Threatened Species and Farming

Giant Gippsland Earthworm

Case study 2:
Management of farm habitats in South Gippsland.

Authors
Beverley Van Praagh
C/o Department of Primary Industries
621 Burwood Hwy
Knoxfield 3180
bvpraagh@optusnet.com.au

Alan Yen
Department of Primary Industries
621 Burwood Hwy
Knoxfield 3180
alan.yen@dpi.vic.gov.au

Neville Rosengren
Department of Civil Engineering and Physical Sciences
La Trobe University
Bendigo
n.rosengren@latrobe.edu.au

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EXECUTIVE SUMMARY

This study was funded by the *Ecologically Sustainable Agriculture Initiative* (ESAI) of the Department of Primary Industries. It is one of seven case studies investigating management techniques for threatened species in the context of improvements in agricultural production that are ecologically sustainable over the long-term.

The Giant Gippsland Earthworm (GGE) has co-existed with agricultural land use since European settlement of South Gippsland in the 1870s and has survived major changes to its habitat mostly associated with agricultural development and expansion. However, the overall effects of these habitat changes on GGE populations and their distribution are not known. The GGE distribution is confined almost entirely to privately owned agricultural land. Therefore, identifying the effects of agricultural and land management practices on GGE remains crucial to the conservation management of this species. Two farms were selected to examine the main topographical and hydrological soil factors influencing the distribution of the GGE within the landscape of an individual farm, and to identify the effects of land management on these factors.

The first study was conducted on a dairy farm at Jumbunna, south of Korumburra situated on the alluvial and colluvial grey clay soils in the south of the species range and is the subject of the first report (Van Praagh *et al.* 2004). The present study occurred at the Department of Primary Industries Research Farm at Ellinbank. This farm is situated in the north of the species range in the soils developed on Tertiary (older) Volcanic basalts, representing the other major soil type in which GGE occurs.

Investigation for evidence of the GGE concentrated on the lower slopes and colluvial and alluvial terrain adjacent to the creeks, where soil texture and moisture were assessed to provide a more amenable worm habitat. GGE were found in 22 of the 57 soil quadrats dug. At least 11 of these quadrats supported live populations. GGE distribution at the Ellinbank Research Farm occured in one main habitat type; the lower slopes and colluvial and alluvial terrain adjacent to the stream channels and just above the level reached by moderate flooding. This is in contrast to the four habitat types described for GGEs in the Jumbunna study area. This may be a result of the morphologically simpler landscape found in the study area which appears to provide less areas of suitable GGE habitat with the appropriate hydrological parameters.

GGE at Ellinbank were restricted to riparian zones, which have largely been fenced off and protected from most agricultural impacts at the site. Therefore it was not possible to make

any assessment of farm management practices in the study area on GGE. It is likely that most recent agricultural practices in the study area have not impacted upon GGE populations. One possible exception to this is pugging when soils are wet and compaction by stock. However, at present, most of the stream banks have been fenced and only one site with pugging was noted. An active population of GGE was found at this site. The major management issue identified that is relevant to the riparian zones is the actual and potential impact on GGE habitat of the dense plantings along sections of Bear Creek and the tributary creeks. Over the past 4 years, there has been extensive replanting and fencing of riparian zones with approximately 40,000 seedling planted. The subject of advocating replanting of habitat for GGE conservation has recently been questioned, particularly the high density plantings which often occur. Dense replanting of riparian zones is increasing throughout the region and is likely to impact on the streamside water table. Whilst the broader benefits of revegetation of riparian zones is acknowledged, the effects of dense replanting of areas occupied by GGEs requires investigation. Increased transpiration rates will lower water tables leading to drying of soils at depths of potential worm habitat on the lower slopes, colluvial slopes and floodplains.

Unfortunately, more extensive sampling of the heavily revegetated areas of the study area was difficult because of access and time of year (summer) and therefore information on the distribution of GGE within these areas was limited. Only one heavily replanted riparian zone was surveyed and GGE were found to only occur on the opposite stream bank where there was very little vegetation with predominantly open pasture. This is similar to other anecdotal evidence obtained for replanted sites.

Despite the preliminary nature of these and previous findings, given the scale of revegetation in the region dense planting of riparian habitat occupied by GGE, may represent one of the most important agricultural management practices that has the potential to impact on GGE populations. However this is not intended to apply to revegetation programs that occur elsewhere on farms within the species overall range.

It is recommended that extensive long-term monitoring programs be developed in order to examine impacts of revegetation on factors such as soil moisture, hydrological patterns, and water table levels and how these might impact on GGE populations. Factors such as density, structure and composition as well as age of plantings should be considered. Once such information is available, informed recommendations regarding management of GGE streamside habitat by farmers can be formulated.

1. INTRODUCTION

1.1 Ecologically Sustainable Agriculture Initiative (ESAI)

"Threatened Species and Farming" is a sub-project of the ESAI. This project will identify how agricultural practices might be modified to help conserve selected threatened species as part of working toward ecological sustainability. The project will document case studies of selected threatened species in four bioregions:the Victorian Riverina, Wimmera, Victorian Volcanic Plain and Gippsland Plain. The farms considered include examples from the meat, wool, dairy and grains industries. This case study focuses on the Giant Gippsland Earthworm *Megascolides australis* McCoy 1878 in the Gippsland Plain region.

1.2 The Giant Gippsland Earthworm

The Giant Gippsland Earthworm (GGE) is considered one of the largest species of earthworm in the world, reaching lengths of over 1 m. The GGE has International, National and State conservation significance. It is listed as Vulnerable by the IUCN (IUCN SSC 2003), Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, and as Threatened under the Victorian *Flora and Fauna Guarantee Act 1988*. About 90 hectares of its habitat has also been listed on the register of the National Estate (Coy 1991). The GGE occurs over approximately 40,000 ha in south and west Gippsland in a triangle roughly bounded by Warragul, Loch and Korumburra. More detailed information on the biology and distribution of the species can be found in Van Praagh *et al.* 2004.

