DWLBC REPORT

Developing industry climate change adaptation strategies: A case study for the McLaren Vale viticulture and Fleurieu Peninsula oliveculture industries

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Government of South Australia
Department of Water, Land and Biodiversity Conservation

Developing industry climate change adaptation strategies:

A case study for the McLaren Vale viticulture and Fleurieu Peninsula oliveculture industries

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on behalf of

Land and Biodiversity Services Division
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FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them for both current users and future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed in a way that advances economic, social and environmental outcomes.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continue to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Climate change has emerged as one of the most important environmental, social and economic issues we are facing and this has been clearly identified by the Government of South Australian (2003, 2007). The community will play a vital role in addressing climate change through both reducing greenhouse gas emissions and adapting to new climate regimes.

This report provides a case study of work undertaken to develop industry strategies to adapt to climate change. In particular, it focuses on the McLaren Vale viticulture and Fleurieu Peninsula oliveculture industries in the context of projections for a warming, drying climate. Expert opinion has also been sought to validate the risk assessment process and recommendations for priority adaptation strategies.

This work was undertaken by the City of Onkaparinga in partnership with DWLBC. Other key partners included the Adelaide and Mount Lofty Ranges Natural Resources Management Board and the Department of Climate Change (formerly Australian Greenhouse Office).

Rob Freeman
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

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- Dr John Virtue for reviewing the report
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SUMMARY

INTRODUCTION

This report presents a case study aimed at developing climate change adaptation strategies for two key horticultural industry groups in the Adelaide and Mount Lofty Ranges (AMLR) region: the McLaren Vale grape growers and Fleurieu Peninsula olive growers. This case study is one from a series of case studies that has been implemented under the project 'A Regional Climate Change Decision Framework for Natural Resource Management', funded in partnership by the Australian Greenhouse Office (AGO), AMLR Natural Resources Management (NRM) Board and the Department of Water, Land and Biodiversity Conservation (DWLBC). This work follows on from an initial assessment of projected climate change impacts in the region, which indicated perennial horticulture was among key sectors vulnerable to projected climate change broadly characterised by a warming and drying trend.

The City of Onkaparinga (the Council) took the lead role in implementing the case study, engaging with key stakeholders and facilitating the adaptation planning process. This work is of particular interest to Council because it highlights climate risks to the region's food and wine industries, with flow-on impacts to regional economic development. The case study reported here is a demonstration of the way Council might engage with the community to help plan a response to the challenges of climate change.

This work involved a participatory approach, engaging and educating key stakeholders, and encouraged a two-way flow of information between growers, researchers, policy and planning organisations. The focus of the case study was to identify <u>initial</u> adaptation strategies and planning directions in response to high priority climate risks. This work provides a foundation for subsequent, more detailed analysis of climate risks and adaptation options.

OBJECTIVES

Objectives of the work included:

- engagement, education and ownership of the climate change issue among stakeholders
- identification of priority climate risks and potential adaptation response strategies, with a focus at the industry level (rather than the individual business level)
- identification of future work, roles and responsibilities for businesses, industry associations and other stakeholders
- generation of feedback on the engagement process and project methodology to assist future adaptation planning work

- informing local industry strategic planning, including: the AMLR NRM Board, the Southern Adelaide Economic Development Plan (SAEDP), the City of Onkaparinga Water Management Strategy, the South Australian Wine Industry Association (SAWIA) climate change response and other natural resources managers in the region
- demonstrating a climate change response model for local government interaction with industry.

Key industry questions of climate change impacts to water security in McLaren Vale and possible increased weed risk from olives were also investigated.

METHODOLOGY

As recommended by the AGO (2006), this work focuses on an initial assessment of climate risks and adaptation responses, for the 'initial assessment stage is where the greatest gains will be made with the least effort'. However, this approach also recognises the need for subsequent, more detailed technical analysis of risks and risk treatments (adaptation responses) following on from this case study.

Adaptation response strategies were developed through a risk management approach, facilitated by Council, with participation from industry stakeholders. The risk management process provided a useful framework for this case study and will also be applicable for future iterations associated with more detailed analysis.

Information used to identify, evaluate and treat climate risks was gathered through workshops with growers and a risk assessment survey questionnaire. In keeping with the approach recommended by AGO (2006), discussions focused on a limited set of projected climate scenarios in order to initiate thinking, limit uncertainty and aid in decision making. In particular, the impacts of drought (which is projected to increase in frequency and severity in the region) and a worst-case scenario for projected climate change were examined in the workshops and survey questionnaire respectively.

Through the workshops, information was initially gathered to help evaluate likely pressures on enterprise (individual business) level production systems. This was translated to impacts at the industry level by assuming that widespread exposure of individual businesses equated to exposure at the industry level. This produced a baseline set of climate risks that the industry might need to manage in the future.

This baseline set of climate risks helped in the design of more detailed information gathering and analysis via a risk assessment questionnaire, which concentrated on a worst-case scenario (from the range of available climate projections). Questions were generated around four themes: irrigation, salinity, changing summer climate and business issues. The scenario used existing climate change modelling (Suppiah et al. 2006), scientific studies (e.g. REM 2007) and regional meteorological data to justify a set of climate assumptions which would minimise the level of uncertainty in the risk assessment survey.

The combined results from the workshops and survey questionnaires were then analysed by Council and the industry focus groups to help evaluate priority climate risks and potential adaptation responses. A process of validation and review by relevant science and industry experts was then conducted to give more objectivity and weight to the project findings.

KEY FINDINGS

VITICULTURE

The main issues identified for the McLaren Vale region's viticulture industry was the potential emergence of soil salinity and water insecurity. These issues are predominantly driven by the quality of water available, but are also related to supply constraints in relation to the groundwater resource. There were additional concerns that industry-wide salinity flushing practices (i.e. excess irrigation water applied to leach accumulated salts) may cause watertables to rise, and potential salinity impacts to soil and groundwater may be a risk to the industry's branding. Further high risks were associated with potential heat impacts causing yield and quality problems, and increased cost pressures on viticultural businesses.

In response to the question 'Is the McLaren Vale wine industry really "waterproof", i.e. does it have sound water security in the context of climate change?', the answer was found to be no. The findings of this case study suggest that groundwater supply and the salinity of both groundwater and recycled water supplies are key management issues for adaptation strategies to focus on in the future.

OLIVECULTURE

The main issues for the Fleurieu oliveculture industry were identified as water security and reduced yields. The possible emergence of soil salinity was also found to be a key risk. Similar to viticulture, there were concerns that industry-wide salinity flushing practices to control salt build-up in soils may cause watertables to rise, and potential salinity impacts to soil and groundwater may be a risk to the industry's branding. Potential risks from increased insect and fungal outbreaks were also identified. In addition, there is a hidden implication arising from increased cost pressures associated with the impacts of climate change. Anecdotal evidence suggests many Fleurieu Peninsula olive businesses are already marginal financially, and an increase in costs may force businesses to fail. This could lead to derelict groves and a location-specific invasive species threat to remnant native vegetation. In the workshop, some growers also stated that they cannot afford to harvest their crop below a minimum anticipated financial return, further adding to the potential scope of this issue. Conditions making it uneconomic to harvest olive crops are likely to vary between businesses, and between years, with variations in input costs.

In response to the question 'Is climate change likely to increase the risk that commercial olives crops will contribute to the feral olive population?', the answer is possibly. While adaptation strategies need to focus on water security, the potential weed threat from derelict groves warrants further attention.

EXPERT REVIEW

To provide greater objectivity and weight to the findings of this case study, a panel of climate science and industry experts were asked to review the project methodology and findings. The rationale for this review was to provide assurance to growers (and other end users) that the case study could provide a solid foundation for moving forward with industry adaptation planning. Their findings are summarised in Discussion (Section 5.3), while detailed comments are contained in Appendix 6.

Overall, the case study was viewed as an excellent starting point, providing the McLaren Vale Grape Wine and Tourism Association (MVGWTA) and Fleurieu Peninsula Olive Association (FPOA) with a framework with which to begin addressing climate change risks and implementing adaptation strategies. It was generally accepted that a focus on reduced water availability and increasing soil salinity was justified, however there were concerns that a number of potential risks had been overlooked during the risk assessment process. A number of additional potential climate risks and adaptation strategies were suggested by the review panel for further investigation. Also, suggestions were made to improve the process for future risk assessments/adaptation planning. A common perception was that involvement of people with a wider experience base and more scientific and technical input during the design of the process, and participating in the risk assessment itself, would have been beneficial.

ADAPTATION STRATEGIES

A range of adaptation response strategies, relevant to each of the industries, have been developed around the major risks identified (see Tables 1 and 2). These are what could be termed ‘no regrets’ responses. They are based on prudent management of the anticipated regional operating environment, but are given increased priority as a result of the risk assessment. More specific strategies have been avoided due to the broad nature of the risk assessment process.

The strategy directions were developed by considering the logical opportunities to build industry resilience to the identified risks. A range of organisations have also been suggested that could be expected to play a role in the strategy implementation (see Glossary for explanation of acronyms).

Note: Additional potential climate risks and adaptation strategies have been suggested through the expert review process (Section 5.3 and App. 6). Future adaptation planning should consider these suggestions and this will add to the list of climate risks and response strategies currently identified.

Table 1. Viticulture—climate change adaptation response strategies and suggested organisational roles

Identified risk area	Potential strategies	Suggested lead body			Potential partner organisations
		MVGWTA	Viticulture enterprises	Agencies	
Irrigation	Ensure water use is at maximum efficiency across the industry	✓			PIRSA, AMLR NRM Board, DWLBC
	Advocate for research into viable low water-use varieties	✓			PIRSA, SARDI, GWRDC, CSIRO
	Encourage at-risk growers to seek greater water security	✓			AMLR NRM Board, WBWC
	Establish working relationships with weather forecasters specific to the needs of the industry	✓			BOM, SARDI

Identified risk area	Potential strategies	Suggested lead body: MVGWTA	Suggested lead body: Viticulture enterprises	Suggested lead body: Agencies	Potential partner organisations
	Provide early warning of anticipated reductions of water allocations			✓ AMLR NRM Board	DWLBC, MVGWTA, SAWIA
	Develop business strategies for remaining viable through periods of drought		✓		PIRSA
	Advocate for industry access to drought relief	✓			PIRSA
Salinity	Advocate for targeted salinity avoidance research	✓			SAWIA, AMLR NRM Board, GWRDC, PIRSA, SARDI, CSIRO
	Develop appropriate salinity avoidance practices			✓ PIRSA, SARDI	MVGWTA, AMLR NRM Board
	Encourage growers to shift to least saline water supplies	✓			AMLR NRM Board, WBWC
	Ensure growers are informed regarding salinity avoidance practices	✓			AMLR NRM Board, PIRSA, DWLBC, WBWC
	Identify areas at high risk of salinity accumulation	✓			SAWIA, AMLR NRM Board, GWRDC, PIRSA, SARDI, DWLBC, WBWC
	Monitor salinity build-up in high risk areas			✓ AMLR NRM Board, DWLBC	MVGWTA, SAWIA, DWLBC, WBWC, AMLR NRM Board
	Review long-term salinity and natural resources impact risk with key stakeholders			✓ AMLR NRM Board	MVGWTA, SAWIA, PIRSA, SARDI, DWLBC
	Promote salinity management as a key pillar of industry environmental management	✓			SAWIA, AMLR NRM Board, DWLBC, PIRSA, SARDI, DWLBC
Impacts of changing summer climate	Advocate for research into heat resistant varieties and heat management techniques	✓			SAWIA, GWRDC PIRSA, SARDI, CSIRO
	Establish working relationships with research bodies investigating climate change impacts on wine grape varieties	✓			SAWIA, PIRSA, SARDI, CSIRO
	Establish working relationships with weather forecasters specific to the needs of the industry	✓			BoM, SARDI
	Ensure growers are informed regarding the management of hot weather impacts on vines	✓			SAWIA, PIRSA, SARDI
Business	Review sustainability of current grape pricing practices		✓		Wine companies, MVGWTA, PIRSA
	Advocate for winery/grower collaboration in grape pricing and wine marketing	✓			Wine companies, growers, SAWIA, PIRSA

Identified risk area	Potential strategies	Suggested lead body: MVGWTA	Suggested lead body: Viticulture enterprises	Suggested lead body: Agencies	Potential partner organisations
	Identify ongoing need (quantity, cost, timing) for salinity flushing irrigation applications			✓PIRSA, SARDI	MVGWTA, AMLR NRM Board, WBWC
	Advocate for targeted research into reduced costs of grape production	✓			PIRSA, SARDI, SAWIA, GWRDC, CSIRO

Table 2. Oliveculture—climate change adaptation response strategies and suggested organisational roles

Identified risk area	Potential strategies	Suggested lead body: FPOA	Suggested lead body: Olive enterprises	Suggested lead body: Agencies	Potential partner organisations
Irrigation	Ensure water use is at maximum efficiency across the industry	✓			PIRSA, DWLBC
	Establish working relationships with forecasters specific to the needs of the industry	✓			BOM, SARDI
	Where possible encourage at-risk growers to seek greater water security	✓			AMLR & MDB NRM Boards, WBWC
	Monitor water allocation trends and alert growers to anticipated reductions			✓ AMLR, MDB NRM Boards	DWLBC, FPOA, OSA
	Develop business strategies for remaining viable through periods of drought		✓		PIRSA
	Advocate for industry access to drought relief	✓			PIRSA
Salinity	Advocate for targeted salinity avoidance research	✓			OSA, Australian Olive Association, PIRSA, SARDI, CSIRO
	Develop appropriate salinity avoidance practices			✓ PIRSA, SARDI	FPOA, OSA
	Ensure growers are informed regarding salinity avoidance practices	✓			AMLR NRM Board, PRISA
	Monitor salinity build-up in high risk areas			✓ AMLR NRM Board, DWLBC	FPOA, OSA, DWLBC, WBWC, AMLR NRM Board
	Review long-term salinity and natural resources impact risk with key stakeholders			✓ AMLR NRM Board	FPOA, OSA, DWLBC

Identified risk area	Potential strategies	Suggested lead body: FPOA	Suggested lead body: Olive enterprises	Suggested lead body: Agencies	Potential partner organisations
	Promote salinity management as a key pillar of industry environmental management	✓			AMLR NRM Board, DWLBC, PIRSA, SARDI, Food SA, Encounter Olives, DWLBC
Impacts of changing summer climate	Advocate for research into olive industry pest and disease management	✓			OSA, Australian Olive Association, Encounter Olives, PIRSA, SARDI, CSIRO
	Investigate effective management of increased pest and disease pressure			✓ PIRSA, SARDI	FPOA, OSA
	Increase grower's capacity to manage pest and disease pressures	✓			PIRSA, DWLBC, AMLR NRM Board
	Improve margins per kg of fruit		✓		FPOA, OSA, Australian Olive Association, Encounter Olives, PIRSA
	Increase plant resilience to pest and heat pressure		✓		FPOA, OSA, Australian Olive Association, Encounter Olives, PIRSA
Business	Review sustainability of current olive product pricing practices		✓		FPOA, OSA, PIRSA
	Identify ongoing need (quantity, cost, timing) for salinity flushing irrigation applications			✓PIRSA, SARDI	FPOA, OSA, AMLR NRM Board
	Identify and monitor high-risk commercial olive groves			✓AMLR NRM Board, PIRSA, DWLBC	FPOA, OSA, PIRSA, DWLBC

WHERE TO FROM HERE

This case study has demonstrated a collaborative model for local government and industry, supported by NRM and research organisations, to respond to climate change. It has reviewed regional industry stakeholder opinions of local issues relating to climate change, identified potential roles for key stakeholders and given direction to future adaptation planning activities.

The engagement of the major stakeholders, the understanding that has been developed and the development of strategy directions all suggest this model has been successful. This has been supported by positive feedback from industry stakeholders.

Adaptation to climate change will require an iterative planning process as better modelling and climate information become available, and implications for NRM become more apparent. It is most appropriately the role of the two industry groups to advance their own adaptation planning. This will require partnerships to be strengthened and new links formed, and for the findings of the case study to be raised with the appropriate lead organisations. The validation and review process has added weight to the findings and suggested further areas of investigation and improvement for the ongoing adaptation planning process.

To implement future adaptation planning activity there is a need to establish a roles and responsibilities framework, to encourage progress and avoid duplication of efforts. In developing such a framework, the mechanism provided by the SAEDP and its partners should be considered. SAEDP articulates a strategic framework for economic diversification for the region, and considers the food and wine industries as priorities for growth. The plan recognises that resilience to climate change will be central to the strength of the region's future economy. If such a roles and responsibilities framework can be integrated with the SAEDP, this will embed the climate change response in the broader terms of regional economic development.

Finally, the understanding of climate change is also progressing rapidly and better information at the local scale is likely to be accessible in the future. This study has raised a number of areas for further inquiry including the risks of soil salinity, industry cost pressures and the possible threat to native vegetation. With this in mind, an appropriate review period and process should be developed as part of the industry adaptation planning. Key research and governance institutions such as The University of Adelaide's Research Institute for Climate Change and Sustainability, BoM, CSIRO, PIRSA, SARDI and DWLBC, and local government (with regional economic development perspectives) could play an important advisory role in this respect.

1. INTRODUCTION

1.1 CLIMATE CHANGE ADAPTATION

Warming of the global climate system over the past century is no longer in doubt, as seen in atmospheric and oceanic temperatures, sea level rise and melting of snow and ice. The scientific consensus is that most of the global warming since the mid-20th century is very likely due to human activities that have increased greenhouse gas levels. While global warming can be slowed through large reductions in greenhouse gas emissions, some warming is unavoidable and adaptation will be needed (CSIRO & BoM 2007).

1.2 NRM DECISION MAKING

In the report, *There's a change on the way,* Bardsley (2006) assesses the AMLR NRM region's key vulnerabilities to climate change. From this assessment, Bardsley (2006) also suggests major directions for adaptation planning. This has prompted the funding of a range of case studies investigating NRM decision making and climate change throughout the AMLR NRM region. These case studies are coordinated through the project 'A regional climate change decision framework for natural resource management'. The project and case studies are funded by the AGO, AMLR NRM Board and DWLBC. Their purpose is to:

- assess key areas of NRM that are vulnerable to climate change
- develop and demonstrate methodologies for creating a regional framework model for managing climate change risks for NRM
- develop adaptation responses.

This report, *Developing industry climate change adaptation strategies,* describes the implementation of one of these case studies. The broad objective was to trial both knowledge building and adaptation planning methodologies with two key horticultural industry groups within the southern AMLR/Fleurieu Peninsula regions: the McLaren Vale grape growers and the Fleurieu Peninsula olive growers.

This work fits within a broader emerging decision-making framework for adaptation to climate change (described in Bardsley and Liddicoat [2007]), which has steps including:

1. Awareness-raising and ownership of change.
2. Vulnerability analysis.
3. Development of adaptation responses.
4. Appropriate integration of adaptation responses into management and planning activities across different timeframes:
   a. incorporation of climate change into risk management approaches in the short-term
   b. the application of adaptive management techniques which can be adjusted over time

   c. the application of the precautionary principle, that is, allowing for increasing long-term risk.
5. Ongoing revision, reassessment and possible alteration of these approaches.

1.2.1 LOCAL CLIMATE CHANGE PLANNING

The Council hosted this case study as it is closely related to its economic development and climate change activities (www.onkaparingacity.com). Suppiah et al. (2006) suggest that local governments are likely to become the focal points for climate change impacts and adaptive responses, so it is appropriate that the Council demonstrated a lead role for adaptation planning in this case study.

The City of Onkaparinga is a large council area including both urban and rural areas, extending from the southern fringes of metropolitan Adelaide to the Fleurieu Peninsula. The local economy includes a significant element of agricultural industry. The Council area includes the McLaren Vale wine industry and a portion of the Fleurieu Peninsula oliveculture industry (see Fig. 1).

The Council is in the process of developing a strategic council-wide response to climate change. As a fundamental part of this process, the Council is establishing its role in community climate change planning. This role is developing around information provision, advocacy and facilitating engagement into the planning process. Although Council has fulfilled these roles previously, there is no available model based around the imperatives of climate change. The case study reported here is a demonstration of the way Council might engage with the community to facilitate a planned response to climate change.

In this case study, Council's role was to:

- develop the case study brief and methodology
- engage the major stakeholders (industry, government and the scientific community)
- gather, interpret and disseminate the scientific information
- gather, analyse and report to stakeholders on the findings of the case study
- assist with the development of adaptation strategies
- participate in the validation steering group and process design.

1.2.2 REGIONAL ECONOMIC DEVELOPMENT

The Council is also a partner in the SAEDP. SAEPD articulates a strategic framework for economic diversification for a significant part of the AMLR NRM region, specifically the Cities of Marion and Onkaparinga. It is widely recognised as the key economic development strategy for the region and is closely aligned with the South Australian Strategic Plan. SAEDP identifies a broad base of existing economic strengths.

