MT HAMPTON

VEGETATION MONITORING

PROJECT

Summary Report to Water Corporation

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David Mitchell (CALM Swan Region) and Nick Woolfrey (DEP) collected the original data. Paul Roberts (CALM Merredin District) collected data in 1998 and 2001. Comments were received from Mike Fitzgerald (CALM Esperence), Brett Beecham (CALM Wheatbelt Region), Dr Neil Gibson (CALM Science). In 2003, Merredin District officers Heather Adamson and Kate Roy-Chowdhury collected further data. Paul Blechynden (CALM Merredin District) and Matthew Williams (CALM Science) assisted with providing statistical analyses and feedback on this report. Brett Beecham provided comments and final editing.

1 INTRODUCTION

1.1: Background

Granite outcrops have been used as a valuable public supply of water since 1890 (Laing and Hauck, 1997). The book *The Beckoning West* (Smith, 1996) tells the story of H.S. Trotman who, in 1894, camped with hundreds of men at the government well at Mt Hampton while waiting for rains. Some granite outcrops function as emergency water sources and are a vital part of Government response plans during times of severe water deficiency (Laing and Hauck, 1997). The Western Australian Department of Agriculture highlighted the Eastern Wheatbelt district, in which Mt Hampton is located, as a water deficient area in 1988. A government strategy has been to provide emergency water supplies within 40km of all farmers in "declared drought affected" areas, and Mt Hampton was identified as being strategically placed to provide a reliable source of water.

In 1993, the former Western Australian Water Authority (WAWA), now referred to as Water Corporation prepared a Consultative Environmental Review (CER) for Mt Hampton Water Supply Source (WAWA, 1993). The CER predicted that the *Allocasuarina* thicket and areas along drainage lines would gradually change towards a grassland association containing fewer trees and possibly some *Acacia* and *Leptospermum* shrubs. Due to an absence of information on the effects of granite rock water supply development has on surrounding vegetation the Water Corporation proposed to monitor changes in the structure and species composition of vegetation annually for a period of three years.

The Environmental Protection Authority (EPA) gave its approval in 1993 to the Water Corporation for the construction of a water supply dam on Mt Hampton Nature Reserve (↑A32995) (EPA, 1993). In giving its approval, the EPA acknowledged that the proposal may cause minor changes to the flora and fauna of the reserve but that the likely impacts on flora were probably overstated in the CER and any changes likely are environmentally acceptable. The EPA Bulletin No. 718 recommended the proposal proceed subject to the proponent's commitments. One of the main commitments (8.3.3) was that the Water Corporation develop a vegetation monitoring program in consultation with the Department of Conservation and Land Management (CALM) and submitted to the EPA for their consideration and endorsement. Monitoring was to be carried out annually for the first three years, with the timing of further monitoring determined following discussions with CALM.

The Water Corporation asked CALM to undertake this work and agreed to provide funding for CALM to carry out this monitoring.

Pre and post catchment construction photographs were taken of the bitumen channel at the base of the eastern side of the rock and the dam (Figure 1a & 1b), as well as the rock wall.

1.2: Granite Outcrops and their uses for Conservation and Water

There are many values of granite outcrops. Granite outcrops have aesthetic and recreational value (picnic sites, lookouts), cultural value (wildflowers), historical value (European and Aboriginal heritage sites), utilitarian value (quarries and water supply) and nature conservation value (natural biodiversity, threatened flora and fauna) (Main, 1997).

1.2.1: Nature Conservation Values.

Granite outcrops in southwest Western Australia are important havens for flora and fauna. Granite outcrops provide important seasonal resources and refuge for fauna of surrounding habitats (Withers and Edward, 1997). Hence, the fringing apron of modified habitat is an important area of interaction between surrounding habitats and the granite rock.

Granite outcrops support a highly endemic and diverse flora (Hopper *e*t al., 1997; Pigott and Sage, 1997). Hopper *et al.* (1997) produced a preliminary list of 1320 plant taxa known to occur on granite outcrops in Western Australia. Pigott and Sage (1997) also listed 271 plant taxa occurring on Yilliminning Rock near Narrogin that included 78 species not listed by Hopper *et al.* (1997). Of the 238 declared rare flora species in 1989, 12% were associated with granite outcrops (Hopper *et al.*, 1990). The rarity of particular species depends on a number of factors including the extent of occurrence within and between granite outcrops, as well as the potential for threatening processes such as invasive weeds, feral animals, grazing, clearing, salinity and disease (Hopper *et al*., 1997).

Figure 1: Photographs of the location of the bitumen-lined channel at base of Mt Hampton showing the general area before (a) and after (b) construction.

1.2.2: Water Harvesting.

There is a long history of granite rocks in the wheatbelt being used to capture water for local area water supplies (Smith, 1966; Laing and Hauck, 1997). Water has often been collected off the rock-face by directing it along rock drains into dams. Similar structures for water harvesting have been constructed at Muntadgin and Hyden's Wave Rock (Wheatbelt Mercury, 1996). The CER (WAWA, 1993) also cites Dulyalbin Rock, Waterbidden Rock, Mount Roe and Gibb Rock as other existing water supply sources in the vicinity of Mt Hampton, although Mt Hampton is the only nature reserve in the area with such a structure.

Particular values of granite rocks are often sensitive to other uses (Main, 1997). The CER (WAWA, 1993) expressed concern that there would be a change in vegetation over time surrounding that part of the rock where water harvesting occurred. The CER (WAWA, 1993) also recognised that there was a lack of information on the effects of such developments on the surrounding vegetation. Main (1997) expressed concern that the diversion of water deprives the surrounding vegetation and soils of recharge consequently contributing to an increase in aridity of the area. However, in responding to submissions, the Water Corporation stated that the impact on the *Allocasuarina* thicket outlined in the CER was conservative, given examination of similar vegetation surrounding a number of other nearby rocks used for water harvesting (EPA, 1993). It is also stated that there appeared to be no thinning of *Allocasuarina* stands at these sites or differences in the understorey and groundcover species associated with drainage structures.

1.2.3: Present Use at Mt Hampton

Inspections of Mt Hampton in 1998 have revealed that the rock drain has not been constructed to the extent of that indicated in the original design. The reason for this is not known, but perhaps it was felt that the rock drain construction was sufficient to meet initial supply requirements.