1.3 Project Background

The GGE has co-existed with agricultural land use since European settlement of south and west Gippsland in the 1870s and has survived major changes to its habitat mostly associated with agricultural development and expansion. However, the overall effects of these habitat changes on GGE populations and their distribution are not clearly understood. The GGE distribution is confined almost entirely to privately owned agricultural land. Agriculture in the Gippsland Region is dominated by dryland pasture farming usually of dairy and beef cows (Thompson et al. 2003). Therefore, identifying the effects of agricultural and land management practices on GGE remains crucial to the conservation management of this species. One of the key requirements in furthering our understanding of threatening processes is to more clearly understand the factors responsible for influencing GGE distribution. Two farms were selected to study the effects of farming practices on GGE distribution. The first study was conducted on a dairy farm at Jumbunna, south of Korumburra. This site was situated on alluvial and colluvial grey clay soils. GGE populations were found in four distinct habitat types. These included; minor creek and drainage lines, flat

to gentle sloping alluvial terraces above present flood levels, steep south facing hillslopes with terracettes and colluvial footslope without terracettes. Examination of the GGE distribution at these sites in relation to geomorphology of the farm site identified various landscape features that may play a role in influencing GGE distribution. These include the nature and depth of the soil, slope, micro-topography and aspect of the steep hillslopes, in addition to site soil and surface hydrology. Agricultural management practices relevant to the habitat types were discussed.

The second farm, the subject of this report, occurs in the north of the GGE range, in the red basalt soils. The aim was to determine possible effects of landscape differences on its distribution, and to ascertain possible effects of different agricultural practices. The second farm was chosen for three reasons: (1) as an experimental DPI property, there were more detailed records available on management of the farm (including detailed information on fertiliser application in individual paddocks); (2) the farm occurred in the north of the species range in the soils developed on Tertiary (older) Volcanic basalts, representing the other major soil type in which GGE occurs and (3) the extensive revegetation of riparian habitat. Previous GGE research suggested that the density of re-vegetation of streamside habitat may impact upon GGE populations with earthworms found in the more open sections of re-planted stream banks or pastured areas adjacent to forest (Van Praagh *et al*. 2004; Van Praagh and Hinkley 1999).

The aim of this project was to determine the main topographical and hydrological soil factors influencing the distribution of the GGE within the landscape of an individual farm, and to identify the effects of land management on these factors.

2. METHODOLOGY

Field work was undertaken between October and December 2004. The study was conducted at the Department of Primary Industries (DPI) Ellinbank Research Farm, in the soils derived from Tertiary volcanic (basalt) parent material south of Warragul. The distribution of the GGE was determined and correlated where possible with land use factors, and topographical and hydrological features.

The following was undertaken:

1. The distribution of GGE was mapped by searching for GGE burrows and listening for the gurgling sounds made by the GGE while moving through their burrows.

2. Current and historical aerial photographs of the study area were examined to ascertain changes in landscape.

3. The Farm Manager was interviewed to obtain present and historical information of land management.

4. Topographical features at GGE and non GGE sites were mapped by measuring aspect, slope and microtopography including terracettes and other surface irregularities. A visual assessment was made of slope stability.

5. Information from tasks 1-4 was integrated to investigate the possible effects of past and present land management practices on GGE distribution.

6. Densely Revegetaed sites were further targeted where possible to examine GGE distribution

2.1 Identification of suitable habitat

The study area was examined on vertical aerial photographs and areas of potential GGE habitat identified from these and inspected in the field. While precise habitat parameters are unknown, several factors that characterise potential GGE habitat have been identified (Smith and Peterson 1982, Van Praagh 1994). These include proximity to water, soil moisture and soil type. The earthworm is often associated with creek banks, in particular smaller tributaries and springs on south facing slopes, often with terracettes, but is generally absent from areas where there is a high level of waterlogging and surface compaction.

The investigation for evidence of the GGE concentrated on the lower slopes and colluvial and alluvial terrain adjacent to the creeks, where soil texture and moisture were assessed to provide a more amenable worm habitat. All safely accessible stream sides were inspected. Some sectors of Bear Creek, where dense vegetation planting and regeneration in grazing exclusion areas obscured the ground, were not examined in the field. In the light of several encounters with snakes, it was judged imprudent to traverse these areas in hot summer weather. A detailed search is planned during next winter to complete the survey.

2.2 Detailed Surveys of areas of suitable earthworm habitat

Sites identified as potential habitat were surveyed for evidence of the earthworms. This involved digging soil quadrats of approximately 50 cm x 50 cm and searching for burrows.

Burrows are easily identified and, if wet, indicate burrows that are currently occupied by a worm. If the ground is wet, presence of the worms can often also be established by banging the ground with a spade and listening for gurgles, the sound that is made when the worms retreat down their wet burrows.

2.3 Study Area

2.3.1 Location

This study was conducted at Ellinbank Research Institute, Department of Primary Industries. Ellinbank is situated 100 km east of Melbourne, south of the township of Warragul, West Gippsland.

2.3.2 DPI Ellinbank farm history

DPI Ellinbank is the largest dairy research site in Australia. The research groups include teams working on nitrogen/greenhouse, milk harvesting, soils-water, soils-nutrients, and feedbase production and utilisation.

DPI Ellinbank began with the donation of Farm A in the late 1950's and grew through the 1960s with the purchase of a further three surrounding farms. The four farms known as A, B, C and D, had a combined total area of 520 acres or approximately 210 ha. Different parts of the farm have been used for a variety of research projects, most of which have been grazing based. According to the farm manager, none of these projects have had any significant residual impact on the soils (maybe need to define what this means and impact on what).

The farm currently runs 3 herds with a total of 480 cows on total grazing area of 185 ha. This is approx 2.6 cows/ha., which is considered well above the district average (J. Laidlaw pers. com. 2005)

Summer cropping of 10-20 ha. per year has been consistent over the last 20 years. Crops have included Brassicas (main crop) with some millett, sorghum, cereal grains and maize over the last 5 years. These have either been strip grazed or made into silage.

2.3.3 Farm activities

Ploughing of the farm has been minimal in recent years. Annual phosphorous fertiliser is applied at approx 40 kg P per year, with minimal potassium due to high natural K levels in the

red soils. Approximately 200 kg of nitrogen per year has been applied over most of the farm except for the steep areas.

Annual spraying of flatweeds has occurred over at least 50% of farm. Pesticides are only used as required mainly for control of lucerne flea (*Sminthurus virdis*: Collembola), cockchafers (scarabaeid beetles) and crop moths. (perhaps leave out names in brackets)

Irrigation of effluent has occurred over areas near the farm dairy and on some crops at Farm D.

None of these activities has had any great impact on the creek banks or drains (J. Laidlaw pers. com).

