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SPECIALISTS IN ENVIRONMENTAL, SOCIAL AND SAFETY PERFORMANCE

TREE HEALTH MONITORING BUSSELTON HOSPITAL SITE MARCH 2012

Prepared for:

Department of Treasury and Finance
& Department of Health
c/- 197 St Georges Terrace
Perth WA 6000

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SPECIALISTS IN ENVIRONMENTAL, SOCIAL AND SAFETY PERFORMANCE

25 May 2012

Department of Treasury and Finance
& Department of Health
c/- 197 St Georges Terrace
Perth WA 6000

Attention: Rory Stemp

Dear Rory,

RE: Assessment on the Health of the Trees Located within the Busselton Hospital Site

Please find attached the results of the March 2012 tree health monitoring for the Busselton Hospital redevelopment site (Coffey Environments Report No. EP2012/153, Version 1).

The March 2012 results have been compared with the March 2011 tree health monitoring results to determine whether the trees are improving or declining in health, or maintaining their baseline health results.

The March 2012 tree health results incorporate the results of the summer drought, to provide additional information to supplement the comparison of September 2010 and September 2011 data.

Should you have any queries please do not hesitate to contact myself or Martine Scheltema on (08) 9355-7100.

For and on behalf of Coffey Environments Australia Pty Ltd

Rachael Pratt
Senior Environmental Consultant

Attachment A: Coffey Environments Report No. EP2012/153 V1

Project director	Martine Scheltema		
Project manager	Rachael Pratt		
Version:	**Details:**	**Approved:**	**Date:**
EP00629DD_001_v1	Initial draft to client	M. Scheltema	May 2012
EP00629DD_001_v2	Final to client	M. Scheltema	July 2012

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ABBREVIATIONS

BOM	Bureau of Meteorology
CCD	Charge-Coupled Device
DBH	Diameter at Breast Height
DMSI	Digital Multi Spectral Imagery
EPA	Environmental Protection Agency
ha	Hectares
IPM	Integrated Pest Management
m	metre
mm	millimetre
nm	nanometre
PCD	Plant Cell Density
WRP	Western Ringtail Possum

1. INTRODUCTION

1.1 Background

The Western Australian Department of Health (DoH) is proposing to redevelop the existing Busselton Hospital site to accommodate the expansion of Busselton and the greater Busselton area (i.e. Dunsborough).

The Busselton Hospital site is 12.3 hectares (ha) of which a large proportion is open Peppermint (*Agonis flexuosa*) woodland, with relatively little understorey. The site is located in the core habitat of the Western Ringtail Possum (WRP) (*Pseudocheirus occidentalis*), which is listed as a threatened species under both State and Federal environmental legislation.

The redevelopment of the existing Busselton Hospital site will impact on the existing Peppermints located within the site. The DoH intends to minimise the impact on the Peppermints and WRP.

Coffey Environments was commissioned to undertake a tree health assessment of the site and to provide advice regarding the WRP habitat and possible linkage corridors to other areas of WRP habitat. Advice on WRP habitat and linkage corridors was provided in Coffey Environments (2011a) and tree health assessments were undertaken in September/October 2010, March 2011, September/October 2011 (Coffey Environments 2011a and 2011b) and March 2012. These results constitute baseline information for the site after the winter (high rainfall) period of September and the after summer (low rainfall or drought) period of March.

To assist with the tree health assessment, Coffey Environments commissioned SpecTerra Services to provide Digital Multi-Spectral Imagery (DMSI) of the Busselton Hospital site and the immediate surrounds. The DMSI is used to monitor changes in vegetation condition using light band wave-lengths.

This report details the results of the March 2012 tree health monitoring. The results from the March 2012 monitoring period will be compared to previous tree health monitoring conducted in March 2011 to determine if the trees are improving or declining in health prior to the redevelopment of the site.

1.2 Scope of Works

The scope of works for the tree health assessment addressed in this report includes:

- March 2012 survey of tree health monitoring using digital aerial imaging (DMSI).
- March 2012 survey of tree health using on-ground surveys.
- Comparison between the September/October 2010, March 2011, September/October 2011 and March 2012 results.
- Provide updates (as appropriate) to recommendations made in previous reports.

1.3 Previous Assessments

A number of technical assessments have been conducted for the Busselton Hospital site, that are directly relevant to this report including:

- A technical evaluation of sites for the Busselton Hospital redevelopment (SKM, 2006).

- An assessment of tree canopy cover (SurvCon Pty Ltd – unpublished data).
- Tree Health and Western Ringtail Possum Habitat Assessment, Busselton Hospital Site March 2011 (Coffey Environments, 2011a).
- Tree Health Monitoring Busselton Hospital Site September 2011/October 2011 (Coffey Environments 2011b)
- A significant fauna and flora values report (Coffey Environments, 2009).
- Targeted Western Ringtail Possum surveys in November 2009, February 2010, December 2010, March 2011, November 2011 and March 2012 (Correspondence dated 20 November 2009, 10 February 2010, 11 January 2011, 14 March 2011, 17 November 2011 and 8 March 2012 respectively).

2. BACKGROUND INFORMATION

2.1 Location and Land Use

The site is located at 203 Bussell Hwy, West Busselton (Figure 1). Busselton is located approximately 200 km south-west of the Perth Central Business District. The Busselton site is bounded by Bussell Highway to the south, Craig Street and private properties to the west, Mill Road to the east and a Foreshore Reserve and Geographe Bay to the north (Figure 2).

Currently the site supports the existing Busselton Hospital and associated infrastructure, the St Johns Ambulance depot and the Kevin Cullen Community Health Centre. The site also supports remnant native vegetation located around the perimeter of the site. The native vegetation is described as open woodland of *Agonis flexuosa* (Peppermint) with a disturbed understorey (SKM, 2006).