Within SAEDP, the food and wine industries are considered to be priorities for future growth. SAEPD recognises that resilience to climate change will be central to the strength of the region's future economy. This case study is therefore an important step in constructing an

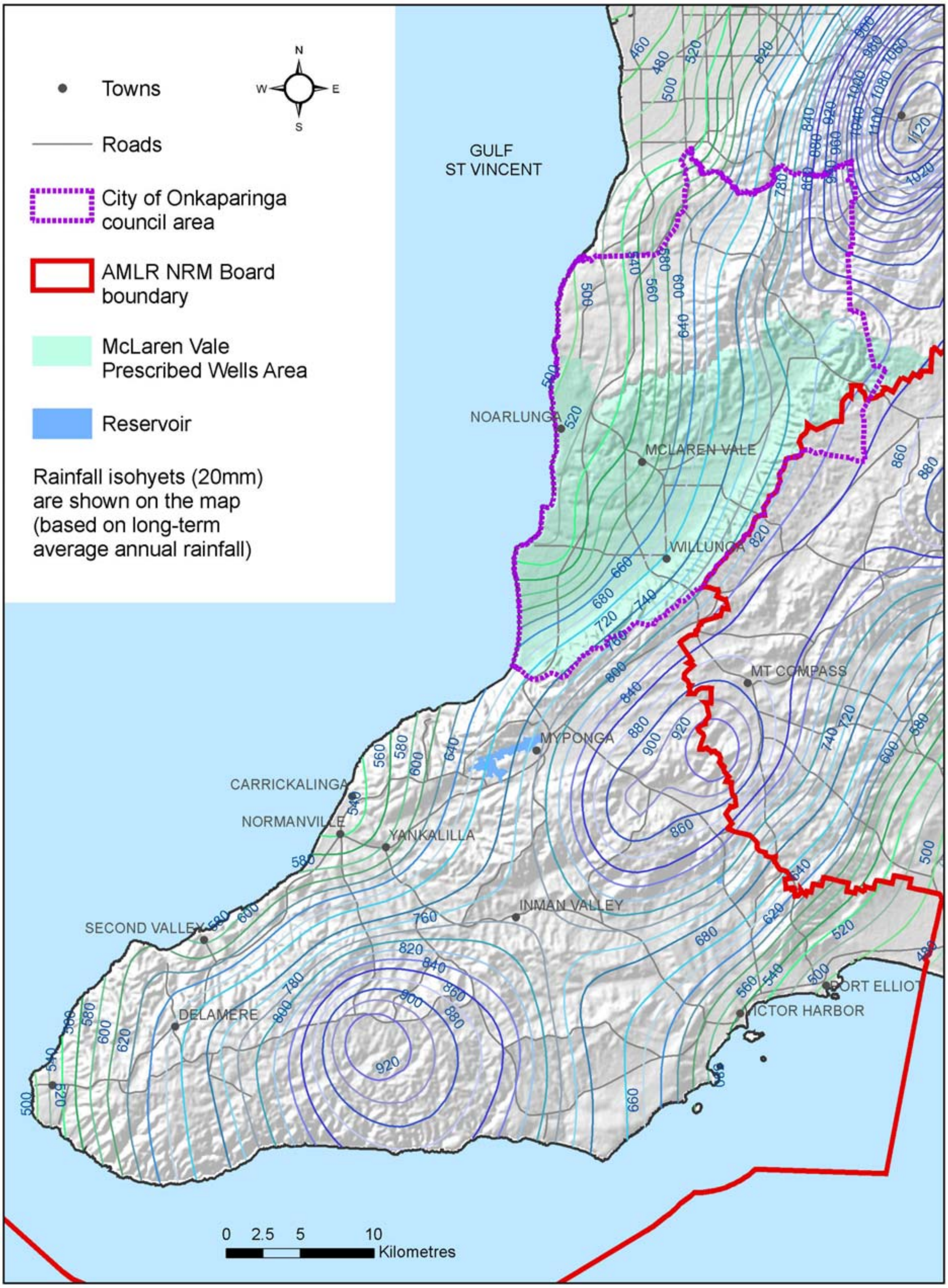

Figure 1. Location of the City of Onkaparinga council area and the Fleurieu Peninsula

understanding of the impacts climate change will have on the region's food and wine industries. This work will begin to highlight the specific risks climate change poses to the regional economy and establish direction for strategic adaptation planning.

1.3 INDUSTRY AND REGIONAL CHARACTERISTICS

Bardsley's (2006) assessment rates the climate change vulnerability of the AMLR NRM horticulture sector as medium to high and highlights it as an immediate priority for further investigation (Bardsley 2006, p. 40). He describes this sector as being sensitive to changes in temperature but buffered by irrigation. In contrast, he also points out that the sector is exposed to a range of primary and secondary factors that may limit irrigation supplies (e.g. reduced surface water availability, water restrictions). Additional exposure comes from the constraints to the sector's capacity to respond. These are primarily the time and investment required to adjust a horticultural crop to new climatic conditions (Bardsley 2006, pp. 40–41). The characteristics of the Fleurieu Peninsula olive and wine industries are consistent with Bardsley's general description.

In terms of climate, the industries are geared to the region's Mediterranean climate which is typically expressed as (MVGWTA 2007):

- hot dry summers
- wet winters
- rainfall averages of 580–700 mm per year
- a lack of drought and frost.

Long-term average annual rainfall isohyets are shown in Figure 1. Long-term monthly average rainfall and evaporation, and minimum and maximum temperatures for selected locations are shown in Figure 2.

Horticultural plant varieties and management practices used by growers reflect these long-term average climate parameters, as well as the range of climate variability and physical geography found across the region. A change to the climate is therefore disruptive to the fundamental factors that have enabled the target industry groups to become established in this region.

1.3.1 VITICULTURE

The viticulture industry in the Onkaparinga council area is geographically concentrated around the McLaren Vale region. The industry has been producing wine commercially since the mid-1800s and is renowned for its world class wines, particularly shiraz. Businesses are typically geared around relatively small harvests of high-quality fruit (MVGWTA 2007).

There are around 500 grape growers and 80 wineries operating in McLaren Vale. More than 75% of growers and nearly all wineries are represented by the MVGWTA. MVGWTA is largely funded through a grower levy and employs a variety of professional staff. It represents the viticulture industry through education, information provision, research and advocacy roles.

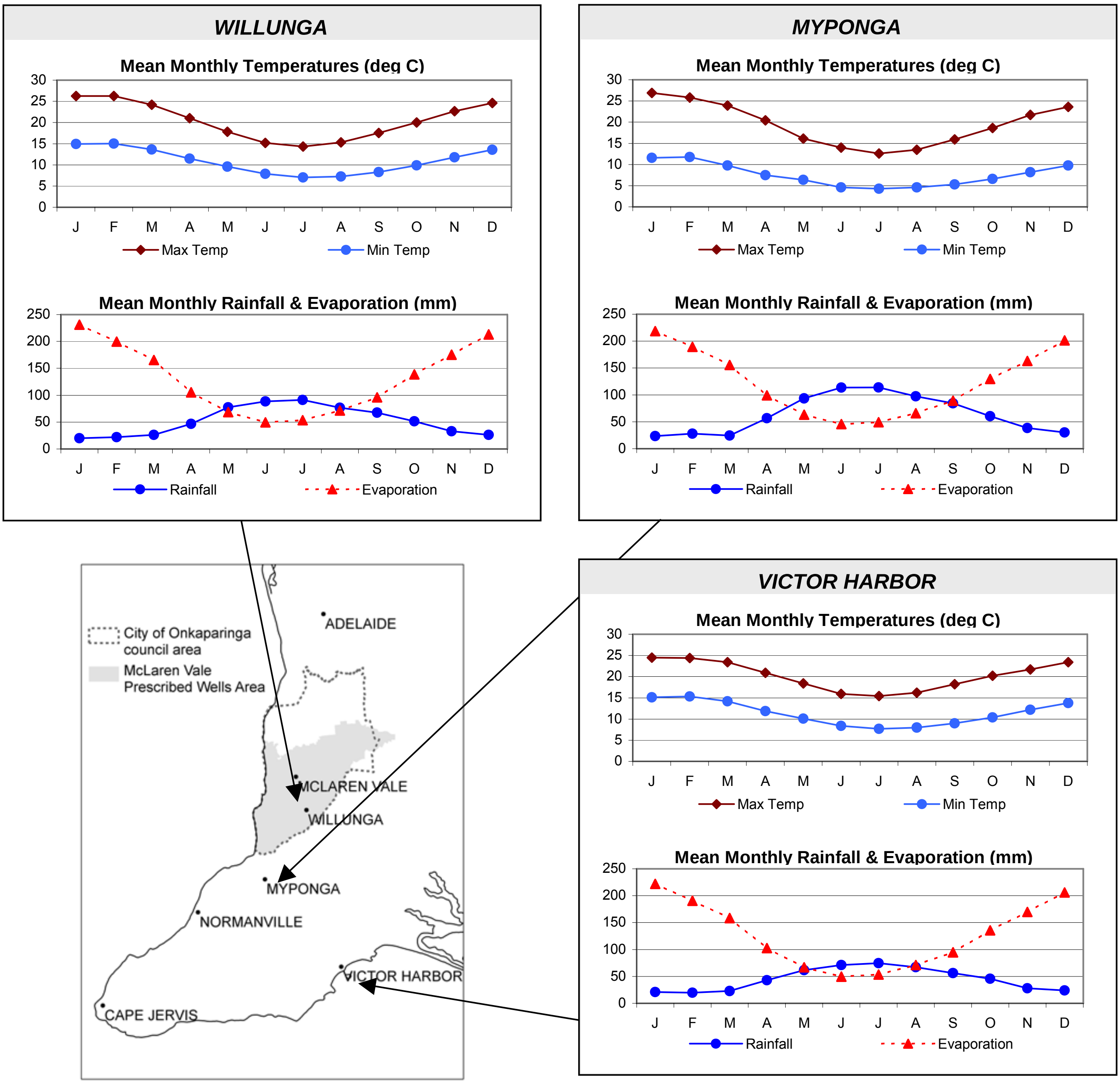

Figure 2. Long-term mean monthly rainfall and evaporation, maximum and minimum temperatures for selected locations (BoM 2008; QLD DNRW 2007)

Regional description (A Richards 2008, pers. comm.)

The McLaren Vale Wine Region comprises about 7000ha of grape vines and produces around 65 000 t of wine grapes. The majority of wine grapes grown in the region are used for the production of high quality, dry table wine. Red wine grape plantings make up over 75% of all plantings in the region and are dominated by shiraz (48%). Shiraz vines in McLaren Vale are generally spur-pruned, produce a range of yields and ripen to at least 12 Baumé.

Temperature during the period of berry ripening (January to February–April) can influence quality and wine style in McLaren Vale. In cool years, Shiraz displays pepper character and good colour and tannin development. However, in cool, wet years, incidence of fungal infection can increase and more frequent applications of fungicides may be required. In warm/hot years fruit tends to have more jammy characters and lower colour. Extreme heat (days over 35ºC) during ripening can reduce yield and quality in some vineyards. Management strategies employed to mitigate the effects of extreme temperature include the application of larger volumes of irrigation water.

Temperature and rainfall extremes can also adversely affect vine performance during key phonological stages such as budburst, flowering and set.

Water and salinity management issues

The industry is generally regarded as having sound water security. It benefits from good winter rains and is buffered against dry spells by sources of irrigation water. There is widespread but controlled access to the McLaren Vale Prescribed Wells Area (MVPWA) groundwater resource (see Fig. 1) and a significant proportion of growers have commercial access to the Willunga Basin Water Company (WBWC) recycled effluent reticulation system (WBWC 2008). About 10% of growers are dependent on surface water (dams and flow in the Onkaparinga River) while many small family-owned vineyards have access to mains water for irrigation (A Richards 2008, pers. comm.).

Highly efficient irrigation practices have been widely adopted in the McLaren Vale region, reflecting the growers' appreciation of water sustainability issues and the need to protect their valuable resource. Irrigators in McLaren Vale rarely apply a leaching fraction to remove salts applied during irrigation because of water supply constraints and demand for high quality fruit (A Richards 2008, pers. comm.). Growers generally rely on winter rainfall to leach accumulated salts from the root zone.

A drier climate and possible regional water shortages represent significant risks. Less available water (e.g. through restrictions or varying allocations) and increased water demand will have direct impacts on the productivity of growers and the industry. Less winter/spring rainfall will reduce winter leaching of salts from the root zone, and soil moisture deficits will require growers to start irrigating earlier, possibly increasing the salt load added to soils. If salt loads increase, this will increase inputs of sodium into the root zone resulting in elevated soil sodicity.

Growers with limited or inflexible options for water supply (e.g. small vineyards with mains water only) are at risk of having their water supply restricted, as evidenced during the recent drought (Owen 2008). The build-up of salt in vineyard soils will also depend on the salinity of irrigation water, which is likely to vary between different sources such as WBWC recycled water or water sourced from Myponga Reservoir.

Of particular interest is whether water sources with higher salinity levels (such as from the River Murray) are likely to be used for irrigation. Reduced inflows associated with prolonged drought in the Murray-Darling Basin have resulted in above average salinity levels in the River Murray (currently 940 µS/cm at Murray Bridge: MDBC 2008).

Mains water in the region from McLaren Vale to Victor Harbor is supplied from Myponga Reservoir, which, unlike other reservoirs, does not receive any water from the River Murray (District Council of Yankalilla 2008).

However, River Murray water is likely to enter McLaren Vale vineyards via recycled water from the WBWC. WBWC takes treated water from SA Water's Christies Beach Waste Water Treatment Plant (WBWC 2008). This wastewater originates from the southern metropolitan suburbs including all of the Noarlunga City Council area, parts of Happy Valley, Marion and Mitcham (United Water 2008). The southern suburbs are supplied by Happy Valley Reservoir which is linked to the Mount Bold Reservoir via releases to the pumping station at Clarendon Weir. Further upstream, Mount Bold Reservoir is linked to the River Murray via the Murray Bridge–Onkaparinga pipeline, which discharges directly into the natural Onkaparinga River channel 10 km upstream of Mount Bold Reservoir. River Murray inputs to this system will vary depending on seasonal demands and local catchment inputs to the Mount Bold and Happy Valley Reservoirs. As a rough guide, 40% of the state's urban water needs are supplied by the River Murray in an average year, but this can increase to as much as 90% in dry years (SA Water 2008).

Salinity build-up in soils is also related to soil properties such as unsaturated hydraulic conductivity and impediments to drainage down the soil profile. In general terms, soils with a higher percentage of clay will impede leaching and hence be more likely to accumulate salts (Richards, Hutson & McCarthy 2007). (Regional maps of % clay content in soils are shown in App. 1.)

1.3.2 OLIVECULTURE

The oliveculture industry is more broadly distributed across the Fleurieu Peninsula. In this region the olive industry is relatively new, with Millar (2004) stating, 'As the majority of the trees in the Fleurieu Peninsula were planted in 2000-01 they are now beginning to reach maturity'. Total olive tree numbers in the region have previously been estimated at 400 000–500 000 trees (Millar 2004; Sweeney 2006), however, recent estimates suggest that plantings in the Fleurieu region may only number 300 000 trees (P McFarlane 2008, pers. comm.). Possible reasons for the downgraded estimates of production capacity include nursery stock not being eventually planted in the region and groves going out of production (P McFarlane 2008, pers. comm.). Millar (2004) describes the growers generally as 'sea-changers' operating small groves for retirement incomes. Typically these groves are less than 2000 trees. However, there are also a number of substantial commercial growers within the region. Sweeney (2006) estimates there may be around 20 medium sized developments throughout the Fleurieu and there are at least four large developments (with more than 80 000 trees) located at Mount Compass, Willunga, Currency Creek and Finniss (P McFarlane 2008, pers. comm.). The olive industry also has a regional industry association. In contrast to the wine industry, the FPOA is much smaller and has far less resources than MVGWTA. It consists of around 30 members, is funded through membership fees rather than a levy and relies entirely on volunteer effort (V Zadow 2007, pers. comm.). FPOA also services its industry through education, information provision, research and advocacy).

Water and salinity management issues

The Fleurieu is now part of the Western Mount Lofty Ranges prescribed area, which has prescribed the surface water, groundwater and watercourse water of the Western Mount Lofty Ranges. Once the water allocation plan is finalised water users will require a licence for water use from these sources (S Gatti 2008, pers. comm.).

Like the wine industry, oliveculture is reliant on good winter rains. However, the access this industry has to alternative irrigation sources is far more varied across the landscape. Depending on location, growers rely on the MVPWA or the WBWC recycled effluent reticulation system. Many also draw from the lower Murray and some are reliant on surface water retention only.

As for viticulture, soil salinity levels will depend on the salinity of irrigation water, applied leaching fractions, soil properties and rainfall.

Plantings in higher rainfall zones will experience greater flushing and dilution of soil salts, compared to those in lower rainfall zones where the influence of evapotranspiration (tending to concentrate salts) will increase.

Invasive species risk

Regardless of the impacts of climate change, the weed risk posed by olive groves is the subject of significant debate. The olive industry has been associated, by some members of the broader community, with the invasive feral olive population present in bushland throughout the AMLR NRM region. However, the olive industry considers the weed risk from commercial groves to be a low risk, suggesting that feral olive populations present in bushland are the legacy of historic olive plantings and that control measures do exist where groves become abandoned (J Fennell 2008, pers. comm.).

Within the NRM community, including the Weed Management Society of SA, olives are considered to be a high risk, particularly where located adjacent to bushland (S Gatti 2008, pers. comm.). There is also the view that today's olive groves will become tomorrow's historic plantings and any olive plantation that is not managed well can pose a weed risk.

It should be noted that good habitat for olives can be found throughout the Mount Lofty Ranges, in areas such as the 'hills face zone' (N Crossman 2008, pers. comm.). Poor accessibility in such areas means that feral olive populations are hard to control. With respect to climate change, early assessments of climate projections suggest that potential habitat areas for olives may become greater with climate change (N Crossman 2008, pers. comm.). The potential for climate change to increase the weed risk from commercial olive groves is raised within this adaptation planning work and will require further investigation in future planning activities.

Legislation to control the invasive risk from abandoned groves is covered within the *Natural Resources Management (SA) Act 2004* (the Act). This Act gives NRM Boards the power to order the control of any plant declared under section 182(2) at the expense of the owner of the land. The Minister's declaration of plants and animals in the Government Gazette 63 of 30 June 2005 declares olives under this section, with the exception of olive trees 'planted and maintained for domestic or commercial use'. It is the view of DWLBC's Senior Pest Plants Adviser that olive trees in an abandoned grove no longer fit the description of 'maintained', and would no longer be exempt. This issue is yet to be tested in the Environment, Resources and Development (ERD) Court, however DWLBC considers two successive years unharvested as an appropriate criterion for defining an abandoned grove (D Cooke 2008, pers. comm.).

2. AIM AND OBJECTIVES

The McLaren Vale grape growers and Fleurieu Peninsula olive growers are two key groups within the southern AMLR in an industry sector (horticulture) that has been identified as being vulnerable to climate change. Accordingly, this work sought to:

- trial knowledge building and adaptation planning methodologies
- engage, educate and encourage ownership of the climate change issue for stakeholders
- implement an adaptation planning process, including:
  - assessment of climate risks and risk levels (with a focus at the industry level, rather than enterprise/individual business level)
  - identification of priority areas for adaptation
  - development of initial adaptation response strategies, and potential roles and responsibilities for business, industry associations and other stakeholders
- provide a broad indication of issues facing the industry groups to help inform:
  - local industry strategic planning
  - future iterations of the SAEDP (in which the Council is a partner)
  - the City of Onkaparinga Water Management Strategy
  - the SAWIA climate change response
  - other natural resources managers in the region.
- provide a case study for industry climate change adaptation planning
- demonstrate a climate change response model for local government interaction with industry
- generate feedback on the engagement process and project methodology — to assist future adaptation planning work.

Two industry specific questions were added to the investigation as they represented important locally held attitudes that may influence climate change adaptation planning:

1. Is the McLaren Vale wine industry really ‘waterproof’, i.e. does it have sound water security?
2. Is climate change likely to increase the risk that commercial olives crops will contribute to the feral olive population?

3. METHODOLOGY

3.1 RISK MANAGEMENT APPROACH

Climate change adaptation response strategies were developed utilising a risk management approach with participation from regional industry stakeholders. Risk management is a standard tool used across many sectors to enhance positive outcomes and reduce negative outcomes, and is increasingly being adopted by business and government organisations in the development of responses to climate change (AGO 2006; CSIRO & BoM 2007; Suppiah et al. 2006). An overview of the risk management process is shown in Figure 3.

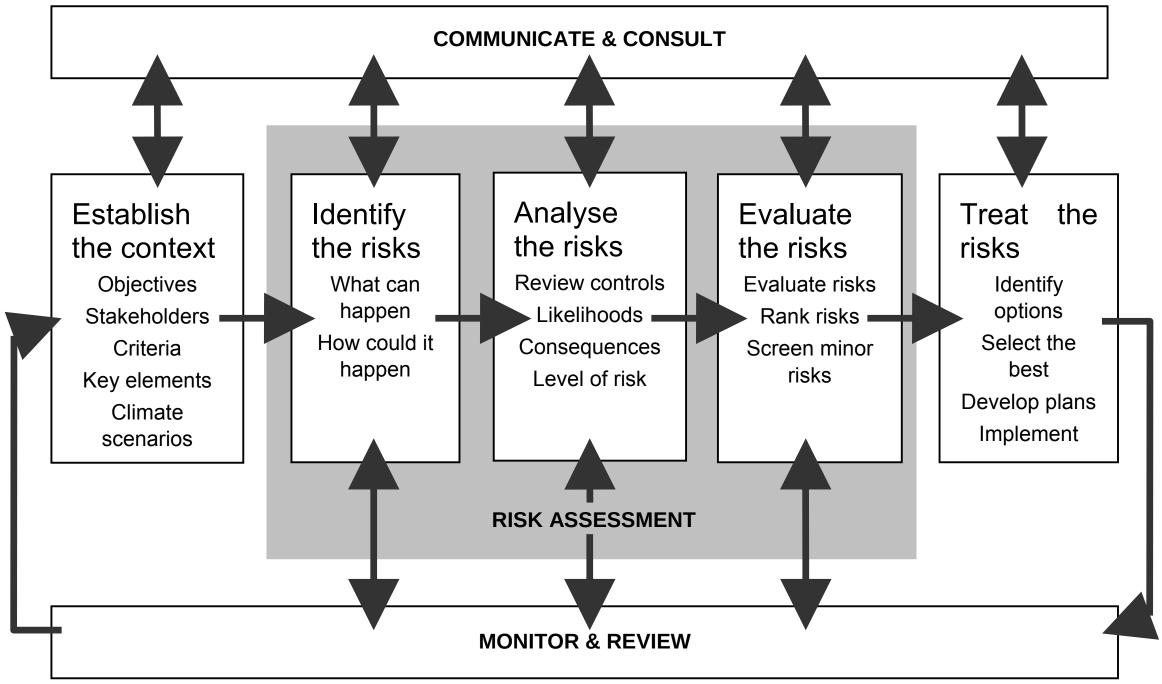

Figure 3. The risk management process (AGO 2006, Standards Australia 2004)

Consistent with the approach recommended by the AGO's *Climate change impacts and risk management* guide (AGO 2006), this work began by focusing on an <u>initial</u> assessment of climate risks and adaptation responses. AGO (2006) suggests that this initial assessment stage is where the greatest gains will be made with the least effort, and 'with relatively simple summary climate change information and a straightforward risk management approach, significant insights may be generated leading to early and effective action'.