2.3.4 Geology and geomorphology

A detailed description of the geology and geomorphology of the study area can be found in Appendix 1.

This study area lies on the northern flanks of the Strzelecki Ranges (also referred to as the South Gippsland Hills) (Appendix 2). The general geology and geomorphology and the landform evolution of these Ranges is described in Van Praagh *et al*. 2004, but the topography and geology of this study area is different from the farm studied at Jumbunna. The Ellinbank farm property lies on the middle reaches of Bear Creek, a tributary of the Moe River. Three minor tributaries of Bear Creek also cross the site. With elevations between 120 and 190 metres AHD, the 70+ metres of local relief is much lower than that across the higher and steeper terrain that forms the bulk of the Strzelecki Ranges. The highest and steepest slopes on the site are in the south and the terrain surface declines gradually to the north. The terrain is typical of the broad, convex ridges developed on weathered basalt landscape at the head of the Moe River south of Warragul, although the valley floors here are narrow as the farm is on the upper reaches of the streams (Figure 1). A limited variety of slope form, angle and aspect is represented. There are two broad north-south trending ridges in the northern section and two broad east-west ridges along the western side of the farm. In the southeast is a broad north-facing slope that steepens to the south. Slopes are straight to gently convex with steepest slopes of 20^0 along the northern side of Bear Creek. Flat surfaces are restricted to the broad rounded ridge crests and along the floodplain and narrow alluvial terraces bordering the creeks.

Bear Creek has a complex meander pattern as it crosses the site from the central south to the northeast. An abandoned channel sector that was cut off during a flood event (this process is called avulsion), occurs along the northeast of the site (Figures 2 & 3).
No rock outcrop was noted and none is likely to occur given the deep weathering of the volcanic rocks and the accumulation of alluvium. Surface materials, and the parent materials of soils are of limited variation. There is only a single bedrock lithology present (the volcanic basalt), and soils are derived directly from this or from residual and modified rock material transported down slopes or along the stream channels.

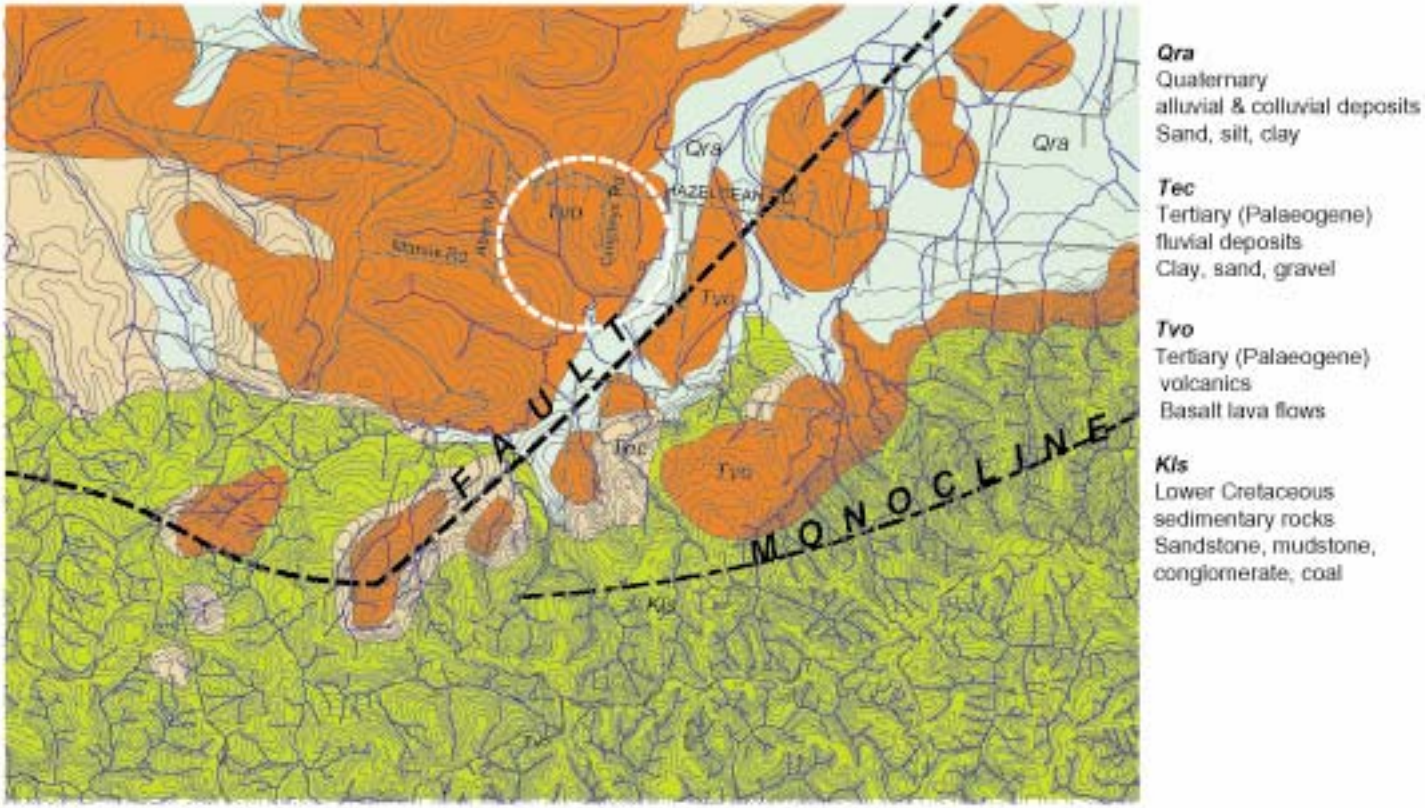
2.4 Revegetation program

Over the past four years, approximately 40,000 indigenous trees and shrubs have been planted at Ellinbank as part of a five-year revegetation program (Keirnan 2005; Cuthbertson pers. comm. 2004). Approx how many plants per ha? – would be useful to know in light of concern over dense replanting. To date all drains, steep slopes and willow-free creeks have been fenced and revegetated, with some natural regeneration observed in these areas.

All species planted are indigenous to the region, although special emphasis was placed on selecting shrubs and trees that provide superior shade and shelter for livestock. Shaded rest areas have also been incorporated into laneways and stock movement zones to help alleviate weather related stress.