The 20,000m^3 dam appears to be constructed to the original design specifications, including its location. However, it is noted that the outlet from the dam appears in a different position (ie now part of the dam wall) to the original position as part of the silt trap. The proposed spillway also does not extend as far as indicated on the original plans.

The frequency of use and purposes to which the water from Mt Hampton is used is not known. Feedback on this point, particularly corresponding use over the years to annual or seasonal rainfall, may be crucial in determining future plans. In visits to Mt Hampton in 1998, overflow of the dam was observed on several occasions. This may indicate that the water is not being used to a great degree at present, which may be a reflection of the relatively wet summer and the time of the year with respect to farm operations. Evaporation may also make estimating use difficult.

1.3: Objectives of the Study

Concerns have been raised about possible the impact of water harvesting and the associated structures at Mt Hampton upon vegetation surrounding this granite outcrop. In particular, there has been some concern for possible decline or death of vegetation, or changes in species composition as a result of changes in local hydrology due to the interception of water that would normally flow into the soils around the rock. The rationale for this study is that there is a general paucity of information relating to possible impacts and this study will shed some further light on the issue.

Concern was also expressed about possible effects on the flora and fauna of reduced water flow into rock pools and shallow soil-filled depressions from construction of the rock wall (drain). Although there will be an interruption of surface flow which will negatively impact frog populations at the base of the rock (WAWA, 1993), responses to submissions (EPA, 1993) indicated that rock pools below the rock drain will fill largely through direct rainfall, albeit more slowly. As many other rock pools over the main rock will be unaffected by the proposal and rock pools below the drain will fill in wet weather, no impact was expected on aquatic invertebrates (WAWA, 1993).

The study is significant for several reasons. Impacts upon fringing vegetation, if any, will be described in this study which will increase the knowledge about water harvesting on granite outcrops. To date, little has been done to qualify and quantify the impacts on granite rocks and their fringing vegetation from water harvesting, other than to visually compare existing facilities. In addition, according to the CER, further expansion of the dam is planned for Mt Hampton. The results from this project may be used to assess future plans for both Mt Hampton and other potential rock catchment options in limited water supply areas. (Need to confirm still!)

Therefore, the principal objective of this study is to determine if there are any longer-term effects of the dam and catchment construction on the vegetation around the granite rock. A number of sub-objectives or questions can be further identified that will contribute to the examination of this principal objective. These are concerned with examination of the fringing vegetation overstorey and understorey and are outlined as follows:

Overstorey:

- Is there any significant change in the dominant overstorey (Allocasuarina huegeliana) dead stems?
- Is there any significant change in the overstorey diversity?

Understorey:

- Is there any significant change in the understorey cover?

2 METHODS

2.1: Location

Mt Hampton rock is located in the Shire of Yilgarn, about 60 km south-west of Southern Cross in the eastern central wheatbelt of Western Australia (Figure 2). Mt Hampton rock occurs on a ‘C’ Class nature reserve (20526) of 594 ha under the management of the Conservation Commission of Western Australia.

The reserve on which Mt Hampton rock is located (Jilbadji location 828) was originally set aside for the purpose of “*Water*” in 1930 under the management of the Minister for Water Supply, Sewerage and Drainage. However, in 1974 the reserve purpose was changed to “*Water and Conservation of Flora and Fauna*” under the management of the Western Australian Wildlife Authority. Also in 1974, adjacent vacant Crown land (Jilbadji location 928) of 1,886 ha was reserved (↑C32995) for the purpose of “*Conservation of Flora and Fauna*” under the management of the Western Australian Wildlife Authority. The vesting authority for this reserve changed to the National Parks and Nature Conservation Authority in 1989 and subsequently the Conservation Commission of Western Australia. Vacant Crown land parcel Jilbadji location 979 was added to reserve 20526 in 1980. Reserves 20526 and 32995 are collectively known as ‘Mt Hampton Nature Reserve’ and total a combined area of about 2,480 ha.

Limited remnant vegetation adjoins the nature reserves, however Mt Bayly Nature Reserve (↑A28323) is only about 1km southeast of Mt Hampton Nature Reserve and sizeable areas of vacant Crown land exist within 10kms to the east and west. Both reserves are accessed from the north and south via Moorine South and Nulla Nulla South Roads and from the east and west via Cramphorne Road. Both reserves lie within CALM’s Merredin District and Wheatbelt Region.

2.2: Climate and Topography

The Consultative Environmental Review (CER) (WAWA, 1993) describes the climate for the area as being on a boundary between a dry, warm Mediterranean climatic region (the wheatbelt) and the semi-desert climatic region further to the north and east. The area lies within the 300 to 350mm annual rainfall zone where rain falls reliably in the winter months and sporadically in summer months from thunderstorms. Rainfall during the period July 2002 to Jun 2004 was somewhat above average.

2.3: Vegetation

2.3.1: Description

Mt Hampton Nature Reserve is located within the Skeleton Rock vegetation system (Beard, 1972) and is part of the Avon Botanical District of the south-west Botanical Province (Beard, 1980). The vegetation to the east of Mt Hampton rock has been mapped by Beard in 1970 as Salmon Gum (*Eucalyptus salmonophloia*) and Gimlet (*E. salubris*) woodlands. Broombush thicket on sandplain dominated by *Casuarina, Acacia* and *Melaleuca* species occurs to the west of Mt Hampton rock. Vegetation classification of associations follows Muir (1977).

The vegetation on the eastern side of the rock in the area of development consists of mainly *Allocasuarina huegeliana* (Rock Sheoak) thicket to a distance of about 100 metres out from the rock. The thicket extends to the north and south, although is replaced or infiltrated in many places by *Acacia*, *Melaleuca, Leptospermum* and *Hakea* thicket. Open grassland generally extends beyond 100 metres from the rock. More comprehensive species lists are contained in the CER (WAWA, 1993). From a total of about 13 hectares (ha) of Rock Sheoak thicket around Mt Hampton (east and west), 2.1 ha has been cleared and 7.3 ha has the potential to be directly affected by the development, leaving about 3.6 hectares of thicket that is unaffected.

2.3.2: Significance

The assessment of significance for nature conservation follows Safstrom (1995) and takes into account the following factors:

- The occurrence of threatened flora, fauna and communities,
- The biotic diversity,

- The area of the reserve and the extent of native vegetation cover,
- The extent of nature reserves with 15km,
- The degree of replication and uniqueness of nature reserves to other Crown land within 15km,
- The level of connectivity between nature reserves and other Crown land.

