Department of Environment and Conservation

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Biodiversity

Monitoring Protocol

Augusta Microbial Threatened Ecological Community

Prepared by:

Kimberly Onton, Conservation Officer (Marine & Coastal), South West Region, DEC South West Regional Office, Bunbury WA

Vanessa Clarke, Senior Project Officer, DEC Species and Communities Branch, Dick Perry Avenue, Kensington WA

Carolyn Harding, Senior Project Officer, DEC Species and Communities Branch, Dick Perry Avenue, Kensington WA

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Significant Native Species and Ecological Communities – Resource Condition Monitoring Project

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1 Introduction

This monitoring protocol provides information and procedures for monitoring the hydrological requirements, growth habits and microbial assemblages of the Augusta Microbial Threatened Ecological Community (TEC) (also known as tufa) across the major seasonal cycles within occurrences between Cape Leeuwin and Cape Naturaliste along the south-west coast of Western Australia (Figure 1).

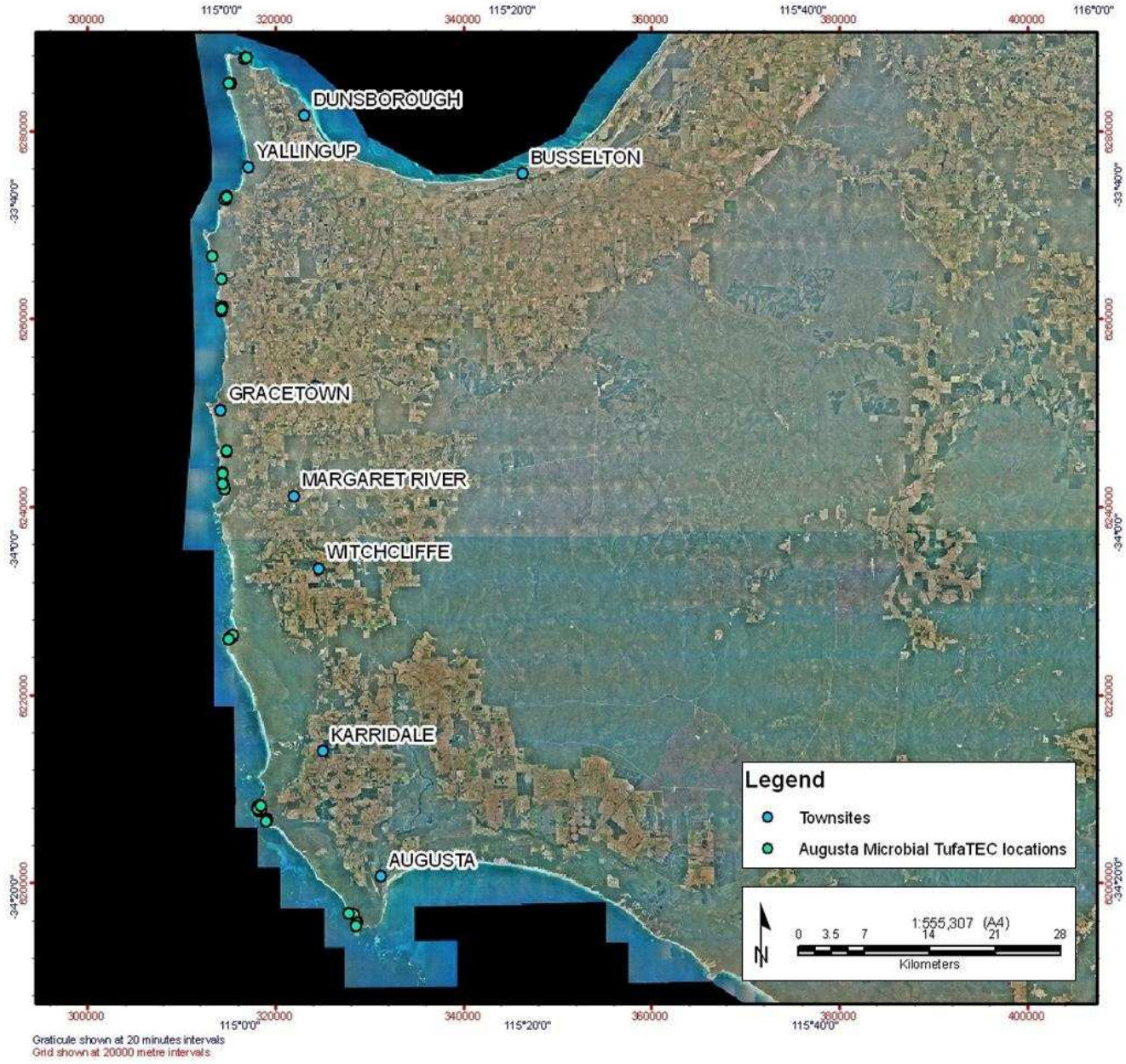

Figure 1: Augusta Microbial TEC occurrences between Cape Naturaliste and Cape Leeuwin.

2 Protocol Constituents

This protocol consists of this Protocol Narrative and the following project specific instructions and procedures:

- Instructions for collecting water quality measurements and samples at tufa monitoring sites (Appendix 2).
- Tufa photogrammetry operational procedures (Appendix 3).

- Procedure for collecting tufa microbial samples (Appendix 4).

3 Background and Objectives

3.1 Background and history

The August Microbial Threatened Ecological Community (TEC), also known as 'tufa', is a listed threatened ecological community ('*Augusta microbial – Rimstone pools and cave structures formed by microbial activity on marine shorelines*'). The TEC is currently ranked as endangered and was endorsed by the Minister in November 2001. Tufa is formed through the growth and metabolic activity of a diverse variety of microbial organisms, including cyanobacteria, diatoms and other algal components forming chemical sedimentary rock composed of calcium carbonate precipitated from freshwater streams and springs.

Tufa has been identified at numerous sites along the south-west coast of Western Australia between Cape Leeuwin and Cape Naturaliste. Threats to tufa include physical damage as a result of recreational activities, changes to hydrological regimes (impacts could occur from both changes in water quantity and quality) and physical collapse of limestone habitat (i.e. cavern collapse).

In 2007 a monitoring program was established to collect baseline information about the Augusta Microbial TEC over an entire annual cycle. The program aimed to determine the seasonal fluctuations in the tufa communities. This involved regular water quality monitoring to determine the tufa's ecological water requirements, seasonal mapping of the tufa surface to determine growth habits via photogrammetry and seasonal analysis of microbial samples to determine the biological composition of the various occurrences throughout the year. In addition, lithological analysis was undertaken to gain an understanding of the mineral and elemental components of the tufa formations.

As some baseline information about the tufa condition and the hydrology supporting it has been collected over an annual cycle, a less intensive ongoing monitoring program has been developed to build on this information and monitor changes in the community over time. There are three major components of the tufa monitoring program:

A. Hydrological monitoring
B. Photogrammetry
C. Microbial analysis

This document outlines the protocols for each component of the tufa monitoring program based on a low-intensity monitoring schedule.

3.2 Rationale for selecting this resource to monitor

The Department of Environment and Conservation (DEC) has primary responsibility for the protection and monitoring of TECs, including the endangered Augusta Microbial TEC, as part of its role in conserving the State's biodiversity. Furthermore, tufa has been identified as having value as both a potential paleoenvironmental archive and an indicator of subtle climatic and hydrological changes. In addition this monitoring protocol provides an example of a procedure for a TEC that is described on the basis of microbes, rather than plants or invertebrates.

The Significant Species and Communities component of the State-wide Resource Condition Monitoring (RCM) project assisted with documenting the already developed protocol for monitoring the Augusta Microbial TEC, as an opportunity to make the protocol available to other departmental staff, NRM officers and external stakeholders seeking to develop monitoring for similar microbial based environments.

3.3 Measurable objectives

The objectives of the Augusta Microbial TEC monitoring program are as follows.

1. Determine the Ecological Water Requirements (EWRs) of the tufa and monitor hydrological change over time.
2. Measure the growth of tufa between seasons and over time.

3. Determine the biological composition of the various tufa occurrences between seasons and over time.

An understanding of these components will assist in the management of the TEC and its habitat, including the identification and mitigation of threats.

4 Sampling Design

4.1 Rationale for selecting this sampling design over others

The sampling parameters and designs were selected based on liaison with various experts in the fields of hydrogeology, microbiology and photogrammetry, as well as with guidance from staff at the South West Region and Species and Communities Branch.

A. Hydrological monitoring

Tufa formations are precipitated from freshwater seeps and springs, therefore monitoring of water quality is critical to understanding and managing the TEC. The collection of field measurements and samples for water quality analysis is undertaken in accordance with Australian Standards (Department of Water, 2006; National Measurement Institute, 2007). Field measurements and sample collection are carried out by DEC personnel and sample analysis undertaken by a recognised laboratory, such as the WA Chemistry Centre or National Measurement Institute. Monitoring sites were selected based on their capacity to hold water throughout the year, to enable water sampling. Sufficient replication and coverage across a range of tufa formations were also considered and DEC hydrologists were engaged in designing the sampling regime.

B. Photogrammetry

Photogrammetry techniques have been applied to organisms such as sponges to measure their growth over time (Abdo *et al*., 2006). This technique has been adapted and applied to map the tufa surface and monitor changes in volume and morphology between seasons and over time. This reveals any growth fluctuations in the tufa and allows for the detection of any drastic growth changes. Four tufa photogrammetry monitoring sites were selected based on their suitability to the photogrammetry technique requirements (e.g. ability to have markers installed, minimal submersion in water). SeaGIS, an Australian company specialising in measurement science software and services, was engaged to assist in the establishment of the photogrammetry monitoring, and undertakes analysis and reporting of results.