Future works will include willow removal and revegetation of two kilometres of Bear Creek front onto DPI Ellinbank land. 7000 sapling tubes are to be planted and the remaining creek front fenced off.

Figure 1 Topography and geology of Northern Strzelecki Ranges around Ellinbank study area



3. RESULTS

3.1 Giant Gippsland Earthworm Distribution at DPI Ellinbank

A total of 57 quadrats were examined for evidence of Giant Gippsland Earthworms (Appendix 3). Evidence of GGEs was found in twenty-two quadrats, with 35 showing no signs of GGEs. At least 11 of the GGE quadrats supported live populations as indicated by gurgles or sightings of individuals. An empty egg cocoon was located at one site. However, the absence of gurgles does not necessarily mean that the site does not support an active GGE population as hearing gurgles is variable and often dependent upon how wet the soils are at the time of sampling.

A subset of 15 quadrats were examined for more detailed geomorphological analysis. Of these, 9 supported GGE. The sites are marked on Figure 2 and Figure 3 and described in Table 1. The stars in the figures represent general locations where GGE were found so that each "star" may represent more than one GGE record.

The majority of GGE sites were situated on the lower slopes and colluvial and alluvial terrain adjacent to the creeks, and swampy drainage channels (Plates 1 & 2). One GGE site occurred approximately 20m uphill from Bears Creek at Abels Hill East. Soils show variation according to topography and reflect the parent materials. On the smooth, convex middle slopes and the straight to gently concave lower slopes, soils are gradation red to red-brown silty clays overlying medium to heavy-textured clays at approximately 0.6 metres depth. Some areas have soils of more uniform texture. On the low terraces and floodplains, soils are uniform, heavier textured red-brown clays with variable organic content. No gravel or coarse sand was encountered in any auger hole or soil pit and there is minimal stratification of sediments on the floodplains and terraces.

GGE were relatively widespread occurring extensively along sections of Bear Creek (north east and south west sections) as well as along the drainage channel to the west of the study area (see Fig 2 & 3). However, apart from one possible site (Site 6), they were notably absent from the northern section of Bear Creek. Although relatively widespread along the creeks and drainage channels, GGE distribution was very patchy and was generally restricted to a fairly narrow band of apparently suitable habitat adjacent to creeks and drainage channels. Where GGE were located near drainage lines, they were generally several metres away from the edge of the swamp/drain.

An active GGE population was found at one site where pugging was evident (Table 1, site 10).

Very little suitable habitat occurred away from the creeks and drainage channels and no reports of GGE by DPI staff have occurred in these areas.

Many of the riparian zones along Bear Creek and the drainage channels themselves have been extensively revegetated (see section 2.5). It was very difficult to sample within these areas due to the density of plants and roots. More extensive sampling was attempted at one section where planting was 3 years old. No signs of GGE were found under the revegetated bank. However, signs of GGE were found on the opposite side of the drainage channel where there had been little replanting and the site was much more open (site 15) (Plate 3 &4).

Table 1 Selected sites for more detailed geomorphological examination.
Should this go in appendix?

SITE NUMBER (Figs. 3 & 4)	GRID REF (GDA94)	GEOMORPHOLOGY
1 .worm burrows	E 0407320 N 5766395	Rise (edge) of narrow terrace above Bear Creek floodplain. Above flood level at upper edge of alluvial terrace - bank 1.6 metres high. Colluvial and older alluvial parent material. Brick- red, mottled clay loam, dry.
2. worm burrows	E 0407326 N 5766398	Topographically immediately below site 1 on floodplain terrace within reach of floods. Brown, silty clay loam, no mottling, moist.
3. worm evidence	E 0407358 N 5766284	High, sloping colluvial terrace 10 vertical metres above Bear Creek channel. Hard, dry red-brown clay loam, dry.
4. worm burrows	E 0407342 N 5766262	Broad, flat alluvial terrace with abandoned stream channel depression at back. Light brown friable silty loam, moist. *(This is the site most similar to the Jumbunna terrace sites with worms).*
5. worm burrows	E 0407302 N 5766218	Steep slope 15 vertical metres above Bear Creek. Hard, dry red-brown clay loam, dry.
6. Abandoned worm burrows?	E 0407574 N 5766740	Bank of Bear Creek - 2 metres high. Silty loam soil, crumbly, moist.
7. “Gurgles” on a previous visit	E 0406509 N 5766494	Base of 15^0 slope at junction of small, dry tributary streams. Dense planting along creek. Dry brown, friable soil upslope, wet grey clay soil beside creek.
8. No worm evidence	E 0406621 N 5766497	Flat floodplain beside creek channel. Very dense planting - fibrous peat soil, with woody root debris, wet. Difficult to dig trench.
9. Worm burrows and empty egg cocoon	E 0406328 N 5765678	Below embankment of dam - disturbed site by roadwork, excavation and fill below 18^0 slope. Flow in channel. Narrow (<8 m wide floodplain) and colluvial terrace - red loam soil, moist with worm burrows.
10. Worm burrows (old?)	E 0406458 N 5765621	Lower terrace above floodplain of Bear Creek below junction of tributary creek. Bear Creek deeply incised with strong flow (21/12/2004). Light-medium clay soil pugged and wet (moisture at surface)
11. Worm burrows (active?)	E 0406481 N 5765273	Terrace (flat with old channel depression) and bank of deeply incised channel of Bear Creek (3 - 4 metres) and recently abandoned channel meander. Incision is young as tree roots are exposed. Low natural levee on opposite bank.
12. Worm burrows reported (farm employee)	E 0407025 N 5766036	Complex of active channel of Bear Creek, cut-off meander and drained tributary to Bear Creek. Yellow-brown mottled clay loam, water-logged.
13 Worm burrows and gurgles	E 0406470 N 5766540	Pasture about 6 metres from drainage channel. Moist, red-brown, friable soil. GGE for 40 metres parallel to channel.
14 worm burrows	E 0406255 N 5766695	Pasture near stream channel. Dry red-brown soil.
15 worm burrows	E 0407495 N 5766325	Terrace above flood level. Opposite side to dense plantings, beside stream channel. Grey-brown clay.