This assessment has focussed on *Allocasuarina huegeliana* (Rock Sheoak) communities. *A. huegeliana* thickets are a dominant community typically found fringing granite rocks. *A. huegeliana* dominated communities have been identified in this study as a vector for expressing change resulting from impacts from water catchments such as Mt Hampton.

Mt Hampton and surrounding Nature reserves

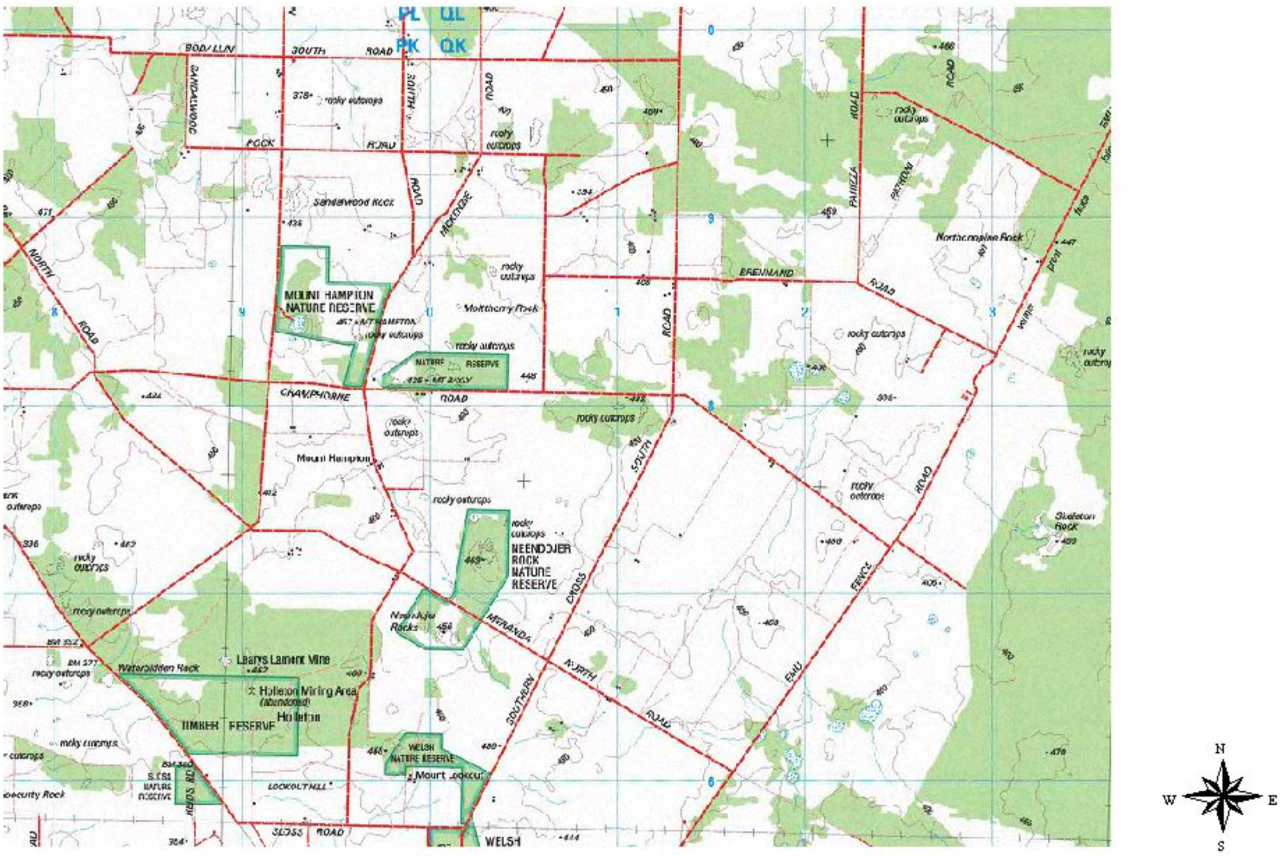


Figure 2: Location of Mt Hampton Nature Reserve in relation to other Crown land tenures and towns in the central Wheatbelt**.**

2.4: Monitoring Program Method

The main objective of the monitoring program is to monitor vegetation around and out from the rock to look for gross changes in health (decline or death) or species composition. Monitoring the site will be conducted by surveying a number of transects as well as taking photos at the same locations on each monitoring visit.

It was also felt during the initial experimental design that there may be two different effects. There was concern that *A. huegeliana* thickets adjacent to the bitumen-lined drain in the north could decline due to a lack of water getting into the soil. South of the dam there could have been general drying effects upon surrounding vegetation from construction of the rock drain, but there may be potential for the vegetation near the spillway to receive significant water from the dam outlet. In the data analyses, data was grouped into three different localities: Transect 2,3,4 and Transect 5 & 6 and Transects B1 & B2.