C. Microbial analysis

The morphology of tufa communities is believed to be influenced by the assemblages of microbes present, and the composition of the assemblages is believed to be affected by habitat characteristics, therefore determining microbial composition is essential to monitoring the communities. Samples are collected from a number of sites across a range of formation types at the wettest and driest times of the year to determine seasonal variability and change over time. Associate Professor Jacob John of Curtin University was engaged in the sampling design and undertakes analysis of samples and reporting of results.

4.2 Site Selection

4.2.1 Criteria for selection

Six tufa hydrological and microbial monitoring sites have been established between Cape Naturaliste and Cape Leeuwin within the Leeuwin-Naturaliste National Park (Figure 2, Table 1).

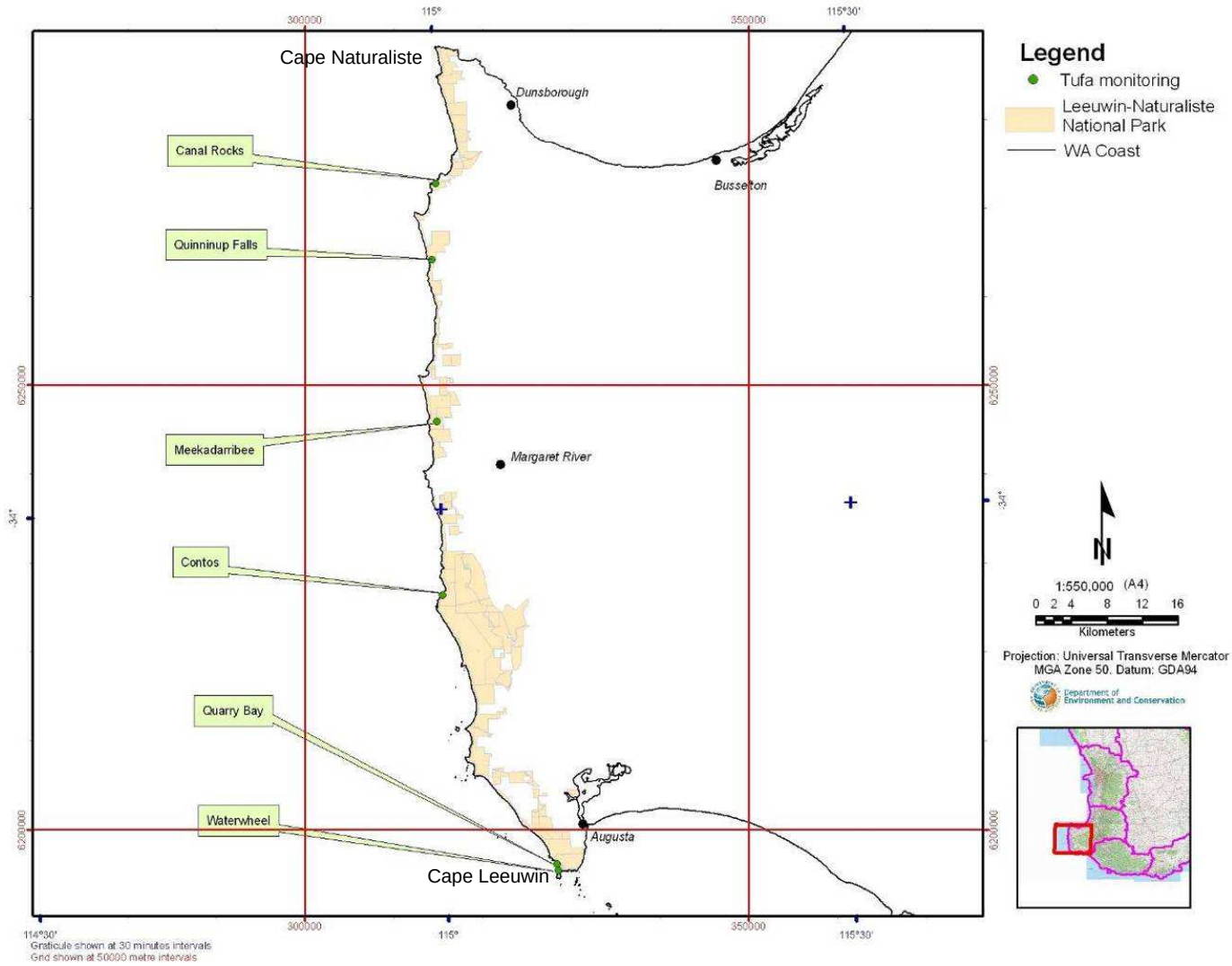

Figure 2: Tufa monitoring sites within the Leeuwin-Naturaliste National Park.

These monitoring sites were selected based on the following criteria:

- Retention of a volume of water throughout the year allowing water quality to be measured;
- Representation of a variety of the tufa formation types, including rimstone pools, overhangs and waterfalls;
- Representation of the geographical extent of tufa occurrences throughout the region; and
- Ease of access.

Four photogrammetry sites complement these monitoring sites (Table 1). These sites were selected based on the following criteria:

- The tufa is not submerged underwater (e.g. in a rimstone pool), as the camera can only take images entirely above water;
- There is a continuous surface of tufa covering an area of at least 500mm x 500mm;
- There is substrate suitable to install either bolts into the tufa and rock beneath, or stick permanent markers (such as benchmarks) onto a smooth dry surface adjacent to the tufa; and
- The site is easily accessible.

4.2.2 Procedures for selecting sampling locations

All known tufa occurrences within the South West Region have been documented (Figure 1). These were each prioritised against the selection criteria (section 4.2.1) and six monitoring sites were identified (Table 1). Within each site, monitoring stations (or sampling locations) were selected based on their representativeness of the various tufa formations at the site, capacity to retain water throughout the year (some sites dry up completely over summer) and accessibility for sampling. These

stations are specific pools or areas at which water measurements and samples (water and microbial) are collected. Three to five monitoring stations were selected at each site, depending on the availability of suitable sampling areas. Distances between monitoring stations within a site ranges from five to 500 metres. The stations provide a means of replication and cover the various tufa formations located at the site.

Table 1: Tufa monitoring sites and stations.

Site	Number of monitoring stations	Monitoring station codes	Photogrammetry site codes
Canal Rocks	3	CR01, CR02, CR03	N/A
Quininup Falls	3	QF01, QF02, QF03	N/A
Meekadarribee & Ellensbrook	4	MK01, MK02, MK03, EB01	N/A
Contos	5	CO01, CO02, CO03, CO04, CO05	N/A
Quarry Bay	5	QB01, QB02, QB03, QB04, QB05	QB01, QB02, QB03
Water Wheel	3	WW01, WW02, WW03	WW01

4.3 Sampling frequency and replication

Hydrological measurements and microbial samples are collected twice per year: once during the driest and once during the wettest seasons (i.e. summer and winter). Each monitoring site is comprised of three to five monitoring stations to provide replication for statistical validity, and coverage of the various tufa formations within a site. One sample (water measurements, water samples or microbial samples) is collected from each monitoring station per sampling season. Similarly, one series of images is taken of each photogrammetry monitoring station per sampling season. It is recommended that measurements and sampling for all parameters be undertaken in the same sampling session for consistency and logistical convenience, which is estimated to take one week per season (i.e. a total of two weeks per year).

4.4 Recommended number and location of sampling sites

A total of six monitoring sites, each comprising three to five monitoring stations (i.e. sampling locations) within a 500m range, plus four photogrammetry monitoring stations, is recommended (Figure 2, Table 1).

4.5 Level of change that can be detected for the amount/type of sampling being instituted

Due to the lack of comprehensive baseline information on the range of tufa occurrences, it is not possible to state the level of change that will be able to be detected over time with continued sampling. Monitoring will have to occur over a number of annual cycles before an understanding of the natural variations and fluctuations can be inferred.

Over the longer monitoring term a number of trends related to the identified threats may become apparent.

5 Field Methods

5.1 Field season preparations and equipment setup

- Personnel involved in monitoring should hold a CLM59 licence to take protected flora from crown land for scientific or other prescribed purposes.
- Contact external parties involved in undertaking analysis of samples to obtain a quote for current analysis rates, and arrange timelines for submission of samples and receipt of analysis results, and to ensure these are compatible with project budgets and timeframes.

Appendix 1 outlines the contact details for the three external parties who undertake analysis as at April 2009.

- Obtain sufficient sample bottles from the laboratory undertaking the water sample analysis (these are usually supplied in an esky with ice bricks).
- Ensure required equipment is available and in working order. This includes testing water monitoring meters and probes, checking the expiry date on buffer solutions and ensuring there are sufficient vials and bottles.

5.2 Sequence of events during field season

1. Engage with external parties to arrange details of sample analysis (including rates and timelines).
2. Organise and prepare equipment for field work.
3. Monitor weather over the season and select a week to undertake field work at the driest time in summer (likely February) and the wettest time in winter (likely August).
4. Arrange staff to undertake field work and become familiar with procedures.
5. Undertake field measurements and sampling.
6. Maintain a record, such as a spreadsheet, of what samples have been collected. Prepare any documentation for consultants to complement the samples.
7. Send samples to the relevant laboratory or consultant.
8. Receive reports on analysis results from laboratory or consultant.
9. Enter all data into the relevant database and undertake analysis as required.
10. File all datasheets, images and reports.
11. Process payments for consultant and laboratory fees.