2.2 Climate

The climate of the Busselton Region is described as a Mediterranean climate with warm, dry summers and cool, wet winters (Beard, 1990). A Bureau of Meteorology (BOM) weather station was located on the Busselton Hospital Site (Weather Station 09569) but has recently been closed. This weather station was operational from 1998 to November 2011, collecting both temperature and rainfall data. A second BOM weather station (No. 09515) was included as a comparison for longer-term regional data. This weather station is located approximately 2.5 km east-southeast from the site near the Shire Offices has been operational since 1877 so provides a suitable long-term comparison to the Busselton Hospital site, however, the station ceased collecting temperature data in 1975. Station 09603 (Busselton Aerodrome) was opened in 1997 and is the only current source of temperature data near the site.

The site receives the majority of its rainfall during the winter months of June, July and August (BOM, 2011) with an annual total between 690mm (Station 09569) and 809 mm (Station 09515). During the hottest three months (January, February and March) of the year the temperature ranges from a minimum of 14.7℃ to a maximum of 28. 5℃. During the coldest three months (June, July and August) of the year the temperature ranges from a minimum of 8.3℃ to a maximum of 17.6℃ (Station 09569; BOM, 2011).

2.3 Vegetation

The Busselton Hospital Site is located within the Geographe Bay Quindalup Dune Plant Community of the Quindalup Dunes Vegetation Complex (Webb et al., 2009). Around 987 ha of the Quindalup Dunes remains vegetated on the Busselton Plain, however, this includes vegetation considered to be Degraded and Completely Degraded. It is estimated that potentially only 20% of the Quindalup Dune vegetation within the Busselton Plain is in Good or better condition.

Currently, there is greater than 30% of the Quindalup Dunes Vegetation Complex remaining on the Busselton Plain, however, as stated above only 20% is considered to be in Good or better condition. Within the Shire of Busselton, approximately 25% of the pre-European extent of the Quindalup Dunes Vegetation Complex remains vegetated (Molloy et al., 2007).

The vegetation is representative of the Geographe Bay Quindalup Dune Plant Community is considered to be regionally significant as it does not meet the minimum nationally recommended levels of retention (30% extent remaining of pre-European vegetation complexes) (EPA, 2006). The National Objectives and Targets for Biodiversity Conservation 2001-2005 recognises that a retention of 30% or more of the pre-clearing extent of each ecological community is necessary if Australia's biological diversity is to be protected (ANZECC, 2000). The EPA has adopted this level of retention within Position Statement No. 2 (EPA, 2000) and Guidance Statement No. 10 (EPA, 2006).

The hospital site supports remnant native vegetation, namely, low woodland of Peppermint (*Agonis flexuosa*) over Coastal Sword-sedge (*Lepidosperma gladiatum*) in the north of the site adjacent to the coast and introduced grasses in the south of the site.

Based on Coffey Environments' site visit, the condition of the vegetation was considered to be Good to Degraded based on the vegetation condition rating scale developed by Keighery (1994) and published within the Bush Forever Strategy (Government of Western Australia, 2000). The condition of the vegetation was considered to be Good to Degraded because of the lack of native understorey species over the majority of the site, the high prevalence of introduced flora species and the presence of several informal vehicle tracks. Keighery's condition rating scale ranges from Pristine (where the vegetation exhibits no visible signs of disturbance) to Completely Degraded (where the vegetation structure is no longer intact and without native plant species). Table 1 below provides a description of each of the vegetation condition rating scales.

Table 1 Vegetation condition rating scale

Rating	Description
Pristine	Pristine or nearly so, no obvious signs of disturbance.
Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are nonaggressive species.
Very Good	Vegetation structure altered obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.
Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often referred to as parkland cleared with the flora composing weed or crop species with isolated native trees or shrubs.

Source – Government of Western Australia (2000)

2.4 Digital Multi-Spectral Imagery

SpecTerra Services provide airborne remote sensing imagery for vegetation mapping and monitoring projects. SpecTerra were commissioned to provide a Digital Multi-Spectral Imagery (DMSI) of the hospital site and surrounds to provide accurate imagery of the health of the vegetation. The initial fly-over is considered to be baseline and further subsequent flights will allow comparisons to be made between the fly-overs. SpecTerra refer to this as 'change detection'. The technique can be used to determine whether the vegetation is improving or declining based on Plant Cell Density (PCD) values (Infrared Reflectance / Red Reflectance).

The PCD is sensitive to the quantity of leaves in each pixel (sample) and the density of healthy plant cells in those leaves. The Red band (675 nm) is positioned at maximum absorption by leaf chlorophyll content and the Infrared band where the leaf structure of healthy plants strongly reflects incoming energy.

3. METHODOLOGY

3.1 On-Ground Tree Health Assessment

Methodology selected to undertake the on-ground assessment of tree health was designed to ensure accurate, science based information was collected that could be compared statistically with itself and with additional sites located in the greater Busselton region.

The following documents were reviewed to assist with the development of the methodology to assess the health of the trees located within the site.

- Schomaker et al. (2007) Crown-Condition Classification: A Guide to Data Collection and Analysis.
- McDonald et al. (1990) Australian Soil and Land Survey: Field Handbook (Second Edition).
- Coffey Environments (2010) Tree Health Monitoring, Provence Public Open Space, October 2009 Monitoring Period.

The methodology involved the establishment of four transects of 100 m in length (Figure 3) and the tagging of 152 individual trees within the site (112 in September 2010 and a further 40 in March 2011). Every tree along the transect 5 m either side of the transect centreline was also tagged. This equated to a total of 290 trees tagged throughout the site (Figure 4; Appendix A). The tags were attached with wire loosely wound around the tree in a way which would not hinder future growth and girth expansion of the tree.

Previous tree health monitoring surveys were undertaken on 21 to 22 September 2010, 24 to 25 March 2011 and 21 to 22 September 2011. These results constitute baseline information for the after winter (high rainfall) period of September and the after summer (low rainfall or drought) period of March. The March 2012 tree health survey was undertaken on 22 and 23 March 2012 which is approximately the same time as the March 2011 survey.