This approach does not downplay the importance of more detailed technical analysis of risks to determine the most effective treatments (also recognised by AGO [2006]), and this aspect was commenced through the ongoing review of findings by industry focus groups and in a subsequent expert review process. It should be noted that detailed analysis of risks will be an ongoing process through future adaptation planning activities for the industry groups.

Within the context of a risk management approach (Fig. 3), major components of this adaptation planning case study are summarised in Figure 4. Risk management is an iterative process and two steps (grower workshops and a risk assessment survey) were used to identify, analyse and evaluate potential climate risks. Following this case study, ongoing and more detailed analysis of risks will be conducted by the industry groups. Some aspects of this process are discussed in more detail in the following sections.

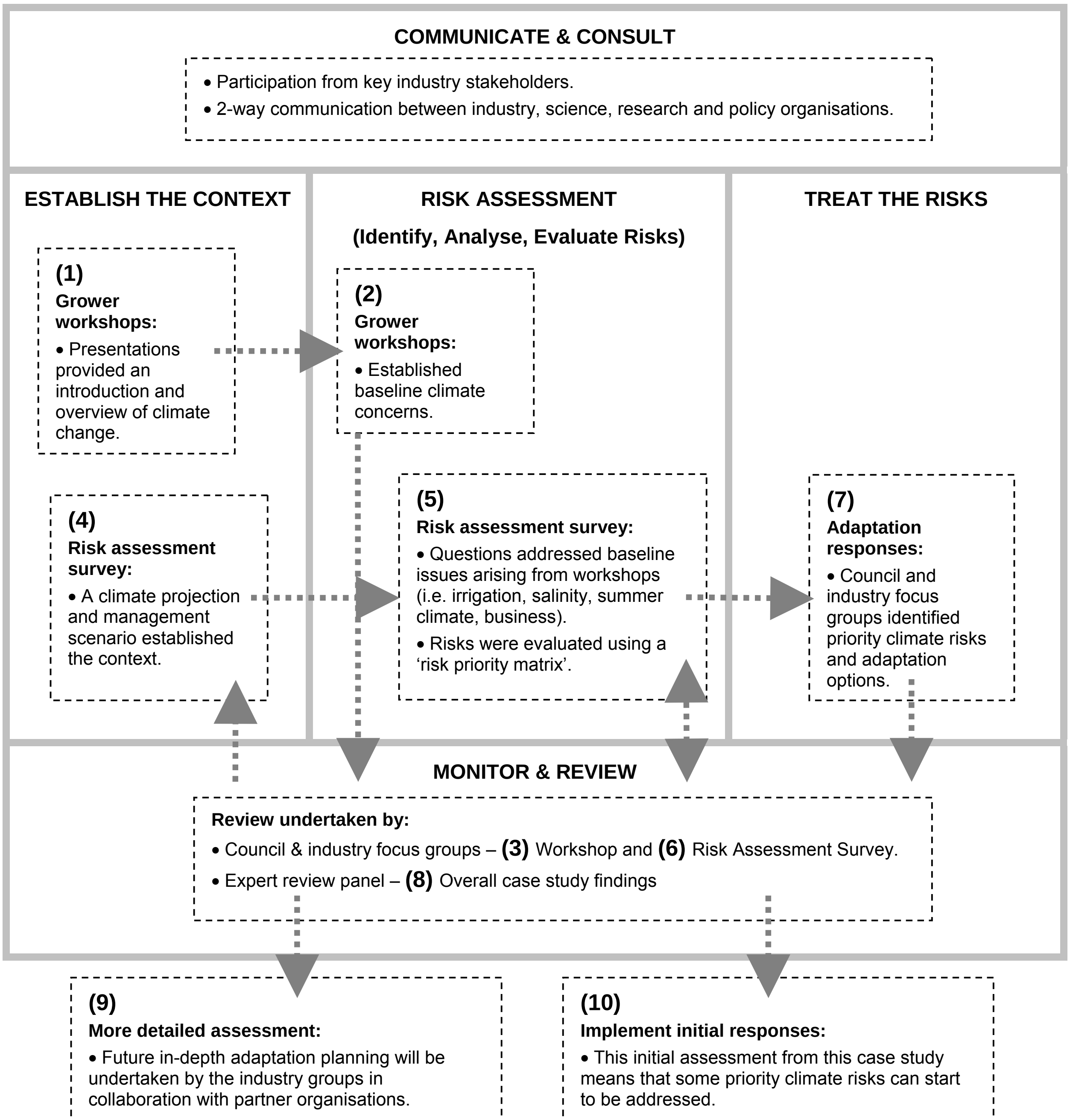

Figure 4. Major components of the adaptation planning process undertaken in this case study (in the context of a risk management framework)

In summary, the major methodological steps within this risk management approach included:

1. Participation of key stakeholders through industry focus groups to guide the implementation of the case study.
2. Adaptation of the AGO Risk Management Guide for business and government.
3. Industry specific workshops with the grape and olive growers to communicate and explore the implications of climate change, particularly with respect to drought. Growers were also presented with an overview of climate change projections, regional water issues and potential climate implications for the respective industries. This generated baseline information of climate issues relevant to the groups.
4. A risk assessment survey of the major climate related issues associated with an assumed scenario of worst-case projected climate and set of management considerations. Questions were generated around four themes: irrigation, salinity, changing summer climate and business issues. The scenario used existing climate change modelling (Suppiah et al. 2006), scientific studies (e.g. REM 2007) and regional meteorological data to justify a set of climate assumptions that would minimise the level of uncertainty in the risk assessment survey.
5. A review of the overall risk assessment findings (from workshops and survey results) and development of priority adaptation response strategies by the industry focus groups and Council.
6. A technical review and validation of the overall project work by a panel of science and industry experts was undertaken to give more objectivity and weight to the findings. Comments and suggestions raised through this review will be of great benefit to future adaptation planning activities.

All stakeholders are learning how to manage the climate change issue, including the lead organisations associated with this case study. Important suggestions for improvement to the adaptation planning process were raised through the expert review and these have been highlighted throughout the report for the benefit of future planning activities (look for 'Learning Points' as shown here).

LEARNING POINTS

3.1.1 STAKEHOLDER PARTICIPATION

Two industry focus groups were established from the beginning of the case study to:

- advise on the development of the growers' workshops
- review the significance of the workshop findings
- assist with the design of an industry-specific risk assessment
- review the risk assessment findings and develop strategy responses.

Participants in each of the industry focus groups are listed in Appendix 2.

The viticulture group was composed of growers and industry specialists. These specialists included grower liaison officers with the major wine companies and viticultural consultants. It was felt that these people represented a broad and informed perspective on successful viticulture business in the McLaren Vale region.

The olive group comprised of selected growers and one of the region's processors. This group represented the best available knowledge in the region's industry.

A combination of approaches was used to engage with industry members. This ensured that the information (flowing in both directions) was relevant to the industries involved, provided contemporary context and framed the risks appropriately.

3.1.2 WORKSHOPS

Two growers workshops were held in June/July 2007 (see participant list in App. 2). The workshops were split into two sessions:

- The first session was used to provide an overview of the climate change science and general implications for the region.
- The second session was used to engage growers in group discussion of the implications of climate change for their businesses.

While information was provided on a range of projected climate impacts, workshop discussions tended to focus on the issue of drought. Under climate change, droughts in the region are projected to increase in frequency so this was seen as a useful starting point to begin thinking about responses to the potential impacts of climate change.

Workshops — Session 1

The viticulture workshop group was presented with the following information:

- ***Overview of the climate science and regional climate implications*** — Professor Barry Brook, Director of the Research Institute for Climate Change and Sustainability, University of Adelaide. This talk summarised climate change assessments conducted by the Intergovernmental Panel on Climate Change (IPCC) and at the regional scale by Suppiah et al. (2006) and McInnes et al. (2003).
- ***Implications for groundwater management in the McLaren Vale PWA*** — Stephen Smith, Director Policy and Planning, AMLR NRM Board. This talk presented groundwater modelling data (REM 2007) suggesting groundwater levels would drop under climate change (reduced rainfall scenarios) and raised the prospect of introducing variable groundwater allocations in line with changing groundwater resource availability.
- ***State wide wine industry responses to climate change*** — Peter Leske, Projects and Technical Adviser, SAWIA Incorporated. This talk introduced a conceptual approach for growers to start thinking about climate change impacts to various aspects of their business, through discussion of various 'what if' scenarios.

The oliveculture workshop group was presented with the following information:

- ***Overview of the climate science and regional climate implications*** — Professor Barry Brook, Director of the Research Institute for Climate Change and Sustainability, University of Adelaide (as per the viticulture workshop)
- ***Implications for water resource management in the Fleurieu region*** — Stephen Smith, Director Policy and Planning, AMLR NRM Board. This talk discussed the prospect of reduced water resource availability and potential introduction of variable allocations to match changing sustainable yields.

- ***Summary of climate implications for olive habitat on the Fleurieu Peninsula*** — Julian James on behalf of Dr Neville Crossman, CSIRO. This talk presented preliminary work looking at changes in olive habitat due to climate change. Results are inconclusive at this stage due to uncertainty in the range of climate parameters which influence olives, however early information suggests that habitat for olives will increase.

Workshops — Session 2: group discussion

The participants were divided into small groups of around six people. They were asked to reflect on the 2006 (winter 2006–autumn 2007) growing season as it was recent and particularly dry. It was explained to the growers that this type of season did not represent climate change per se but that it reflected the pressures that may be associated with a warming drying trend, especially in drier than average years.

Growers were then asked to discuss the main pressures that they experienced in their business and what they did to ease the pressure. They were provided with a tabulated record sheet to record the discussion. The table had been developed by the focus groups and divided the viticulture and oliveculture businesses into the main business systems (see App. 3).

The participants were then asked to prioritise these pressures if 2006 became the average climate they expected to be growing in. The results of this are discussed in Section 4.

LEARNING POINT

To avoid potential bias towards particular climate issues, information on a range of climate parameters should be presented and discussed (C Soar 2008, pers. comm.).

LEARNING POINT

Care is required in communication about climate change and it is important to distinguish between drought (e.g. 2006) and a new climate mean. The year 2006 is useful as a focus for thinking about adaptation options, however this should be recognised as an extreme that would be more common in a drier climate, not as an example of the new mean (P Hayman & L Webb 2008, pers. comm.).

Method of analysis — workshops

The responses to the group workshop discussion were summarised on the basis of:

- each group's chosen priorities
- recurring themes across all groups.

A prioritised summary of the discussion was then generated.

Information was gathered to help evaluate likely pressures on individual business level production systems as a result of this projected climate change. It was assumed that widespread exposure at the individual business level equated to exposure at the industry level. Hence a baseline set of climate risks that the industry might need to manage in the future was developed.

This set of climate risks fed into more detailed information gathering and analysis via a risk assessment questionnaire. The risk assessment results were then analysed by industry focus groups to help evaluate priority climate risk areas and potential adaptation responses. A process of validation and review by relevant science and industry experts was then conducted to give more objectivity and weight to the project findings.

3.1.3 RISK ASSESSMENT SURVEY

Using the workshop findings as a baseline, the next stage of the case study sought to further investigate major climate change risks for the industries. The AGO (2006) methodology was adapted in the following ways to increase its applicability to this case study:

- Best available climate change projections were interpreted using region specific information where possible.
- Risks were assessed from an industry level rather than an enterprise (individual business) level perspective.
- Consequence scales were developed to reflect an industry level analysis and key stakeholder roles in any response.
- Major climate risks were identified (from workshops and industry focus group discussions) and presented to participants in survey form.

These adaptations were informed by the work of Muirden (2007) who had recently used the AGO (2006) guide to assess shared risk between multiple stakeholders in the Mount Lofty Ranges watershed.

This part of the risk assessment process had two core components:

1. A *survey questionnaire* (see App. 4).
2. A *common set of assumptions* both for projected climate change and management considerations (see Tables 3–7). The assumed climate scenario (looking out to 2030) was chosen to reflect the worst-case scenario within the range of possible climate projections.

Survey questions

A set of questions were constructed to probe what were viewed as the major areas of climate change risk faced by the two industries. The risk areas and the initial set of questions were drawn from the grower workshop findings. These were refined through group discussion with the focus groups and worked into a survey format (see App. 4).

The survey questions focused on the four main climate risk areas that were identified:

- irrigation (water availability)
- salinity
- changing summer climate
- business (economic) issues.

The survey was then provided to a small group of industry stakeholders which included the focus group members and the ‘risk assessment extras’ (see App. 2) (N=12 [viticulture], N=8 [oliveculture]).

The survey respondents were asked to assess the risks against the climate change assumptions and considerations discussed in the previous section.

Assumed climate scenario

Dealing with uncertainty in climate projections

Uncertainty in climate change projections arises because of the different modelling approaches used by various global and regional climate change models, as well as differences in possible future greenhouse gas emissions scenarios (e.g. SRES 2000). This range of uncertainty occurs between the various modelling outputs and does not include further uncertainty associated with knowledge about the climate system itself.

At the time the risk assessment was undertaken, Suppiah et al. (2006) provided the most up-to-date climate projection information for the region[1]. Suppiah et al. (2006) derived a range of temperature and rainfall projections from 13 global climate models (GCM) which they assessed as performing satisfactorily across South Australia. They also considered two types of emissions scenarios:

- Special Report on Emissions Scenarios (SRES) (2000) which exclude policies to reduce emissions.
- Emissions reductions scenarios which stabilise CO_2 concentrations at:
  - 450 parts per million (ppm) by 2100
  - 550 ppm by 2150.

Hence, outputs from the various climate models and emissions scenarios provide a range of possible climate outcomes.

In keeping with the recommendations of AGO (2006, pp. 26–27), a common set of assumptions for projected climate change were used to limit uncertainty in the risk assessment decision making. AGO (2006) suggests that assumed climate change scenarios can provide a plausible summary of the changes to climate variables applicable in the region and timescale of interest, and provide a consistent and efficient basis for assessing climate related risks across different organisations. AGO (2006) recommends that only a limited number of scenarios be used to represent major plausible climate changes, with one or two scenarios generally being sufficient. In this case study a single climate change scenario was used in the risk assessment survey.

This approach is consistent with the range of potential approaches[2] described by Preston, Jones and Hennessey (2007) (CSIRO & BoM 2007, p116) for dealing with uncertainty in climate projections within risk assessments.

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[1] It should be noted that climate projection data has since been updated by CSIRO and BoM (2007), see Appendix 5.

[2] Preston, Jones & Hennessey (2007) suggest that a hierarchy of approaches can be used to explore uncertainty in climate projections. These include multi-model studies that produce probability

To reflect the precautionary principle, the 2030 SRES (which exclude policies to reduce emissions) for the AMLR NRM region were used as the basis for the direction, timing and magnitude of changes (Suppiah et al. 2006, p. 31). From within the range of SRES climate projections (App. 5) a worst-case scenario was selected.

The regional implications of the selected climate scenario was characterised using:

- records of the local and seasonal climate
- knowledge of a range of other variables significant to the industries.

A simple linear relationship was assumed to exist between the climate change scenarios (Suppiah et al. 2006) and the regional climate. In other words, it was assumed the regional climate will change in the same way as projected by the available climate models[3]. For example, in the worst-case scenario selected, summer rain events are projected to become more extreme so respondents were asked how they would respond to an increase in the extreme summer rainfall events that have been observed historically in the region. It was acknowledged to participants that this did not reflect what change will occur or the complexity of climate systems. The approach was justified on the basis that it would indicate broad risks and highlight initial directions for adaptation planning and/or further investigation.

Tables 3 to 6 outline the:

- common assumptions regarding the regional implications of climate change
- justification for the selection of regional implications
- sources of this information.

It is noted that Preston et al. (2007) (CSIRO & BoM 2007, p. 114) point out that, due to internal inconsistencies, there is the potential for error (i.e. unrealistic climate scenarios to be presented) when using projections created from more than one climate model. Two such inconsistencies exist in the following table.

1. The number of hot days projected for Adelaide come from a different resource (Hennessey, Macadam & Whetton 2006) than the other projection modelling used (Suppiah et al. 2006). It is uncertain which model(s) this information was drawn from.
2. The groundwater resource modelling referred to (REM 2007) is based on likely drying scenarios informed by modelling described in McInnes et al. (2003). The time frames used are also inconsistent with the Suppiah et al. (2006) modelling used for the other projections. The authors of the groundwater modelling also acknowledge that the understanding and therefore ability to model the groundwater system is limited (REM 2007, p. 13).

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distributions, sampling methods applied to quantified ranges of uncertainty, expert judgement, sensitivity studies, and 'what if' scenarios (as was used in this case study).

[3] This assumption ignores any locally important climate influences such as topography. Finer scale climate projections can be developed, however, different methods of 'downscaling' from global climate models have different advantages and disadvantages (Suppiah et al. 2006, p. 52).

> ***LEARNING POINT***
> Climate change information is continually being updated. Some of the climate projection data used in this risk assessment has since been updated by CSIRO and BoM (2007) (see App. 5) (D Ray 2008, pers. comm.).

> ***LEARNING POINT***
> Knowledge of seasonal/critical crop requirements will help identify what climate data is needed (P James 2008, pers. comm.).

Table 3. Rainfall — assumed climate scenario for the risk assessment

2015–30 trends	**Where trends are outlined below, it is assumed that these become more exaggerated or reach the average measures stated by 2030**
Winter/spring	• The combined winter–spring season continues to become drier (Suppiah et al. 2006, p. 26). • Suppiah et al. (2006) projections for worst-case % rainfall reductions under SRES (2000), were applied to long-term averages from Bureau of Meteorology (BoM) historic rainfall records for Willunga. This suggests winter rainfall could be reduced to 234mm (11% reduction) and spring rainfall to 150mm (20% reduction) on average by 2030 (Suppiah et al. 2006, p. 31; BoM 2007).
Summer (Dec–Feb)	• The same Suppiah et al. (2006) projections, under SRES, suggest there is the potential for an increase in average summer rainfall by 6%. For McLaren Vale this would result in average summer rainfall of 71mm (Suppiah et al. 2006, p. 31; BoM 2007). The potential for increased summer rain was considered because of the adverse impacts on grape vines. • Extreme rainfall events will become more intense and more frequent (McInnes et al. 2003). • To describe an extreme event, one standard deviation from the average record was used as a proxy (McInnes et al. 2003, p.36). Using this criteria, extreme summer rainfall was described as a total above 106mm for the summer season. Historically this has occurred once or twice every ten years (BoM 2007). • Historic increases in summer rainfall were plotted in MS-Excel® using the trend function. This showed that any increases in summer rainfall have been most commonly associated with December, only slightly with February and not at all with January (BoM 2007). This was conveyed to participants as when more extreme summer rainfall may occur. • For December, on average, extreme rainfall (monthly totals) have historically been above 40mm and have occurred around one year in five (BoM 2007). • Humidity is likely to be greater in December than in January or February (BoM 2007).

Drought	• Droughts are likely to become more frequent and more severe (Hennessey, Macadam & Whetton 2006, p. 14).
	• Again, one standard deviation from the average record was used as a proxy for an extreme event. For this region, these are defined as (BoM 2007):
	  ○ winter rainfall of less than 183mm
	  ○ spring rainfall of less than 114mm.
	• The BoM historic data shows that these low seasons have occurred approximately once in every ten years (BoM 2007).

> ***LEARNING POINT***
> It may be misleading to present only selective data on projected changes to climate. Some models show increased summer rainfall, but others show projected rainfall reductions for summer. Participants should at least be aware of the entire range of climate projections (L Webb 2008, pers. comm.).

> ***LEARNING POINT***
> Extremes are also now covered by CSIRO & BoM 2007.

> ***LEARNING POINT***
> It is good to define extreme values, however, one standard deviation is not a large deviation. It will be exceeded about 15% of the time for high rainfall or temperature and 15% of the time for low rainfall or temperature, i.e. one in three years (30%) will be 'extreme' highs or lows. Drought policy uses one in 20 years or 5th percentile. The 2003 heatwave in the UK was three standard deviations (P Hayman 2008, pers. comm.).

Table 4. Temperature — assumed climate scenario for the risk assessment

Hot days	• The number of days each year above 35°C could average 29 in Adelaide (now 17) (Hennessey, Macadam & Whetton 2006, p. 14).
Harvest	• Due to warming conditions, harvest is expected to occur earlier than it has in the past (as advised by industry focus groups).