5.3 Details of taking measurements, with example field forms

A. Hydrological monitoring

To monitor the water quality of tufa sites, both field measurements and sampling for laboratory analysis are undertaken. Field measurements are taken using handheld water monitoring equipment, calibrated prior to use, to measure parameters such as temperature, pH, electrical conductivity (EC), dissolved oxygen (DO) and the oxidation/reduction potential (ORP) of the water. In addition, a Hach alkalinity test kit is used to measure total alkalinity. Measurements are taken on site using water collected from the designated monitoring stations and recorded onto a data sheet. Data are later transposed into DEC databases.

Simultaneously, samples are also collected for laboratory analysis of water chemistry. This involves collecting three samples from each monitoring station: two (250ml and 150ml) 'general' or unfiltered samples and one (150ml) filtered sample. Samples are delivered to a recognised laboratory, in this case the Chemistry Centre of Western Australia, for analysis of the following parameters: basic cations (Ca^{2+}, K^{2+}, Mg^{2+}, Na^{2+}) and anions (Br^-, Cl^-, F^-), total alkalinity and acidity, nutrients (NH_3, NO_3, SO_4, Total N and P) and conductivity. Note: parameters measured can be removed or added depending on the requirements of the project and cost restrictions. During handover of the samples to the laboratory, a completed DEC chain of custody form should be signed by the laboratory for departmental records. On completion of analysis a digital and hard copy of the data are provided by the laboratory.

Appendix 2 outlines the detailed procedures for taking water quality measurements and collecting samples, including data sheets.

B. Photogrammetry

Photogrammetry is a technique whereby a series of photographs are taken of tufa alongside fixed reference markers which are then analysed through a software package to generate a 3D mapped surface of the tufa with corresponding height measurements. The technique involves calibrating the camera using a specifically designed calibration cube and scale bar, locating the permanent fixed reference points at the monitoring station then taking a series of photographs in the field. The images are later forwarded to SeaGIS for analysis. The analysis involves identifying points on the tufa surface and running the images through SeaGIS's *CAL* and *Photomeasure* software packages. The output is a 3D plot of the tufa surface supported by a Microsoft Excel spreadsheet of the measurement data (or

'epoch'). SeaGIS also provide an interpretation of the results in a report.

Appendix 3 outlines the detailed procedures for taking photogrammetry images, including data sheets.

C. Microbial sampling

Samples of tufa are collected and forwarded to Associate Professor Jacob John at Curtin University. Sampling involves the collection of sections of tufa at each monitoring station, ensuring a range of formations are sampled. Samples are contained in labelled vials and photographs of the sampling sites are taken. Samples are then forwarded to Curtin University for examination under light and electron microscope. Species are identified, a multivariate analysis is undertaken utilising water quality data, and a report is produced.

Appendix 4 outlines the guidelines for collecting microbial samples.

5.4 Post-collection processing of samples

A. Hydrological monitoring

- Send water samples to the laboratory. Transport in an esky with an ice brick accompanied with an outline of which analyses are required (such as a 'Request for Analysis' form). Vigilance should be shown to ensure samples remain out of direct sunlight and kept at ambient temperatures prior to delivery to the laboratory.
- Enter all measurement and sample data in the Microsoft Access Tufa Monitoring database. Forward all data to the DEC Natural Resource Management Branch for entry into the corporate HYSDSTRA database.
- File images, data sheets and lab reports and send copies to the TEC specialist group at Species and Communities Branch (SCB), Kensington.

B. Photogrammetry

- Sort, label and file images and data sheets.
- Send a copy of the labelled images and a copy of the data sheets on a disc to SeaGIS.
- File images and report from SeaGIS, and provide copy to SCB, Kensington.

C. Microbial analysis

- Compile and file a spreadsheet of all samples collected and corresponding water quality data.
- Sort, label and file images.
- Send tufa samples to Associate Professor Jacob John at Curtin University. Transport in an esky with an ice brick accompanied by a copy of the spreadsheet and images on a disc.
- File images and reports and provide copy to SCB, Kensington.

5.5 End-of-season procedures

At the end of the field week, clean all equipment, including a final rinse with deionised water. Replace as necessary any stocks of deionised water, buffer solutions, filter membranes, Hach kit powder sachets and sulphuric acid. Consider having the meters and probes serviced every one to two years.

6 Data Handling, Analysis and Reporting

6.1 Metadata procedures

Metadata is "data about data". That is, a statement about a dataset which describes the content, quality, currency and location and custodianship of the data.

The Australia New Zealand Land Information Council has developed guidelines for the collection of metadata (ANZLIC, 2001). Metadata collection under this protocol will be compliant with these guidelines.

The data custodian should develop the original metadata record. Metadata records can be created in a Word document or text file and should be saved in the same directory as the dataset.

Metadata for this project will be for the data collected from the monitoring components of this protocol.

The DEC South West Region server will be the repository for the metadata statements, with a copy sent to the TEC group of the DEC Species and Communities Branch in Kensington.

6.2 Overview of database design

DeBacker *et al*. (2004) recognise that biodiversity monitoring creates large numbers of files and folders to store various databases; reports; GIS data; etc. and the organisation and linkages increase in complexity as data accumulates through time. The authors also note that foresight in database design is integral to ensuring data quality.

Monitoring data collected according to this monitoring protocol will be stored on the DEC South West Region server.

6.3 Data entry, verification and editing

All hydrological data are stored in the Microsoft Access (Microsoft Office 2003) Tufa Monitoring Database housed on the DEC South West Region server (T:\427-Operations (Region)\Nat_Cons\THREATENED COMMUNITIES\TEC Operations and Maps\Tufa\Tufa Monitoring\Tufa Database\Tufa Monitoring Database v*date*). This data should then be forwarded to the DEC Natural Resource Management Branch for input into the corporate HYDSTRA database. Having the data stored in two databases provides additional data security and provides an opportunity for vetting of the data by a hydrologist. In addition, all other data will be copied to the TEC Specialist group, Species and Communities Branch, Kensington.

6.4 Recommendations for routine data summaries and statistical analyses to detect change

A critical component of any long-term monitoring protocol is a consistent and systematic way of analyzing (sic) and reporting on information (data) collected (DeBacker *et al*., 2004, p. 33). DeBacker *et al*. (2004) also note that data summaries and statistical analyses need to describe the current condition, or status of the subject being monitored and be robust enough to detect community changes through time. The information provided in data summaries must be complete, descriptive and easily interpretable.

Any management interventions that may influence these indicators need to be noted in the data summaries.

Data summaries will be undertaken after each monitoring occasion (see reporting schedule below). Given that monitoring is recommended on a biannual basis, data summaries at this interval should not be too laborious. Analyses will focus on water quality and chemistry and assessment of photogrammetry. A multivariate analysis of microbial data as related to water chemistry data will be completed at the conclusion of all microbial sampling. As subsequent data are collected, appropriate analyses will be undertaken to detect temporal trends in the monitoring data.

6.5 Recommended reporting schedule

An electronic copy of the data from the water chemistry will be submitted to DEC within two months of receipt of the samples. A report prepared by SeaGIS of the photogrammetry results will be submitted to DEC within six months of submission of each series of images. A report prepared by Associate Professor Jacob John of the microbial composition, including light and electron micrographs, a species list and results of multivariate analysis will be submitted to DEC.

DEC hydrologists should provide an annual report on hydrological trends. The Project Leader should consider compiling a brief summary report annually as a means of compiling and examining the various components of the monitoring program simultaneously.

6.6 Recommended methods for long-term trend analysis

Long-term trend analysis should be undertaken every five years, incorporating each of the components of the monitoring program.

6.7 Data archival procedures

All measurement data is entered into the Microsoft Access Tufa Monitoring Database which is stored on the DEC South West Region server.

All site images are labelled and filed electronically annotating the site name and date located on the DEC South West Region server. Light and electron micrographs should be labelled according to site and species and copied to a disc and stored on the DEC South West Region digital archive.

All electronic reports from consultants and the laboratory should be filed electronically on the DEC South West Region server (as appropriate under T:\427-Operations (Region)\Nat_Cons\THREATENED COMMUNITIES\TEC Operations and Maps\Tufa) and hard copies filed on the relevant corporate file (i.e. 2008/004748 at April 2009).

Hard copies of all data sheets should be stored on the relevant corporate file (i.e. 2008/004748 at April 2009).

Back-up copies of the Access database and all images should be stored on disc.

As noted above, copies of all data (except hydrological information) will be provided to the SCB, Kensington.

7 Personnel Requirements and Training

7.1 Roles and responsibilities

The following outlines the responsibilities of the key roles involved in monitoring the Augusta Microbial TEC.

Project Leader
- liaise with managers and other stakeholders, particularly external parties involved in analyses
- coordinate field trips
- compile and prepare reports
- data management, including data entry and distribution
- send samples and imagery to relevant consultants and laboratory
- coordinate contribution of various external parties, including arrangement of agreed payments
- determine budgets and timelines

Field Assistant
- assist Project Leader in collecting field samples, data entry and equipment maintenance

Hydrologist
- provide advice regarding the establishment of a suitable sampling regime to deliver hydrological information.
- coordinate entry of data into HYDSTRA
- analyse hydrological data
- contribute to reporting on hydrology

Photogrammetry Specialist (i.e. SeaGIS)
- analyse imagery using software
- prepare reports on tufa morphology status
- provide technical advice regarding photogrammetry technique

Microbiologist (i.e. Associate Professor Jacob John)
- examine tufa samples for biological composition and structure
- undertake multivariate analysis of tufa microbial composition
- provide light and electron micrographs
- provide a species list per site
- prepare reports on microbial composition

Laboratory (e.g. Chemistry Centre of WA)
- analyse water samples for requested water chemistry parameters
- provide sample bottles, esky and ice bricks
- provide a report on water chemistry analysis

7.2 Qualifications

The following outlines the basic qualifications required of the key roles involved in monitoring the Augusta Microbial TEC.