The four transects were established within areas of dense canopy growth in the north of the site and the south-west corner. Posts were left in the ground at 10m intervals with photos taken from each post. Photos were taken from the north side of every individual tree, where practicable. These photos may or may not be used in determining the health of the tagged trees. The following information was collected from each tagged tree within the site:

- **Estimated height** – The height of each tagged tree was estimated visually to the nearest half metre (i.e. the nearest 0.5 m).
- **Number of trunks** – The number of trunks originating from the base of the tree was counted. This value can be fairly arbitrary with the possibility of two or more trees being considered to be one tree.
- **Crown Position** – The position of the crown was estimated based on the height of the tree and is considered to be a function of the individual live crown in relation to the surrounding overstorey. Tree height between 2.5m and 7m was considered to have a Lower Crown Position; tree height between 7.5m and 8.5m was considered to have a Middle Crown Position; and tree height exceeding 9m was considered to have an Upper Crown Position.

- **Diameter at Breast Height (DBH)** – A DBH tape was passed around the trunk of the tree with the value recorded. In the instance of a tree having several trunks, the trunk the tag has been attached to was sampled.
- **Vigour** – A visual assessment of the crown vigour of individual trees classified into three categories. Vigour Class 1 are trees that are considered to have a healthy percentage of live canopy, generally >35% and Vigour Class 3 are trees that are considered to have a very poor-degraded percentage of live canopy, generally <20%. Vigour Class 2 are trees that are considered to be somewhere between healthy and unhealthy, generally having >20% or <35% of live crown. The Vigour Class ratings ranged from 1 (for a healthy tree) through to 3 (for unhealthy, dying or dead trees) with a rating of 1.5 or 2.5 used for trees considered to be in between either 1 and 2 or 2 and 3.
- **Crown Density** – Is an estimate of the proportion of the crown volume that contains biomass (i.e. green foliage, branches and reproductive structures) compared to if the entire canopy was well vegetated (i.e. 100%). Crown density is recorded as a percentage.
- **Foliage Transparency** – Is an estimate of the absence of foliage where foliage would normally occur. Foliage transparency is directly related to Crown Density. Foliage Transparency is recorded as a percentage.
- **Crown Dieback** – Is a measure of the proportion of the crown that has experienced recent dieback from branchlets and canopy branches. Crown Dieback has been recorded into one of seven categories based on a percentage of crown dieback. The categories are:
  - 0-5% = Category 1;
  - 6-10% = Category 2;
  - 11-20% = Category 3;
  - 21-40% = Category 4;
  - 41-60% = Category 5;
  - 61-80% = Category 6;
  - 81-100% = Category 7;
- **General Tree Observations** – The following observations of each tagged tree were also recorded. These observations do not generally suggest a tree is in decline.
  - **Insect Damag**e – Notes were taken from each tagged tree on obvious signs of insect damage (i.e. damage from borers). Generally trees are able to cope with some form of insect activity and trees provide a niche for many insect species (i.e. spiders etc).
  - **Pathogens** – Notes were taken from each tagged tree if obvious signs of pathogens were evident (i.e., cankers, fruiting bodies).
  - **Epicormic Growth** – Notes were taken from each tagged tree if epicormic growth was seen. Epicormic growth is a response to stress (i.e., fire) and new shoots are produced from epicormic buds.
  - **Flowering and/or Fruiting** – Notes were taken from each tagged tree if the tree was flowering or had new fruits.
  - **Presence of Possums or Dreys** – Notes were taken from each tagged tree if a possum was sighted in the tree (asleep in the tree during the day) or a possum drey was recorded from the tree.

3.2 Digital Multi-Spectral Imagery

SpecTerra have completed four flights over the Busselton Hospital site to capture the Plant Cell Density (PCD) of the trees located within the site. The flight details are provided below in Table 2. The imageries were taken at four band lengths ranging from Blue (450 nm) to Near Infra-red (780 nm) with additional Green (550 nm) and Red (675 nm) Band lengths.

Table 2 SpecTerra Flight Details for the Busselton Hospital Site

Flight Date	Camera	Focal Length (mm)	Charge-Coupled Device (CCD) Array Size	Acquisition Resolution (m)
1 October 2010	HiRAMs07-01	28.00	2048 x 2048	0.25
14 March 2011	HiRAMs0803	28.00	2048 x 2048	0.25
21 October 2011	HiRAMS0803	28.00	2048 x 2048	0.25
23 March 2012	HiRAMS-SR1101	12.50	2452 x 2056	0.25

The imagery provided by SpecTerra, with the True and False colour imageries, for the March 2012 fly-over is provided in Appendix B. The imagery for the March 2011 fly-over is provided in Appendix C.

SpecTerra compared the PCD values between the October 2010 flight and the March 2011 flight with the results reported in Coffey Environments 2011a and between the October 2010 flight and the October 2011 flight as reported in Coffey Environments 2011b to determine whether there was a notable PCD change between the periods.

The March 2011 and March 2012 PCDs will be compared to provide meaningful ‘change detection’ between two comparative seasons.

4. RESULTS

The March 2012 data collected from the 138 tagged trees located along the four transects and the 152 individually tagged trees is provided in Appendices D1 to D5. The March 2011 data is provided in Appendices E1 to E5.