Figure 2 GGE localities and sites selected for further analyses on topographic map of study area. The stars in the figures represent general locations where GGE were found so that each "star" may represent more than one GGE record**.**

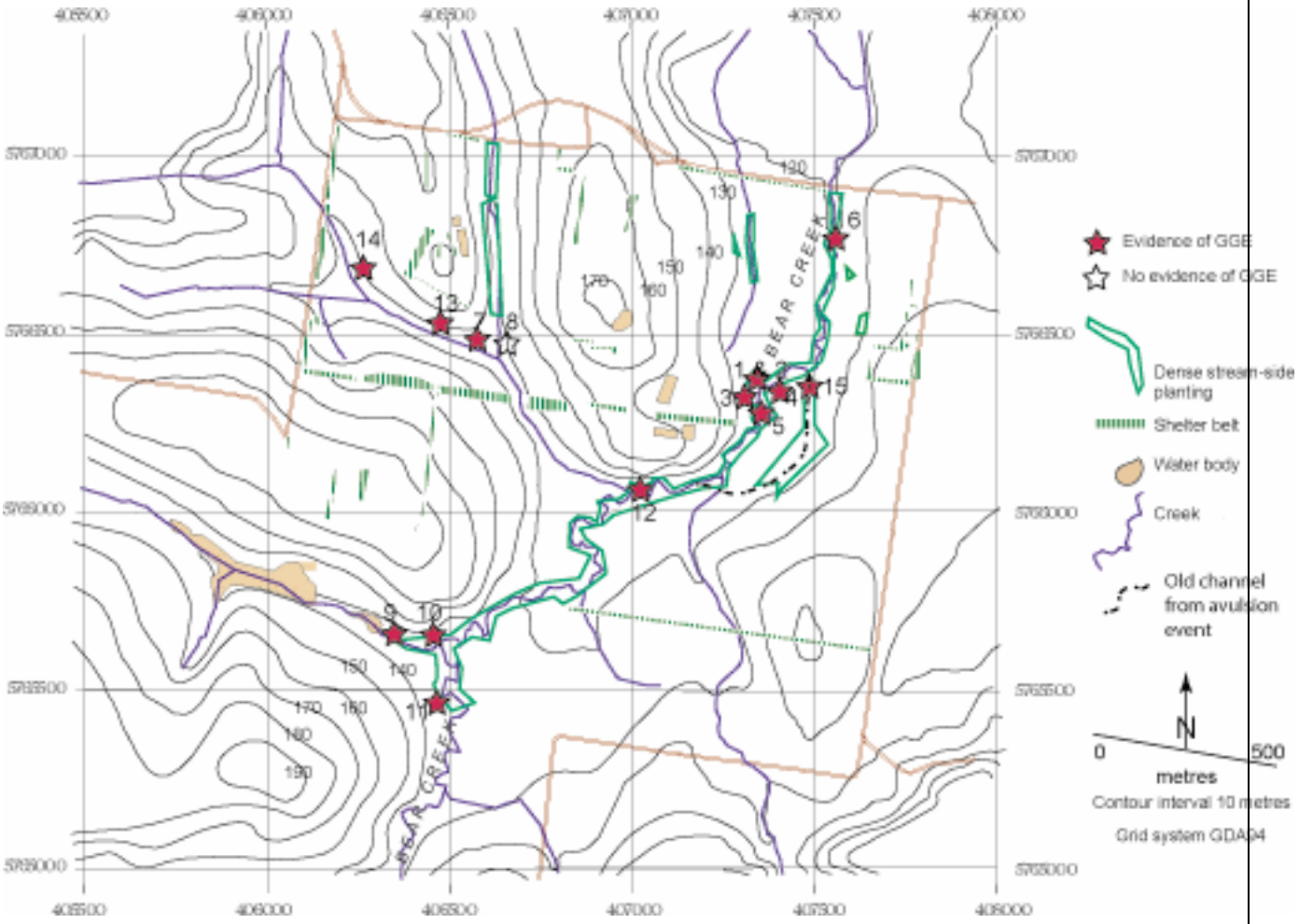


Figure 3 GGE localities and sites selected for further analyses on aerial photo of study area. The stars in the figures represent general locations where GGE were found so that each "star" may represent more than one GGE record

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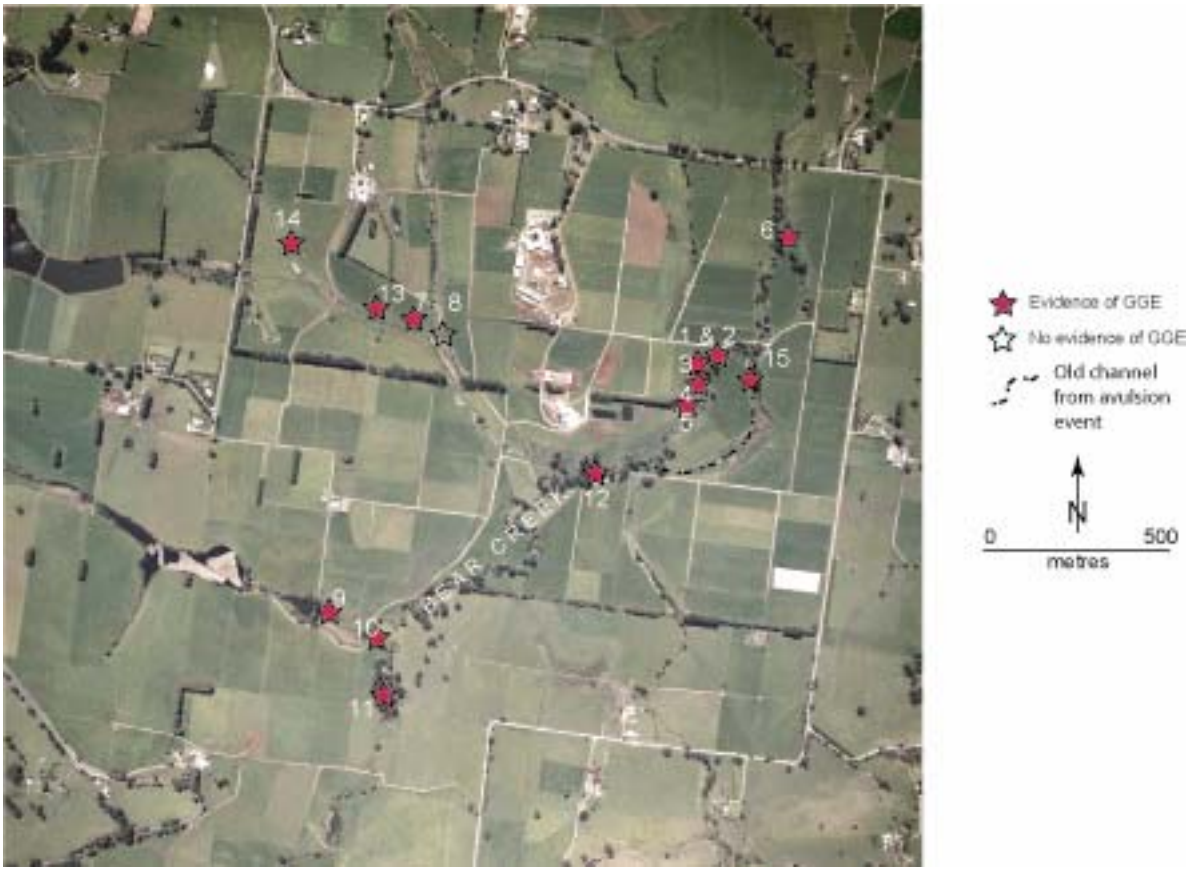