Table 5. Water supply — assumed climate scenario for the risk assessment

Groundwater supply	• Groundwater allocations now a percentage of resource rather than volumetric (S Smith 2007, pers. comm.). • Climate change and groundwater modelling (REM 2007) indicates that: ○ the resource is not impacted significantly by reduced rainfall recharge and it will continue to be accessible for consumptive use, however ○ users of the resource may be faced with revised seasonal allocations and increased price in times of low supply (REM 2007, p. 8).
Groundwater quality	• Groundwater salinity is stable due to ongoing monitoring and management. • The Maslin Sands Aquifer ranges from less than 500mg/l to 1500mg/l (Stewart 2006, p. 46). • The Port Willunga Formation Aquifer is typically below 1000mg/l but reaches 2000 mg/l in places (Stewart 2006, p. 45).
WBWC Water	• Recycled water supply continues as per commercial contracts (N Doole 2007, pers. comm.).
Mains and recycled water quality	• As there is currently no infrastructure in place for the removal of dissolved salts, WBWC salinity levels are affected by the salinity of primary water sources, such as the Murray (N Doole 2007, pers. comm.). • Current levels of WBWC salinity are 700–900 mg/l (N Doole 2007, pers. comm.).
Lower Murray water supply	• It is anticipated that water rights will have changed to reflect a share of the pooled resource (C Welsh 2007, pers. comm.). • Under this allocation regime, water availability can be expected to fluctuate on a season by season basis (MDB NRM Board 2007).

Table 6. Business — assumed scenario for the risk assessment

Viticulture practices	• Consider only current common irrigation sources and crop management practices.
Oliveculture practices	• Consider only current common irrigation sources and crop management practices.
Market conditions	• The price of McLaren Vale wine/olive oil is stable at $15/bottle equivalent in both 2015 and 2030 (as advised by industry focus groups). • Electricity costs may have increased above CPI increases due to a price on carbon emissions.

Additional Implications

For participants to make an informed assessment of risk, a range of implications for additional variables was also presented. These implications were drawn from a range of existing information sources that are summarised in Table 7.

Table 7. Major impacts to consider — assumed scenario for the risk assessment

Irrigation considerations	• Soil moisture levels likely to be low at the beginning of the growing season. • Evaporative demand high throughout spring and summer (as advised by industry focus groups). • Increased need for early irrigation (as advised by industry focus groups). • Greater reliance on irrigation overall (as advised by industry focus groups). • Groundwater allocations become variable depending on rainfall variability (REM 2007, p. 8). • Water restrictions may be in place on all mains water users due to increased demand and reduced supply.
Salinity considerations	• Major irrigation sources will contribute dissolved salts into the regions soils (N Doole 2007, pers. comm.; Richards, Hutson & McCarthy 2007; Stewart 2006). • Under drought conditions, winter/spring rainfall may not be sufficient to flush salinity from soils (N Doole 2007, pers. comm.; Richards, Hutson & McCarthy 2007; Stewart 2006). • Salt added in irrigation water has increased potential to accumulate across seasons (Richards, Hutson & McCarthy 2007). • Salinity leaching strategies are likely to be necessary (Richards, Hutson & McCarthy 2007). • Increased soil salinity may impact on vine health and productivity (Richards, Hutson & McCarthy 2007).
Summer considerations	• Viticulture/oliveculture is generally reliant on irrigation sources (as advised by industry focus groups).
Business considerations	• Yield and quality are stressed by salinity, drought and heat conditions (as advised by industry focus groups). • Costs are up due to lower economies of scale, losses and the need for additional inputs. • Cost of pumping is particularly affected by electricity pricing (as advised by industry focus groups).

LEARNING POINT

Care is required in defining 'damaging heat conditions'. Understanding the effects of heat is an area of current research. Not all heat is bad. Warmer conditions can be better for quality but there is some evidence that 'heatwaves' impact on quality, but we do not know if this is a heat effect per se, or a heat/wind/water issue. (C Soar 2008, pers. comm.).

Risk scales

Under the AGO (2006) framework, risk is determined from the combination of the likelihood of an occurrence and the consequence of that occurrence. The likelihood and consequence scales used in the risk assessment survey are described in Tables 8 and 9. The consequence scale was adapted from that provided by AGO (2006, pp. 35–37). At the low end, consequences were considered to be those that could be managed by or confined to growers at the enterprise level. This is not to suggest these are low risks to the enterprise but that risks that affect only a few businesses are not a risk to the industry as a whole. The intermediate levels of consequence were those that are broad enough to affect the whole industry but that could be managed within the industry's resources. The high end of consequence are risks that are beyond the industry's capacity to manage and require the attention of external organisations.

Table 8. Likelihood scale — for use in the risk assessment survey

LIKELIHOOD OF OCCURRENCE		
Rating	**Score**	**Description**
Rare	1	Extremely unusual circumstances and only a remote possibility of occurring
Unlikely	2	Can happen but it is unlikely that these circumstances will occur
Moderate	3	Appreciable likelihood that these circumstances will occur
Likely	4	It is as likely as not that these circumstances will occur
Almost certain	5	These circumstances will almost certainly occur

Table 9. Consequence scale — for use in the risk assessment survey

CONSEQUENCE OF OCCURRENCE		
Rating	**Score**	**Description**
Insignificant	1	Likely to affect only a small number of growers; and/or Minimal temporary impact only, no remedial or management action required Easily addressed by growers
Minor	2	Likely to affect a significant number of growers; and/or Minimal impact remedial or management action may be required Easily addressed by growers but may require an allocation of industry resources
Moderate	3	Likely to affect more than half of growers; and Ongoing impact, remedial or management action required May require a planned industry response and allocation of resources
Major	4	Likely to affect all growers; and Significant impact and permanent remedial or management action required Will have a permanent impact on industry operations Will require: • detailed planning by industry and allied stakeholders • ongoing allocation of industry resources
Catastrophic	5	Likely to severely affect all growers Will require: • an immediate high level response by industry and allied stakeholders • a prolonged far-reaching reallocation of industry resources • changes to long-term regional priorities

The intent of using such a scale was to focus the minds of respondents to the risk assessment survey on industry wide issues and to set the groundwork for planned strategy development. The tool also established a basis from which to explore the role of individual enterprises, the industries as a whole and that of additional organisations in any adaptation response.

Method of analysis — risk assessment

The survey responses were collated using an MS-Excel® spreadsheet and the consequence and likelihood scores (1–5) were averaged to provide the assessed level of risk. These average consequence and likelihood scores were rounded to the nearest integer and transferred to the AGO (2006, p. 40) risk priority matrix (Table 10). Risk scores (product of consequence x likelihood scores) were also calculated.

Table 10. Risk priority matrix (AGO 2006)

Likelihood	Consequences				
	Insignificant (1)	**Minor (2)**	**Moderate (3)**	**Major (4)**	**Catastrophic (5)**
Almost certain (5)	Medium (5)	Medium (10)	High (15)	Extreme (20)	Extreme (25)
Likely (4)	Low (4)	Medium (8)	High (12)	High (16)	Extreme (20)
Possible (3)	Low (3)	Medium (5)	Medium (9)	High (12)	High (15)
Unlikely (2)	Low (2)	Low (4)	Medium (6)	Medium (8)	Medium (10)
Rare (1)	Low (1)	Low (2)	Low (3)	Low (4)	Medium (5)

Note: Likelihood (L), Consequence (C) and Risk scores are shown in brackets. Risk score = LxC

To limit the masking effect of an average score, an indication of the level of disagreement between respondents was also determined. This was completed for both likelihood and consequence responses for each survey question. The following criteria were used to describe the different levels of disagreement between questions:

- **None** 80+% of responses in one score
- **Low** Responses clearly clustered around a particular level of risk (i.e. bulk of responses clustered around 2 scores)
- **Medium** Responses evenly spread across 3–4 scores
- **High** Responses spread across the whole range of scores

All results were presented back to the industry focus groups for comment.

4. RESULTS

4.1 WORKSHOP RESULTS

4.1.1 VITICULTURE WORKSHOP

The growers participating in the workshop identified a number of areas where the hot dry conditions pushed their viticulture businesses past the threshold of existing management techniques. The result was felt as a significant drop in yield and declining grape quality.

Table 11 summarises the findings of the viticulture workshop. The upper section of the table outlines, in order of priority, the key pressures that growers would need to manage if the average growing season was to become like that of 2006. The lower section summarises the ways in which growers have managed the impacts of previous drought conditions. These reflect the region’s dependence on high quality grape production and the importance of winter rainfall and the groundwater resource.

It appears that there is a definite threshold that McLaren Vale viticulture can tolerate with regard to heat. When this heat occurs is also critical. Grower observations included:

- The effects of heat and drought in the 2006 vintage had different effects on white and red varietals. The hotter period brought the ripening periods forward.
- 2006 could have been worse as the normal pre-Christmas hot spells did not occur.

Growers were unanimous that winter rainfall is critical to the success of the coming season. It lessens the effect of heat on soil moisture, evaporation and the need for irrigation. The rainfall received over the 2006 season was ideally placed for white but not red varieties.

There was general agreement that the heat and drought associated with the 2006 season resulted in significant reductions in yield. Some comments suggested this was different between whites and reds, with a higher risk of heat impacts downgrading the quality of whites.

There was a distinct difference of opinion regarding the management of drought conditions, which reflected the competing needs of growers and winemakers. Some growers felt that the solution was the application of more water. However, the winemakers in the room felt this would produce fruit of an unacceptable quality for the region’s market position. Given the relatively small scale of production in the region it is not seen as feasible to compete in the lower grade bulk wine market. Therefore the management of grape quality is a critical issue for the industry’s future economic viability.

4.1.2 OLIVECULTURE WORKSHOP

Table 12 summarises the findings of the oliveculture workshop using the same format as Table 11. As with the viticulture workshop, the olive growers identified a number of areas where the hot dry conditions created significant pressure on their businesses. In particular, their discussion identified a reduction in winter rainfall as a major pressure. In keeping with the earlier description of the olive industry, a lack of industry knowledge in coping with such conditions was also identified as a key concern.

The growers identified a number of areas where the hot dry conditions put pressure on their crops and existing management techniques. The impact was predominantly felt through the reduction in winter rainfall and subsoil moisture. This led to increased demand for irrigation and found some growers reaching the limits of their irrigation allocations.

Many growers reported a significant drop in yield, however this was not a uniform experience. The growers that had access to additional irrigation or irrigated early in the season stated they were less affected. Those that were affected found the reduced yield in turn put pressure on business incomes and exacerbated any limitations in their crop management.

Interestingly, the potential for the build-up of salinity in soils was not raised as an issue. One group felt that olives are relatively salt tolerant. Although this issue may not have direct business implications it does have potential NRM consequences. This issue was revisited in the risk assessment stage of this case study.

The potential for olives to become more invasive under climate change was also discussed, however it was not felt to be a significant issue. This was also revisited in the risk assessment process.

Table 11. Viticulture workshop summary (focus on drought)

Priority areas for adaptation management	Irrigation management	Soil management	Fruit quality/yield	Cost management
Impacts — in order of priority	• Less surface and ground moisture: ○ early irrigation required. • Water quality: ○ salt level higher earlier. • Water shortages: ○ more water trucked in ○ maintenance very important/no buffer left in irrigation. • Pest impacts on irrigation system. o rabbits eating dripline.	• Salinity. • Soil/subsoil drying: ○ increased erosion risk. • Soil compaction. • Decreased water holding capacity.	• Decreased yields: ○ lower bunch weights ○ split berries. • Damage to vine: ○ heat/sunburn ○ defoliation. • Change in quality. • Flavour? • Perceived increase in quality? • Early harvest. • Varietal differences.	• Water costs: ○ higher pumping costs ○ changing sources ○ need for transfers. • Increased cost per tonne for harvesting. • Reduced yield and quality.
Adaptation responses — in order of priority	• Early supplemental irrigation. • Use more water: ○ increase irrigation where possible ○ purchased water ○ bores going dry — drill new bores on lower pumps. • Increased/constant monitoring. • Improved efficiency/scheduling: ○ channelled water to viable areas ○ mulching.	• Mulching. • Better irrigation practices.	• Grower/winery liaison. • Variety selection: ○ root stocks that are drought and salinity resistant ○ new varieties. • Canopy/bunch management: ○ trimming and wiring ○ thinning/dropping. • Early vintage. • Night harvesting of reds.	• Cost savings: ○ reduced chemical use ○ reduced need for slashing ○ reduced pruning due to thin or reduced canopy. • Business planning. • Cost management: ○ irrigation ○ block management ○ monitoring.

Table 12. Oliveculture workshop summary (focus on drought)

Priority areas for adaptation management	Irrigation	Knowledge	Fruit quality/yield	Cost	Soil	Pests and disease
Impacts — in order of priority	• Dry winter and lack of subsoil moisture • Early and more irrigation required. • Insufficient water availability. • Groundwater allocations. • Access to recycled water. • Wrong timing of irrigation affects fertiliser absorption. • Some growers not prepared for drought. • Insufficient soil moisture monitoring: • Late irrigation led to vigour problems.	• Difficult season put pressure on growers' knowledge and skills, in particular: ○ irrigation management ○ pest and disease management ○ soil conditioning ○ wind management (windbreaks) ○ pruning ○ timing of harvest.	• Decreased yield: ○ kg fruit/tree and % oil ○ not necessarily felt across the industry. • Frost. • Wind when flower set.	• Drought leads to reduced yield and reduced income: ○ costs increased across the board due to sparse fruiting (water, harvesting, processing) ○ many growers already not breaking even due to market conditions. • Crop below viable harvest: ○ fruit left on trees. • Poor season has a compounding effect: ○ effects following season's production and therefore income.	• Limited comment was given on the impacts on soil so all comments have been summarised as follows: ○ groundwater salinity went up ○ salinity not a problem ○ erosion not considered a problem ○ compaction could be a problem.	• Increased pest activity: ○ could be site specific ○ ants, scale, curculio ○ humidity in July, August, September, October ○ more spraying required. • Trees vulnerable to attack due to stress: ○ nutrition not absorbed due to low rainfall. • Drought in other regions pushing pests into Fleurieu: ○ e.g. wingless grasshoppers — the drier it is up north, the sooner they migrate.
Adaptation responses — in order of priority	• Increased and constant soil moisture monitoring: ○ use of soil moisture probes. • Irrigate in optimum times: ○ bud set, fruiting ○ begin irrigation in August • Pruning. • Purchase more water.	• Utilise information sources: ○ industry associations ○ consultants ○ technical journals. • Implement olive care and participate in audit.	• Nutrition and irrigation: ○ management needs to be integrated ○ appropriate timing and quantities are essential.	• Increase market demand/price for Fleurieu olives: ○ export marketing via Encounter Olives ○ public education of positives of extra virgin olive oil.	• Minimise irrigation; where possible: ○ mulch ○ improve soil structure.	• Increased use of non chemical controls: ○ monitoring, use of dacron banding, pruning and air flow. • Increase use of pesticides: ○ spot spraying (young trees and scale), bran soaked in malathion.

4.2 RISK ASSESSMENT SURVEY RESULTS

4.2.1 RISK ASSESSMENT SURVEY — SUMMARY

The industry focus groups decided that the priority risks were those falling into the categories of high to extreme, and elected to treat only those key risks. Tables 13 and 14 summarise the priority risks as identified by each industry group.

The complete results of the risk assessments (with calculated risk scores) are detailed in Tables 15 and 16 in the following section.

Table 13. Viticulture risk assessment survey summary

Risk area	Risk summary
Irrigation	• Given the assumed climatic change scenario, grape production will almost certainly require regular additional water applications to produce a viable crop. • The availability and potential reduction of groundwater allocations was identified as high to extreme risk depending on the level of reduction and background climatic conditions.
Salinity	• Risks associated with soil salinity were considered to be an emerging issue over the long-term, i.e. 2030. • The risk of soil salinity caused by the application of saline irrigation water is regarded as an extreme threat to vine health and productivity. • There was an additional concern that industry-wide salinity flushing practices (i.e. excess irrigation water applied to leach accumulated salts) may cause watertables to rise. • The potential for soil salinity to lead to impacts on the natural resources of soil and groundwater was also rated as a high risk. Inaction on this issue was perceived as a high risk to the industry's branding.
Impacts of changing summer climate	• The high risk presented by the assumed changes in summer conditions was associated with vine damage through heat stress and sunburn. • Other high risks were: ○ reduced yield ○ reduced quality of white varieties ○ cumulative vine damage ○ long-term (2030) reduced capacity for the region to produce high quality fruit.
Business	• The combined pressures of the assumed climate changes were assessed as presenting a high risk of increasing the costs of production. This has additional high risk implications insofar as increased costs may: ○ limit ability of growers to purchase additional irrigation water for soil flushing ○ increase the number of marginal viticulture businesses in the long-term (2030).

Table 14. Oliveculture risk assessment survey summary

Risk area	Risk summary
Irrigation	• Given the assumed climatic changes, olive production will almost certainly require regular additional water applications to produce a viable crop. • Water availability and the potential reduction of allocations was identified as a high to extreme risk depending on the level of reduction and background climatic conditions. This risk escalates from a medium to high risk in the assumed normal years to an extreme risk in drought years.
Salinity	• Risks associated with soil salinity were considered to be an emerging issue over the long-term, i.e. 2030. • The risk of soil salinity caused by the application of saline irrigation water is regarded as an extreme threat to olive tree health and productivity. • There was an additional concern that industry-wide salinity flushing practices (i.e. excess irrigation water applied to leach accumulated salts) may cause watertables to rise. • The potential for soil salinity to lead to impacts on the natural resources of soil and groundwater was also rated as a high risk. Inaction on this issue was perceived as a high risk to the industry's branding.
Impacts of changing summer climate	• The high risk presented by the assumed changes in summer conditions was associated with an increase in insect and associated fungal pressures.
Business	• The combined pressures of the assumed climate changes were assessed as presenting a high risk of increasing the costs of production. This has additional high risk implications insofar as increased costs may: ○ limit ability of growers to purchase additional irrigation water for soil flushing ○ lead to the failure of olive businesses.

4.2.2 RISK ASSESSMENT SURVEY — DETAILED RESULTS

Table 15. Viticulture risk assessment survey — detailed results

Section 1 — Irrigation		Level of disagreement		Additional criteria	Overall average risk rating	Mean risk score
		Likelihood	Consequence			
1a	What is the risk that in an average year, additional irrigation applications (relative to historic levels) will be required to produce a viable crop based on current varieties?	low	low	**Average year**	**High**	**13**
1b		low	none	**Drought year**	**Extreme**	**19**
2a	What is the risk that in an average year, existing vineyard irrigation infrastructure will not be sufficient to deliver sufficient water to produce a viable crop based on current varieties?	med	low	**Average year**	**Medium**	**5**
2b		high	medium	**Drought year**	**Medium**	**10**
3a	Assuming additional water is unavailable, what is the risk that a 25% reduction in groundwater allocations below 2007 levels will be insufficient in an average year to produce a viable yield based on current varieties?	low	low	**Average year**	**High**	**12**
3b		med	low	**Drought year**	**High**	**17**
4a	Assuming additional water is unavailable, what is the risk that a 50% reduction in groundwater allocations below 2007 levels will be insufficient in an average year to produce a viable yield based on current varieties?	med	low	**Average year**	**Extreme**	**19**
4b		low	none	**Drought year**	**Extreme**	**21**

Section 2 — Salinity		Level of disagreement		Additional criteria	Overall average risk rating	Mean risk score
		Likelihood	Consequence			
1a	What is the risk that an increased frequency and severity of drought could lead to inter-seasonal accumulation of soil salinity from irrigation?	low	low	**2015**	**High**	**11**
1b		low	low	**2030**	**Extreme**	**17**
2a	What is the risk that an inter-seasonal accumulation of soil salinity will impact on vine health and productivity?	low	medium	**2015**	**Medium**	**10**
2b		low	low	**2030**	**Extreme**	**16**
3a	Given that soil salinity may accumulate as a result of drought, what is the risk that industry wide salt leaching strategies may impact on the watertable?	high	medium	**2015**	**Medium**	**9**
3b		high	high	**2030**	**High**	**13**
4a	What is the risk that the absence of salt leaching strategies could lead to land becoming unviable for viticulture?	low	low	**2015**	**Medium**	**8**
4b		low	medium	**2030**	**High**	**13**
5a	What is the risk that the failure to appropriately manage soil salinity could undermine the regions environmental stewardship and brand integrity?	low	low	**2015**	**Medium**	**9**
5b		low	low	**2030**	**High**	**12**

Section 3 — Impacts of changing summer climate		Level of disagreement		Additional criteria	Overall average risk rating	Mean risk score
		Likelihood	Consequence			
1	What is the risk that fungal outbreaks will be more of a problem than before 2007?	low	medium	–	**Medium**	**8**
2	What is the risk that insect outbreaks will be more of a problem than before 2007?	low	low	–	**Medium**	**6**
3	What is the risk that vine damage such as defoliation, heat stress and sunburn will lead to reduced yield?	low	low	–	**High**	**11**
4a	What is the risk that vine damage may accumulate over time and reduce their ongoing productivity or viability?	low	medium	**2015**	**High**	**11**
4b		low	low	**2030**	**High**	**15**
5	What is the risk that summer rainfall could lead to widespread soil compaction from equipment during harvest?	low	low	–	**Medium**	**6**
6a	What is the risk that the consequences of climate change will reduce the quality to the point that they may be downgraded?	low	low	**red**	**Medium**	**10**
6b		low	low	**white**	**High**	**14**
7	What is the risk that the region's grape quality will be affected by unforseen smoke damage associated with bushfire?	med	low	–	**Medium**	**6**
8a	What is the risk that the consequences of climate change will reduce the region's capacity to produce high quality fruit?	low	low	**2015**	**Medium**	**7**
8b		low	medium	**2030**	**High**	**12**

Section 4 — Business		Level of disagreement		Additional criteria	Overall average risk rating	Mean risk score
		Likelihood	Consequence			
1	What is the risk that climate change impacts will increase the costs of production and force growers to reassess the price of grape contracts?	low	medium	–	**High**	**15**
2	What is the risk that climate change will create financial distress to the extent that growers will not be able to afford to purchase additional irrigation water necessary to flush salinity from soils?	low	medium	–	**High**	**12**
3a	What is the risk that the combined pressures of climate change will push growers out of the region?	med	low	**2015**	**Medium**	**7**
3b		low	medium	**2030**	**High**	**12**