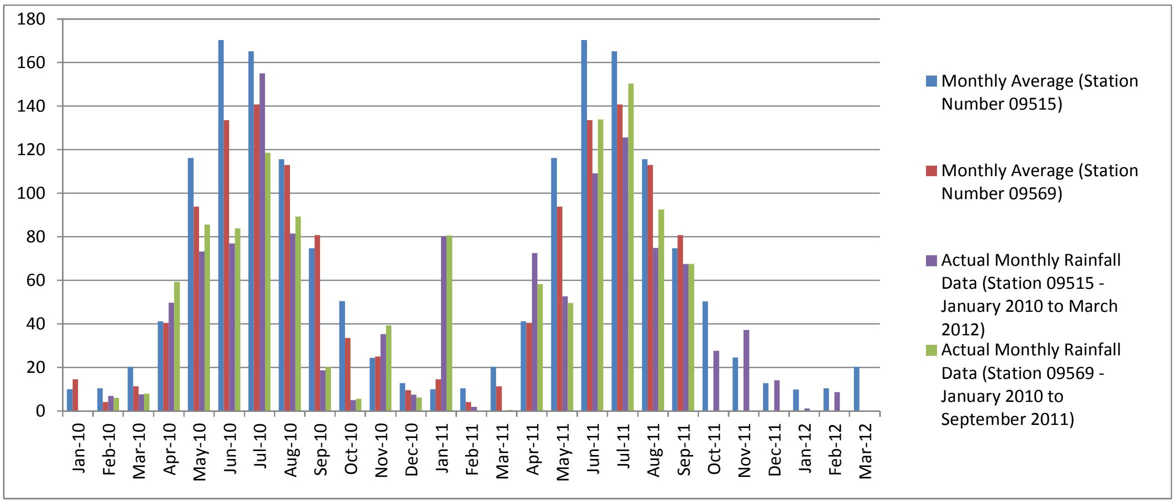
4.1 Climate

Data from Station 09515 indicates that the summer of 2011-2012 was substantially drier in January than the summer of 2010-2011, which received unusually high rainfall in two events (totalling ~70 mm) roughly a fortnight apart. By contrast, December 2011 and February 2012 were wetter than in 2010-2011. The summer of 2011-2012 was slightly drier than the long term average (Table 3).

Table 3 Summary of rainfall information at weather stations near the site

	Station 09596 Busselton Hospital Site	**Station 09515 City of Busselton**	**Station 09603 Busselton Aerodrome**
Winter 2010	Drier than average	Drier than average	Drier than average
Summer 2010-2011	Wetter than average	Wetter than average	Wetter than average
Winter 2011	Near average	Drier than average	Drier than average
Summer 2011-2012	Decommissioned	Slightly drier than average	Slightly drier than average

Chart 1 provides a visual breakdown of the rainfall received from the beginning of 2010 to March 2012 for Station 09515 compared to the long-term average.

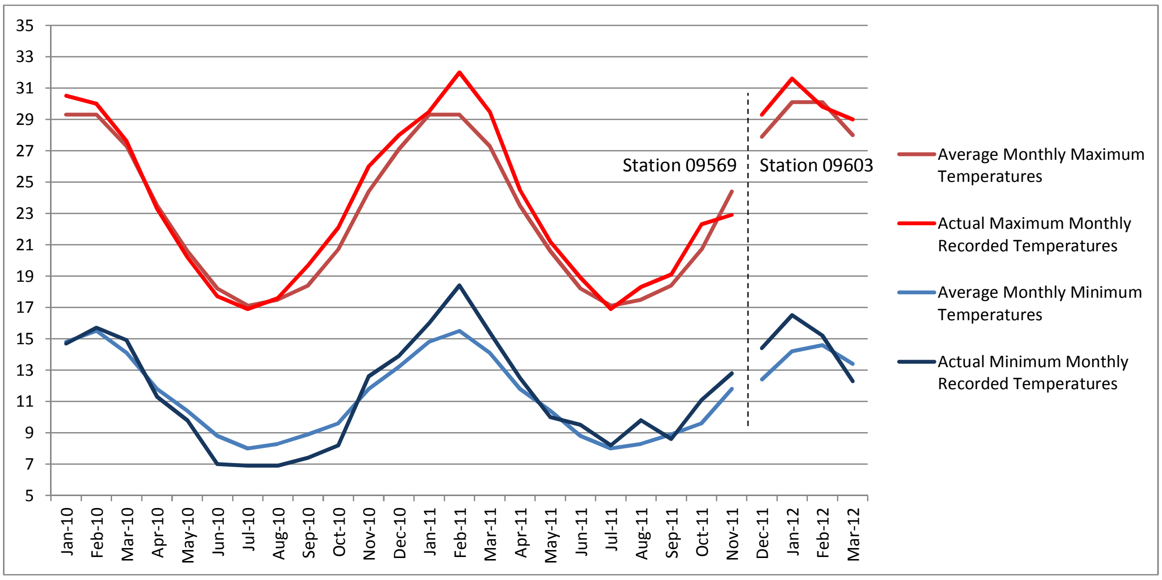


Source – Publicly available data from the BOM website (BOM, 2012)

Chart 1 Comparison between monthly average and monthly rainfall total at Weather Stations 09515 and 09569 from January 2010 to February 2012

The mean monthly summer temperatures were higher than the long term average at Busselton Aerodrome (Station 09603) (BOM, 2012) during both the summer preceding the March 2011 survey and the summer preceding the March 2012 survey.

Chart 2 shows the average monthly temperatures compared with the mean monthly temperatures recorded from January 2010 to March 2012, displaying data from both the Busselton Hospital site and the Busselton Aerodrome (from December 2012 onwards).



Source – Publicly available data from the BOM website (BOM, 2012)

Chart 2 Monthly Temperatures from January 2010 to November 2011 for Station 09659 and December 2011 to March 2011 from Station 09603

The weather during the two days spent on site in March 2012 was fine and warm with minimal cloud cover and temperatures in the high twenties (BOM, 2012).

4.2 Tree Species

Agonis flexuosa, *Melaleuca* sp. and *Eucalyptus* sp., were recorded and tagged from within the hospital site. Only one *Eucalyptus* sp. and two *Melaleuca* sp. were tagged, the remaining 287 trees tagged were *Agonis flexuosa*. The Eucalyptus and Melaleuca species are cultivars (i.e. nursery or horticulture varieties) that have either been planted or have escaped from nearby areas.

All tree species 5m either side of the transect centreline were tagged. Only Peppermint trees were tagged for the individual trees over the site due to importance of Peppermint as a habitat for the Western Ringtail Possum. Peppermint trees comprise greater than 90% of the 4.092 ha of canopy tree cover recorded from the site (SurvCon Pty Ltd – unpublished data).

4.3 Vigour

The average vigour of each of the tagged trees during the March 2012 assessment was 1.80 (Table 4), indicating the trees generally had a reduced crown density with some crown dieback. The average vigour of the tagged trees in March 2012 was worse than that in September 2011, March 2011 and September 2010 when it was 1.47 to 1.72 (Table 4).