Plate 1 Examples of Stream /drainage side habitat of GGE at DPI Ellinbank

★ **GGE sites**

Plate 2 Revegetation of creeks and drainage channels at DPI Ellinbank

4. DISCUSSION

Giant Gippsland Earthworm distribution at the Ellinbank Research Farm occurs in one main habitat type; the lower slopes and colluvial and alluvial terrain adjacent to the stream channels and just above the level reached by moderate flooding. This is in contrast to the four habitat types for GGE described at the Jumbunna study area. This may be explained in terms of the difference in geomorphology between the two sites. At Ellinbank, the slopes are morphologically simple and lack the distinct segmentation observed at Jumbunna in the steeper, higher terrain of the Strzelecki Ranges. There are no major differences in slope form between the upper and lower slopes in the Ellinbank study area and the ridge crests are broad and gently rounded. The slopes also lack the distinctive tread and riser terracing ("sheep tracks"), that is a characteristic of the steeper terrain developed on sedimentary rocks, and soils were more coherent and with lower moisture content than the terraced features. This morphologically simpler landscape appears to provide less areas of suitable GGE habitat with the appropriate hydrological parameters. Whether these features are characteristic of the broader geomorphology of the basalt-derived soil landscapes in the north of the species range requires further investigation.

In the Jumbunna study area GGE were located in a variety of habitat types, including areas away from stream banks, and were therefore exposed to a wide range of farming practices. In contrast, GGE at Ellinbank were primarily restricted to riparian zones, which have largely been fenced off and protected from most agricultural impacts at the site. Only one site occurred away from a riparian zone (approx 20m upslope from stream bank) and this site was also fenced from stock. Therefore it was not possible to make any assessment of farm management practices (such as the addition of superphosphate) on GGE distribution. It is likely that most agricultural practices in the study area have not impacted upon GGE populations. One possible exception is pugging of wet soils and compaction by stock. However, at present, most of the stream banks have been fenced and only one site with pugging was noted. An active population of GGE was found at this site. In general, GGE have been absent from sites heavily bugged by cattle. However, it should be noted that the Ellinbank farm is an experimental one with higher staffing levels and more intensive management than would be the case with a typical farm. Despite the higher than average stocking rate, the study area has smaller fenced paddocks and more active rotation of cattle between paddocks, possibly resulting in less intensive pugging at each location.

Van Praagh *et al*. (2004) reported on agricultural management issues for streamside habitat likely to negatively impact upon GGE populations. These included intensive stocking on wet soil, (pugging & compaction), changes in water flow and water course and dense

revegetation. The major management issue relevant to the riparian zones in the study area is the actual and potential impact on GGE habitat of the dense plantings along sections of Bear Creek and the tributary creeks. These plantings may be having an impact on the sub-surface area available for GGE habitat by filling potential occupation space with tree roots and woody debris. There is also the likely impact on the water table, whereby increased transpiration rates will lower water tables leading to drying of soils in potential worm habitat on the lower slopes, colluvial slopes and floodplains. Whilst not all factors influencing GGE distribution are known, one of the most important is related to soil hydrological factors. Active GGE populations are always found in moist soils and the burrows are very wet often with a significant amount of free water flow in them.

At present, revegetation programs are widely advocated by local Landcare groups for a variety of reasons including; soil erosion control, to reduce water logging and to protect water quality of streams, as well as for provision of shade and shelter for stock (G. Trease pers.com. 2005, Thompson *et al*. 200). Increasing the nature conservation value of an area may also be included, and for the past 10 years revegetation of GGE habitat has been one of the key recommendations for GGE conservation on private land (e.g. Van Praagh 1991, Talyor *et al*. 1997). Plantings are used in a variety of situations including riparian strips, gullies, landslips, windbreaks and as linkages between remnant vegetation. Plantings usually occur at 2.5 m spacing. The current recommendations for revegetation include approximately 2000 plants per ha with a species composition of 15-25% trees, 40% mid storey and the remainder understorey and grasses. However, the composition of tree species in the area has been as high as 40% (G Trease pers. com. 2005). Dense planting and regeneration on streamsides and grazing exclusion areas has the potential to lower the water table and diminish suitable GGE habitat. Offsetting this in part may be the positive impact of vegetation providing moister, shaded sites and reducing evaporative loss from the shaded channels. Revegetation of waterlogged areas has a potential negative and positive impact on GGE habitat. Lowering the water table may lead to drying of adjacent areas upslope where the GGE currently occur. However, it is also possible that it may make areas closer to the drainage channel more suitable for earthworms as waterlogging is reduced.

No historical information is available on the distribution of the GGE in relation to streams when the area had pre-European settlement forest cover. The GGE has survived in pastures near streams, but it is unclear as to whether this is an historical distribution or whether the species was once more widespread. If it is the latter, then we can infer that it has managed to survive by occupying a relatively narrow area based on soil hydrological factors. As noted in Van Praagh *et al.* (2004), most of the area in which the GGE now occupies is a managed landscape. Since the mid 1800's, extensive forest clearing, introduction of grazing animals

and the maintenance of a more-or-less continuous ground cover of sown pasture has greatly altered the surface and sub-surface hydrology. A major consequence of land clearing has been an increase in run-off, particularly during storms. This has increased the quick-flow of streams and provided more energy for streams to incise channels and to scour the bed and banks of alluvial material. This process has affected Bear Creek and tributaries, causing deepening and widening of the main channels and exposure of sediment and soil in the channel wall. There are several meander cutoffs along Bear Creek and an old channel several hundred metres long apparently abandoned during a flood avulsion, (an event where the creek cuts a new course across the floodplain). A further consequence of land clearing would be an increase in the rate of surface and groundwater drainage and probable lowering of the water table. However, this would in part be offset by the lowered transpiration demand as a result of removing the forest canopy and suppressing tree regeneration. It is now possible that major alteration to soil hydrology in the current landscape, such as extensive tree planting, may pose a threat to the GGE.