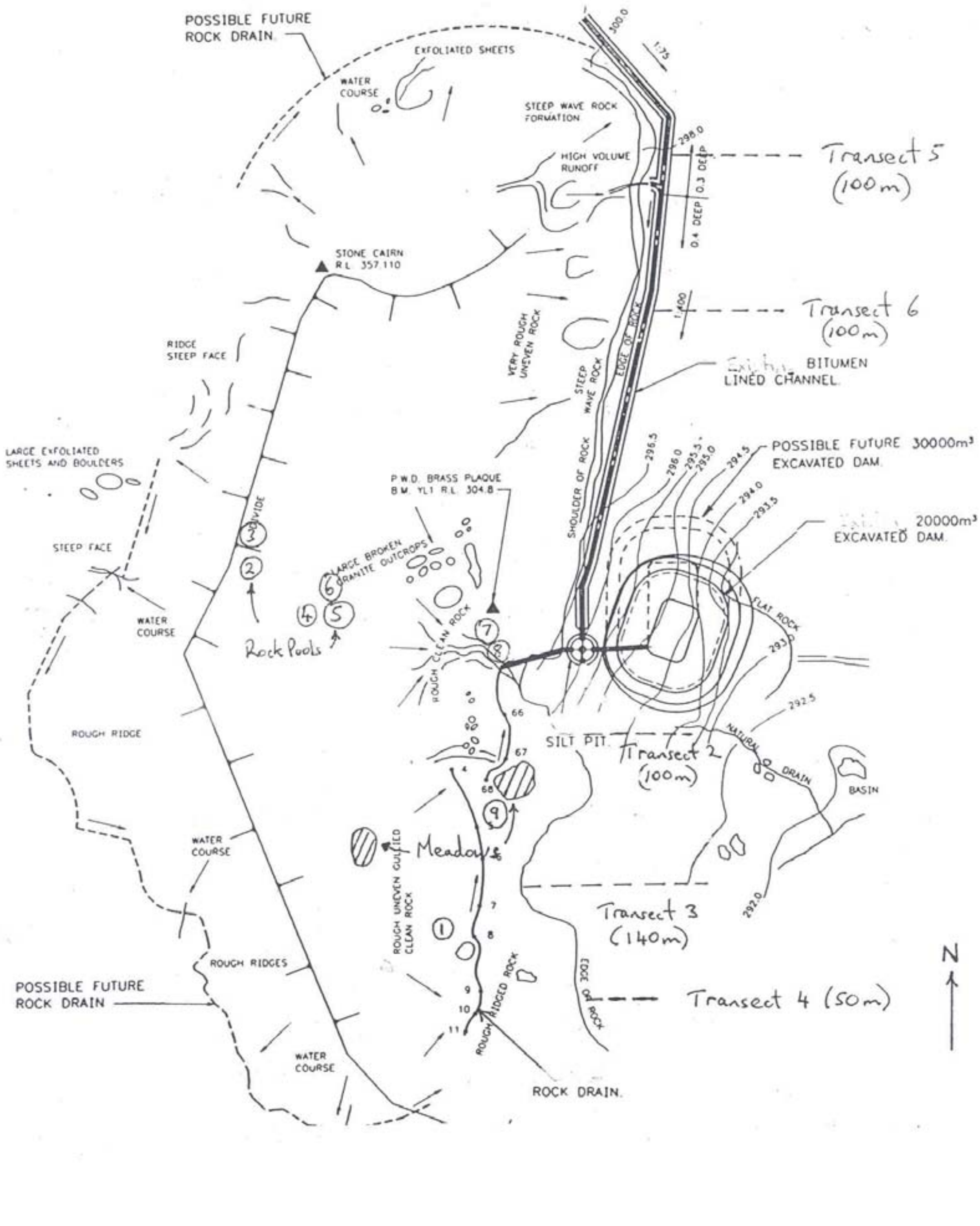
Although it was recognised that there may be some short-term changes identified within the initial three-year monitoring period, some changes may only become apparent after a longer period of time. Hence, the proponent made a commitment in the CER (WAWA, 1993) that monitoring would continue on at least four more occasions at three year intervals after this initial 3-year project, up to at least 15 years post-construction.

Monitoring of soil water, pH and herbaceous rock meadows has been eliminated from the programme because of a lack of baseline data and the different sampling techniques used on previous monitoring visits. It was also considered that the monitoring results for soil water, pH and herbaceous rock meadows would be more sensitive to rainfall variability than to any changes due to the water catchment.

2.4.1: Vegetation Transects

In 2003, vegetation monitoring was conducted at 5 established sites at Mt Hampton, all within areas that had the potential to be affected by the rock wall or drainage channel. Transects were mostly 100 metres long running from the base of the rock out through the fringing vegetation (Figure 3). One transect was only 50 metres long (Transect 4), whilst another was 140 metres long (Transect 3). These were placed in representative vegetation types around the eastern side of the rock with three transects below the rock wall and two adjacent to the drainage channel.

Figure 3: The dam and catchment at Mt Hampton rock (Scale 1:2000) showing the bitumen-lined channel (north east), rock drain (south east), existing 20,000m3 dam (east), approximate locations of vegetation transects 2 to 6.



Established transects originally numbered 1 to 8. However, transects 1, 7 and 8 were deleted from this study because transect 1 was found to be located in the position of the intended dam, and transects 7 and 8 were not measured. Two control transects were also measured at Mt Bayly to the southeast of Mt Hampton. These transects were located in *Allocasuarina huegeliana* vegetation, similar to that at Mt Hampton, but were only 50 metres long. Transects were measured in 1995 and again in 1998/9 (Table 1).

Transects were originally marked at their start with a steel ‘dropper’ and numbered tag. Steel ‘droppers’ were then established every ten metres thereafter along each transect. The start of transects were re-marked with yellow flagging tape in 1998, as the start of some transects (ie 5 and 6) were destroyed by construction of the bitumen-lined channel. In 2003, the transects were marked again with pink flagging tape and a peg was placed at the start of each transect. Flagging tape was used to identify each monitoring point in 2003 and GPS points were taken at each monitoring site and are listed in Appendices 1 & 2.

Date	2	3	4	5	6	B1	B2
28/8/95	M1		M1				
4/10/95		M1		M1			
10/10/95					M1	M1	M1
29/11/98				M2			
23/12/98	M2		M2		M2		
5/1/99		M2				M2	M2
8/2/01			M3	M3			
13/2/01	M3				M3		
14/2/01		M3				M3	M3
27/10/03	M4	M4	M4			M4	M4
28/10/03				M4	M4		

Table 1: Initial measurement (M1) and re-measurement dates in 1998 (M2), 2001 (M3) and in 2003 (M4) of transects 2-6 at Mt Hampton and B1-2 at Mt Bayly in Merredin District.

At ten metre intervals along each transect, measurements were taken of the overstorey within a 5-metre radius and understorey within a 2-metre radius. Within the overstorey, the following factors were measured and recorded:

- Species,
- Number of stems,
- How many stems were both alive and dead
- Estimated height (in metres) of the general overstorey canopy.

Within the understorey, the following factors were measured and recorded:

- Species,
- Estimated average height (in metres) of each species, and
- Percentage cover of each species (to the nearest 10%). The category of '<10%' was interpreted in this study to be '5%' for the purposes of data analysis.

Photographs from recorded photo-points were taken in 1995 and 1998 to provide a comparative visual measure of vegetation health. The photos from 1998 were not successfully developed and the photos from 1995 have been misplaced. In 2003, photos were taken and the site and direction of the photo was recorded (see Appendix 3).

In 1995 and 1998 photos were taken at the start of each transect. Some of these were replicated by chance in 2003, although these were not originally part of the photo monitoring points. The location of these photos has been recorded as the first point of each transect. Future photographs should try and capture the same image that was originally taken (see Appendix 1). These additional photo monitoring points should be included with current photo monitoring sites.