The average vigour of each of the tagged trees during the September 2010 assessment was considered to be fairly high with the overall average of every tagged tree at 1.47.

The September 2011 average vigour level of all the tagged trees was less than the March 2011 values which is considered to measure plant vigour after the summer drought, suggesting the trees had improved in health since March 2011 following winter rains.

The average vigour of each of the tagged trees during the March 2011 assessment was 1.57, which indicates that the trees generally have a greater than 30% crown density with minimal crown dieback.

Table 4 Average combined Vigour Class

Survey	**Average Combined Vigour Class**
September 2010[1]	1.47
March 2011[1]	1.72
September 2011[1]	1.57
March 2012	1.8

1. Source: Coffey Environments (2011a and 2011b).

Table 5 provides a breakdown of the average vigour ratings for trees from Transects 1, 2, 3 and 4 and from the individually tagged trees between the September 2010 assessment and the September 2011 assessment. As the table shows, there is a significant decrease in vigour between the two assessment periods for all four transects and the individually tagged trees.

Tables 6 compares the average vigour class ratings for the March 2011 and March 2012 assessments and the frequency of each vigour class across the two assessment periods. March 2011 results are considered to represent the summer drought baseline results. As indicated in Table 6, there is a decrease in vigour between the March 2011 and March 2012 assessments in all transects and also in the individual trees.

Table 5 Average Vigour Class recorded from the September 2010 and September 2011 assessment

	Average Vigour Class		Number of Trees											
			Vigour Class 1		Vigour Class 1.5		Vigour Class 2		Vigour Class 2.5		Vigour Class 3		Total Tagged Trees	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Transect 1	1.60	1.92	20	8	18	15	9	18	2	6	6	8	55	55
Transect 2	1.55	1.89	9	2	12	9	9	15	0	4	1	1	31	31
Transect 3	1.57	1.85	8	4	14	8	1	9	1	3	3	3	27	27
Transect 4	1.60	1.92	9	2	8	9	4	8	2	3	2	3	25	25
Individual	1.34	1.55	65	37	27	74	13	33	5	5	2	3	112	152
Combined	1.47	1.72	111	53	79	115	36	83	10	21	14	18	250	290

Table 6 Average Vigour Class recorded from the March 2011 and March 2012 assessment

	Average Vigour Class		Number of Trees											
			Vigour Class 1		Vigour Class 1.5		Vigour Class 2		Vigour Class 2.5		Vigour Class 3		Total Tagged Trees	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Transect 1	1.70	2.03	14	5	17	12	12	21	6	9	6	8	55	55
Transect 2	1.64	2.02	6	0	14	10	8	11	2	9	1	1	31	31
Transect 3	1.67	1.87	7	3	9	9	5	9	3	4	3	2	27	27
Transect 4	1.84	2.00	2	2	10	7	9	8	1	5	3	3	25	25
Individual	1.45	1.63	56	26	62	78	25	34	5	11	4	3	152	152
Combined	1.57	1.80	85	36	112	116	59	83	17	38	17	17	290	290

4.4 Crown Density and Foliage Transparency

In the March 2012 monitoring, Crown Density across all transects had declined from the March 2011 results by an average of 2%. A slight improvement was seen in Transect 4 since September 2011, with the average Crown Density rising from 23.80% as reported in Coffey Environments 2011a to 24.00% in March 2012, however, this may fall within normal observational variance ranges. Overall, Crown Density had decreased by an average of approximately 4% between September 2010 and March 2012 as shown in Table 7.

Table 7 Average Crown Density and Foliage Transparency

Survey	Average Crown Density	Average Foliage Transparency
September 2010[1]	30.11%	69.93%
March 2011[1]	27.97%	72.03%
September 2011[1]	26.44%	73.58%
March 2012	25.94%	74.06%

1. Source: Coffey Environments (2011a and 2011b).

The Foliage Transparencies observed in March 2012 had also worsened, with a corresponding average increase of approximately 4% compared to March 2011.

Foliage Transparency is the opposite of Crown Density and as a result is the value of 100% minus Crown Density. During the March 2011 assessment the average Foliage Transparency ranged from approximately 70% for Transect 2 to 75% for Transect 4. The combined average Foliage Transparency was approximately 72%, which is approximately 2% higher than the September 2010 assessment.

In March 2012, the average Foliage Transparency ranged from approximately 73% for Individual Trees to 76% for Transect 4. The combined average Foliage Transparency was approximately 74%, which is approximately 2% higher than the March 2011 assessment. Foliage Transparency values ranged from 100% (for dead trees with no live vegetative material; Tree No. 043, 045, 057, 116 and 123) to 30% (Tree No. 036).

Crown Density and Foliage Transparency recorded in the March 2012 and March 2011 tree health assessment is provided in Table 8.

Table 8 Comparison of average Crown Density and average Foliage Transparency values for the March 2011 and the March 2012 Assessments

	Average Crown Density (%)		Crown Density Range (%)		Average Foliage Transparency (%)		Foliage Transparency Range (%)	
	2011	2012	2011	2012	2011	2012	2011	2012
Transect 1	29.09	25.36	0 – 70	0 – 70	70.91	74.64	30 – 100	30 – 100
Transect 2	30.16	26.29	0 – 45	0 – 40	69.84	73.71	55 – 100	60 – 100
Transect 3	25.74	25.22	10 – 45	1 – 45	74.26	74.78	55 – 90	55 – 99
Transect 4	25.40	24.00	0 – 45	0 – 50	74.60	76.00	55 – 100	50 – 100
Individual	27.94	26.53	10 – 50	8 – 45	72.06	73.47	50 – 90	55 – 92
Combined	27.97	25.94	0 – 70	0 – 70	72.03	74.06	30 – 100	30 – 100

4.5 Crown Dieback

All of the tagged trees showed signs of crown dieback with either the small outer branchlets dead or larger branches or limbs dead. Crown dieback is common in naturally occurring bushland and can be a result of insect or fungal attack or a deficiency in water, nutrients or trace elements in the soil or the limb may just be old. In general trees can cope with crown dieback at a small scale; however, crown dieback coupled with other environmental factors (i.e. drought) can cause detrimental effects on the tree, with the loss of large limbs or the entire tree itself.