Table 16. Oliveculture risk assessment survey—detailed results

Section 1 — Irrigation		Level of disagreement: Likelihood	Level of disagreement: Consequence	Additional criteria	Overall average risk rating	Mean risk score
1a	What is the risk that in an average year, additional irrigation applications (relative to historic levels) will be required to produce a 35 kg per tree crop based on current varieties?	medium	low	**Normal year**	**Medium**	**8**
1b		low	low	**Drought year**	**High**	**16**
2a	What is the risk that in an average year, existing oliveculture irrigation methods will not be sufficient to deliver sufficient water to produce a viable crop based on current varieties?	medium	low	**Normal year**	**Medium**	**7**
2b		low	low	**Drought year**	**High**	**14**
4a	Assuming additional water is unavailable, what is the risk that a 25% reduction in water allocations below 2007 levels will be insufficient in an average year to produce a viable yield based on current varieties?	low	low	**Normal year**	**Medium**	**11**
4b		low	low	**Drought year**	**High**	**15**
5a	Assuming additional water is unavailable, what is the risk that a 50% reduction in water allocations below 2007 levels will be insufficient in an average year to produce a viable yield based on current varieties without additional supplementary irrigation?	low	none	**Normal year**	**High**	**15**
5b		low	low	**Drought year**	**Extreme**	**20**

Section 2 — Salinity		Level of disagreement: Likelihood	Level of disagreement: Consequence	Additional criteria	Overall average risk rating	Mean risk score
1a	What is the risk that an increased frequency and severity of drought could lead to inter-seasonal accumulation of soil salinity from irrigation?	low	low	**2015**	**Medium**	**11**
1b		low	low	**2030**	**High**	**17**
2a	What is the risk that an interseasonal accumulation of soil salinity will impact on olive tree health and productivity?	low	medium	**2015**	**Medium**	**9**
2b		medium	low	**2030**	**High**	**17**
3a	Given that soil salinity may accumulate as a result of drought, what is the risk that industry wide salt leaching strategies may impact on the watertable?	low	medium	**2015**	**Medium**	**10**
3b		low	low	**2030**	**High**	**15**
4a	What is the risk that the absence of salt leaching strategies could lead to land becoming unviable for oliveculture?	low	medium	**2015**	**Medium**	**11**
4b		low	medium	**2030**	**High**	**17**
5a	What is the risk that the failure to appropriately manage soil salinity could undermine the regions environmental stewardship and brand integrity?	low	low	**2015**	**High**	**12**
5b		low	low	**2030**	**High**	**17**

Section 3 — Impacts of changing summer climate		Level of disagreement		Additional criteria	Overall average risk rating	Mean risk score
		Likelihood	Consequence			
1	What is the risk that insect outbreaks will be more of a problem than before 2007?	low	low	–	**High**	**11**
2	What is the risk that fungal outbreaks will consequentially be more of a problem than before 2007?	low	medium	–	**High**	**12**
3a	What is the risk that pest damage to olive trees may accumulate over time and lead to reduced kg per tree?	low	medium	**2015**	**Medium**	**9**
3b		low	medium	**2030**	**Medium**	**11**
4	What is the risk that olive tree damage such as defoliation, heat stress and sunburn will lead to reduced kg per tree?	medium	medium	–	**Medium**	**8**
5a	What is the risk that the consequences of climate change will reduce the quality of oil varieties to the point that they may be downgraded?	low	medium	**Oil varieties**	**Medium**	**8**
5b		low	medium	**Table varieties**	**Medium**	**9**
6	What is the risk that the region's olive quality will be affected by unforseen smoke damage associated with bushfire?	medium	medium	–	**Medium–Low**	**5**

Section 4 — Business		Level of disagreement		Additional criteria	Overall average risk rating	Mean risk score
		Likelihood	Consequence			
1	What is the risk that climate change impacts will increase the costs of production and force growers to reassess the price of olive products?	low	low	–	**High**	**15**
2	What is the risk that climate change will create financial distress to the extent that growers will not be able to afford to purchase additional irrigation water necessary to flush salinity from soils?	none	low	–	**High**	**15**
3a	What is the risk that the combined pressures of climate change will push growers out of the region?	low	low	**2015**	**Medium**	**10**
3b		medium	medium	**2030**	**High**	**14**

Note: Levels of disagreement on the likelihood and consequence categories were assessed using the following criteria:

- **None** 80% of responses and above in one score
- **Low** Responses clearly clustered around a particular level of risk (e.g. bulk of responses clustered around 2 scores)
- **Medium** Responses evenly spread across 3–4 scores
- **High** Responses spread across the whole range of scores

4.3 ADAPTATION RESPONSE STRATEGIES

Assisted by Council, the industry focus groups reviewed the findings of the risk assessment survey. Consistent with the survey structure, the major climate risks were perceived to fall into the categories of irrigation, salinity, impacts of changing summer climate and business issues. A range of adaptation strategies were then developed to address the climate risks in each of these areas (Tables 17 and 18).

Note: Additional potential climate risks identified through the expert review are discussed in Section 5.3.

Table 17. Viticulture — priority risk areas and potential adaptation strategies

Identified risk area	Potential adaptation strategies
Irrigation	Ensure water use is at maximum efficiency across the industry
	Advocate for research into viable low water-use varieties
	Encourage at-risk growers to seek greater water security
	Establish working relationships with weather forecasters specific to the needs of the industry
	Provide early warning of anticipated reductions of water allocations
	Develop business strategies for remaining viable through periods of drought
	Advocate for industry access to drought relief
Salinity	Advocate for targeted salinity avoidance research
	Develop appropriate salinity avoidance practices
	Encourage growers to shift to least saline water supplies
	Ensure growers are informed regarding salinity avoidance practices
	Identify areas at high risk of salinity accumulation
	Monitor salinity build-up in high risk areas
	Review long-term salinity and natural resources impact risk with key stakeholders
	Promote salinity management as a key pillar of industry environmental management
Impacts of changing summer climate	Advocate for research into heat resistant varieties and heat management techniques
	Establish working relationships with research bodies investigating climate change impacts on wine grape varieties
	Establish working relationships with weather forecasters specific to the needs of the industry
	Ensure growers are informed regarding the management of hot weather impacts on vines
Business	Review sustainability of current grape pricing practices
	Advocate for winery/grower collaboration in grape pricing and wine marketing
	Identify ongoing need (quantity, cost, timing) for salinity flushing irrigation applications
	Advocate for targeted research into reduced costs of grape production

Table 18. Oliveculture — priority risk areas and potential adaptation strategies

Identified risk area	Potential adaptation strategies
Irrigation	Ensure water use is at maximum efficiency across the industry
	Establish working relationships with forecasters specific to the needs of the industry
	Where possible encourage at-risk growers to seek greater water security
	Monitor water allocation trends and alert growers to anticipated reductions
	Develop business strategies for remaining viable through periods of drought
	Advocate for industry access to drought relief
Salinity	Advocate for targeted salinity avoidance research
	Develop appropriate salinity avoidance practices
	Ensure growers are informed regarding salinity avoidance practices
	Monitor salinity build-up in high risk areas
	Review long-term salinity and natural resources impact risk with key stakeholders
	Promote salinity management as a key pillar of industry environmental management
Impacts of changing summer climate	Advocate for research into olive industry pest and disease management
	Investigate effective management of increased pest and disease pressure
	Increase grower capacity to manage pest and disease pressures
	Improve margins per kg of fruit
	Increase plant resilience to pest and heat pressure
Business	Review sustainability of current olive product pricing practices
	Identify ongoing need (quantity, cost, timing) for salinity flushing irrigation applications
	Identify and monitor high risk commercial olive groves

These adaptation strategies are what could be termed ‘no regrets’ responses. They are based on prudent management of the anticipated regional operating environment but are given increased priority as a result of the risk assessment. More specific strategies have been avoided due to the broad nature of the risk assessment process. The strategy directions were developed by considering the logical opportunities to build industry resilience to the identified risks.

Although the intention was to only treat risks occurring at the high to extreme level, some enterprise level strategies have also been included. To comprehensively plan for industry climate change adaptation, some responsibility must fall to individual businesses. The suggested strategies reflect where this might occur appropriately.

Organisational roles

A range of lead and partner organisations have been suggested to outline where responsibilities for implementation may lie (see Tables 1 and 2 in the Summary). This allocation of responsibility is commensurate with the stakeholder role considerations that were integrated into the risk assessment consequence scales as described in the methodology.

This allocation of roles was determined by the nature of each strategy and considering how it could reasonably be implemented. The following implementation criteria guided this decision making, i.e. whether the strategy can be implemented:

- at the regional scale by the industry
- by the industry with assistance
- by another party at the regional scale
- most appropriately at a broader (e.g. national) scale.

The organisations were then identified by the Council and the industry focus groups on the basis of a quick scan of:

- their regulatory jurisdiction
- area of research or funding
- lobbying capacity
- market involvement.

It must be emphasised that these organisational roles are only suggested as a best fit for purpose. No formal contact has been made nor has any acceptance of responsibility or endorsement of the strategies been made.

5. DISCUSSION

5.1 WORKSHOP EFFECTIVENESS

Discussions held during the grower workshops indicated that they were effective in providing growers with a general understanding of the local impacts of climate change. Reflection on the recent drought gave participants a more relevant understanding of particular climate change pressures. This in turn provided a useful baseline summary to inform the more detailed risk assessment process.

The workshop summaries also provide an important record of actual grower responses to drought. In planning for drought, this resource can be used to explore the following questions:

- Are these practices the best ways for managing drought in this region?
- Do they represent common practice?
- Are they effective in overcoming prolonged drought or do they have limited potential?

LEARNING POINT

The focus of the workshops was drought. This is still a valid focus, given that drought is expected to increase in frequency and severity, and growers will need to adapt to these new extremes. However, it should be clear to growers that there will be many different aspects to climate change.

The workshop methodology should be readily adaptable to other NRM situations. An identifiable system (such as a business) is important to create a focus for participants. There also needs to be sufficient knowledge of climate interactions with the system elements to explore possible impacts. A similar process would be effective for discussing the possible impacts of changes in policy or market environments as well, i.e. non-physical implications of climate change.

Rather than focus on a single aspect of climate, such as drought, future workshops could present a range of possible change parameters and allow participants to brainstorm the implications for their system elements. Where it is possible, recent and salient experiences bring depth to the discussion.

5.2 RISK ASSESSMENT SURVEY EFFECTIVENESS

Compared to the workshops, the risk assessment survey was found to be the most effective tool for identifying and prioritising specific climate change threats to industry and NRM. Sufficient information has been generated regarding the impacts on the target industries to initiate adaptation planning. For future adaptation planning, this risk assessment technique can accomodate a broad range of climate change parameters and impacts.

Some key insights on the use of the risk assessment tool for climate change planning are outlined below.

Limiting uncertainty

In order to limit the subjectivity of the risk assessment, the clearest possible picture of the future (i.e. projected climate scenario) needed to be presented to participants. This ensured that decision making was based on a common set of assumptions within the group.

To provide meaningful information, only implications that could be substantiated were used. Potential climate change impacts on secondary influences were established by communicating with policy makers and examining the current literature. These influences included increased irrigation demand, changes to water allocation policy and the ongoing availability of the recycled water resource.

Extreme events

The main challenge came in trying to go beyond the climate averages to give some indication of climate variability and the magnitude and direction of extreme events. McInnes et al. (2003) present climate projections for extreme events (pp. 32–44) however, this is based on quite coarse scale modelling (McInnes et al. 2003, Fig. 11, p. 22). Suppiah et al. (2006) provided updated climate projection information at regional scales, however they did not update information on climate extremes. Consequently, at the time the risk assessment was conducted there was a lack of information regarding extreme events or climate variability specific to the AMLR.

LEARNING POINT

Regional projections of climate extremes and their likelihood of occurrence (10th, 50th, 90th percentiles) are now covered by CSIRO and BoM (2007) (see App. 5).

A technique for describing an extreme event typical to this region was chosen, consistent with an approach taken by McInnes et al. (2003, p. 36). This involved finding one standard deviation from the mean of an historical record for a given climate parameter. Due to limited historic data, this could only be presented in terms of rainfall. Other historic records such as daily temperature were unavailable.

The main limitation with this technique was that it was unclear what the probability was of such an event occurring. As such, the risks that were identified around extreme events (such as the increased frequency of drought) could not be used to inform growers of the urgency of response that is required. These risks do, however, indicate the required level of industry resilience toward such an event.

It should be noted that the BoM provided significant assistance with the historic datasets.

Identification and framing of possible risks

The survey was found to be an effective tool to generate risk assessment responses against the climate change assumptions. Having participants assess risk in isolation minimised the possibility of group thinking and ensured their participation. The survey was also sent to additional participants outside of the focus groups. This enabled the views of additional industry experts to be gauged (these are the ‘risk assessment extras’ listed in App.2).

In developing the survey the initial risk areas and specific risks were identified by discussion with the focus groups. The aim was to create unambiguous and mutually exclusive questions that would lead logically from one question to the next and build a thorough risk profile. This was simply a matter of sifting through the set of questions as a group and making incremental improvements.

The method of averaging and clustering the voting on risk highlighted the level of disagreement on the risks. This provides some confidence for end users of the results.

Limitations, improvement and validation of results

The generic risk assessment process (Fig. 3) can be a robust and objective tool for quantitatively assessing risks. However, it is recognised that some degree of subjectivity entered this climate risk assessment through:

- limited numbers of participants, and
- limited experience/expertise of participants, which in turn influenced:
  - a limited number of risk areas that were addressed through the risk assessment survey questionnaire
  - average risk scores arising from the survey results.

This in turn may limit stakeholder confidence in the case study findings for future decision making and planning for climate change.

To address this issue, relevant experts were sought to review and validate the case study findings (Section 5.3). The aim of this was to identify gaps in the risk assessment or priority risks and advise on any undue weighting that may have been attributed to particular risks. Opinions were sought from scientific groups working on climate change and agriculture as well as experts in irrigation, salinity and risk management.

The differing knowledge base of participants is an important consideration for future risk assessments of this nature. Importantly:

- Questions requiring local knowledge are often best answered by industry participants (e.g. the impact of groundwater reductions on crops).
- Questions of a technical nature may best be answered by experts in the field (e.g. the impact of soil flushing practices on groundwater, or crop responses to changes in a particular climate parameter).

Dividing the risk assessment in this way would provide a more accurate and credible assessment of climate change risk. This is worth considering if the risk assessment is to be used in another region or to review progress on adaptation planning within the case study industries. Providing future industry participants with expert guidance may also assist in their decision making.

Caveat on use of results

It should be noted that although this framework has been used to generate climate change adaptation priorities, the detail used has been developed specifically for the target region and industry groups. The information and possible directions generated should not be considered to be broadly applicable without additional testing.

While the techniques described are not without limitations, the case study has been an exercise in testing methodologies to build knowledge. Overall, the risk assessment was successful in providing focus on the issues facing the region. It is a relatively simple precursor to more detailed risk assessment and adaptation planning.

5.3 VALIDATION AND REVIEW

A panel of science and industry experts was asked to review the adaptation strategies, identify any gaps in the risk assessment process and otherwise make suggestions for improving the process. The rationale for this review was to provide assurance to growers (and other end users) that the case study could provide a solid foundation to:

- progress the identified priority risks towards implementation
- further investigate additional climate risks.

Detailed comments from this expert review are contained in Appendix 6, however a number of important points have been summarised in the following sections. This information will benefit future adaptation planning activity for the respective industries.

Some comments will apply to both viticulture and oliveculture industries, while others are industry specific.

5.3.1 REVIEW OF ADAPTATION STRATEGIES AND GAPS IN THE RISK ASSESSMENT

General comments

Overall, the project work was seen as an excellent starting point, providing the MVGWTA and FPOA with a framework with which to begin addressing climate change risks and implementing adaptation strategies. For example:

> 'From this work, the industry bodies can now initiate projects and form linkages to address the key issues identified in the study.'
>
> (A Richards 2008, pers. comm.)

It was generally accepted that the focus on reduced water availability and increasing soil salinity was justified, however there were concerns that a number of potential risks have been overlooked.

Water-use efficiency versus controlling soil salinity

There will be a trade-off between maximising water-use efficiency and avoiding soil salinity build-up. Maximum water-use efficiency is achieved when there is zero leaching below the root zone during the growing season—but this will lead to the accumulation of added salt in the root zone. If water quality declines, some leaching may be required to ensure that soil salinity levels do not reach harmful levels (A Richards 2008, pers. comm.).

Further potential adaptation strategies include:

- Grower education programs covering irrigation scheduling, timing and leaching.

Water availability — allocations and restrictions

A lack of governmental regulation and process in relation to water restrictions has led to uncertainty for mains water users. This problem could be minimised by developing guidelines for mains water restrictions in collaboration with SA Water and the Minister for Water Security. These guidelines may include regulation and provision of 'top up' water during periods of restriction (A Richards 2008, pers. comm.).

Growers use a range of different water supplies. For example, 10% of McLaren Vale grape growers use surface water from dams and flow in the Onkaparinga River. Different adaptation options may need to be investigated for different situations. Also the use of reclaimed water is expected to increase in the future and impacts of this should be investigated (A Richards 2008, pers. comm.).

Further potential adaptation strategies include:

- Develop guidelines and processes for allocations and restrictions, including provision for 'top up' water during periods of restriction.
- Investigate potential for assisting conversion to reclaimed water. (The McLaren Vale Water Fund proposal has been submitted to federal and state governments. If successful, the fund will assist mains water irrigators with costs of conversion to reclaimed water, significantly reducing the region's reliance on mains water.)
- Investigate potential for development of mains water-use guidelines, in collaboration with SA Water, AMLR NRM Board and DWLBC, for growers who cannot access other water resources.
- Assess the impact of importing increased volumes of reclaimed water for irrigation (e.g. monitoring and computer modelling), if WBWC can secure winter storage.
- Assess the impacts of reduced winter/spring rainfall on surface water resources (dams, flows in the Onkaparinga).

Sodicity

Increased soil salinity will result in higher soil sodium levels and increased sodicity. Higher sodicity increases the risk of soil structural decline, particularly in soil types with high clay contents (Richards, Hutson & McCarthy 2007). This has implications for soil structural decline and was not considered in the risk assessment. Targeted salinity and sodicity management and research would benefit growers. Some salinity will not be avoided but growers need to prevent salt and sodium from accumulating to harmful levels (A Richards 2008, pers. comm.).

Further potential adaptation strategies include:

- Growers should be educated about salinity and sodicity.
- A standard soil salinity and sodium monitoring strategy for the region could be developed.
- Long-term salinity and sodicity risks from the use of the various water resources (groundwater, surface water, reclaimed water and mains water) should be regularly reviewed.

Economics

Business and regional industry sustainability under current operating conditions needs to be assessed before assessing business risks from climate change (L Ravetti 2008, pers. comm.; J Fennell 2008, pers. comm.).

Greater consideration of economic factors, production efficiencies ($profit/quantity water used) and different business models is needed. Economic impacts on full-time commercial olive groves or vineyards, from any proposed climate change adaptation or mitigation strategies (e.g. increasing the price of water), should be properly assessed to ensure that the industry as a whole is not worse off (J Fennell 2008, pers. comm.).

Economic impacts from yield or quality issues are not considered. In olives particularly, poor crop levels can also affect subsequent potential biennial bearing capacity (P James 2008, pers. comm.).

Frost

A higher incidence of frosts can be expected, in association with increased frequency of drought. This is because low humidity levels in the air and low levels of soil moisture are significant contributing factors to an increased incidence of frosts. Extensive areas of South Australia and Victoria have suffered some of their worst frost events in history during the recent drought years. Consequently, a higher incidence of frost damage, reducing crop levels and value, can be expected in drier winter and spring conditions (L Ravetti 2008, pers. comm.).

There is no provision for extra irrigation required for frost protection (P James 2008, pers. comm.).

Heat (viticulture)

It was agreed by a number of reviewers that this type of adaptation planning would be improved by greater investigation and discussion of temperature and heat effects (P Hayman 2008, pers. comm.; A Richards 2008, pers. comm.; C Soar 2008, pers. comm.; L Webb 2008, pers. comm.).

Increased temperature can lead to a series of changes, e.g. hastening harvest, or compressed vintages, alcohol levels, shrivel, quality issues, etc. Some of these issues are raised in the scientific literature (see Leanne Webb's detailed comments in App. 6).

The impacts of heat, prolonged hot weather, associated hot, dry winds, and interactions with elevated CO_2 (which may improve crop water-use efficiency) are areas of ongoing research. CSIRO Plant Industry in Adelaide currently has a research project looking at variation in drought and heat tolerance across varieties. Similarly, CSIRO in Merbein have an advanced breeding program for both rootstock and scion varieties tolerant to heat and moisture stress. Whilst this research is nationally focused it is appropriate that they be listed as a potential partner organisation (C Soar 2008, pers. comm.).

Increased average temperatures and increased frequency of consecutive very hot days or 'heatwaves' should be discussed as separate issues (C Soar 2008, pers. comm.).

Timing of heat is important. Extreme heat late in season will result in significant shrivel (this was observed recently during the record March heatwave and resulted in significant losses in yield and quality):

> ‘Prolonged extreme heat at harvest can lead to high incidence of sunburn and shrivel, as was observed in March 2008. The record heatwave caused some ripe fruit to shrivel on the vine before wineries were able to pick and process. Significant losses have been incurred by some growers. If longer and later heatwaves become more commonplace under a warmer climate, the logistics of harvest and processing may need to be reviewed.’
>
> (A Richards 2008, pers. comm.)

