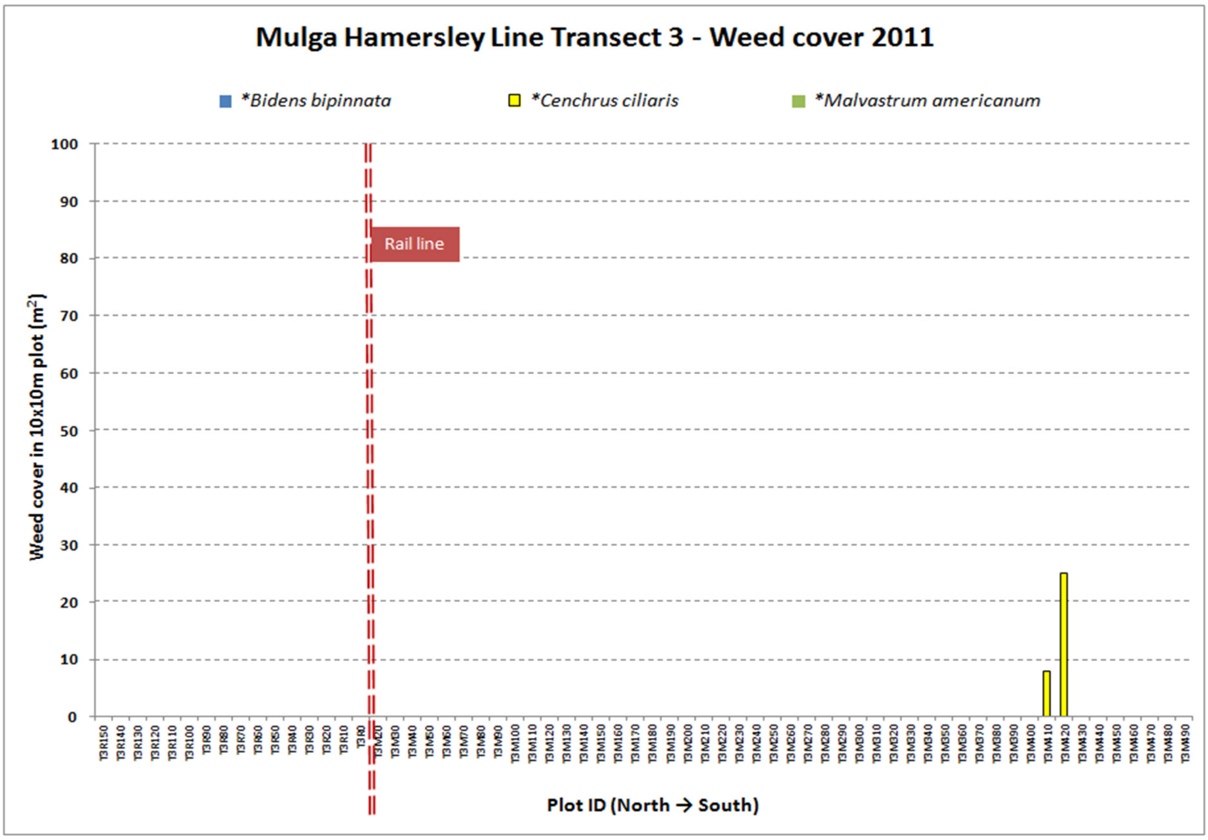


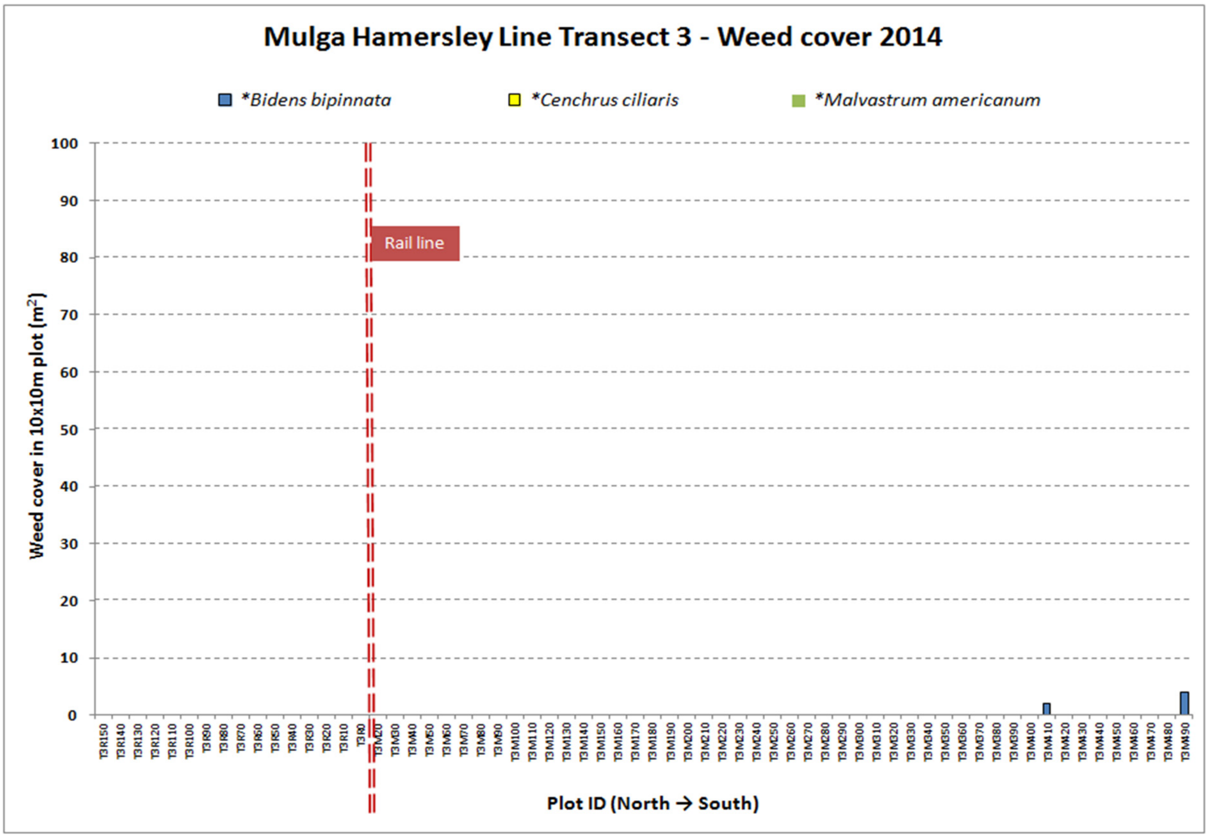
Mulga Hamersley Line Transect 1 - Weed cover 2014
*Bidens bipinnata
*Cenchrus ciliaris
*Malvastrum americanum
Weed cover in 10x10m plot (m2)
Plot ID (North → South)