Greater crown dieback is normal during the summer monitoring as observed during March 2011, however, crown dieback had increased substantially between the March 2011 assessment and the March 2012 assessment (Chart 3 and Table 10). In March 2011, 40% of the 290 tagged trees were considered to be within category 1 (the healthiest category). In March 2012, this had decreased to 21%, with an accompanying increase in trees in higher categories. An additional 10 trees were assessed as being in Categories 5 to 7 since the March 2011 assessment.

In March 2012, approximately 8% of the tagged trees have greater than 41% of crown dieback (Categories 5, 6 and 7), while 72% of the tagged trees have crown dieback between 6 and 40% (Categories 2, 3 and 4). Ten trees (Tag No. 006, 043, 044, 045, 047, 055, 057, 108, 123 and 267) had a crown dieback category of 7; therefore, the trees are under severe stress. Tables 9 and 10 show the comparisons between crown dieback categories across the four transects and the 112 individual tagged trees between September 2010-September 2011 and March 2011-March 2012 respectively. A visual presentation of Crown Dieback Category frequencies is presented in Chart 3.

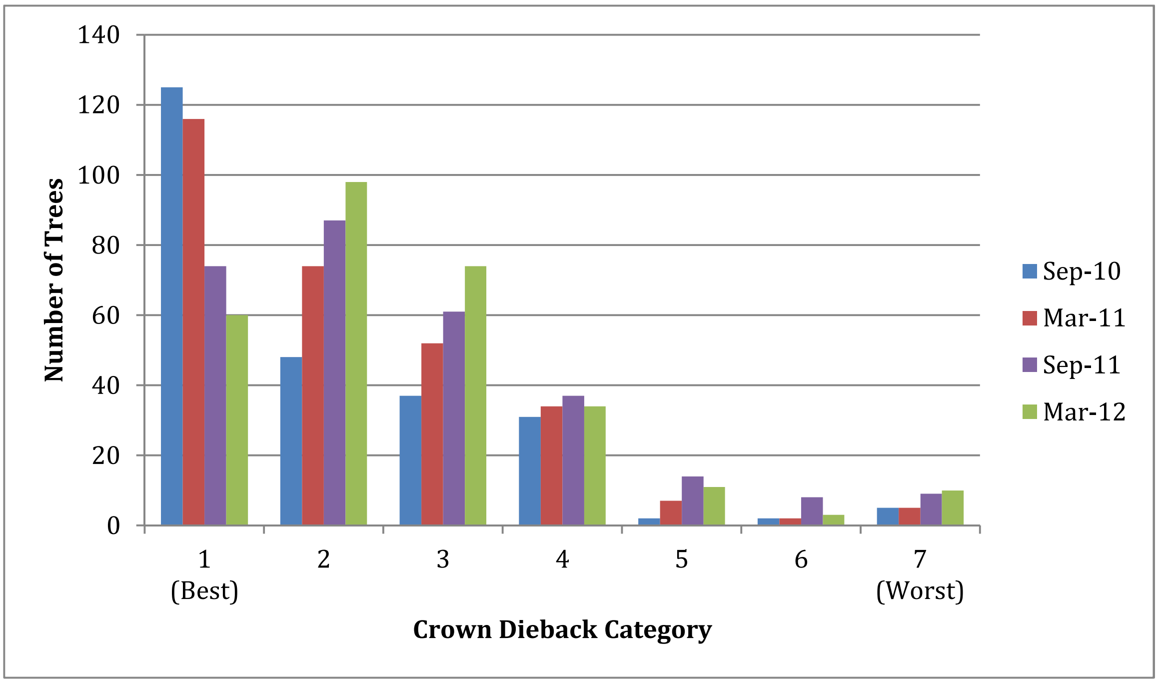


Chart 3 Comparison of Crown Dieback from September 2010 to March 2012

Table 9 Crown Dieback Categories recorded from the site between the September 2010 and September 2011 sampling periods

Crown Dieback	No. of Trees											
	Transect 1		Transect 2		Transect 3		Transect 4		Individual		Combined	
Category	2010 (%)	2011 (%)	2010 (%)	2011 (%)	2010 (%)	2011 (%)	2010 (%)	2011 (%)	2010 (%)	2011 (%)	2010 (%)	2011 (%)
1 (0-5%)	21 (38)	10 (18)	14 (45)	1 (3)	14 (52)	5 (19)	14 (56)	4 (16)	62 (55)	54 (36)	125 (50)	74 (26)
2 (6-10%)	12 (22)	9 (16)	4 (13)	11 (35)	4 (15)	12 (44)	4 (16)	8 (32)	24 (21)	47 (31)	48 (19)	87 (30)
3 (11-20%)	10 (18)	14 (25)	6 (19)	6 (19)	5 (19)	2 (7)	2 (8)	1 (4)	14 (13)	38 (25)	37 (15)	61 (21)
4 (21-40%)	8 (15)	7 (13)	6 (19)	11 (35)	4 (15)	4 (15)	2 (8)	8 (32)	11 (10)	7 (5)	31 (12)	37 (13)
5 (41-60%)	0 (0)	5 (9)	0 (0)	0 (0)	0 (0)	3 (11)	1 (4)	1 (4)	1 (1)	5 (3)	2 (1)	14 (5)
6 (61-80%)	1 (2)	4 (7)	0 (0)	2 (6)	0 (0)	0 (0)	1 (4)	2 (8)	0 (0)	0 (0)	2 (1)	8 (3)
7 (81-100%)	3 (5)	6 (11)	1 (3)	0 (0)	0 (0)	1 (4)	1 (4)	1 (4)	0 (0)	1 (1)	5 (2)	9 (3)

Table 10 Crown Dieback Categories recorded from the site between the March 2011 and March 2012 sampling periods