Further potential adaptation strategies include:

- Encourage research into extreme heat events and effect on vine physiology.
- Review winery capacity to pick fruit earlier in a shorter time period if extreme heat events occur around harvest again.
- Advocate for improved grower/winery relations in regard to heat/moisture stress, fruit quality and logistics of harvest.

Disease pressure (viticulture)

Under the summer conditions assumed in the risk assessment, increased disease pressure in December and potential for increased pesticide use may be an issue (A Richards 2008, pers. comm.).

Radiation (viticulture)

Changes in radiation and impacts such as sunburn to crops were not addressed (C Soar 2008, pers. comm.).

Changing humidity/evaporative demand (viticulture)

While higher evaporative demand may be implied within this case study scenario, this area requires further investigation (C Soar 2008, pers. comm.).

Rising CO_2 (viticulture)

Elevated CO_2 levels may have a fertiliser effect and may improve crop water-use efficiency. Research is ongoing (C Soar 2008, pers. comm.).

Adaptation from existing crops (viticulture)

There will be a crop response and some degree of adaptation within exisiting grapevine and viticultural systems. This may be a positive or negative response to climate change (C Soar 2008, pers. comm.).

Detailed comments (viticulture)

Further detailed comments on the viticulture risk assessments have been made by Chris Soar (SARDI) and Leanne Webb (CSIRO/University of Melbourne) (see App. 6).

Physiological impacts to plants (oliveculture)

Climate induced impacts to olive trees throughout their seasonal growth cycle are not considered and require further analysis. This requires consideration of changes in seasonal conditions throughout the year (particularly at critical growth stages) and knowledge of plant physiology (P James 2008, pers. comm.; L Ravetti 2008, pers. comm.).

Production efficiencies (oliveculture)

There is a lack of knowledge of production efficiency levels ($ profit/quantity of water used) within businesses across the olive industry. This type of information would be useful for the development of incentive schemes to encourage better use of the water resource (J Fennell 2008, pers. comm.) (also see comments in App. 6).

Disease (oliveculture)

There should be more scientific input to the risk assessment, in particular to look at the potential for disease impacts (J Fennell 2008, pers. comm.).

Equally important will be its potential as a source of pests and diseases for other groves in the area. The social impact of abandoned groves should also be considered not only for the growers themselves but also for service providers, local business, suppliers, casual labour in the area, etc.

Abondoned groves (oliveculture)

Potential for climate change induced impacts to fruit quality, yields and business viability raise a number of concerns, including weed risk.

> 'It would be useful to identify whether growers are less likely to harvest fruit in times of increased climate variability and uncertainty (e.g. fruit too small, yields to low). If they are less likely to harvest, then the risk of their olives spreading into native vegetation would be greater. I think there is a gap in the risk assessment from a conservation perspective.'
>
> (N Crossman 2008, pers. comm.)

Equally important will be the potential for abandoned groves to act as a source of pests and diseases for other groves in the area. The social impact of abandoned groves should also be considered not only for the growers themselves but also for service providers, local business, suppliers, casual labour in the area, etc. (L Ravetti 2008, pers. comm.).

Detailed comments (olives)

Further detailed comments on the oliveculture risk assessments have been made by Leandro Ravetti (Modern Olives) and Paul James (Rural Solutions SA) (see App. 6).

5.3.2 OTHER SUGGESTIONS FOR IMPROVING THE PROCESS

Wide versus narrow focus

While the aim of this initial work was to identify priority climate risks and areas for adaptation, care is required to avoid bias towards certain issues (e.g. water and salinity) at the expense of other issues which may be overlooked (C Soar 2008, pers. comm.).

Some of the assumptions used in the risk assessment scenario (e.g. use current irrigation and management practices) may limit thinking about adaptation options. Successful adaptation may require us to think ‘outside the box’ (J Fennell 2008, pers. comm.).

Representation

In assessing climate risks and developing adaptation responses it is appropriate that participants adequately represent the range of industry conditions experienced through the region (e.g. soil types, management systems, mesoclimates). If representation is limited, this can potentially bias the results. The risk assessment process would be improved by including a wider spread of participants with a range of experience and expertise (A Richards 2008, pers. comm.).

Scientific and technical input

The risk assessment process would benefit from greater input from scientific and technical experts:

- during the early stages of designing the process — to ensure good communication of climate data and sufficient and balanced consideration of a range of potential climate risks
- during risk analysis (e.g. assessing impacts to crops under climate scenarios). For example, greater knowledge of plant physiology would help provide growers with information on potential impacts from different climate parameters during the different seasonal growth stages of a particular crop (P James 2008, pers. comm.).

Risk assessment techniques

A number of different risk assessment techniques are available and could help identify more potential climate risks (D Bruhn 2008, pers. comm.) (see App. 6).

5.4 LESSONS LEARNT

Major successes

Adaptation planning is still at an early stage, however, this initial activity has raised awareness, encouraged industry thinking about addressing climate change risks and helped to establish links with partner organisations (research, policy, industry, etc.) that will be needed to implement successful responses to climate change. Industry ownership of the issue and the establishment of links between industry and external stakeholders are major positive outcomes.

Having a limited focus for this work helped industry to start thinking about climate impacts while not becoming overwhelmed or losing interest because of all the possible outcomes. At the same time this limited focus was also a limitation, with potential for important impacts to have been overlooked.

The risk management framework that was central to this case study provided a very useful guide for this initial adaptation planning work. This framework will also be relevant for subsequent iterations associated with more detailed analysis.

Major limitations

By the very nature of the approach, this initial analysis was only intended to have a limited focus, i.e. analysis was undertaken on a small set of potential climate outcomes. Climate change projections deliver a large range of possible climate outcomes, dependent on various emissions scenarios and the internal assumptions of the GCM used to generate climate change projections. Therefore it is important that industry members are given a balanced view of the range of possible climate change outcomes.

The experience and expertise of the participants has been recognised as a limitation, i.e. outputs are limited by the inputs. A wider range of experience and expertise will help to identify a greater range of potential climate risks.

Greater scientific/technical input early in the process would have helped inform participants of the range and complexity of possible impacts to production systems from climate change. For example, experts in plant growth/plant physiology would have been able to discuss possible impacts to growth cycles from a range of different climate parameters. However, to some extent this type of detailed knowledge may be lacking and still subject to ongoing research.

What else is required for future adaptation planning?

As reflected in the reviewer's comments, more detailed analysis is required for a number of potential climate impacts. It was always the intention that more detailed analysis and planning should follow this case study.

Access to the latest climate projections and communications tools is essential. Links with BoM, CSIRO and SARDI personnel will ensure the most up-to-date information is available.

Having the right mix of representative, local industry knowledge and technical and scientific expertise will produce the best team to undertake future risk assessments.

More thinking 'outside the box' may be useful for future work. If climate change tracks along the worst-case scenario, it is likely that changes to climatic and production systems will be unprecedented. Solutions may require whole new ways of thinking.

6. SUMMARY

A risk assessment methodology provided guidance for the industry groups to explore potential climate risks and adaptation options. Risk assessment activities (workshops and risk assessment survey) focused on a limited set of climate change parameters, however, this is recognised as an initial step in the process of ongoing and more detailed adaptation planning. This work has enabled industry stakeholders to improve their understanding of the risks presented by climate change. The findings of this case study, along with the suggested improvements and additional potential climate risks identified through the expert review, provide a solid foundation for future work.

6.1 VITICULTURE

The main issues identified for the McLaren Vale region's viticulture industry was the potential emergence of soil salinity and water insecurity. These issues are predominantly driven by the quality of water available but are also related to supply constraints in relation to the groundwater resource. There were additional concerns that industry-wide salinity flushing practices (i.e. excess irrigation water applied to leach accumulated salts) may cause watertables to rise, and potential salinity impacts to soil and groundwater may be a risk to the industry's branding. Further high risks were associated with potential heat impacts causing yield and quality problems, and increased cost pressures on viticultural businesses.

In response to the question 'Is the McLaren Vale wine industry really "waterproof", i.e. does it have sound water security in the context of climate change?' the answer was found to be no. The findings of this case study suggest that groundwater supply and the salinity of both groundwater and recycled water supplies are key management issues for adaptation strategies to focus on in the future.

6.2 OLIVECULTURE

The main issues for the Fleurieu oliveculture industry were identified as water security and reduced yields. The possible emergence of soil salinity was also found to be a key risk. Similar to viticulture, there were concerns that industry-wide salinity flushing practices to control salt build-up in soils may cause watertables to rise, and potential salinity impacts to soil and groundwater may be a risk to the industry's branding. Potential risks from increased insect and fungal outbreaks were also identified. In addition, there is a hidden implication arising from increased cost pressures associated with the impacts of climate change. Anecdotal evidence suggests many Fleurieu Peninsula olive businesses are already marginal financially, and an increase in costs may force business failures. This could lead to derelict groves and a location-specific invasive species threat to remnant native vegetation. Some growers in the workshop also stated that they cannot afford to harvest their crop below a minimum anticipated financial return, further adding to the potential scope of this issue.

In response to the question 'Is climate change likely to increase the risk that commercial olives crops will contribute to the feral olive population?' the answer is possibly. While adaptation strategies need to focus on water security, the potential weed threat from derelict groves warrants further attention.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

This work has provided a case study for the development of initial industry climate change adaptation planning. It has reviewed regional industry stakeholder opinions of local issues relating to climate change, identified potential roles for key stakeholders and given direction to future adaptation planning activities.

This case study has demonstrated a collaborative model for local government and industry, supported by NRM and research organisations, to respond to climate change. The engagement of the major stakeholders, the understanding that has been developed and the development of strategy directions all suggest this model has been successful. This has been supported by positive feedback from industry stakeholders.

The expert review supports the view that this work has been successful in generating initial industry directions for climate change adaptation. It also suggests that outputs from future risk assessment and planning processes can benefit from a wider range of experience and expertise during the input phase.

7.2 RECOMMENDATIONS

It is recommended that:

- The information provided through this case study be used as the foundation for future adaptation planning work in these industries.
- The respective industries move to implement adaptation strategies for the priority climate risks identified thus far (Tables 1 and 2).
- The respective industries further investigate the potential climate risks and adaptation strategies identified through the expert review (Section 5.3 and App. 6).
- The capacity of the industries to meet or deliver their adaptation goals be reviewed.
- The type of adaptation planning approach adopted in this case study be viewed as an initial step in the ongoing process of climate change adaptation planning, with a view to reorganising industries to address both the short-term and longer-term impacts of climate change.

7.3 WHERE TO FROM HERE

Adaptation to climate change will require an iterative planning process as better modelling and climate information become available, and implications for NRM become more apparent.

Ideally the information presented in this case study (and particularly in Tables 1 and 2) will provide initial directions for the climate change adaptation planning of targeted olive and viticulture industries. That said, it is most appropriately the role of the two industry groups to advance their own adaptation planning. This will require partnerships to be strengthened and new links formed, and for the findings of the case study to be raised with the appropriate lead organisations. The validation and review process has added weight to the findings and suggested further areas of improvement for the ongoing adaptation planning process.

To implement future adaptation planning activity (including the findings from this case study) there is a need to establish a roles and responsibilities framework, to encourage progress and avoid duplication of efforts. As part of the development of such a framework, the mechanism provided by the SAEDP and its partners should also be considered. SAEDP articulates a strategic framework for economic diversification for the region and considers the food and wine industries as priorities for growth. The plan recognises that resilience to climate change will be central to the strength of the region's future economy. If such a roles and responsibilities framework can be integrated with the SAEDP, this will embed the climate change response in the broader terms of regional economic development.

Finally, the understanding of climate change is also progressing rapidly and better information at the local scale is likely to be accessible in the future. This study has raised a number of areas for further inquiry including the risks of soil salinity, industry cost pressures and the possible threat to native vegetation. With this in mind, an appropriate review period and process should be developed as part of the industry adaptation planning. Key research and governance institutions such as The University of Adelaide's Research Institute for Climate Change and Sustainability, BoM, CSIRO, PIRSA, SARDI and DWLBC, and local government (with regional economic development perspectives) could play an important advisory role in this respect.

APPENDICES

1. REGIONAL SOIL MAPS — % CLAY CONTENT

Maps indicating the percentage of clay content in soils can be accessed online through the Australian Soil Resource Information System (ASRIS): **http://www.asris.csiro.au**. ASRIS data from South Australia is derived from DWLBC's Soil and Land Information database.

Data is available at different scales and represents different layers within a soil profile. Layers 1–3 are shown below. Layers 1 and 2 refer to the A horizon (usually an A1 and A2 horizon respectively), while layer 3 represents the upper part of the B horizon.

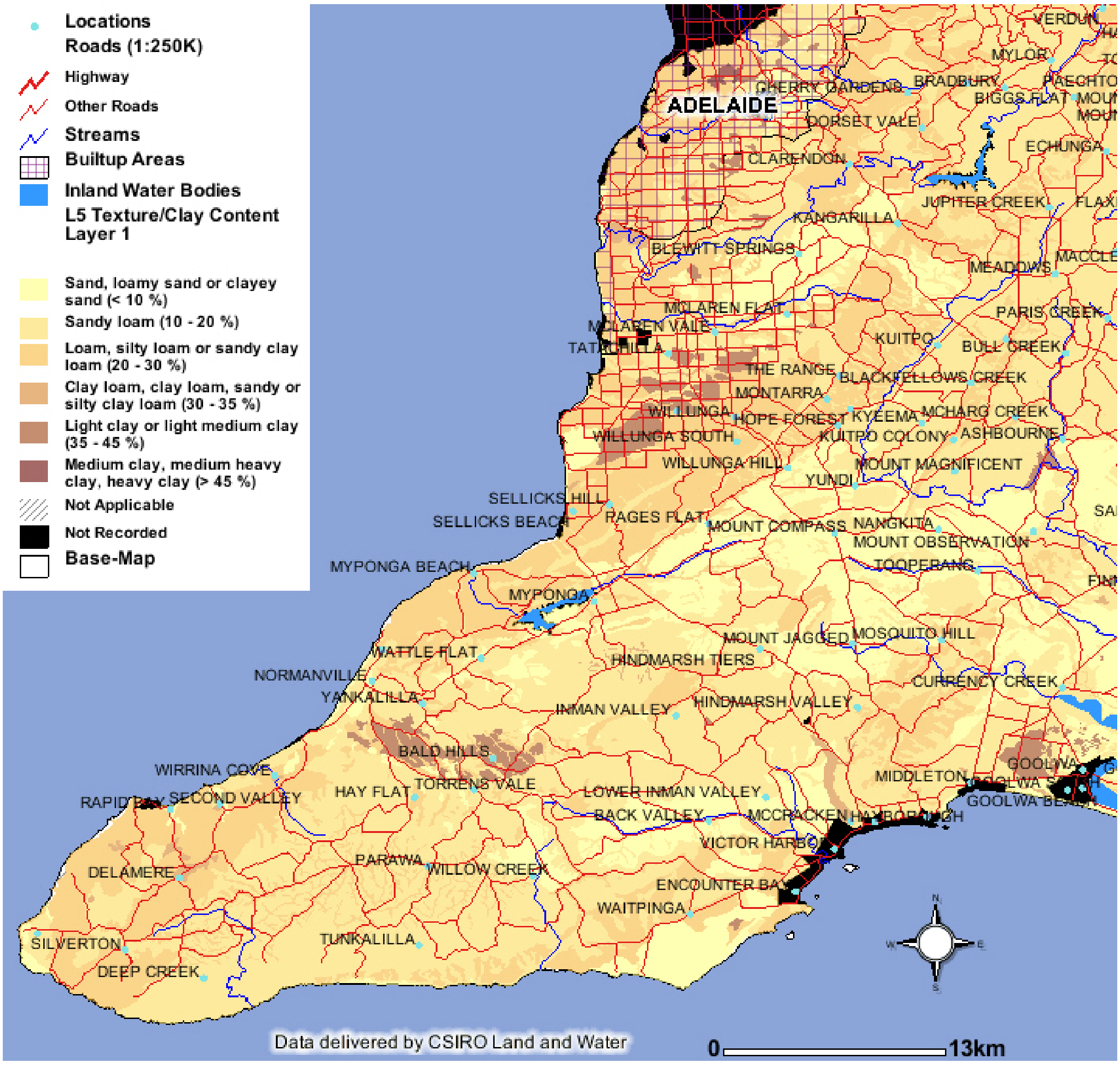

Figure A1.1. ASRIS soil mapping — % clay content layer 1/A1 horizon (CSIRO 2008)

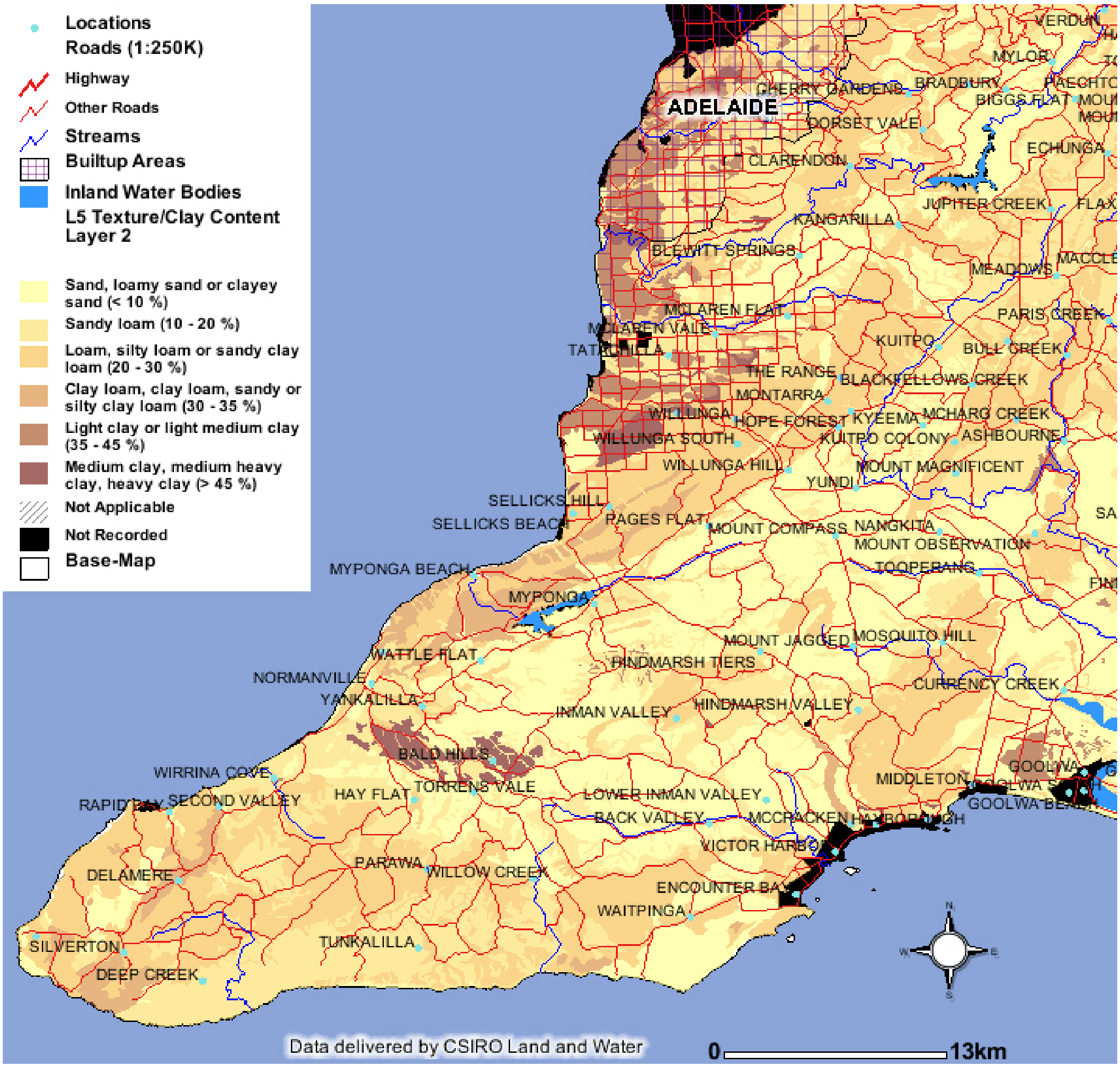

Figure A1.2. ASRIS soil mapping — % clay content layer 2/A2 horizon (CSIRO 2008)