Project Leader
- preferably experience in undertaking scientific research, particularly water sampling, with basic training under the guidance of a hydrologist.

Hydrologist
- preferably post-graduate qualification and experience in the field of hydrology.

Photogrammetry Specialist
- thorough understanding of photogrammetry techniques and knowledge of relevant SeaGIS software.

Microbiologist
- post-graduate qualification and experience in microbiology or related field.

Laboratory
- recognised laboratory that meets Australian Standards for analysis of water chemistry.

7.3 Training procedures

The Project Leader and Field Assistant should be skilled in the use of water monitoring equipment and undertake training under the guidance of a qualified hydrologist. Personnel should be familiar with the protocols outlined in this document.

8 Operational Requirements

8.1 Annual workload and field schedule

The water quality monitoring and sampling, photogrammetry and microbial sampling should be completed simultaneously in one field season, as this is logistically most efficient and ensures complementary data are available for each component. It is estimated that this will take one week per season (summer and winter) for two field staff. Additional days would be required for any data analysis which should be undertaken by a hydrologist. Reporting may also require additional days, depending on the level of reporting required.

Microbial analysis will be undertaken on an ad hoc basis. Microbial sampling requirements should be clarified with the microbiologist through liaison prior to collection.

8.2 Facility and equipment needs

Facility requirements
General office facilities are required, including hardware and software for data management, storage and reporting (e.g. Microsoft Access, software compatible with camera image download requirements). Laboratories, additional software and technical equipment are required for water sample and photogrammetry analysis - these are provided by the relevant external parties as part of their analysis commitments.

Field equipment
The following equipment is required to undertake the field component of the monitoring:

A. Hydrological monitoring

- Water monitoring meters for pH, EC and DO
- Water monitoring probes for pH, EC, DO and ORP
- pH 7 and 10 buffer solutions
- 1413 calibration solution for EC
- Zoebell's solution for redox
- Hach alkalinity test kit
- Plastic beakers (at least two)
- Deionised water (at least 1L)
- Tissues
- Filter unit
- Hand pump with hose
- 0.45µm pore filter paper (at least 20)
- Sample bottles (at least 23 x 250ml and 66 x 150ml to cover all monitoring stations)
- Esky and frozen ice brick
- Permanent marker and pen/pencil
- Data sheet
- Map of sites
- Camera
- GPS (to locate sites if necessary)

B. Photogrammetry

- Digital SLR camera (such as Canon 400D EOS)
- 20mm fixed lens (such as Canon EF 20mm f/2.8 USM wide angle lens)
- Additional camera battery
- Light-coloured umbrella (to reduce glare in photographs on sunny days)
- Calibration cube (from SeaGIS)
- Scale bar (from SeaGIS)
- Thermometer
- Data sheet
- Pen/pencil
- Map of sites
- GPS (to locate sites if necessary)

C. Microbial sampling

- Vials (at least 25)
- Dissection kit (particularly scalpel/knife and forceps)
- Esky and frozen ice brick
- Vial labels
- Permanent marker and pen/pencil
- Sample record spreadsheet
- Camera
- Map of sites
- GPS (to locate sites if necessary)

In addition, personal protective equipment should be worn, including sun protection (sunscreen, long shirt and pants, hat, sunglasses) and steel-capped boots. Waders or gumboots may be required for the Quininup Falls site. Nitrile gloves should be worn when handling chemical buffer solutions.

8.3 Startup costs and budget considerations

Table 2 outlines the annual resource requirements for budget consideration.

Table 2: Annual resource requirements for tufa monitoring (current at April 2009)

RESOURCE	DETAILS	AMOUNT	COSTS
Staff	Field measurements, sample collection and data management undertaken by DEC South West Region staff.	1-2 staff for two weeks per year (1 week per season)	Staff salary plus travel*
	Analysis of hydrological data undertaken by hydrologists (DEC Natural Resource Management Branch).	1 staff member for 1-2 days	Staff salary plus travel*
Equipment	Water quality monitoring - Water monitoring meters and probes for pH, electrical conductivity, dissolved oxygen and redox - Hach alkalinity test kit - Beakers, distilled water, relevant buffer solutions for probes, camera (DEC South West Region)	1 measurement kit	All equipment already purchased and housed at DEC South West Region. Small costs may be incurred to service meters and replace consumables (<$1,000).
	Water quality sampling - Sample bottles and esky (provided by the analysing laboratory) - Filter including membranes, distilled water, suction pump, permanent marker (DEC South West Region)	1 sampling kit for 23 sample sites	
	Photogrammetry - Digital SLR camera with fixed 20mm lens - Calibration cube - Scale bar (DEC South West Region)	1 photogrammetry kit	
	Microbial sampling* - Vials, dissection kit, labels, markers - Camera (DEC South West Region)	1 sampling kit for at least 12 sites	
Contracts	Water quality samples analysed by laboratory (such as WA Chemistry Centre)	Two batches of samples from 22 sites measuring 13 parameters	$10,000
	Photogrammetry analysis undertaken by SeaGIS	Two batches of samples from 4 sites	$2,000
	Microbial samples analysed by Associate Professor Jacob John (Curtin University)	Two batches of at least 12 samples	$3,000 ($120 per sample)
		TOTAL	**$15,000** per year + staff & travel costs

*Travel costs include vehicle, any field allowances, accommodation and food.

9 References

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10 Appendices

Appendix 1: Contact details for personnel involved in South West Region tufa monitoring.

Appendix 2: Instructions for collecting water quality measurements and samples at tufa monitoring sites.

Appendix 3: Tufa photogrammetry operational procedures.

Appendix 4: Procedure for collecting tufa microbial samples.

Appendix 1: Contact details for personnel involved in South West Region tufa monitoring.

Name	Position	Organisation	Postal Address	Email Address	Phone number	Project role
Kim Onton	Conservation Officer (Marine & Coastal), South West Region	Dept Environment and Conservation	PO Box 1693 BUNBURY WA 6231	kim.onton@dec.wa.gov.au	(08) 9725 4300	Project Officer
Kim Williams	Regional Nature Conservation Coordinator, South West Region	Dept Environment and Conservation	PO Box 1693 BUNBURY WA 6231	kim.williams@dec.wa.gov.au	(08) 9725 4300	Project Manager
Val English	Principal Ecologist, Species and Communities Branch	Dept Environment and Conservation	Locked Bag 104 BENTLEY DELIVERY CENTRE WA 6983	val.english@dec.wa.gov.au	(08) 9334 0409	Threatened Ecological Communities
Ryan Vogwill	Senior Hydrologist, Natural Resource Management Branch	Dept Environment and Conservation	Locked Bag 104 BENTLEY DELIVERY CENTRE WA 6983	ryan.vogwill@dec.wa.gov.au	(08) 9334 0267	Hydrogeologist
Matt Forbes	Hydrologist, Natural Resource Management Branch	Dept Environment and Conservation	Locked Bag 104 BENTLEY DELIVERY CENTRE WA 6983	matt.forbes@dec.wa.gov.au	(08) 9334 0138	Hydrologist
James Seager		SeaGIS Pty Ltd	PO Box 1085 Bacchus Marsh VIC 3340	jseager@seagis.com.au	0412 019 344	Photogrammetry specialist
Jacob John	Associate Professor, Aquatic Biology	Curtin University		j.john@curtin.edu.au	(08) 9266 7327	Microbial specialist

Appendix 2

Instructions for collecting water quality measurements and samples at tufa monitoring sites.

IMPORTANT NOTES:

It is important that samples and the sample site are not contaminated with chemicals such as buffer solutions from probes or sunscreen/moisturiser from hands. Ensure all containers are sterile (i.e. rinsed with deionised water at the least) so that no water from other sites will contaminate new samples.

Avoid direct contact and inhalation of any chemicals used in water monitoring, such as buffer solutions. Read the relevant safety guidelines or Material Safety Data Sheets for appropriate considerations and first aid.

Procedures are in accordance with Australian Standards as outlined in:
Department of Water (2006) *A guideline to the development of surface water quality monitoring programs*, Department of Water, Western Australia.

Field measurements

Field measurements are taken once at each monitoring station for pH, dissolved oxygen, electrical conductivity and redox potential using meters and probes. Alkalinity is also measured using a Hach alkalinity test kit.

1. Locate the monitoring station using a map and GPS unit if necessary.
2. To prevent contamination of the water sample, rinse beakers first with deionised water, then with a small amount of water collected from the monitoring station. Discard rinse water away from the sample site.
3. Collect a sample of water. The volume should be sufficient to cover the tips of the measuring probes (at least 6cm high).
4. Rinse probes with deionised water and affix probes to the compatible meter unit. Caution should be taken with the probe tip as this is the most fragile component.
5. Calibrate the probes using the relevant buffer solutions and take measurements of the samples (Attachment 1). Ensure the probes are rinsed after calibration and between samples.
6. To measure alkalinity, rinse all glassware in the Hach kit with deionised water and follow the procedures outlined in the instructions with the kit.
7. Record all measurements from the meters and alkalinity test on the data sheet. Also record the date, name/s of recorder/s, site codes, times of measurements and environmental observations on the datasheet (Attachment 2).
8. Take photographs of the monitoring site to show the condition of the tufa and supporting water supply.
9. Rinse all probes and equipment with deionised water and repeat the above process for each monitoring station at each site.
10. At the conclusion of the field work, enter all data sheets into the Tufa Monitoring Microsoft Access Database and file the data sheets on the appropriate corporate file. Label photographs with the site code and date and file accordingly.
11. Submit a copy of the data to the DEC Natural Resource Management Branch for entry into the corporate HYDSTRA database.