Crown Dieback	No. of Trees											
	Transect 1		Transect 2		Transect 3		Transect 4		Individual		Combined	
Category	2011 (%)	2012 (%)	2011 (%)	2012 (%)	2011 (%)	2012 (%)	2011 (%)	2012 (%)	2011 (%)	2012 (%)	2011 (%)	2012 (%)
1 (0-5%)	16 (29)	8 (15)	7 (23)	0 (0)	11 (41)	4 (15)	7 (28)	4 (16)	75 (49)	44 (29)	116 (40)	60 (21)
2 (6-10%)	9 (16)	15 (27)	8 (26)	11 (35)	6 (22)	13 (48)	6 (24)	6 (24)	45 (30)	53 (35)	74 (26)	98 (34)
3 (11-20%)	15 (27)	11 (20)	9 (29)	8 (26)	5 (19)	5 (19)	8 (32)	10 (40)	15 (10)	40 (26)	52 (18)	74 (26)
4 (21-40%)	9 (16)	12 (22)	6 (19)	9 (29)	4 (15)	2 (7)	3 (12)	3 (12)	12 (8)	8 (5)	34 (12)	34 (12)
5 (41-60%)	2 (4)	2 (4)	0 (0)	2 (6)	1 (4)	2 (7)	0 (0)	0 (0)	4 (3)	5 (3)	7 (2)	11 (4)
6 (61-80%)	1 (2)	1 (2)	0 (0)	0 (0)	0 (0)	0 (0)	1 (4)	1 (4)	0 (0)	1 (1)	2 (1)	3 (1)
7 (81-100%)	3 (5)	6 (11)	1 (1)	1 (3)	0 (0)	1 (4)	0 (0)	1 (4)	1 (1)	1 (1)	5 (2)	10 (3)

4.6 General Tree Observations

4.6.1 Insect Damage

During the March 2012 assessment 64 tagged trees (22%) showed evidence of insect borers and 11 tagged trees (4%) showed evidence of termites. A further 20 tagged trees (7%) showed other signs of insect damage that are causing stress that were not attributed to borers or termites.

The vast majority of the tagged trees showed signs of insect attack; however, this is common in naturally occurring bushland. The assessment concentrated on termites and a larger boring insect which were present at the site. Insect attacks at the site have not altered substantially from previous observations as shown in Table 11.

Table 11 Trees displaying evidence of insect attack

Survey	Borers	Termites
September 2010[1]	24%	1%
March 2011[1]	16%	6%
September 2011[1]	18%	8%
March 2012	22%	4%

1. Source: Coffey Environments (2011a and 2011b).

Borers interrupt the phloem (organic nutrient transporting system) and xylem (water transporting system) passages of the tree. Disruption to these systems can have detrimental effects to the tree.

The bore holes are approximately 2 to 4 cm in length and 0.5 to 1 cm wide. The species creating them was not determined as it would involve cutting into the tree to extract specimens. Borers can include beetles, wood moths, weevils and termites but are mostly beetles and their larvae. Images of the bore holes seen are presented in Coffey Environments 2011a.

Termites can disrupt the structural integrity of branches and limbs which makes them more susceptible to breaking off during strong winds, storms or when they cannot support their own weight. The species of termite was not determined and it is not known whether they are a species of environmental significance.

4.6.2 Pathogen Damage

None of the trees previously identified as infected during previous tree health assessments in September 2010, March 2011 and September 2011 presented any evidence of pathogen infection in March 2012.

4.6.3 Tree Deaths

In March 2012, one additional tree had died since September 2011; this was the tree labelled with Tag No. 123 and is the only new death since observations began at the site in September 2010. Approximately 17 trees were recorded as being very unhealthy with crown densities below 10% and a high percentage of crown dieback (i.e. greater than 40%), compared with 14 recorded as very unhealthy in September 2011.

4.6.4 Epicormic Growth

In March 2012, 49 of the 290 tagged trees showed epicormic growth (17%) compared with 83 trees (29%) in March 2011. There has been a continuing decline in epicormic growth since observations began at the site in September 2010 as shown in Table 12.

Table 12 Summary of epicormic growth

Survey	Percentage of Trees with Epicormic Growth
September 2010[1]	46%
March 2011[1]	29%
September 2011[1]	19%
March 2012	17%

1. Source: Coffey Environments (2011a and 2011b).

4.6.5 Presence of Western Ringtail Possum

Four Western Ringtail Possums and eight possum dreys were recorded from the 290 tagged trees during the March 2012 summer survey. The possums and dreys were scattered over the site. These recordings were opportunistic sightings and not considered to be a comprehensive assessment of the presence of WRP. Comprehensive WRP assessments have been undertaken by Coffey Environments in 2009, 2010, 2011 and 2012 while comprehensive drey surveys were undertaken in 2009 and 2011.

4.7 Digital Multi-Spectral Imagery

The true and false colour imagery for the March 2012 and March 2011 fly-overs are provided in Appendix B and C. The March 2011 imagery has been used as baseline imagery for subsequent flights (including the March 2012 flight) to determine changes in the plant cell density, more commonly referred to as Change Detection.

A comparison between the March 2011 and March 2012 data has been undertaken. A comparison between two comparative months (i.e. March 2011 compared with March 2012) provides greater clarity in the leaf cell density change. The potential error provided by climatic conditions (i.e. summer drought compared with winter rain) is generally mitigated when the same months are compared.

4.7.1 Change Detection

Change detection or Plant Cell Density (PCD) change is a simple Remote Sensing image analysis technique for measuring plant canopy density and health. The PCD (Infrared Reflectance/Red Reflectance) is sensitive to the quantity of leaves in each pixel (sample) and the density of healthy plant cells in those leaves. The Red band (675 nm) is positioned at maximum absorption by leaf chlorophyll content and the Infrared band where the leaf structure of healthy plants strongly reflects incoming energy. PCD is strongly related to both leaf biomass and leaf area index.

SpecTerra have mapped the resulting PCD change based on the tree polygons drawn by SurvCon Pty Ltd. The PCD change is provided in Appendix F. The PCD change is based on the results of the March 2011 data acquisition and the March 2012 data acquisition.