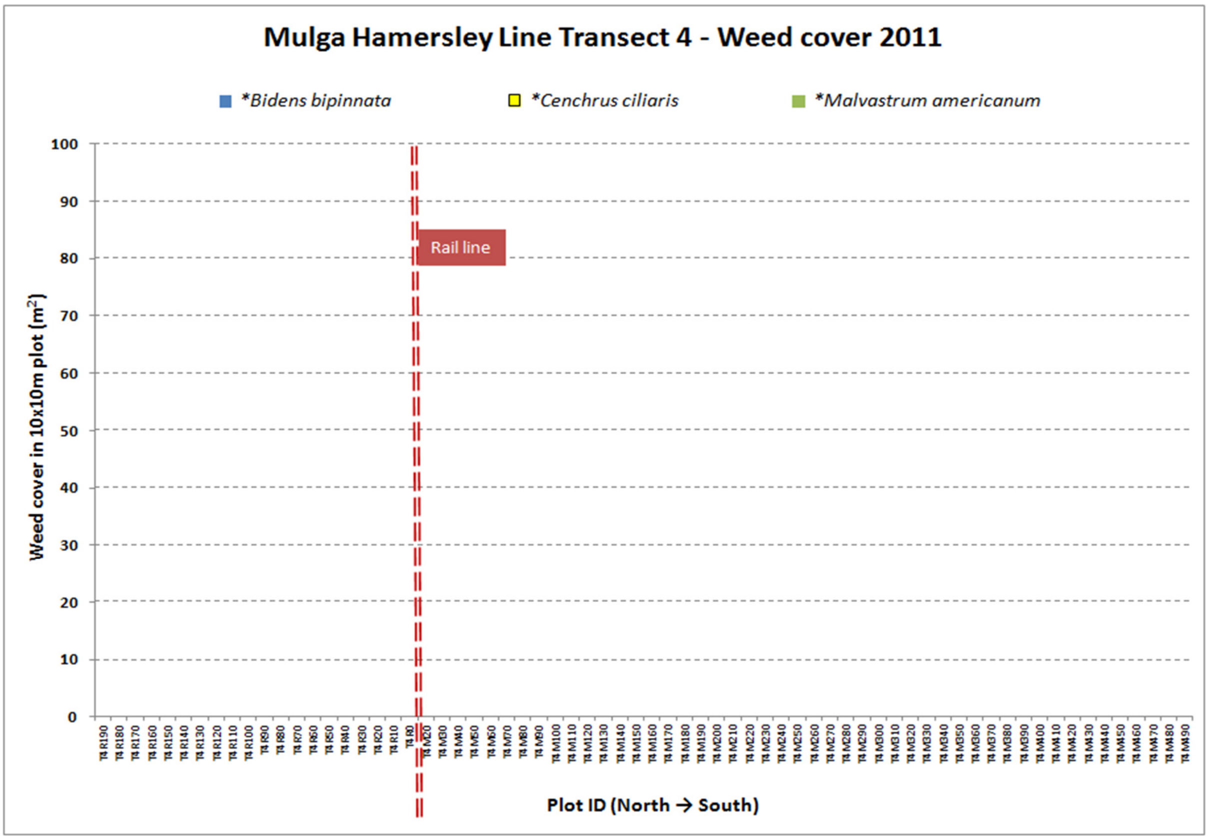


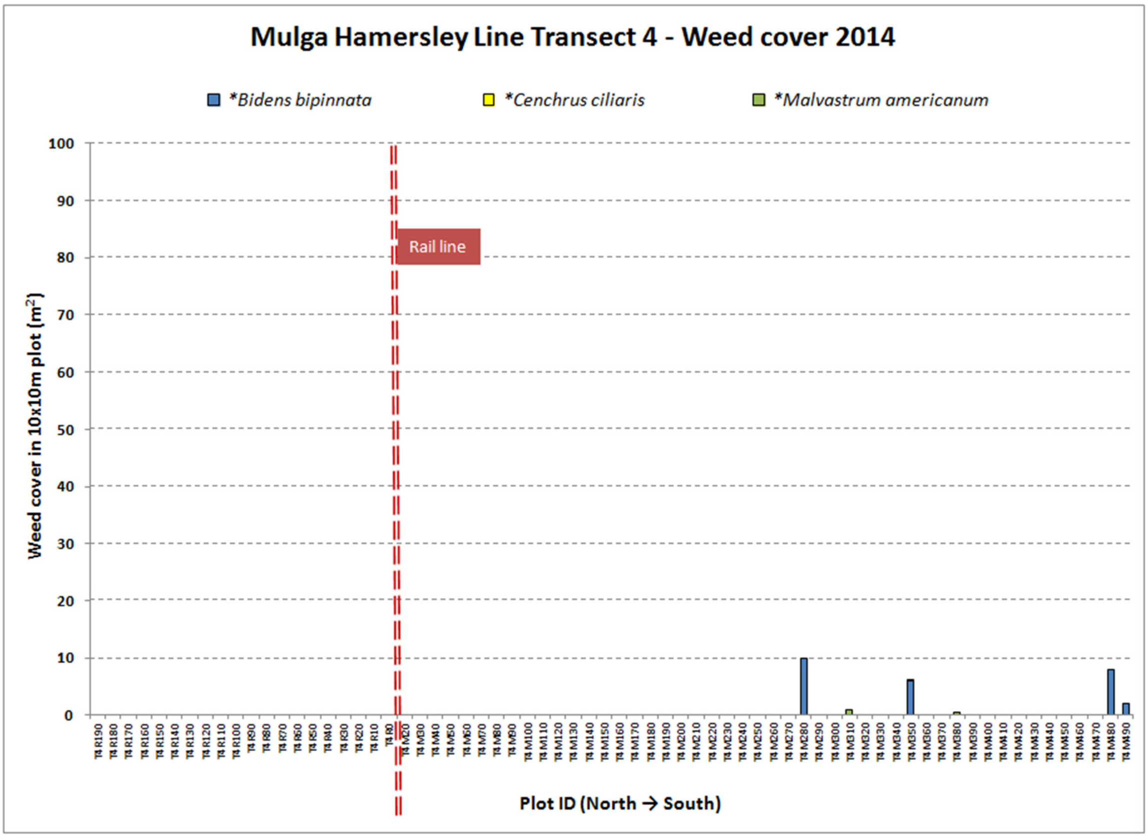


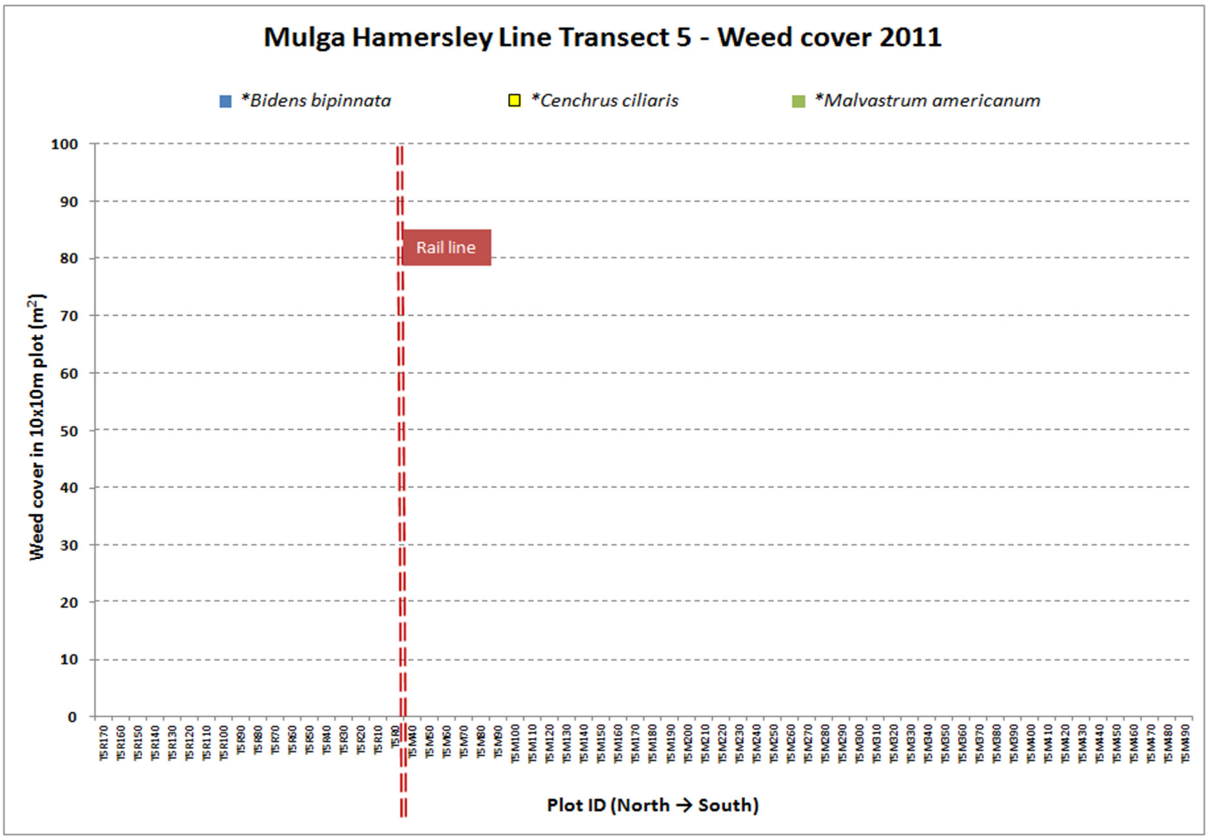
Note: The difference between years is likely to reflect subtle differences between the assessment methods. In 2011 high weed cover values were recorded, but with low weed % cover (less than 10% in all cases) within the affected areas. In 2014 low weed cover values were recorded, but with high weed % cover (commonly 100%) within the affected areas.