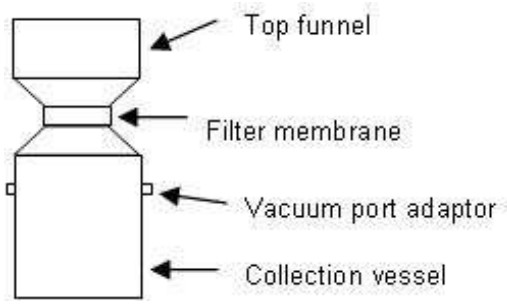
Sampling for laboratory analysis

Samples are collected for water chemistry analysis by a laboratory. Samples are tested for the following: Acidity, Alkalinity, Electrical conductivity, Total N, Total P, NH_3, NO_3, SO_4, and basic anions (Br^-, Cl^-, F^-) and cations. (Ca^{2+}, K^{2+}, Mg^{2+}, Na^{2+}). This requires the collection of three water samples: two ‘general’ (250ml and 150ml) or unfiltered samples and one (150ml) filtered sample.

1. Collect unfiltered samples by filling two bottles with water directly from the site (if containers are used to do this, ensure they are sterile). Label bottles with the date, time of collection, type of sample (i.e. UNFILTERED), site code, and a name and contact number for the sample batch.
2. To collect filtered samples, a beaker or container will be required to collect the sample. Rinse the beaker firstly with deionised then sample water and discard the rinse water away from the site. Collect a water sample (sufficient volume to fill a sample bottle plus extra for rinsing the filter unit).
3. Rinse the filter unit with deionised water.
4. Carefully place a 0.45µm cellulose acetate filter onto the filter membrane. Take care not to touch the filter paper or the filter membrane as oil and dirt from the skin can contaminate samples – use the waxy lining or packaging of the filters, or tweezers. Place on the filter unit with the grid lines facing upwards

ensuring that the mesh grid is completely covered. Assemble the rest of the unit.

5. Attach a pump to the vacuum port adaptor and place a rubber bung over the other vacuum port adaptor.
6. Filter 20-30mL of the sample through the filter via the top funnel and use this to gently wash the collection vessel. Discard the filtered water through the vacuum port adaptors (do not disassemble the unit).
7. Filter a sufficient volume of the sample to fill the required sample bottle.
8. Fill the sample bottle with the filtered water and label with the date, time of collection, type of sample (i.e. FILTERED), site code, and a name and contact number for the sample batch.
9. Keep track of which samples have been collected on the data sheet (Attachment 2).
10. Keep the samples cool, preferably in an esky with an ice brick, and deliver to the relevant laboratory within one week of collection.



Attachment 1

WATER QUALITY MONITORING EQUIPMENT
Instructions for use

IMPORTANT NOTES
Avoid direct contact and inhalation of any chemicals used in water monitoring, such as buffer solutions. Nitrile gloves are recommended. Read the relevant safety guidelines or Material Safety Data Sheets for appropriate safety considerations and first aid.

Store all solutions in the fridge as this improves their longevity. However DO NOT immediately use the chilled solutions – wait for them to warm to the surrounding environment temperature.

Instruments require calibration prior to taking measurements. Instruments should only require calibration once per day, however if the temperature varies significantly throughout the day (i.e. a dramatic temperature change from when the instrument was calibrated to when it is used to take field measurements) the instruments should be recalibrated.

Instrument WTW pH 330 – **pH meter**

pH

Calibration

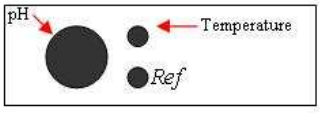
1. Remove storage cap from pH probe, wash probe with deionised water and pat dry with a tissue.
2. Immerse probe in neutral buffer 7.
3. Turn pH meter [ON] and select 'AutoCal TEC' (two point calibration) by toggling through the three options using the [CAL] button. (The meter should automatically be in AutoCal TEC mode).
4. CE1 (with the top horizontal of the 'E' missing) will appear on the main screen.
   - CE1 is the start or neutral buffer that must be used to calculate the slope from 7-10 or 7-4 depending on the pH of the water sample.
5. Select [RUN/ENTER]. 'AR' will flash on the screen whilst the meter is calibrating. When finished 'AR' will stop flashing and disappear and CE2 will appear on the screen.
6. Remove the probe, rinse with deionised water, pat dry with a clean tissue and immerse the probe in the required buffer for the expected pH range of the sample/s i.e. 10 or 4. (pH 10 buffer should be used for freshwater tufa sites).
7. Select [RUN/ENTER]. 'AR' will flash on the screen whilst the meter is calibrating. When finished 'AR' will stop flashing and disappear. Record the millivolt [pH/mV] reading and assess whether the reading is within the tolerance of -60 to -55mV. When the slope increases to -55mV replace the probe.
8. Select [RUN/NTER]. The meter will now show the pH. Check that the reading is close to the correct pH value for the current temperature of the buffer using the table below.

The following are the Perth Scientific colour coded buffers as a function of temperature:

Temp (℃)	**pH value**		
	pH 4.00	**pH 7.00**	**pH 10.00**
5	4.01	7.09	
10	4.00	7.06	
15	4.00	7.04	10.26
20	4.00	7.02	10.13
25	**4.01**	**7.00**	**10.00**
30	4.01	6.99	9.87
35	4.02	6.98	
40	4.03	6.97	

9. To store, rinse the probe with deionised water, pat dry with a clean tissue and replace the storage cap filled with a small volume of 3 mol/L KCl storage solution. The probe tip should never be stored dry.

Note: The smaller cable (temperature cable) goes into the top hole adjacent to the main pH cable hole (the hole that does not say 'Ref').



Measurements

1. Remove storage cap from pH probe, wash probe with deionised water and pat dry with a tissue.
2. Immerse probe tip in water to be measured.
3. Turn pH meter [ON] and select [AR] then Select [RUN/ENTER]. 'AR' will flash on the screen whilst the meter is measuring. When finished 'AR' will stop flashing and disappear and a pH value will appear on the screen. Use the [pH/mV] button to toggle between pH and mV readings.
4. Rinse the probe with deionised water between samples and replace the storage cap filled with 3 mol/L KCl storage solution after use.

Redox Potential

Obtaining Reference

1. Use a pipette to mix equal portions of Zoebell's solutions A and B in a sealable container (see instructions on Zoebell's solution bottles). Do not pipette from the original solution container, use gloves and avoid inhalation of the solutions. This mixture serves as the reference solution for measurement of redox potential using the ORP probe and pH meter unit.
2. Remove storage cap from ORP probe, wash the probe with deionised water and pat dry with a tissue. Connect the ORP probe to the pH meter.
3. Immerse probe tip in the Zoebell's solution mixture.
4. Turn pH meter [ON] and toggle the [pH/mV] button until a mV reading appears. Wait for the reading to stabilise and record the measurement.
5. Remove probe, rinse with deionised water, pat dry with a clean tissue and replace the storage cap filled with a small volume of 3 mol/L KCl storage solution.

Measurements

1. Remove storage cap from ORP probe, wash probe with deionised water and pat dry with a tissue.
2. Immerse probe tip in the sample to be measured.
3. Toggle the [pH/mV] button until a mV reading appears. Record the measurement once the reading has stabilised.
4. Remove probe, rinse with deionised water, pat dry with a clean tissue and replace the storage cap filled with a small volume of 3 mol/L KCl storage solution.

Instrument WTW Oxi 330 – **Oximeter**

Calibration

1. With the probe in the white storage cap, turn the meter [ON] then select [CAL] then [RUN/ENTER]. "AR" will flash on the screen whilst it is calibrating. The meter should read approximately 100% once calibrated. (Use the [0_2] button to toggle between % and mg/l)

Measurements

1. Remove large white storage cap from the probe.
2. Rinse the probe with deionised water. (The small black cap should be screwed on to the probe. If errors are occurring, this cap can be unscrewed and replaced).
3. Place the probe in the solution to be measured.
4. Press the following buttons in sequence: [ON]
   [AR
   [RUN/ENTER]
5. "AR" will flash at the bottom of the screen
6. Once the "AR" stops flashing take the reading in either mg/l or press [O_2] button to toggle to **%**.
7. Note: greater than 100% is an acceptable reading for dissolved oxygen.
8. Remove the probe from solution, rinse with deionised water and gently pat dry with a tissue. Replace the white storage cap and twist the cap on until it is secure (it should not be loose).

Note:

- The sponge at the base of the white storage cap (accessed from the outside of the cap) should always be kept moist with deionised water.

Instrument WTW LF 330 - **Conductivity Meter**

Calibration

1. Remove probe from storage cap. Rinse the probe with deionised water and gently pat dry with a tissue.
2. Place the probe into 0.01 mol/L KCl calibration solution (aka 1413 solution or Control Standard for Conductivity Cells). Switch the meter [ON] then select [C] and toggle until CAL appears on the screen. Select [RUN/ENTER]. "AR" will flash on the screen whilst it is calibrating. Once the "AR" stops flashing, check that the reading matches that of the relevant temperature on the back of the KCl solution bottle.
   e.g.