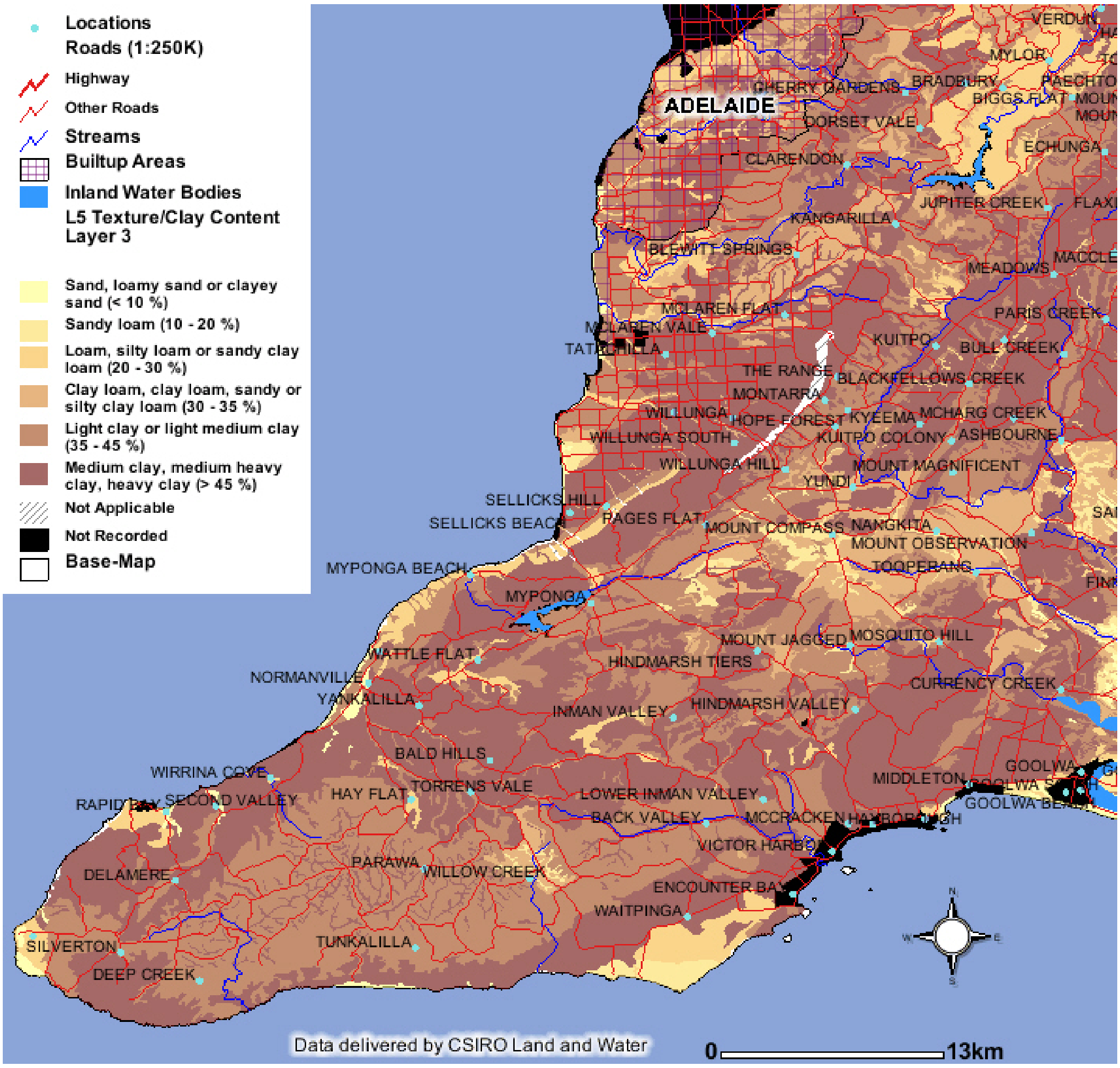

Figure A1.3. Clay ASRIS soil mapping — % clay content layer 3/upper B horizon (CSIRO 2008)

2. INDUSTRY FOCUS GROUP PARTICIPANTS

Wine industry focus group

Focus group	
James Hook	MVGWTA
Tony Hoare	Hoare Consulting
Liz Pitcher	Fosters Group
Ben Pridham	Pridham Viticulture
David Williams	Fosters Group
Sami Gilligan	Gilligan Contracting
Emmanuelle Walton	Wirra Wirra Vineyards

Risk assessment extras	
David Hanson	Fosters Group
Gary Lyons	Fosters Group
Russel Johnstone	Orlando Wyndham
Kym Ayliff	Fosters Group
Melissa Brown	Gemtree Vineyards/The Terraces Vineyard Management

Wine industry workshop participants

Charles Whish	Fosters Group
Peter Leske	SAWIA
Wayne Ledson	Grower
Russell Johnstone	Orlando Wines
James Hook	MVGWTA
Carol Banman	JO and CA Banman
Ben Pridham	Pridham Viticulture
Tony Hoare	Hoare Consulting
Melissa Brown	Gemtree Vineyards/The Terraces Vineyard Management
Kathy Daish	Hardy's Wine Company
David Williams	Fosters Group
Guilo Dimasi	d'Arenberg
John Hilditch	Grower
Linda Hilditch	Grower
Peter Hayman	SARDI
Sue Harnett	d'Arenberg
Andrew Tothill	d'Arenberg
Barry Brook	The University of Adelaide
Daniel Lavernic	Paxton Vineyards

Olive industry focus group

Focus group	
Vicki Zadow	Grower/FPOA President
Daryl Pinch	Grower
Robin Schliebs	Grower
Helen Morgan	Grower
Tony Harding	Grower
Tony Colliver	Grower

Risk assessment extras	
Chris Redwood	Grower
George Konidis	Processor/grower

Olive industry workshop participants

Barry Peek	Grower
Leanette Guy	Grower
Graham Guy	Grower
Jan Redwood	Grower
Chris Redwood	Grower
Parry Barnard	Grower
Vicki Zadow	Grower/FPOA President
Tony Harding	Grower
Brian Swanson	Grower (Table Olives)
Vince Scarfo	Processor/grower
George Konidis	Processor/grower
Tony Coliver	Grower
Robin Schliebs	Grower
Michelle Morris	Grower
K McCallum	Grower
Margaret McCaul	Grower
Daryl & Jenni Pinch	Grower
Susan Benger	Grower

3. WORKSHOP RESPONSE SHEETS

Viticulture group discussion response table

MANAGEMENT AREAS	WHAT PRESSURES OCCURRED	THINGS THAT YOU DID THAT EASED THE PRESSURES
Fruit Quality/Yield **For example: variety, pruning, bunch thinning, canopy management.**		
Soil Management **For example: traffic, over cropping, health.**		
Irrigation Management **For example: type, quantity, timing, and efficiency.**		
Skills **For example: workforce, business, and management.**		
Cost Management		
Environmental Management **For example: native vegetation, soil and salinity.**		
Other		

Olive workshop group discussion response table

MANAGEMENT AREAS	WHAT PRESSURES OCCURRED	THINGS THAT YOU DID THAT EASED THE PRESSURES
Fruit Quality/Yield		
Soil Management **For example: salinity, erosion, compaction, traffic, over cropping, health.**		
Irrigation Management		
Pest and Disease Management		
Knowledge **Anything you or your staff needed to know more about.**		
Cost Management		
Environmental Management **For example: native vegetation, soil and salinity.**		
Other **For example: access to labour, equipment.**		

4. RISK ASSESSMENT MATERIALS

Likelihood scales

LIKELIHOOD OF OCCURRENCE		
RATING		**Description**
Rare	1	Extremely unusual circumstances and only a remote possibility of occurring
Unlikely	2	Can happen but it is unlikely that these circumstances will occur
Moderate	3	Appreciable likelihood that these circumstances will occur
Likely	4	It is as likely as not that these circumstances will occur
Almost Certain	5	These circumstances will almost certainly occur

Consequence scales

CONSEQUENCE DESCRIPTORS		
RATING		**Description**
Insignificant	1	Likely to affect only a small number of growers; and /or Minimal temporary impact only, no remedial or management action required Easily addressed by growers
Minor	2	Likely to affect a significant number of growers; and /or Minimal Impact remedial or management action may be required Easily addressed by growers but may require an allocation of industry resources
Moderate	3	Likely to affect more than half of growers; and Ongoing Impact, remedial or management action required May require a planned industry response and allocation of resources
Major	4	Likely to affect all growers; and Significant impact and permanent remedial or management action required Will have a permanent impact on industry operations. Will require: Detailed planning by industry and allied stakeholders, Ongoing allocation of industry resources.
Catastrophic	5	Likely to severely affect all growers Will require: An immediate high level response by industry and allied stakeholders A prolonged far-reaching re-allocation of industry resources and Changes to long-term regional priorities.

VITICULTURE RISK ASSESSMENT SURVEY

(L is used for Likelihood and C for Consequence)

Section 1 Irrigation

Given the assumptions provided, rate the risk the following scenarios present to the industry.

1. What is the risk that in an average year, additional irrigation applications (relative to historic levels) will be required to produce a viable crop based on current varieties.

L	C

In a Drought Year?

L	C

2. What is the risk that in an average year, existing vineyard irrigation infrastructure will not be sufficient to deliver sufficient water to produce a viable crop based on current varieties.

L	C

In a Drought Year?

L	C

3. Assuming additional water is unavailable, what is the risk that a 25% reduction in groundwater allocations below 2007 levels will be insufficient in an average year to produce a viable yield based on current varieties.

L	C

In a Drought Year?

L	C

4. Assuming additional water is unavailable, what is the risk that a 50% reduction in groundwater allocations below 2007 levels will be insufficient in an average year to produce a viable yield based on current varieties.

L	C

In a Drought Year?

L	C

Section 2 Salinity

Given the assumptions provided, rate the risk the following scenarios present to the industry.

1. What is the risk that an increased frequency and severity of drought could lead to interseasonal accumulation of soil salinity from irrigation.

	L	C
by 2015		
by 2030		

2. What is the risk that an interseasonal accumulation of soil salinity will impact on vine health and productivity?

	L	C
by 2015		
by 2030		

3. Given that soil salinity may accumulate as a result drought what is the risk that industry wide salt leaching strategies may impact on the watertable.

	L	C
by 2015		
by 2030		

4. What is the risk that the absence of salt leaching strategies could lead to land becoming unviable for viticulture.

	L	C
by 2015		
by 2030		

5. What is the risk that the failure to appropriately manage soil salinity could undermine the regions environmental stewardship and brand integrity?

	L	C
by 2015		
by 2030		

Section 3 Impacts of Changing Summer Climate

Given the assumptions provided, rate the risk the following scenarios present to the industry.

1. What is the risk that fungal outbreaks will be more of a problem than before 2007

L	C

2. What is the risk that insect outbreaks will be more of a problem than before 2007

L	C

3. What is the risk that vine damage such as defoliation, heat stress and sunburn will lead to reduced yield

L	C

4. What is the risk that vine damage may accumulate over time and reduce their ongoing productivity or viability

	L	C
by 2015		
by 2030		

5. What is the risk that summer rainfall could lead to widespread soil compaction from equipment during harvest?

L	C

6. What is the risk that the consequences of Climate Change will reduce the quality of red varieties to the point that they may be downgraded

L	C

White varieties?

L	C

7. What is the risk that the region’s grape quality will be affected by unforseen smoke damage associated with bushfire

L	C

8. What is the risk that the consequences of Climate Change will reduce the region's capacity to produce high quality fruit

	L	C
by 2015		
by 2030		

Section 4 Business

Given the assumptions provided, rate the risk the following scenarios present to the industry.

1. What is the risk that Climate Change impacts will increase the costs of production and force growers to reassess the price of grape contracts?

L	C

2. What is the risk that Climate Change will create financial distress to the extent that growers will not be able to afford to purchase additional irrigation water necessary to flush salinity from soils.

L	C

What is the risk that the combined pressures of Climate Change will push growers out of the region.

	L	C
by 2015		
by 2030		

OLIVE RISK ASSESSMENT SURVEY

Section 1 Irrigation

Given the assumptions provided, rate the risk the following scenarios present to the industry.

1. What is the risk that in an average year, additional irrigation applications (relative to historic levels) will be required to produce a 35 kg per tree crop based on current varieties.

L	C

In a Drought Year?

L	C

2. What is the risk that in an average year, existing oliveculture irrigation methods will not be sufficient to deliver sufficient water to produce a viable crop based on current varieties.

L	C

In a Drought Year?

L	C

3. Assuming additional water is unavailable, what is the risk that a 25% reduction in water allocations below 2007 levels will be insufficient in an average year to produce a viable yield based on current varieties.

L	C

In a Drought Year?

L	C

4. Assuming additional water is unavailable, what is the risk that a 50% reduction in water allocations below 2007 levels will be insufficient in an average year to produce a viable yield based on current varieties without additional supplementary irrigation.

L	C

In a Drought Year?

L	C

Section 2 Salinity

Given the assumptions provided, rate the risk the following scenarios present to the industry.

1. What is the risk that an increased frequency and severity of drought could lead to interseasonal accumulation of soil salinity from irrigation.

	L	C
by 2015		
by 2030		

2. What is the risk that an interseasonal accumulation of soil salinity will impact on olive tree health and productivity?

	L	C
by 2015		
by 2030		

3. Given that soil salinity may accumulate as a result drought what is the risk that industry wide salt leaching strategies may impact on the watertable.

	L	C
by 2015		
by 2030		

4. What is the risk that the absence of salt leaching strategies could lead to land becoming unviable for oliveculture.

	L	C
by 2015		
by 2030		

5. What is the risk that the failure to appropriately manage soil salinity could undermine the regions environmental stewardship and brand integrity?

	L	C
by 2015		
by 2030		

Section 3 Impacts of Changing Summer Climate

Given the assumptions provided, rate the risk the following scenarios present to the industry.

1. What is the risk that insect outbreaks will be more of a problem than before 2007

L	C

2. What is the risk that Fungal outbreaks will consequentially be more of a problem than before 2007

L	C

3. What is the risk that pest damage to Olive trees may accumulate over time and lead to reduced kg per tree?

	L	C
by 2015		
by 2030		

4. What is the risk that Olive tree damage such as defoliation, heat stress and sunburn will lead to reduced kg per tree?

L	C

5. What is the risk that the consequences of Climate Change will reduce the quality of oil varieties to the point that they may be downgraded

L	C

Table varieties?

L	C

6. What is the risk that the region's Olive quality will be affected by unforseen smoke damage associated with bushfire

L	C

Section 4 Business

Given the assumptions provided, rate the risk the following scenarios present to the industry.

1. What is the risk that Climate Change impacts will increase the costs of production and force growers to reassess the price of Olive products?

L	C

2. What is the risk that Climate Change will create financial distress to the extent that growers will not be able to afford to purchase additional irrigation water necessary to flush salinity from soils.

L	C

3. What is the risk that the combined pressures of Climate Change will push growers out of the region.

	L	C
by 2015		
by 2030		

5. SUMMARY OF CLIMATE PROJECTION DATA

This Appendix contains climate projection data from:

1. Suppiah et al. (2006) — from which worst-case scenarios, under SRES, were used in the risk assessment assumed climate.
2. CSIRO and BoM (2007) — which provides more recently updated climate projections. Improvements in this dataset include projections for a greater number of climate parameters and the provision of probabilistic information on some projections including the probability of exceeding the 10^{th}, 50^{th} and 90^{th} percentiles.

1. Summary of Suppiah et al. (2006) (p31–32) projections for the AMLR in 2030 and 2070, under SRES

Note: Temperature and rainfall changes are projected relative to the climate averages from 30 years (1975–2004) centred 1990.

Variable	Season	2030	2070
Temperature warming (°C)	Annual	0.4 to 1.2	0.8 to 3.5
	Summer	0.4 to 1.3	0.8 to 4.0
	Autumn	0.4 to 1.2	0.8 to 3.7
	Winter	0.4 to 1.1	0.8 to 3.4
	Spring	0.4 to 1.2	0.8 to 3.8
Rainfall change (%)	Annual	-10 to -1	-30 to -3
	Summer	-11 to +6	-30 to +17
	Autumn	-7 to +2	-20 to +5
	Winter	-11 to -1	-35 to -3
	Spring	-20 to -2	-60 to -4

2. Summary of CSIRO and BoM (2007) projections for Adelaide in 2030 and 2070.

Variable	Season	2030 A1B 10p	2030 A1B 50p	2030 A1B 90p	2070 B1 10p	2070 B1 50p	2070 B1 90p	2070 A1FI 10p	2070 A1FI 50p	2070 A1FI 90p
Temperature (ºC)	Annual	0.6	0.9	1.3	1	1.5	2.1	1.9	2.8	4
	Summer	0.6	0.9	1.4	1	1.6	2.3	2	3	4.4
	Autumn	0.6	0.9	1.3	0.9	1.5	2.2	1.8	2.8	4.2
	Winter	0.5	0.8	1.2	0.8	1.3	2	1.5	2.4	3.8
	Spring	0.6	0.9	1.3	1	1.5	2.2	2	3	4.3
No. days over 35ºC (current 17)	Annual	21.3	23.0	25.5	24.0	26.4	30.6	28.9	35.6	46.6
Rainfall (%)	Annual	-11	-4	+2	-18	-7	+4	-32	-13	+8
	Summer	-14	-2	+11	-23	-3	+18	-39	-5	+35
	Autumn	-11	-1	+9	-18	-2	+14	-31	-4	+28
	Winter	-15	-6	+2	-23	-10	+3	-40	-19	+6
	Spring	-19	-8	+3	-30	-12	+4	-50	-23	+8
Potential evaporation (%)	Annual	0	+2	+4	+1	+3	+7	+2	+6	+14
	Summer	0	+2	+5	0	+3	+8	-1	+6	+15
	Autumn	+1	+3	+5	+2	+5	+9	+4	+10	+17
	Winter	+1	+5	+12	+2	+8	+20	+3	+16	+39
	Spring	-1	+1	+3	-2	+1	+5	-4	+3	+10
Wind-speed (%)	Annual	-3	0	+3	-6	0	+5	-11	0	+10
	Summer	-1	+2	+6	-2	+4	+10	-3	+7	+19
	Autumn	-6	0	+5	-9	-1	+8	-18	-1	+15
	Winter	-8	-2	+4	-13	-3	+6	-25	-6	+11
	Spring	-6	0	+5	-10	0	+8	-18	-1	+16
Relative humidity (%)	Annual	-1.5	-0.7	+0.0	-2.6	-1.1	+0.1	-5.0	+2.1	+0.1
Solar radiation (%)	Annual	-0.2	+0.4	+1.2	-0.4	+0.7	+2.1	-0.7	+1.4	+4.0

These projections are based on the following emissions scenarios which represent possible future worlds (SRES 2000):

- **A1B** — This represents very rapid economic growth, a peak in global population mid century and decline thereafter. There is rapid introduction of new and more efficient technologies. Underlying themes include convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1B scenario has a technological emphasis characterised by balance across all types of energy sources (fossil and non-fossil energy).
- **B1** — This scenario has a population growth and decline pattern similar to A1B, however, there are rapid changes in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.
- **A1FI** — This scenario is similar to A1B except that it has a technological emphasis on fossil fuel intensive energy sources.

These are a subset of a larger number of modelled scenarios for the future undertaken by SRES (2000), each of which are considered equally likely.

6. EXPERT REVIEW

Experts in a number of relevant fields were asked to review the approach and outcomes of this adaptation planning process, as outlined in the table below. To aid future planning activities the comments provided by each of these reviewers (where not already contained within the report itself) are provided in this Appendix.

In addition to the specific areas mentioned in the table below, reviewers were asked if they had any other suggestions for improvement to the process.

Area	Task	Person (organisation)
Risk assessment methodology	Review the risk assessment methodology,	(1) Darryl Bruhn (South Australian Government Captive Insurance Corporation [SAICORP])
Climate projections	Review climate projections as used in the risk assessment,	(2) Darren Ray (BoM) (3) Peter Hayman (SARDI)
Viticulture	Review of impacts to viticulture under climate scenario used in risk assessment (e.g. warmer, drier, increased salinity, changing seasonal conditions). Identify gaps in risk assessment (business/agronomic). Review adaptation strategies.	(4) Chris Soar (SARDI) (5) Leanne Webb (CSIRO/Uni Melb) (*) Amy Richards (MVGWTA)
Oliveculture	Review of impacts to oliveculture under climate scenario used in risk assessment (e.g. warmer, drier, increased salinity, changing seasonal conditions). Identify gaps in risk assessment (business/agronomic). Review adaptation strategies.	(6) Leandro Ravetti (Modern Olives) (7) Paul James (Rural Solutions SA) (8) John Fennell (PIRSA) (9) Jim Rowntree (Rowntree Management) (*) Neville Crossman (CSIRO)
Overall process	Review overall planning process/risk assessment	(10) Douglas Bardsley (University of Queensland)

(*) These comments have been incorporated directly into the text of the report.

EXPERT REVIEW (1) — RISK ASSESSMENT METHODOLOGY

Comments by: Darryl Bruhn (Risk Management Coordinator, SAICORP)

Scope/context

The broad environment is well understood and the project has clearly defined objectives.

Risk identification

Baseline set of risks due to climate change occurring were defined. Also two additional questions were posed. By being grouped under four headings and stated as outcomes with a number of scenarios, participants were provided with a clear realistic focus for their verification and assessment.

Risk assessment

Conducted by questionnaire with most industry stakeholders in the region, validated by appropriate experts and various quantitative risk assessment techniques.

Risk evaluation

Overall 'levels of risk' have been calculated using the AGO risk assessment risk tables, suitably modified to ensure their relevance to the stated context. These ratings are used to assist in determining the priorities for action.

Risk treatment

Potential strategies were developed including identification of lead bodies, partner organisations and again grouped around the identified risk area headings. Central to the adaptation is the need for a collaborative model of response to maximise influence and effectiveness.

Monitoring and review

Continual monitoring and review will be undertaken to ensure that the latest knowledge and understanding on climate change, adaptation activities and timeframes is considered.

General comment

It would seem as though the project leaders have found the risk management approach useful for this project. From my point of view, the application of the risk management process and risk management principles has been excellent.

This case study has clearly helped to increase knowledge and understanding of the readily identifiable risk exposures for the key stakeholders.

Suggestions for consideration

Improvements that could be considered, to identify risks prior to commencing work on the adaptation strategies summarised in Tables 1 and 2 of the Summary, are:

- use of some other techniques (see below)
- use a wider group of participants.

One of the problems working with baseline risks only is that harder to identify, less obvious risks can be overlooked. Of course, any risk not identified will not get rated let alone considered as part of risk treatment or any adaptation strategies being proposed. It is not unknown for some risk to come out of 'left field' with major impact while diligently implementing the strategies developed for the identified risks.

Participants in such an assessment would include representatives of the industry groups already consulted as well as various experts and others that may have a broader perspective than has occurred.

Some techniques to consider are discussed below.