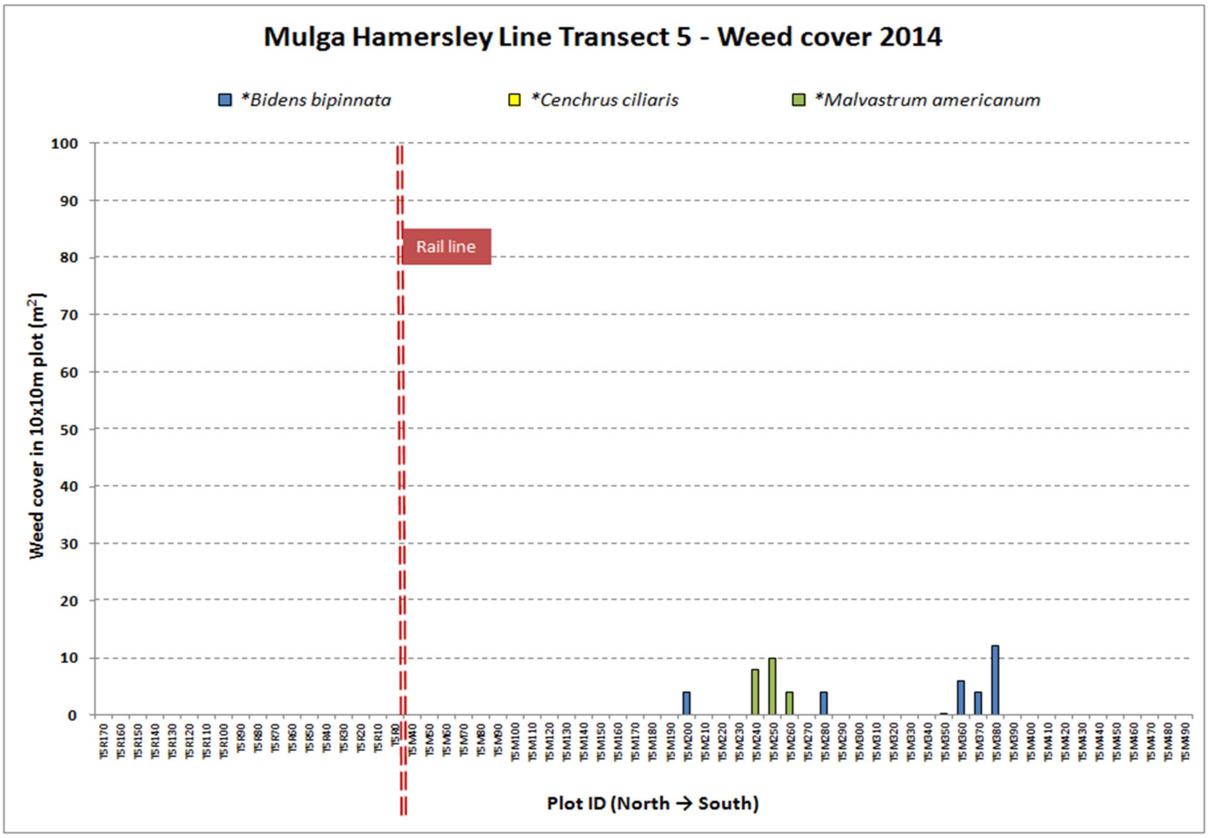

Mulga Hamersley Line Transect 3 - Weed cover 2011
*Bidens bipinnata
*Cenchrus ciliaris
*Malvastrum americanum
100
90
80
70
60
50
40
30
20
10
0
Weed cover in 10x10m plot (m²)
Rail line
Plot ID (North → South)


Mulga Hamersley Line Transect 3 - Weed cover 2014
*Bidens bipinnata
*Cenchrus ciliaris
*Malvastrum americanum
100
90
80
70
60
50
40
30
20
10
0
Weed cover in 10x10m plot (m²)
Rail line
Plot ID (North → South)


Mulga Hamersley Line Transect 4 - Weed cover 2011
*Bidens bipinnata
*Cenchrus ciliaris
*Malvastrum americanum
Weed cover in 10x10m plot (m2)
Rail line
Plot ID (North → South)


Mulga Hamersley Line Transect 4 - Weed cover 2014
*Bidens bipinnata
*Cenchrus ciliaris
*Malvastrum americanum
Weed cover in 10x10m plot (m2)
Rail line
Plot ID (North → South)


Mulga Hamersley Line Transect 5 - Weed cover 2011
*Bidens bipinnata
*Cenchrus ciliaris
*Malvastrum americanum
Rail line
Weed cover in 10x10m plot (m²)
Plot ID (North → South)


Mulga Hamersley Line Transect 5 - Weed cover 2014
*Bidens bipinnata
*Cenchrus ciliaris
*Malvastrum americanum
Rail line
Weed cover in 10x10m plot (m²)
Plot ID (North → South)