3 DATA ANALYSIS METHODOLOGY

Initially, the transects were classified into 3 localities: Mt Hampton north (transects 5 & 6), Mt Hampton south (transects 2, 3 & 4) and Mt Bayly (transects B1 & B2). At each locality, data from plots equidistant from the rock were combined to determine average cover (understorey) or the average number of live and dead stems (overstorey). Thus at each locality there were 9, 10 and 6 samples, respectively, each of which was assessed on three occasions (1995, 1998 and 2003).

Using these data, the understorey and overstorey community structures were compared between localities using the generalized discriminant analysis method of Anderson and Robinson (2003). This ordination technique comprises three stages.

First, the similarity between each pair of samples is calculated, using the Bray-Curtis dissimilarity measure. This metric takes values between 0 and 1: at one extreme indicating identical species assemblages (dissimilarity = 0); at the other indicating completely different assemblages with no species in common (dissimilarity = 1).

Second, the resulting matrix of pairwise dissimilarities is used to produce a metric multi-dimensional scaling (principal coordinate) ordination or plot that effectively represents the similarity between samples. In such a plot, similar samples will appear close to each other, and the further the distance between samples, the greater the dissimilarity of the two samples.

Finally, canonical discriminant analysis of the principal coordinate axes is used to test for differences between *a priori* treatment groups. The number of principal coordinates (m) chosen in the second previous step is that which maximizes the discrimination between groups, so that the error rate in classifying a particular sample to its treatment group (the mis-classification rate) is minimized. In this study, the treatments were either the three locations, or the three sampling years. To determine whether the treatments differ, a randomization test is employed to determine the probability that the observed pattern in the canonical discrimination is likely to have arisen by chance alone. In all cases, 9999 randomizations were used in addition the one result obtained from the empirical data.

For each pair of plots in each locality, the proportion of dead to live stems of the dominant overstorey tree, *Allocasuarina huegeliana*, was calculated and localities and sampling years were compared using analysis of variance. Proportions were transformed to arcsine (sqrt) prior to analysis, as is usual for proportion data (Fry 1993).

4 RESULTS

4.1 Comparison of understorey cover at the three localities

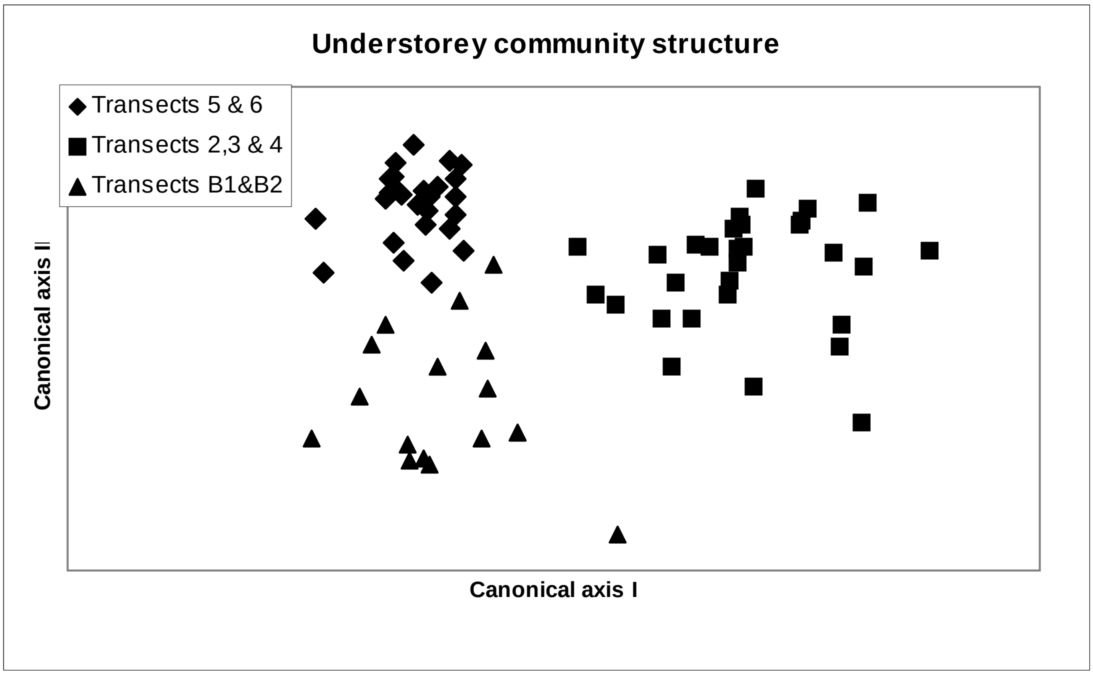


Table 2: Ordination of the multivariate understorey cover data from two locations at Mt Hampton, and one location at Mt Bayly, using generalized canonical analysis. The two Mt Hampton localities comprised transects 5 & 6, and transects 2, 3 & 4; the control site transects were B1 and B2. The cover data were averaged across paired plots within each transect and the Bray-Curtis dissimilarity calculated between all pairs of observations.

Results:

For the canonical procedure, m=8 principal coordinates were calculated, which explained 88.5% of the total variablility of the species cover data. The cross-validation produced a 12% mis-classification rate, and the randomization analysis indicated a highly significant difference ($p<0.0001$) between the three localities. This indicates that the understorey assemblages at each of the three localities are, with very little overlap, different.

The lack of similarity between the understorey assemblages at the two Mt Hampton sites, and between Mt Hampton and the control site, indicate that temporal changes in understorey assemblages are unlikely to provide useful information to assess any changes due to changes in hydrology at the Mt Hampton site. However, changes between years within a locality may still provide information about temporal changes that may be due to the effects of changing hydrology. Thus, the data from transects 5 & 6 were analysed separately to determine if there had been any temporal changes in understorey cover between the three sampling years. No significant difference between the three years were found (p=0.315).