℃	µS/cm
20	1278
25	1413

3. Rinse probe with deionised water, pat dry with a tissue and replace storage cap.

Default settings to maintain on LF330 instrument:

Check that the settings are as follows by using the relevant key combinations:

Standard Setting	Key Combinations
TREF (=25℃)	Hold 'x' then 'ON'OFF'; 'RUN/ENTER' (until t20 or t25); ↑ or ↓ to select t25; then 'x'.
Lin (Uncompensated)	'TC' until 0.000%/K; then 'x'.
Cell constant = 0.475	'C' (until 0.475); then 'x'.
Auto Ranging (Enabled)	Hold 'x' on then 'ON/OFF'; then 'RUN/ENTER' until 'ARN; ↑↓ until 'Yes'; then 'x'.
Salinity Mode	'x' (until 'Sal')

There is no need to calibrate the LF330 instrument, even though there is an option to do so. Attempting to calibrate it will only lead to incorrect settings. The default settings are: Temp Reference = 25℃; Cell constant = 0.475; Auto Ranging 'ON' and Linear functionality enabled (viz. Uncompensated mode).

Measurements

1. Remove probe from storage cap. Rinse the probe with deionised water and gently pat dry with a tissue.
2. Place the probe in the solution to be measured.
3. Switch the meter [ON] and record the reading once it has stabilized. Use the [X] button to toggle between Salinity (ppm), Total Dissolved Solids – TDS (mg/l) and Electrical Conductivity (µS/cm).
4. Rinse probe with deionised water, pat dry with a tissue and return to storage case, ensuring the cap is twisted on until it is secure.

Note:

- Ensure the gap in the probe tip is completely submerged in solution when calibrating and taking measurements.

Attachment 2: Tufa water monitoring data sheet.

Date: Site Name: Recorders:

Field Measurements											**Field Observations: Water Surrounding Tufa**						
							Alkalinity (Hach Kit)										
Sub-site code	Time	Depth (cm)	pH	Electrical Conductivity	Dissolved Oxygen	Redox - Eh (mV)	Pink→Clear # drops H_2SO_4	Green→Pink # drops H_2SO_4	High Range/ Low Range?	Total Alkalinity (mg/L)	Colour	Turbidity	Oily film	Nuisance organisms	Floating debris	Odour	Froth
				S/cm	%												
				mg/L	mg/L												
			ºC	Sal	ºC												
				ºC													
				S/cm	%												
				mg/L	mg/L												
			ºC	Sal	ºC												
				ºC													
				S/cm	%												
				mg/L	mg/L												
			ºC	Sal	ºC												
				ºC													
				S/cm	%												
				mg/L	mg/L												
			ºC	Sal	ºC												
				ºC													
				S/cm	%												
				mg/L	mg/L												
			ºC	Sal	ºC												
				ºC													

Weather				
Wind speed (knots)	Cloud Cover (%)	Rain (y/n)	Tide (H/M/L)	Swell

Notes:

• Water samples taken? Y / N

	______	______	______	______	______
1) General water	☐	☐	☐	☐	☐
2) Filtered	☐	☐	☐	☐	☐
3) Unfiltered	☐	☐	☐	☐	☐
• Photos	☐	☐	☐	☐	☐

Appendix 3

Tufa Photogrammetry Operational Procedures

Prepared by Kim Onton, February 2008

Introduction

Tufa is chemical sedimentary rock composed of calcium carbonate precipitated from freshwater streams and springs. Tufa is formed through the growth and metabolic activity of a diverse variety of microbial organisms, including cyanobacteria and diatoms. Tufa structures seemingly grow and recede depending on the activity of these organisms and their production of calcium carbonate. An understanding of the tufa microbial composition and the seasonal fluctuations in tufa growth may assist in identifying cues as to when tufa are distressed and may be an indicator of subtle hydrological changes.

The tufa of south-west Western Australia has been categorized as a Threatened Ecological Community (entitled 'Augusta microbial – Rimstone pools and cave structures formed by microbial activity on marine shorelines'). The current status of the community is Endangered. Threats to tufa include physical damage as a result of recreational activities, changes to hydrological regimes and quality and physical collapse of limestone habitat.

The Department of Environment and Conservation (DEC) is responsible for the monitoring of Threatened Ecological Communities as part of its role in conserving the State's biodiversity. In 2007, the South West Region received state and federal government funding through the South West Catchments Council to implement a tufa monitoring program.

A component of the program identified as a priority is the investigation of photogrammetry as a technique to measure the growth of tufa. It is believed that tufa is likely to undergo periods of growth and recession throughout the seasons depending on the presence and strength of groundwater flow.

SeaGIS Pty Ltd has been contracted to assist in the photogrammetric measurement of tufa for this project. SeaGIS is an Australian company specialising in measurement science software and services. It provides services to a number of government and other agencies around Australia and internationally for a variety of projects ranging from measuring the growth of sponges to the length of sharks. Photogrammetric techniques are not known to have been previously applied to tufa. A visit by SeaGIS's James Seager and DEC staff to a number of tufa sites between Cape Leeuwin and Cape Naturaliste confirmed that photogrammetric techniques could be applied to monitor the growth of tufa demonstrating changes in tufa volume and formation. Field measurements (the collection of suitable imagery) will be taken by DEC staff and forwarded to SeaGIS for analysis. SeaGIS software is available for purchase should the Department wish to analyse the data independently in future.

This document outlines the standard operating procedures for photogrammetric monitoring of tufa. It also provides a reference of each site that has been established and explains the results that will be provided by SeaGIS.

Aim

To determine seasonal variation in the growth and formation of tufa occurrences.

Equipment

- Digital SLR camera (such as Canon 400D EOS)
- 20mm lens (such as Canon EF 20mm f/2.8 USM wide angle lens)
- Additional camera battery
- Light-coloured umbrella (to reduce glare in photographs)
- 1L container (to capture water for temporary cessation of water flow, if necessary)
- Calibration cube (from SeaGIS)
- Scale bar (from SeaGIS)
- Thermometer

Additional equipment required for establishing new sites:

- Measuring tape
- Targets – either stainless steel nails or stick on targets (or benchmarks)
- Hammer (for nails)
- Liquid nails (for stick on targets)

Methods

Calibration

The camera needs to be calibrated prior to and after photographing the tufa. The calibration can be carried out anywhere, however it is suggested that it be carried out in the office rather than in the field, as it is often easier and poses less risk of damaging the calibration cube.

1. Place the assembled calibration cube on a cleared, flat surface. Place the scale bar alongside.
2. Select a large aperture value (F18-22) on the camera. Select the fixed aperture program function (on Canon camera, select program Av). The large F setting is to maximize depth of field.

Note: Turn off any vibration reduction/stabilizer and dust remover functions on the camera.

3. Hold the camera approximately 1m above the cube. Use the manual focus control to focus the image (confirm the focus is to approximately 1m on the outer markings on the camera lens). Once focused, the focus setting cannot be changed as it will defeat the purpose of the calibration.
4. If necessary, the flash can be used.
5. Take five sets of images, rotating the camera four times, from approximately 1m above the cube on an angle of approximately 30° on each of th e four edges of the top of the cube, plus one set from directly above the cube (Figure1). This will result in a total of 20 photographs for each calibration. Ensure the cube and scale bar are visible in the image.

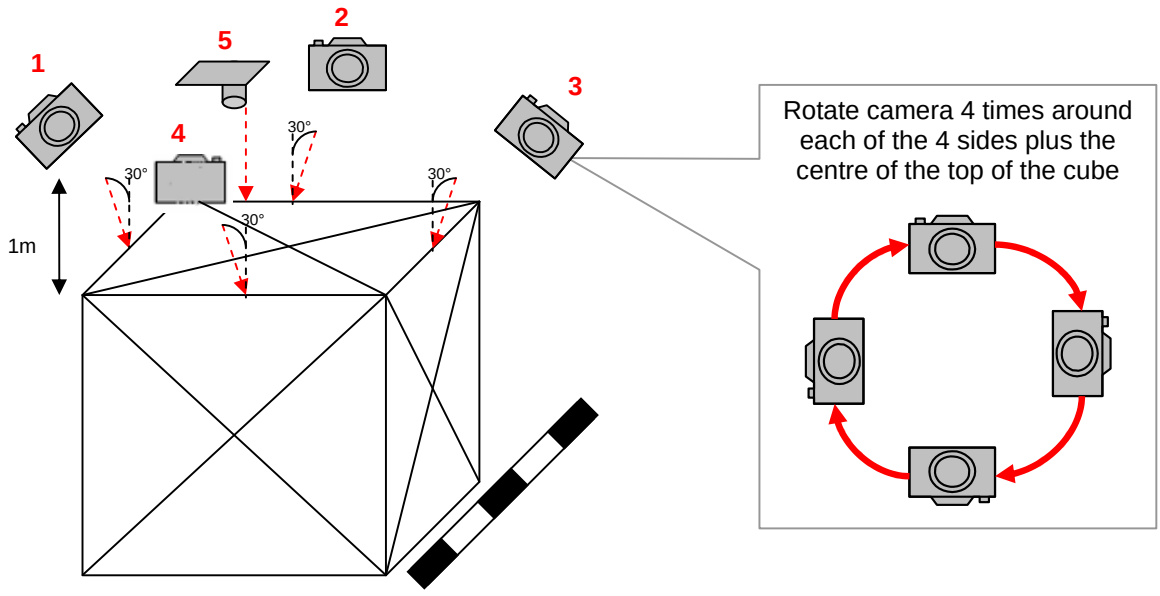


Figure 1: Camera positioning for calibration.

6. The camera has now been calibrated. Download, label and store the images (as per instructions below in 'Data preparation and storage'). Ensure the camera focus settings do not change. The camera is now ready to take field photographs of tufa.
7. Repeat the process without re-focusing the camera at the end of the day once all field images have been taken.