At present the effect of revegetation of GGE habitats is unknown and remains speculative. However, the absence of GGE from heavily vegetated sites at Jumbunna (Van Praagh *et al.* 2004), preliminary investigation at this site and their presence in pasture adjacent to native forest at Mt Worth State Park (Van Praagh and Hinkley 1999) suggest that recommendations to revegetate GGE habitat for GGE conservation needs reassessing. In a recent report on Best Management Practices for riparian habitats in Gippsland dairy regions, Thompson *et al.* (2003) found that their suggested index of riparian condition indicated that an excellent condition score required vegetation 30 metres wide on either side of a stream. Whilst the broader benefits of revegetation of riparian zones is acknowledged, the effects of dense replanting of areas occupied by GGEs requires investigation. Very few areas in South Gippsland currently have 30 metres of vegetation on either side, and if revegetation projects aim to recreate buffers of this width, then the effects on GGE has to be considered. Despite the preliminary nature of these findings, given the scale of revegetation in the region and in particular, the often very dense planting of riparian GGE habitat, revegetation may represent one of the most important potential impacts for GGE populations. It is recommended that quantitative, long-term monitoring programs be developed in order to examine impacts of revegetation on factors such as soil moisture, hydrological patterns, and water table levels and how these might impact on GGE populations. Factors such as density, structure and composition as well as age of plantings should be considered. Studies should be conducted over a wide range of farms throughout the species range.

5. CONCLUSION

Giant Gippsland Earthworms are restricted to the riparian zones of creeks and drainage lines at Ellinbank. This may be a result of the morphologically simpler landscape found in the study area which appears to provide less areas of suitable GGE habitat with the appropriate hydrological parameters. As these riparian zones in the study area have largely been protected from most agricultural activities, it appears likely that current farming practices have not had a major recent impact on the species.

The most important land management issue arising out of this study is whether intensive revegetation directly within or close to the fairly narrow confines of their known or likely habitat could be a threat to the GGE because of resultant changes in underground hydrology. This is significant because tree planting has generally been advocated as a means of conserving the GGE. However this caution is not intended to apply to revegetation programs that occur elsewhere on farms within the species overall range. It is recommended that a detailed study and monitoring program is developed to examine the impacts of revegetation of GGE habitat on GGE populations. Once such information is available, informed recommendations regarding management of GGE streamside habitat by farmers can be formulated

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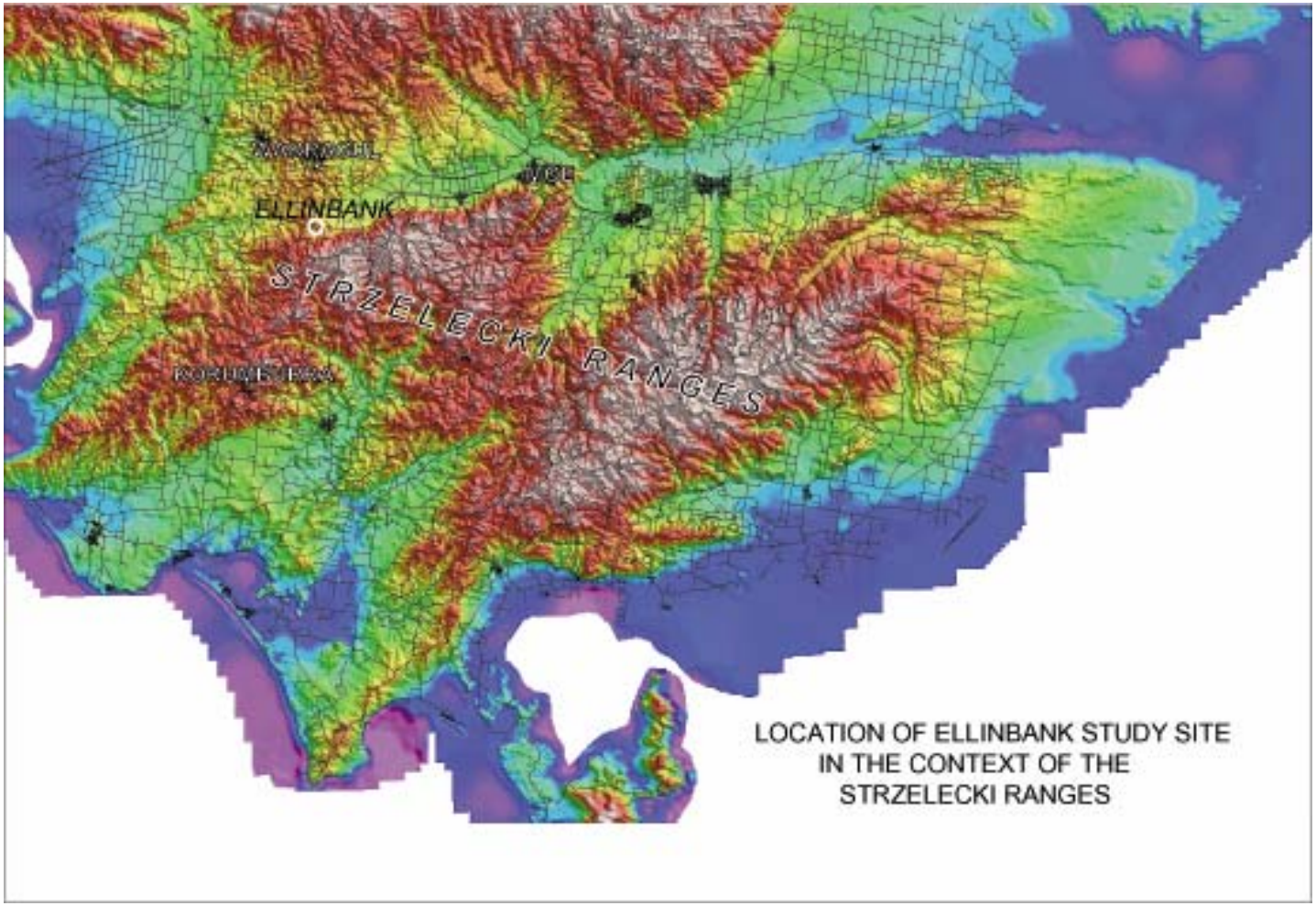
APPENDIX 1. Geology and geomorphology of worm environments, DPI Dairy Research Farm, Ellinbank