4.2 Comparison of overstorey at the three localities

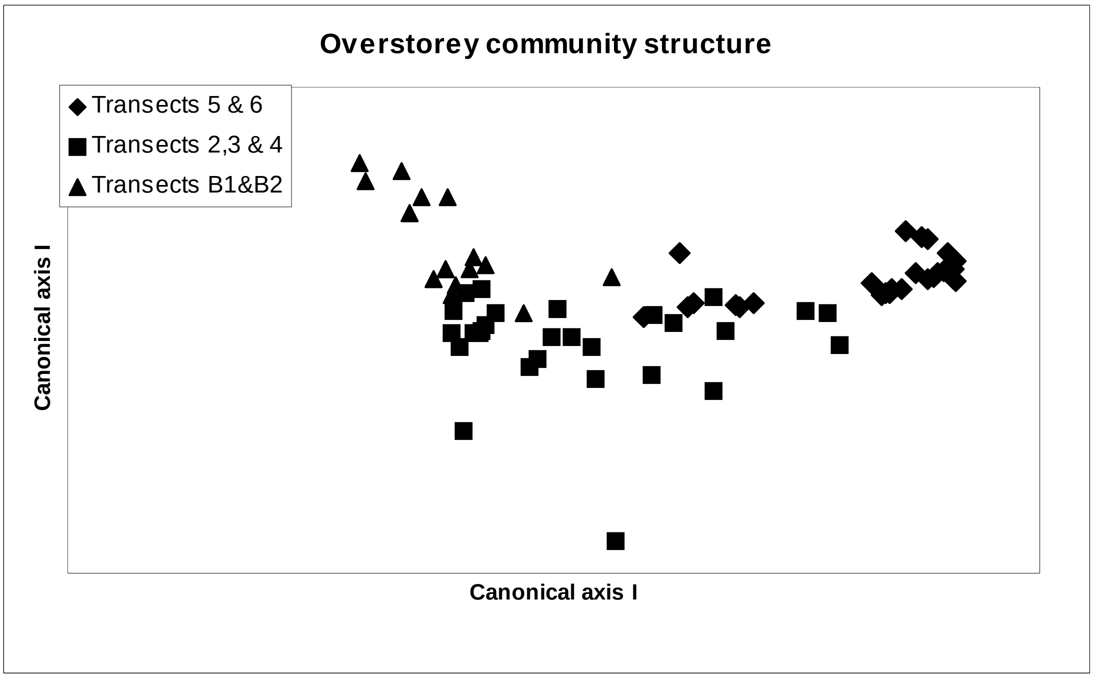


Table 3: Ordination of the multivariate overstorey live and dead stems data from two locations at Mt Hampton and at Mt Bailey using generalized canonical analysis. The two Mt Hampton localities are transects 5 & 6, and transects 2, 3 & 4; the control site transects are B1 and B2. The data were averaged across plots within each transect and the Bray-Curtis dissimilarity calculated between all pairs of observations.

Results:

For the canonical procedure, m=10 principal coordinates were calculated, which explained 98.9% of the total variablility of the species cover data. The cross-validation produced a 21% mis-classification, but the randomization analysis indicated a highly significant difference (p<0.0001) between the three groups. This indicates that the the overstorey assemblages at each of the three localities are, with some overlap, very different. At the Mt Hampton north locality, plots closest to the rock (1-6) were distinctly different to all other plots; however, plots 7, 8 and 9 were similar to the plots on transects 2, 3 and 4. There was also some similarity between the two control site transects and transects 2, 3 and 4, but the overstorey at the control site and Mt Hampton north were very distinct. To assess temporal changes in the Mt Hampton north overstorey, the samples from plots 1-6 were analysed separately to test for differences between the three sampling years. No significant difference between the three years were found (p=0.389).

The lack of similarity between the overstorey assemblages at the two Mt Hampton localities, and between Mt Hampton and the control site, indicate that temporal changes in overstorey assemblages are unlikely to provide information on any changes due to hydrology. Being different, these overstorey communities are unlikely to respond in the same manner to external disturbances. Within the locality (Transect 5 & 6) most likely to be affected by the construction of the dam wall, there was no evidence of any temporal change in the overstorey assemblage.

4.3 Changes in the proportion of dead *A. huegeliana*

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between localities	0.159727	2	0.079864	1.17765	0.313863	3.123901
Within localities	4.882757	72	0.067816			
Total	5.042484	74				

Table 4: One way analysis of variance (ANOVA) of the proportion of dead *A. huegeliana* stems in each locality.

4.4 Changes in the proportion of dead A. huegeliana over the three monitoring years at Mt Hampton locality (Transects 5 & 6)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between years	0.080469	2	0.040235	1.255177	0.303074	3.402832
Within years	0.769318	24	0.032055			
Total	0.849787	26				

Table 5: One way analysis of variance (ANOVA) of the proportion of dead *A. huegeliana* stems in each year at the Mt Hampton locality including Transects 5 & 6.

Results:

There was no evidence of any difference in the proportion of dead *A. huegeliana* stems between the three localities (p=0.314), or between sampling years at the Mt Hampton locality where transects 5&6 occur. (p=0.303).

5 DISCUSSION

5.1: Is there any significant difference in the understorey between the three localities sampled at Mt Hampton and Mt Bayly? (Table 1)

According to statistical analyses outlined in Table 2, there was a distinct lack of similarity between the understorey cover at two Mt. Hampton localities and the Mt Bayly locality.
The vegetation surrounding Mt Hampton varies between the two localities. Transect 5 & 6 are dominated by tall stands of dense *A. huegeliana*.

However the vegetation along Transects 2,3 & 4 is dominated in areas by *Leptospermum* thickets as well as *A. huegeliana* to a lesser degree. The changes in overstorey vegetation between the localities suggests a change in soil type and/or hydrology affecting vegetation. These differences can also affect understorey species and cover which has been identified by the statistical analyses.

There are also changes in overstorey species and cover between Mt Bayly and Mt Hampton. Whilst the vegetation at first appears similar, further inspection reveals that understorey and overstorey communities vary from those found at Mt Hampton. Therefore, the lack of similarity indicated extends between the three localities.

The analyses of the understorey species cover at each locality over the three years surveyed indicated that there was no change. This identifies that the change in hydrology resulting from establishing of the rock wall has no direct effect on the percentage cover of understorey species at each locality.

A factor which may have caused errors in these results is the various seasons in which these vegetation surveys have been conducted. Surveys that were conducted in the drier summer months may have recorded poorer understorey cover than those completed in the wetter winter months. Species such as the rock fern and orchids are more likely to be apparent during the wet season.