Substantial decline in tree health was observed by SpecTerra between the October 2010 and the March 2011 flights, as might be expected when comparing data after the summer drought period to data taken following winter rains. Further decline in health was noted across the northern half of the site when SpecTerra compared the October 2010 flight data to October 2011 as reported in Coffey Environments 2011b.

Comparison between March 2012 and March 2011 flights indicated that approximately half of the site has experienced a decline in health while the tree health in the remaining half has stayed fairly consistent (Appendix F). A band of vegetation roughly 100m from the coastline has experienced a decline in PCD in some trees, which was generally `a minor to moderate change, while trees in the southern half of the site adjacent to Bussell Highway has stayed fairly consistent in PCD with only minor change. Scattered trees within the southern half, some trees on the primary coastal dunes and scattered trees throughout the site have recorded a maximum gain in PCD (i.e. become healthier). Occasional trees experienced maximum loss in PCD; two were adjacent the beach, one beside a track and three beside roads. It is likely that these six trees are being affected by their proximity to high traffic areas. One tree elsewhere in the site (within the grounds of the aged care facility) experienced maximum loss.

Aerials showing composite change and pseudo colour have been provided in Appendix F.

5. DISCUSSION AND RECOMMENDATIONS

5.1 Discussion

The March 2012 monitoring recorded a decline in tree health at the site, with Crown Densities decreasing by approximately 2% from the March 2011 baseline, average Vigour Class worsening from 1.57 to 1.80 and an increase in the number of trees displaying Crown Dieback. Tree health has generally worsened from the September/October 2011 monitoring, and from September 2010 (Coffey, 2011b).

There may be several reasons as to why the trees in the north and north-west of the site are experiencing a more severe decline than the trees in the south of the site. Two possible reasons for the variation in the decline across the site may be salinisation of the soil from a dropping water table and sea spray and greater competition due to the higher density of the trees in the north and north-west of the site compared with that in the south of the site where trees are spread out more and potentially have greater access to water and nutrients.

A review of existing information and data available on Peppermint decline suggest there is a range of factors potentially causing decline in tree health. These include falling water tables, drought, loss of native understorey and beneficial soil microbes, insect infestations, changed fire regimes and plant fungal diseases. It is possible that some; a combination of; or all of these factors are contributing to the decline in Peppermint trees across the south-west of Western Australia (Dakin *et al*., 2010).

Based on the information available for the Busselton Hospital site it is possible that all of the above factors, with the exception of changed fire regime, may be affecting the health of the Peppermint trees. Borers, fungal pathogens and a lack of native understorey species are quite evident on the site.

Although the Busselton region is not considered to be in drought, the weather stations in Busselton have recorded inconsistent rain over the last 14 years with rainfall totals fluctuating between 1059mm in 1999; 438mm in 2001; and 767mm in 2009 (Station 09569), which may be affecting the recharge rates of the groundwater table.

A discussion with the Department of Water should be explored to determine if there is an overall drawdown of the groundwater table in the Busselton Region. Groundwater information can freely be obtained from the Department of Water.

GeoCatch (Geographe Catchment Council) are currently exploring Peppermint decline within the Busselton region with the assistance of the Centre of Excellence for Climate Change, Woodland and Forest Health (CCWFH) and are trialling treatments to improve the health of Peppermint trees. One such method is injecting stem implants into the trunk and branches of trees to provide them with a nutrient supplement. The stem implants can be implanted into unhealthy trees to arrest the decline or into healthy trees as a preventative measure. Consideration should be given to liaising with GeoCatch to improve tree health at the site.

Epicormic sprouting and growth is a result of a stress factor (i.e. drought, fire, insect damage) and is the tree's mechanism for recovery. Epicormic growth at the site continued to decline in March 2012, indicating that the trees are recovering from an early stressful event, despite the gradual decline in tree health.

Digital Multi-Spectral Imaging by SpecTerra did not detect as great a difference in health between the March monitoring periods as was detected in the September/October assessments. Some trees in high traffic areas adjacent to car parks or walk ways suffered more decline in health than trees elsewhere in the site. The reduced tree health observed in the north of the site during September/October 2011 monitoring was still present.

Given that the Summer of 2010-2011 was substantially wetter than average, it may be that the decline in health between 2011 and 2012 is attributable to variation in summer rainfall and may be partially offset by a reduction in the presence of fungal pathogen at the site. As discussed in the September/October 2011 monitoring report, it is likely that the band of trees nearer to the coast are more susceptible to stress due to some environmental factors that are not a consequence of development at the site (Coffey, 2011).

5.2 Recommendations

Based on the results of the March 2012 and previous tree health assessments the following recommendations have been made:

- Insect borers were noted as occurring within the Busselton Hospital site. Insect borers can cause stress on a tree and at times death. Infestations can be worse in trees that are already stressed (for example, through lack of water). Therefore, an Integrated Pest Management (IPM) plan should be prepared and implemented to control the insect borer infestation within the site.
- Upgrade the existing Busselton Hospital reticulation (Figure 5) to provide additional water during tree planting and periods of prolonged drought.
- Discuss options of nutrient enrichment with GeoCatch or an equivalent organisation that may assist with improving the health of the trees.
- Review the groundwater levels in the Busselton region with the Department of Water to determine if there is a general drawdown of the groundwater table that may be affecting general tree health.
- Incorporate additional planting of understorey species into the site design to increase understorey density throughout the site to improve the environmental values.
- Minimise vehicle access over the hospital grounds where there are no formal parking bays or driveways. Uncontrolled vehicle access can cause compaction and damage of the roots, especially the fine feeder roots close to the surface, which can lead to stress for the trees.
- Prepare a rehabilitation strategy and management plan for the site. The rehabilitation strategy should include provisions to improve the understorey of the site, minimise access, control weed infestations, mulch, control insect infestations especially borers and watering regimes and nutrient supplements for the Peppermint trees.
- Obtain regional data from SpecTerra to determine if the Peppermint trees in the Busselton region are showing decline or is the decline is site specific.
- The monitoring of the health of the trees, including SpecTerra's DMSI assessment, is conducted on a six-monthly basis, with the subsequent monitoring undertaken in October 2012.

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