Note: The camera settings can be altered slightly only once when in the field, unless the camera is

re-calibrated. i.e. Calibrate the camera, take photos, make a camera set up change, take photos, calibrate. Different sites may require different settings E.g. open air sites will require certain settings that must be changed for a dark site such as caves – if moving from light to dark conditions it is best to alter the camera ISO setting and/or use the flash rather than change the F setting. The recalibration at the end of the day will correct for this. Ensure any setting changes throughout the day are noted and provided to SeaGIS with the images.

Field measurements

The following outlines the steps for taking photogrammetry images at established sites.

1. Locate the tufa photogrammetry site using a map, GPS and photographs.
2. Ensure all 4 targets are visible. Place the point of a nail or pencil towards the targets (this will assist in the analysis of the images as the small targets can be difficult to identify against the tufa). Do not cover any part of the target.
3. Place the scale bar besides the tufa photo site.
4. Photograph the tufa ensuring all four targets plus the scale bar are in view.
5. Hold the camera at approximately 1m above the photo site (that is, at a range that matches the focus setting used when calibrating the camera). Take 3 sets of images, rotating the camera 4 times directly above, and to the left and right sides of the photo site (Figure 2). The distance between camera images should be approximately 200 – 300mm. This will result in a total of 12 photographs.

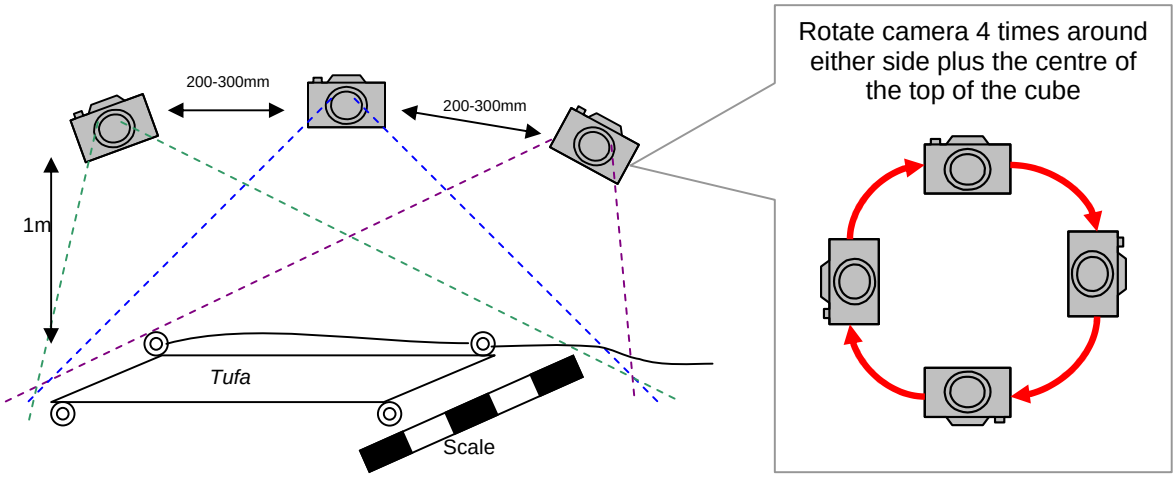


Figure 2: Camera positioning for photographing established tufa sites.

6. Use an umbrella to reduce glare if required. (Significant glare will reduce measurement accuracy). Be aware of glare produced by the flash if used also.
7. For sites with large quantities of flowing water, temporarily block the water flow by collecting water in a container until the flow slows. Take the photographs then cease blocking the water so that it returns to its natural flow rate.
8. Using the thermometer take an air temperature reading (this is taken to correct for any expanding of the scale bar). Record the temperature reading, camera settings and any other observations about the site on the data sheet (Attachment 1).

Note: Take care not to disturb or trample any tufa whilst getting to the tufa photo site or whilst taking photographs. Also take care not to damage the scale bar as slight scratches to the markings can lead to significant errors in measurements.

Establishing a new site

The following outlines how to establish a new photogrammetry monitoring site.

1. Calibrate the camera as outlined above.
2. Select a site comprised of tufa. Ensure that the site is easy to access and revisit, does not hold any great depth of water (i.e. water does not pool, or large volumes of water do not

'pour' over the site), can be accessed without trampling or disturbing tufa, has a substrate suitable for use of nails or stick on targets and is not a particularly sensitive or high traffic site.

3. The tufa area to be monitored should be less than 1000mm x 1000mm – preferably around 500mm x 500mm.
4. Install a minimum of four targets per site. Use either stainless steel nails hammered into the tufa or rock, or a plastic benchmark glued onto hard rock, such as granite adjacent to the tufa. The targets should be at the extremes of the area to be monitored. The targets need to be located and installed so they remain stable over time.
5. Measure the distances between each point to the nearest 10mm (Figure 3).

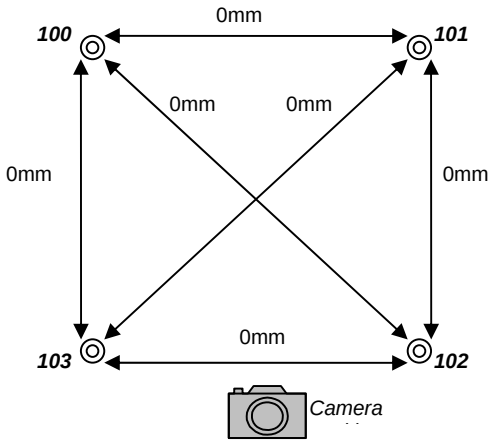


Figure 3: Measurements between each target to be taken to the nearest 10mm.

6. Place the point of a nail or pencil towards the targets (this assists in locating the targets during image analysis). Do not cover any part of the target.
7. Place the scale bar beside the tufa photo area.
8. Hold the camera at approximately 1m above the photo site (that is, at a range that matches the focus setting used when calibrating the camera). Take 3 sets of images, rotating the camera 4 times directly above, and to the left and right sides of the photo site (Figure 4). The distance between camera images should be approximately 200mm – 300mm. This will result in a total of 12 photographs.

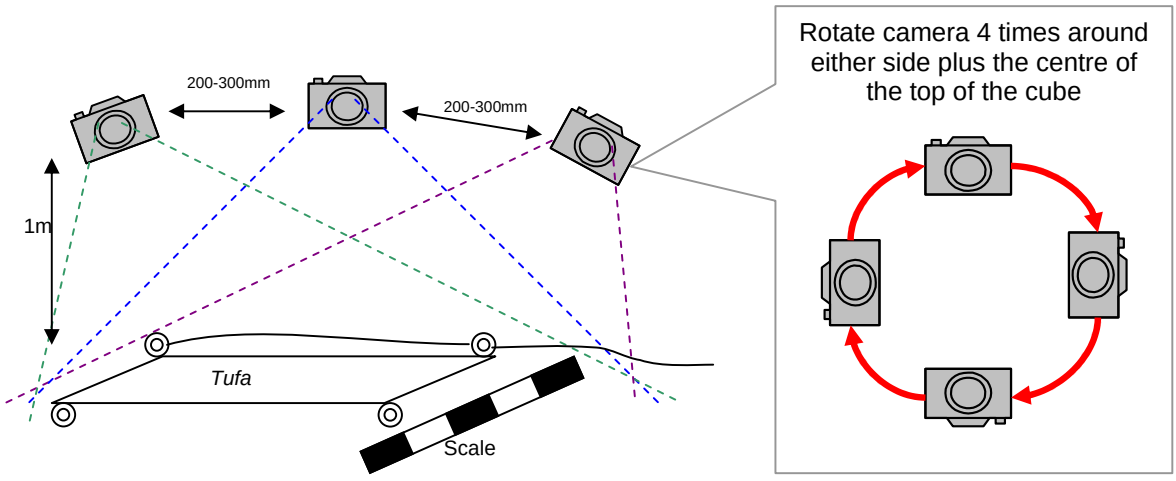


Figure 4: Camera positioning for photographing a new tufa site.

9. Use an umbrella to reduce glare if required. Be aware of glare produced by the flash if used also. (Significant glare will reduce measurement accuracy).

10. Using the thermometer take an air temperature reading (this is taken to correct for any expanding of the scale bar). Record the temperature reading, camera settings and any other observations about the site on the data sheet (Attachment 1).
11. Draw a sketch of the tufa photo site including all measurements, from which side the photos were taken, the direction of the sketch and the position of the site in relation to any land features (e.g. granite boulders, pools of water, ocean, etc). Record a GPS position.

Data preparation and storage

- All images need to be downloaded and saved as soon as possible.
- Each image should be labelled: *site name_date_unique image number* e.g. QB01_030508_01
- Images should be stored electronically in files in the following hierarchy:

Date - Calibration 1 - *Site name (1)*
Site name (2)
Site name (3)
Calibration (after)
- Calibration 2 - *Site name (4)*

e.g.
29.01.08 - Calibration 1 - Quarry Bay
Contos

- Make two disc copies of the files. Place one disc on the DEC Augusta Microbial *BUN2001F223* file. Send the other disc, along with datasheets and other relevant notes, in a package to:

  James Seager
  SeaGIS Pty Ltd

  PO Box 1085
  Bacchus Marsh VIC 3340

  (Email: jseager@seagis.com.au)

- A copy of the images should also be store on the DEC South West Region server at T:\427-Operations (Region)\Nat Cons\THREATENED COMMUNITIES\TEC Operations and Maps\Tufa\Photogrammetry\Photogrammetry Imagery.

Data analysis

Analysis of the images will be performed by SeaGIS. The following information has been provided by James Seager of SeaGIS and outlines what analyses will be performed and how the results will be provided.