Understorey species and percentage cover is generally not a good indicator of changes in hydrology. Many of these plants are annual and rely on winter rainfall to complete their lifecycles. Other factors such as density and type of overstorey species can also influence understorey species composition through allelopathic effects, or through competition for nutrients, light and moisture. The lack of continuity in surveyors as well as timing of surveys can also significantly impact on results.

5.2: Is there any significant difference in the overstorey species diversity?

There is a distinct lack of similarity between the overstorey species diversity at both the Mt Hampton and Mt Bayly localities. As mentioned above, there are differences in the overstorey vegetation across the communities and this may be a result of a variety of factors including changes in soil type, change in hydrology (prior to recent changes for the water catchment) and changes in soil depth.

Analyses carried out on the changes in overstorey diversity at the Mt Hampton locality where Transect 5 &6 occurs (where the water catchment is believed to be having the most impact due to 100% of run off being caught by the rock wall) shows that over the three years that monitoring has taken place there has been no significant difference on vegetation assemblage. Significant changes in overstorey diversity may not become apparent for many years after the disturbance has occurred. Therefore changes in hydrology caused by the water catchment may potentially take decades to have a significant impact on overstorey species diversity.

5.3: Is there any significant change in proportion of dead *A. huegeliana* between the three localities?

According to Tables 3, 4 and 5 there was no change in the proportion of dead *A. huegeliana* between the three localities. This may be because there has not been enough time for any effects to become apparent. Therefore monitoring should continue, in order to identify any long term ecological changes resulting from developing the water catchment.

There were also no changes in the proportion of dead *A. huegeliana* in any of the specific localities over the three monitoring years. However the impacts of any hydrological changes on overstorey species are unlikely to become evident in the short term.

5.4: Limitations to the data

- Sample data for overstorey and understorey vegetation are assumed to be representative of the surrounding vegetation in which the transects were randomly selected. Vegetation sampled at Mt Bayly appears to display a number of characteristics that differentiate it from that at Mt Hampton. These include lower stem densities, association with eucalypt species and a lower percentage of smaller understorey species. These factors may restrict the use to which comparisons between the transects of the two rocks could be put, although Mt Bayly would be useful as a 'regional' control only.

- Monitoring in 1995 and 1998 recorded *Leptospermum roei*, however in 2003 this species was recorded as *Leptospermum nitens*. For the purposes of data analysis, all 1995 and 1998 data have been changed to *Leptospermum nitens* for comparison given that the two species are very similar.
- The current method does not indicate the difference between overstorey and understorey species. Therefore this may account for sampling errors and must be considered in the interpretation of statistical analyses.
- The data in 1995 and 1998 does not consider the cause of death of plants. The data recorded in 2003 has made reference to the probable cause of death of plants due to storm damage. The results in 2003 reflect the difference between drought deaths and death resulting from storm damage.
- The sampling radii of 5m and 2m at each plot is also a point for sampling error and may further reduce the correlation of data.
- The sampling points were sometimes difficult to locate and not all the data collected in 2003 was taken from the exact sampling points in 1995 and 1998. This sampling error needs to be considered when interpreting the statistical analysis. The sampling points were referenced with a GPS location so that they can be relocated in the future. This information will be incorporated in the revised method.
- Species information collected in 1995 and 1998 was not fully identified and some species were recorded as descriptions only. This data has been included in the overall analysis of data for 2003 although obviously there will be some discrepancies. Species descriptions from 1995 and 1998 were matched with data from 2003, however data that did not match was omitted.
- Seasonal variables such as annual rainfall and climate can alter the presence and absence of understorey species such as orchids and *Stypandra* spp.

5.5: Future Monitoring

As outlined in Section 2.4, the proponent made a commitment in the CER (WAWA, 1993) that monitoring would continue for at least four more occasions at three year intervals after this initial 3-year project, up to at least 15 years post-construction. This was in recognition that some changes may only become apparent after a longer period of time, even though there may be some acute impacts that may be expressed within the initial three-year monitoring period. The future formal monitoring years have been identified as 2006 with potential conclusion and review of the programme in 2009.

In spite of the previous report (Roberts, 2001) indicating that there were minor changes in the vegetation, the latest statistical analyses has not drawn any significant conclusions indicating changes in the vegetation at Mt Hampton since the water catchment was installed in 1995.

The lack of continuity and understanding of the project over the three monitoring years already completed has increased error in the data and simplification of the monitoring programme and statistical analyses has been outlined in Appendix 4 to overcome these issues in the future monitoring years.

5.6: Weeds

There were minimal weeds sited around the rock catchment at Mt Hampton. Some cape weed (*Arctotheca calendula*) and wild oats (*Avena* spp.) were noted around the car park area and along the edges of the water catchment channels.

6 CONCLUSION AND RECOMMENDATIONS

No significant change in the overstorey vegetation diversity or mortality, or understorey cover has occurred at Mt Hampton since the pre-construction measurements in 1995. However the impacts of any changes to the local hydrology are unlikely to be evident in the short-term. The lack of any statistically significant change in vegetation health or composition to date probably reflects some limitation in the sampling design, the generally average to above average rainfall experienced in the general area, and the relatively short time since the construction of the dam and rockwall.

The experimental design of this vegetation monitoring project requires further investigation and modification. Some recommendations have been made in Appendix 4.

If similar constructions of rock catchments are planned for other natural rock formations, particularly in the wheatbelt, it is recommended that these be subject to thorough environmental investigation, including the long-term monitoring of impacts.