Context

This study area lies on the northern flanks of the Strzelecki Ranges (also referred to as the South Gippsland Hills) (Appendix 2). The general geology and geomorphology and the landform evolution of these Ranges is described in Van Praagh et al. (2004) but the topography and geology of this study area is different from the Jumbunna study area. Ellinbank is on the lower northern slopes of the Narracan Block, a structural unit of the Strzelecki Ranges. The farm is in the headwaters of the Moe River, part of the of the Latrobe River drainage system at elevations between 120 metres AHD to just over 190 metres AHD. To the south of the farm site, the topography steepens rapidly along the northern slope of the Narracan Block into the foothills of Mount Worth, with the narrow valleys and ridges and local relief of 150 to 200 metres typical of the central Strzelecki Ranges. The bedrock geology of the Narracan Block is Lower Cretaceous sediments and these crop out across most of the Strzelecki Ranges. The northern margin of the Narracan Block is defined by the Yarragon Monocline, a 50 kilometre-long structure that forms the dissected east-west escarpment along the southern side of the Moe River valley. The monoclinal escarpment crosses about three kilometres south of the Ellinbank study area (see Figure 1). Patches of deeply weathered basalt lava crop out along the lower slopes and base of the escarpment. The Ellinbank site lies on the southern edge of a broad, undulating, weakly incised plateau that forms the divide between the Moe River and Lang Lang Rivers. This plateau is also covered by deeply weathered basalt of the Thorpdale Subprovince, a unit of the South Coast Volcanic Province of Victoria. The volcanic activity is 21 to 26 million years old and as the basalt lavas are deeply weathered, there is little outcrop across the entire subprovince.

APPENDIX 2. Location of Ellinbank study area in the context of the Strzelecki Ranges



APPENDIX 3. Distribution of quadrats surveyed for GGE at DPI Ellinbank Research Farm.

Date	Site No.	Paddock	Altitude	Observations
9-Nov 04	1A		134	GGE burrow & gurgle Low GGE density
.	1B	B21	133	GGE burrow & Gurgle
.	1C		136	GGE burrow & cast, and head obsv
.	1D		142	GGE burrow (wet) High Density.
.	2A	Abels Hill E	134	GGE burrow & cast. Live GGE obs about 20m up from crk
	2B		137	No GGE. Red Soil
.	2C		139	GGE burrow, cast, brown/red grey clay, moist, open pasture
.	2D		138	No GGE
	2E		136	No GGE
	2F		139	No GGE (up hill), red soil. Steeper part of hillslope
.	3A	opp 2F	135	No GGE
.	3B		148	No GGE (near dam)
.	3C		156	No GGE
.	4	D6	151	No GGE (above small dam) Red Soil
.	5A	D5	156	No GGE. Dam side of fence. Water fills holes at 40 cm depth.
.	5B	D5?	157	No GGE. Lower part of terracette. Very dry.
.	5C		160	No GGE. Upper part of terracette. Very dry.
.	5D		156	No GGE. Fence by dam.
.	5E		156	No GGE. Dam side of fence.
.	5F		156	No GGE. Dam side of fence. Very wet.
.	6A	D7	148	GGE specimen; empty egg capsule. Adjacent to swamp. Red Clay
			150	GGE
.	6B	D7	145	GGE gurgle
.	6C	D7	151	GGE gurgle. Swamp.
.	6D	D1b	149	No GGE. Other side of track from swamp.
.	6E	D1b	149	No GGE. Other side of track from swamp.

APPENDIX 3. cont. Distribution of quadrats surveyed for GGE at DPI Ellinbank Research Farm.

Date	Site No.	Paddock	Altitude	Observations
.	7A	D1a	146	GGE burrows & specimen (wet & pugged).Grey/brown soil. Shallow rise above creek
.	7B	D1a	148	No GGE Shaded, dry, red soil
.	7C	D1a	151	No GGE- shaded drier red soil
.	7D	D1a	145	GGE gurgle, wet grey clay
.	7E	D1a	146	No GGE
.	7F	D1a	147	GGE burrow & cast, Brown/Grey clay
.	7G	D1a	152	GGE burrow
10-Nov 04	1A	A14/A7?	138	No GGE. Drainage channel
.	1B	A5	137	GGE burrows in pasture, not swampy edges of drainage channel. Red/brown soil
.	1C	A5	137	GGE burrow.
.	2A	A12	138	No GGE
.	2B	A12	138	No GGE
.	2C	A13	136	GGE burrow. In pasture about 6m away from Drainage Channel. GGE for approx 40 m adjacent to Drainage Channel.
.	2D		135	No GGE
.	2E		137	No GGE
.	2F		137	GGE gurgle
.	3A	adj A22	140	GGE burrow (wet), gurgle. Site adjacent to thick reveg, in open area
.	3B		139	No GGE
.	3C		139	No GGE
.	4A	near C7	142	GGE burrow. Revegetation site.
.	4B		134	Grass area: no GGE

APPENDIX 3. cont. Distribution of quadrats surveyed for GGE at DPI Ellinbank Research Farm.

Date	Site No.	Paddock	Altitude	Observations
.	4B1?	C6?		GGE burrows. Just before revegetated wet area. Terrace above flood level. Brown Grey clay
				No GGE. Under revegetation.
.	4C	C7	133	Possible GGE burrow? Stream side embankment.
.	4D	Silage Flat 2.2	133	GGE burrow & cast.
.	5A	Flat A Bear Crk	135	No GGE
.	5B	Flat Bear Crk	131	No GGE
.	5C	Flat Bear Crk	135	No GGE
.	5D	Flat Bear Crk	131	No GGE
.	5E	Flat Bear Crk	128	No GGE
.	5F	Flat Bear Crk	120	No GGE