For each field site at each measurement epoch the following will be provided:

1) 3D surface plot.
2) Summary of control points.
3) Summary of tufa surface measurements.
4) A note if anything abnormal is noticed about the camera calibration.

1. 3D Surface Plot

The following is a 3D plot of the surface generated for the 'Quarry Bay 2' site. The surface is interpolated from approximately 1400 points measured by photogrammetry. Note that there is significant z scale exaggeration.

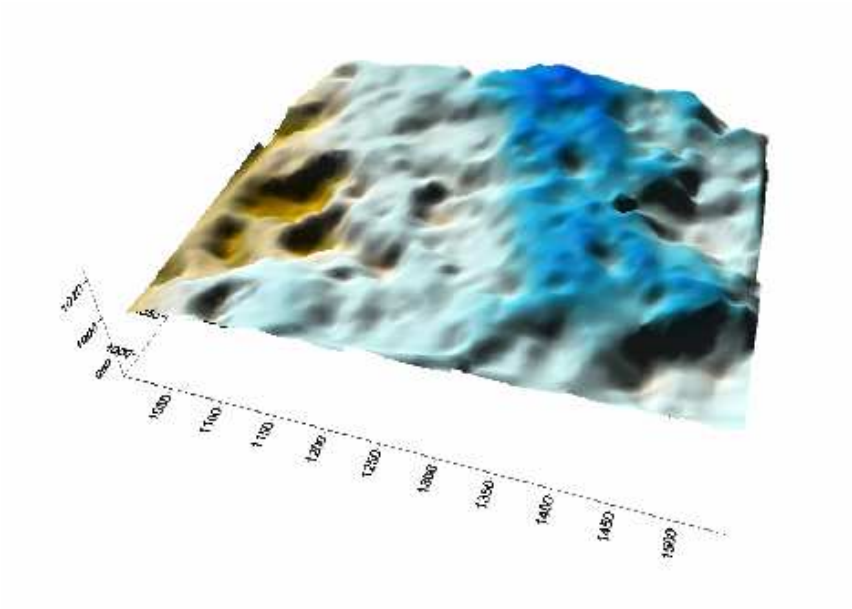


Figure 5: 3D surface plot of tufa surface.

The 3D surface plot provides a good visual reference for the measurement and level of detail attained. However, the actual essence of the monitoring will be contained in a text report that provides numeric height data describing the surface.

2. Control points

For every measurement epoch all control point coordinates and standard deviations will be listed. Any trends or suspected control point instability will be highlighted. The report will include results from all previous epochs to reinforce the monitoring aspect and highlight any trends in control point stability.

3. Tufa surface measurement

The process of surface monitoring will involve making dense photogrammetric measurements of the tufa surface, then generating a gridded surface. The same gridded surface will be generated for each measurement epoch, allowing an effective comparison of surface height between epochs. From the gridded surface, cross sectional profiles through the tufa and an estimate of volume can be derived.

The gridded approach allows epoch comparison at a variety of scales:

- Fine scale: comparison of surface height at an individual grid point over epochs.
- Medium scale: comparison of sections through the tufa over epochs.
- Coarse scale: comparison of volume over epochs.

The appropriate grid size is still to be determined, but will be something in the order of 5 – 10mm.

Note that each time a new measurement epoch is added results from previous epochs will be recomputed. This is to ensure that a consistent grid comparison is made over all measurement epochs. Also, the z datum used in volume calculations will always be the minimum z value of all measured points. As this datum value may change with the addition of a new measurement epoch, volumes from all previous epochs are re-calculated when a new epoch is added. This approach is not problematic as an entirely new updated report including all measurement epochs will be issued for each additional measurement epoch.

The file ‘Sample epoch output.xls’ is an Excel sample report (Figure 6). For the purposes of illustration only the report has two measurement epochs: both are from the same set of imagery, one epoch has a lot of measurements, the other has very few. As more measurement epochs are made, there would be more columns added to the report. Working in order through the report it contains:

- A summary of the grid (origin and size).
- A list of polygons defining regions used in the surface generation. There will always be one polygon that defines the boundary of the gridded region. There may be other polygons used to exclude regions within the grid (for example around vegetation). The vertices of each polygon are listed.
- The report now lists data for each epoch in a column. In the example there are 2 epochs, and the coordinates file names associated with each epoch are listed.
- The computed volume for each epoch.
- A summary of the measured surface points, including the total number of points measured, and the range of x, y, z coordinates, the minimum, maximum and average standard deviation of the measured points, and the intersection RMS maximum and average (the intersection RMS provides an indication of point measurement and calibration quality – small is good).
- Tables of gridded point data. The data are laid out in cross sections along the x coordinate axis. Each table starts with a y value, and then gives heights in each measurement epoch for x values. Note that there might not be height values for every x, y grid position, but where there is height data for an x, y position it will be present in every measurement epoch. The data are laid out in this fashion to allow easy generation of cross-sectional plots in Excel.

Surface analysis report			
Generated: Sunday, January 13, 2008 23:54:44			
All data in mm			
Generation parameters			
Grid origin	(1000, 1000)		
Grid size		10	
Polygon definitions			
Polygon		1	
Include points inside			
Point 1	(900.000, 900.000)		
Point 2	(900.000, 1500.000)		
Point 3	(1600.000, 1500.000)		
Point 4	(1600.000, 900.000)		
Point 5	(900.000, 900.000)		
Epoch data			
	Epoch 1		Epoch 2
Input data file	Coordinate summary_Auto.TXT		Coordinate summary_Manual.TXT
Volume (mm^3)		10457379.3	10131754.9
Measured point information			
No. points		1457	41
X Min		1000.538	1000.538
X Max		1541.117	1541.117
Y Min		975.433	975.433
Y Max		1418.43	1425.637
Z Min		984.569	959.216
Z Max		1025.325	1023.016
X Min SD		0.209	0.209
X Max SD		0.331	0.331
X Average SD		0.245	0.25
Y Min SD		0.246	0.246
Y Max SD		0.607	0.62
Y Average SD		0.381	0.433
Z Min SD		0.843	0.843
Z Max SD		1.036	1.051
Z Average SD		0.906	0.92
Intersection RMS max		0.504	0.585
Intersection RMS average		0.037	0.092
Gridded data and cross sections			
Data for y = 1000			
X	Epoch 1 Z		Epoch 2 Z
1000			
1010		994.542	993.991
1020		996.601	995.585

Figure 6: Extract of a sample epoch output from a Microsoft Excel report.

Attachment 1: Tufa Photogrammetry Data Sheet

Date: _____ Site: _____ Recorder/s: _____

Time: _____ Latitude*: _____ Longitude*: _____ *(*New sites only)*

Temperature: _____ ℃ Umbrella used? ☐ Yes ☐ No Number of photos taken: _____

Camera settings: F-stop _____ ISO _____ Flash ☐ Yes ☐ No

Tufa appearance: _____

_____

Comments:

_____

_____

_____

_____

_____

_____

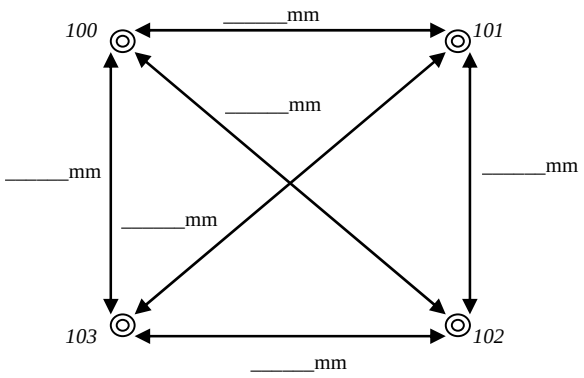
_____

_____

_____

_____

Image diagram: *If establishing a new site, mark measurements, distinguishing features (tufa & landscape), camera positioning and direction of north.*



Appendix 4

Procedure for collecting tufa microbial samples

Tufa microbial samples should be collected twice per year at each monitoring site during the extreme seasons. Samples are sent to Jacob John at Curtin University for analysis.

1. One sample should be collected at each monitoring station.
2. Samples are collected by cutting a section of tufa (using a knife or scalpel) and placing it in a vial with tweezers. The depth of the section will depend on the tufa formation being sampled – if possible the entire depth of the live tufa component should be sampled with sufficient volume to half-fill a 25-50 ml vial. Attempt to maintain the structure of the tufa by half-filling the vial and packing it loosely. Ensure there is some water from the site in the vial to keep the tufa damp but not saturated.
3. Take samples of a variety of tufa formations, including those exhibiting unique features such as variations in colour, texture and formation.
4. Label samples with a unique number, the date, site name and name of the collector (Figure 1).

TUFA MICROBIAL SAMPLES

Department of Environment and Conservation

Date: 22/02/2008
Site: Meekadarribee *Code:* MK01
Collector: Kim Onton
Sample #: 001

Figure1: An example tufa microbial sample vial label.

5. Once collected, keep the samples cool and refrigerated (but not frozen, as the ice crystals can alter the structure of the tufa). Samples may not be analysed for months and will preserve sufficiently for extended periods if stored in a refrigerator.
6. Take photographs of the sample site to show the formation of the tufa in context with its water source.

Figure 2: Examples of photographs of the tufa microbial sampling sites showing the specific sample site and the sample site in the context of the broader water source.

7. Compile a spreadsheet as a record of samples taken and note any associated environmental and water quality parameters measured (e.g. insert a relevant extract from the Tufa Hydrological Monitoring Database).
8. Deliver samples and a disc containing the site images and spreadsheet to Associate Professor Jacob John at Curtin University for analysis. Transport samples in an esky with a frozen ice brick.