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APPENDIX 1 - MT HAMPTON GPS POINTS FOR MONITORING TRANSECT

Transect	Monitoring point	Latitude	Longitude
2	1	31 45’44.2”	119 04’ 19.8”
2	2	31 45’50.3”	119 04’ 19.0”
2	3	31 45’44.1”	119 04’ 20.5”
2	4	31 45’44.2”	119 04’ 21.1”
2	5	31 45’44.2”	119 04’ 21.4”
2	6	31 45’44.2”	119 04’ 21.7”
2	7	31 45’44.3”	119 04’ 22.1”
3	1	31 45’47.5”	119 04’ 17.9”
3	2	31 45’47.5”	119 04’ 18.3”
3	3	31 45’47.4”	119 04’ 19.0”
3	4	31 45’44.8”	119 04’ 17.7”
3	5	31 45’47.4”	119 04’ 19.3”
3	6	31 45’47.4”	119 04’ 19.8”
3	7	31 45’47.3”	119 04’ 20.0”
3	8	31 45’47.3”	119 04’ 20.4”
3	9	31 45’47.5”	119 04’ 20.9”
3	10	31 45’47.5”	119 04’ 21.3”
4	1	31 45’50.2”	119 04’ 19.3”
4	2	31 45’50.2”	119 04’ 19.4”
4	3	31 45’50.2”	119 04’ 19.9”
4	4	31 45’50.4”	119 04’ 20.2”
4	5	31 45’50.6”	119 04’ 20.7”
4	6	31 45’50.4”	119 04’ 21.1”
4	7	31 45’50.4”	119 04’ 21.6”
4	8	31 45’50.4”	119 04’ 22.0”
5	1	31 45’28.5”	119 04’ 24.3”
5	2	31 45’28.1”	119 04’ 24.8”
5	3	31 45’27.9”	119 04’ 25.2”
5	4	31 45’27.7”	119 04’ 25.3”
5	5	31 45’27.5”	119 04’ 25.6”
5	6	31 45’27.2”	119 04’ 25.8”
5	7	31 45’27.2”	119 04’ 26.1”
5	8	31 45’26.9”	119 04’ 26.4”
6	1	31 45’30.0”	119 04’24.7”
6	2	31 45’30.0”	119 04’25.2”
6	3	31 45’29.9”	119 04’25.9”
6	4	31 45’29.9”	119 04’26.3”
6	5	31 45’30.0”	119 04’26.8”
6	6	31 45’29.9”	119 04’27.1”
6	7	31 45’29.9”	119 04’27.4”
6	8	31 45’29.9”	119 04’27.8”
6	9	31 45’29.9”	4’28.1”

APPENDIX 2 - MT BAYLEY GPS POINTS FOR MONITORING TRANSECT

Transect	Monitoring point	Latitude	Longitude
B1	1	31 47’15.1”	119 06’45.3”
B1	2	31 47’15.5”	119 06’45.3”
B1	3	31 47’15.8”	119 06’45.3”
B1	4	31 47’16.1”	119 06’45.4”
B1	5	31 47’16.3”	119 06’45.3”
B1	6	31 47’16.7”	119 06’45.4”
B2	1	31 47’16.2”	119 06’50.4”
B2	2	31 47’16.3”	119 06’50.4”
B2	3	31 47’16.6”	119 06’50.4”
B2	4	31 47’17.0”	119 06’50.5”
B2	5	31 47’17.6”	119 06’50.6”
B2	6	31 47’18.1”	119 06’51.1”

APPENDIX 3 - MT HAMPTON PHOTO MONITORING SITES.

Photos taken in October 2003 were with a 38mm lens. Datum: WGS 84

Monitoring point	**Lat**	**Long**	**Direction of photo**	**Subject description**
1	31 45’ 38.8”	119 04’21.4”	East	Near main gate
2	31 45’39.7”	119 04’21.6	North	Same spot as P/P1
3	31 45’38.4”	119 04’20.7”	North	Bitumen catchment
4	31 45’ 34.0”	119 04’20.9”	SE	Looking over dam and bitumen catchment
5	31 45’33.6”	119 04’21.0”	NNE	Fringing vegetation & paddocks
6	31 45’31.4”	119 04’17.7”	NE	Bitumen, fringing vegetation and paddocks
7	31 45’30.8”	119 04’17.8”	East	Fringing vegetation & paddocks
8	31 45’26.6”	119 04’19.6”	East	Fringing vegetation w/out catchment and vegetationn beyond catchment
9	31 45’33.1”	119 04’16.9”	South	Looking across rock
10	31 45’36.3”	119 04’12.1”	SE	Across rock to fringing vegetation and dam
11	31 45’42.3”	119 04’11.2	NE	Looking down at dam and main channel
12	31 45’47.1”	119 04’13.8”	NE	Rock wall and dam
13	31 45’47.8”	119 04’13.9”	SE	Rock and paddocks
14	31 45’49.0”	119 04’18.4”	East	Start of transect 3
15	31 45’42.4”	119 04’17.6”	ENE	Rock wall
16	31 45’47.3”	119 04’17.1”	East	Start of transect 4
17	31 45’49.8”	119 04’18.2”		Fringing vegetation


Monitoring Point 1


Monitoring Point 2

Monitoring Point 3

Monitoring Point 4


Monitoring Point 6


Monitoring Point 7


Monitoring Point 8


Monitoring Point 9


Monitoring Point 10


Monitoring Point 11

Monitoring Point 12

Monitoring Point 13


Monitoring Point 14


Monitoring Point 15


Monitoring Point 16


Monitoring Point 17

APPENDIX 4 - SUGGESTED CHANGES TO METHODOLOGY

- Overstorey height should be defined and estimated by the dominant trees in the overstorey.

- 'Overstorey' to be defined as the most dominant genus. Either *Leptospermum* or *Allocasuarina* should be identified. Other genus such as *Hakea* or *Acacia* are not dominant and will not indicate gross changes in the ecology resulting from changes in the local hydrology.

- The diversity and cover of understorey species are influenced by a number of uncontrolled variables such as rainfall and overstorey cover. Any impact of altered hydrology on the understorey due to the dam and rock wall catchment would be difficult to detect, and therefore the monitoring understorey cover and diversity should be excluded in future.

- A further two transects should be established as a control at Mt Hampton where there is no catchment effect. These transects should be through vegetation that is similar to Transects 5 and 6. Further north and west of Transects 5 and 6 may be an ideal site for establishing these new transects.

- It would be better to mark the exact sampling points so they can be relocated. Whilst each of the sites has been recorded with a GPS location, it would be better to mark each site with a permanent fixture. Some sites have been marked with fence droppers, although where rock is close to the surface, or vegetation is very dense, flagging tape has been used. To relocate the exact sample site during the next monitoring round, a fixture should be spray painted and left at the sampling point i.e. Painted rock or brick.

- Transect 4 only has six sample points because of the lack of vegetation due to the proximity of rock to the ground surface. Monitoring this transect should be discontinued.

- The length of all transects should be altered so that they have the same number of monitoring points. Transects should finish where the vegetation type clearly changes from *Allocasuarina*-*Leptospermum* shrubland to *Acacia*-*Allocasuarina campestris* (Tammar) shrubland.

- Include additional photo monitoring sites as referred to on p.18 under 'Method'.