Additional techniques for identifying risks

1. 'PEST' or 'PESTLE'

The acronym PEST or PESTLE is a useful tool to trigger consideration of factors which are external to the business or organisational environment. The letters stand for:

P – Political

E – Economic

S – Social or socio-cultural

T – Technological

L – Legislative

E – Ecological or environmental

2. 'Risk spectrum'/layers of risk

It is often argued that we can never know a risk completely. Whenever we peel away one layer of risk, we find another. A response to one risk inevitably creates a new risk. What is the scope of risk or 'uncertainties' that affect an organisation? The following working diagram may help you to visualise this.

The organisation sits within encircling risks and responses. The outer layer is 'global'. It describes uncertainties that are rarely 'manageable' but have significant potential to affect the organisation.

These global risks are surrounded by 'organisational risks' that are more susceptible to our control. Internal specialists have attacked these risks for years, but separately, not together. However, risks are not easily contained in discrete boxes. Risks invariably overlap and are interconnected as we discover when investigating and analysing the causal factors and the consequential impacts of risk events.

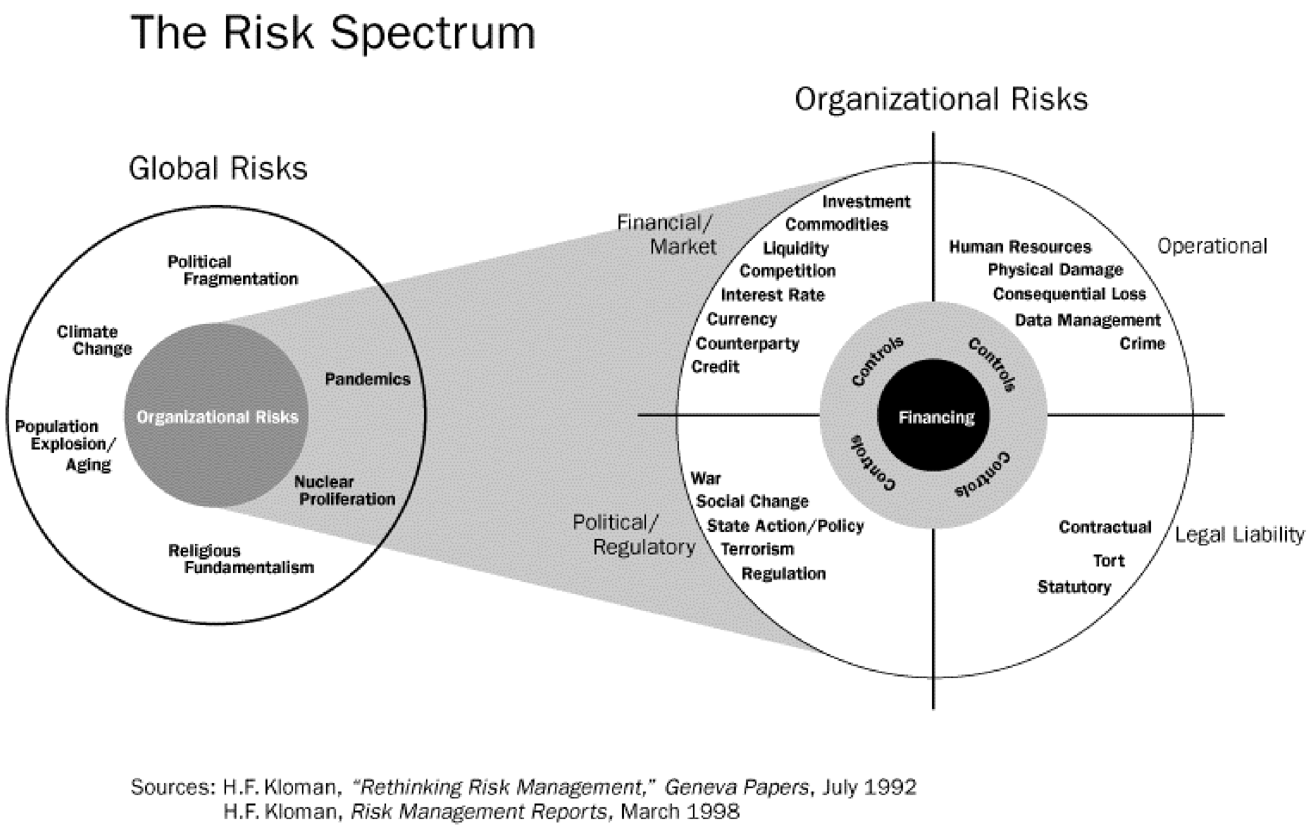

Figure A6.1 The 'risk spectrum' conceptual diagram

EXPERT REVIEW (2) — CLIMATE PROJECTIONS

Comments by: Darren Ray (Senior Meteorologist, Climate Services, BoM)

General comment

I have had a look through the draft report and it generally looks like a nice piece of work.

Updated data

The Suppiah et al. (2006) report that you refer to was pretty good, and used projections from the IPCC Fourth Assessment report, with the models chosen that best represented changes to date.

The CSIRO and BoM (2007) report is better in some ways in that while it also uses the models that best represent Australian observed changes, it also incorporates the probability distribution functions for the spread of the models.

The point in Section 3.1.3 — Assumed climate scenario, about cautioning the use of the number of hot days is fair enough but the CSIRO and BoM (2007) report has figures on page 61 you could quote instead, so I wondered why you put the Hennessey, Macadam & Whetton (2006) figure into Table 4? *[Authors' note: updated climate projection data is now shown in Appendix 5.]*

Summer rainfall

I had a look at the Willunga data and the broader South Australian observed trends in rainfall and they agree with the statements about drier seasons, particularly autumn and winter, while summer gets wetter, though in recent decades the trend towards wetter summers has reversed in the eastern states of Australia and this extends into eastern South Australia. This is also seen in the Willunga rainfall data, so I wouldn't overemphasise the summer increased rainfall necessarily! The area of what is causing these seasonal shifts is a topic of much research. From what we can see so far it is probable that a warmer Indian Ocean is creating more rainfall in the north-west extending across Australia, but this is competing against a possible trend to more El Niño-like conditions drying the east.

Autumn/winter drying trend

The autumn/winter drying trend in recent decades is a pretty solid trend based on strengthening of the subtropical ridge referred to in CSIRO and BoM (2007, p. 106) as one of the most robust signals in the projections for future global warming and ozone depletion in the stratosphere.

Adaptation strategies—new information products

In terms of the potential strategies mentioned in Table 1 in the Summary, there will be a range of water-use products available in the next few years. A trial evapotranspiration (ET) calculation from Automatic Weather Station (AWS) product is already available to help irrigators plan water use, and more comprehensive gridded calculations of water balance are being developed and will come in through the Water Initiative over the next year or so.

A heatwave forecast service has been recently proposed as a project for BoM. I am not sure what forecast services are being referred to in Table 1, whether short-term or better seasonal forecasts.

Improved and longer range seasonal forecasts have been recognised as a need to address, and there are trial extended seasonal forecast dynamic computer model forecasts called Predictive Ocean Atmosphere Model for Australia (POAMA) which the BoM will move into over the next year or so.

EXPERT REVIEW (3) — CLIMATE PROJECTIONS

Comments by: Peter Hayman (Principal Scientist, Climate Applications, SARDI)

Assumed climate scenario

It is good to have clearly stated assumptions for the purpose of the risk assessment. It may be useful to include the summary from Suppiah et al. (2006).

I think that Leanne Webb's comments *[see later]* are really useful in terms of the climate scenarios and they echo many of the quick comments that I have made.

Regarding assumptions for extreme summer rainfall, it is good that the extreme values are defined. However, one standard deviation is not a large deviation — it will be exceeded about 15% of the time for high rainfall or temperature and 15% of the time for low rainfall or temperaturethat is one in three years will be extreme (i.e. 30% will be high or low). Drought policy uses one in 20 years or 5th percentile. The 2003 heatwave in the UK was three standard deviations.

Temperature

The issue of temperature in this region is important. Warming conditions are likely to not only influence harvest time, but ripening time and the complex relationships between growth, ripening and flavour development — this should be investigated/discussed further.

It would be beneficial to include a reference to mean temperature.

There is high confidence in terms of trends and projections for temperature compared to rainfall.

Rainfall

Perhaps it should be made clear that the issue that was right in front of growers was water supply. At the one meeting I went to, Barry Brook (University of Adelaide) and Peter Leske (SAWIA) spoke I did a bit of a survey, but I think that this was too rushed and not in context.

To my mind the really valuable part was the level of discussion amongst industry people, and the question is whether the scenarios were pitched to guide this discussion well.

It should be clarified just how severe 2006 was in terms of rainfall decline as suggested by Leanne Webb, and clarify in the table what the rainfall decline (%) was applied to Willunga.

The difficulty is whether 2006 was considered an indicator of the new mean around which rainfall would vary — or recognised as an extreme that would be more common in a drier climate.

I would think that they understood the scenario of using 2006 as not the new mean but an example of an extreme — I am not sure, but I think that this point was raised on the night that I was there.

The process can be seen as a form of scenario planning where 2006 was used as an event to focus the mind on adaptation options etc. for an extreme event that may be more common rather than as the new climate for the region.

I think that the new Climate Change in Australia's technical report (http://www.climatechangeinaustralia.gov.au/resources.php), which offers the results as probabilities, is an excellent resource — it was not available at the time, but it might be worth pointing people to it.

EXPERT REVIEW (4) — VITICULTURE

Comments by: Chris Soar (Senior Research Officer, Climate Risk, SARDI)

Case study focus/potential bias

The case study is really focused on reduced water availability and the follow-on consequences such as salinity rather than an all encompassing view of the impacts of climate change. This is not a criticism as such as declining and shifting patterns in water availability may prove to be the most critical component to threaten profitable production in some regions. Also to cover all of the elements of climate change in the one case study could be overwhelming and the impacts of some of the other elements are probably less apparent to the industry.

However, the report title and content implies a comprehensive consideration of climate change issues when I think in reality there is a strong bias towards water issues. Some other impacts of climate change that have not been explicitly dealt with are:

- prolonged extreme heat events (as opposed to changes in average temperature)
- rising CO_2
- changes in radiation
- changing humidity/evaporative demand (although this last one is implied).

Whilst I think the focus on water is justifiable, I think some reference to the other elements of climate change should at least be made.

General comments

I think the case study overall is well put together and is an important step in preparing the local industries for future sustainability. I think the approach used is sound and the conclusions are well considered and the adaptation strategies presented are quite comprehensive. I have made a few comments on the text itself, however in addition I have two broader comments that I would like to make which both really relate to the wine industry side of things because that is the area in which I have the most knowledge, however they may also relate to oliveculture.

1a. The impact of heat and CO_2

There is frequent comment within the wine industry that also emerges in this case study that ‘heat is bad’. My concern is that the industry as a whole, but also at the regional scale, does not have a clear definition of what defines damaging heat. Climate change-invoked changes in temperature might be split into two components: increased average temperatures and increased frequency of consecutive very hot days or ‘heatwaves’. I think this case study has really only considered increased average temperatures and not the effects of heatwaves.

Generally, elevated temperatures or even an increase in the total average days over 35ºC will not necessarily translate into a loss of yield and/or quality. In fact, depending on the region, higher mean temperatures may increase yields and even improve quality through more even and rapid ripening, this all on the provision that irrigation remains adequate — which is clearly a recurring theme in this case study. So will these increases in temperature mean more water will be required to maintain yield and quality? Well, as this case study suggests I think the answer is undoubtedly yes, but the increase in irrigation requirement may not be proportional to the changes in temperature.

One of the big uncertainties with crop response to climate change is the response to increasing CO_2. Increased CO_2 may have the impact of improving crop water-use efficiency: in effect this means that the amount of water that needs to be lost in order to 'fix' a unit of carbon will decrease. So the need for extra irrigation water to maintain yield and quality based on the heat component of climate change alone may be an overestimate without considering the potential 'beneficial' impacts of rising CO_2. Crop response to CO_2 is very uncertain and is an area where significant research is needed.

1b. Prolonged hot weather

Another issue is prolonged hot weather where the industry experiences consecutive days of very hot weather. I do not think this case study has delved much into the issue of 'heatwaves' despite the fact that I believe that when the wine industry expresses concerns regarding 'heat' it often relates more to recollections of the damaging effects of heatwaves rather than the concerns of increases in mean temperature. The climate scenario mentions the annual number of 'hot days' above 35°C, but I think the issue of consecutive days over this threshold is more important. It is indisputable that we have witnessed conditions in the recent past where prolonged periods of extreme heat have caused substantial damage in terms of both yield and quality. But what aspect of the heat caused the problem, i.e. was it the temperatures that were reached, the duration of the heatwave or was it because of other related conditions such as hot strong northerly winds?

I think there is a very strong link between heat and water and that has certainly been made clear in this case study. But I think there is a perception in the wine industry that there could be some 'heatwave conditions' in which the crop is adversely affected regardless of whether there is access to sufficient irrigation water or not. I think the wine industry and possibly the oliveculture industry needs a clearer sense of exactly what conditions define a damaging heat event and how much of the effects of damaging heat can be offset by irrigation versus the need to also find other ways of safeguarding against heatwaves. We are involved in a GWRDC funded project that specifically aims to identify the effects of extreme heat versus smaller increases in mean temperature, so some of the research needed is underway.

2. Crop adaptation

The grapevine and viticultural systems have a large capacity for adaptation. This has been acknowledged in this report by the mention of new varieties and rootstocks tolerant to heat/drought and salt. However, existing plantings may also adapt to hotter/drier conditions in other ways as well, for example improvements in water-use efficiency relating to CO_2 changes as mentioned above. There may also be other changes such as in leaf morphology, root morphology, fruit to vegetative growth ratios, crop phenology and even changes in the finer detail of biochemical pathways and gene expression. These changes are hard to predict and will all be driven by plant survival, and so in terms of profitable production and fruit quality they may be of no advantage or even present a disadvantage. However, it should be recognised that there will be a crop response that may change the management requirements over and above the considerations discussed in this case study.

EXPERT REVIEW (5)—VITICULTURE

Comments by: Leanne Webb (CSIRO Marine and Atmospheric Research/University of Melbourne, Institute of Land and Food Resources)

I wish to premise this review by stating that my expertise is in the field of impacts of climate change to viticulture, and I have limited understanding of climate effects on the culture of olives.

General comments

The process undergone in order to complete this analysis is an excellent first step in addressing this challenging issue. In this emerging field of research where the methodology is still evolving, the process of engagement with industry experts and stakeholders, conducting workshops facilitating two-way knowledge gathering, followed by an overall review, appears to be a robust and rigorous approach. The key to this process is in providing up-to-date, authoritative summaries of current and future climate in relation to both temperature and rainfall in a manner easily accessible to participants.

Concerns

The main concern I have with the draft document is not, as stated, with the process, but with the content of some of the information given to workshop participants. It appears that the participants were asked to focus in the year 2006 as an indication of what they might expect with a projected 2030 climate. Though it is understandable that an analogous year be presented so as to allow the participants a point of focus, I have reservations about the selection of this climate analogy. While 2006 is a fair representation of the projected 2030 temperatures, the rainfall for this year was extremely low, much lower than the mean rainfall projections by the year 2030 (Suppiah et al. 2006). Of course, this may have been explained, but the explanation is not documented in the adaptation report, so I am just listing what could be misinterpreted (having only had access to the written report). Presumably this report will be the document on which future actions will be based.

1. Drought vs. climate change

While scientists are now attributing most of the **warming** since 1950 to increases in greenhouse gases, there is **uncertainty** about the causes of **rainfall trends**. In Australia, increases in rainfall in the north-west may be due to natural variability and a shift in monsoon rainfall due to increases in Asian aerosols. Decreases in rainfall in the east are mainly due to an increase in El Niño years since 1975, the cause of which is unknown. Decreases in rainfall in the south are due to a southward shift in weather systems. In the south-west of the continent this is likely due to natural variability **and** increases in greenhouse gases. Increasing greenhouse gas concentrations may also be linked to recent drying in the south-east, however this is an area of active research and attribution to this forcing factor has not been established (K Hennessy, pers. comm.).

Figure (i) depicts the rainfall variability in South Australia up to the year 2007. The exceptionally dry period in recent years may be due to natural rainfall variability, not greenhouse gas increases. While the trend in greenhouse gas induced projected spring rainfall changes for this part of the region are, on average, -20% to -2% by 2030 (compared with average 1961-1990 rainfall) (Suppiah et al. 2006), natural rainfall variability is expected to continue to produce both wetter periods and drier periods (around this average decrease).

I include a rough calculation of the percent spring rainfall reduction in 2006 (spring rainfall anomaly in South Australia for 2006 was -38mm to average spring rainfall of about 60mm [BoM 2007]) and this results in about a 65% reduction compared to average rainfall — Fig. (i) — much greater than the projections for 2030. (Similar calculations show annual rainfall was 36% below average for 2006 in South Australia, while projections indicate annual reductions in the range 1 to 10% [Suppiah et al. 2006]). Furthermore, this low spring rainfall follows on from two years of below average annual rainfall in this region; and in the Murray-Darling Basin, a major provider of irrigation supplies for the region, there were five years of below average rainfall (BoM 2007) and below average inflow (MDBC 2006)—Figure (ii)—so stored water sources (in soil and above ground) were depleted.

If being asked to consider pressures on the production of grapes and olives in this context (i.e. 2006), participants may have been more sensitive to water stress/shortage than if the survey and discussion were conducted with regard to a non-drought year. From reading the draft report it is unclear how, or if, these differences between drought and climate change projections were explained.

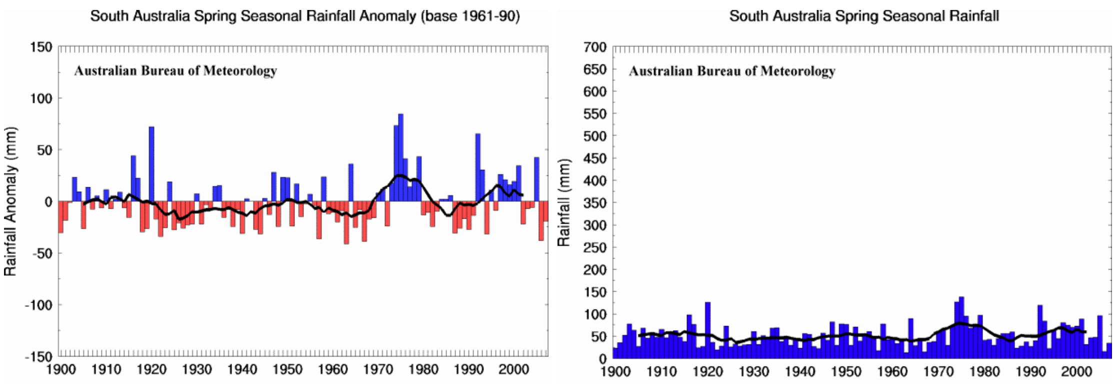

Figure (i) Spring rainfall anomaly (left) and totals (right) for South Australia (1900–2007)

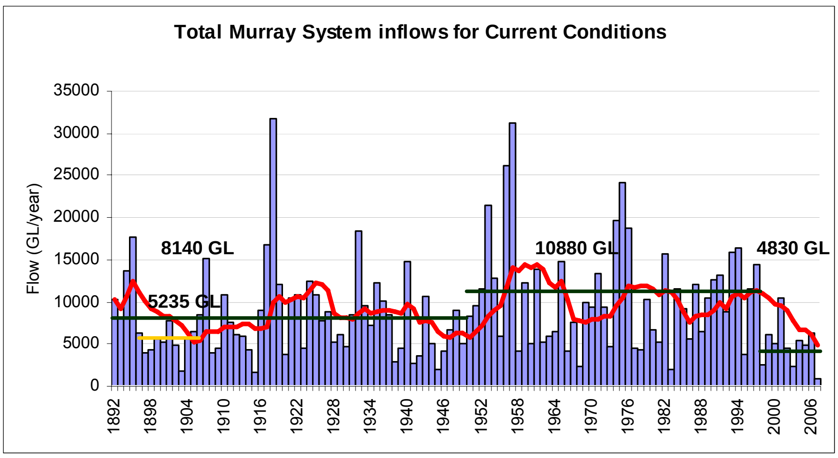

Figure (ii) Total Murray system inflows for the Murray-Darling Basin (1900–2007) (MDBC 2006)

Again, so as to clarify the distinction between drought and climate change, the questions relating to drought in the risk assessment survey might be kept separate. Agricultural drought (this definition of drought allows for the consideration of reduced rainfall and also temperature/evaporation increases) is defined as a period of extremely low soil moisture, i.e. a drought is declared ‘commenced’ when soil moisture reaches the lowest 10% on record (for three month period). A drought is considered to have ended if the soil moisture (for a three month period) is above the seventh decile (highest 30% on record). Agricultural droughts are projected to increase in future climates, and results based on two models indicate a 20% increase in frequency of droughts by 2030 in eastern Australia (CSIRO & BoM 2007).

2. Temperature

The temperature anomaly for 2006 of +0.82°C is in line with the warming projections by 2030. How much was temperature change mentioned in the information sessions? Temperature changes listed in the climate projection table only included changes to the number of hot days, not changes to mean temperature. There is also some mention of earlier harvests and potential impacts on quality. Many more impacts have been reported in the literature (see below) including compressed vintages (which I believe have caused all sorts of problems this year), alcohol levels, etc. Were these discussed?

Workshop participants expressed some concerns due to possible impacts of increasing temperature on their enterprises, and the risk assessments describe some temperature impacts as ‘high risk’, however these concerns are not included in the summaries/ Summary. The findings of the report emphasise concern with regard to access to water and also increasing problems with salinity. While I absolutely agree that these are major areas of concern, increasing temperature will also impact on the quality/quantity/logistics of production and these impacts may have been overlooked given concern with regard to water availability.

3. What was presented?

As was previously raised, it would be instructive for the readers of the report to have access to more detailed information regarding the workshop presentations, whether by access to an extended abstract in the Appendix, or a more detailed summary in the text. The level of detail with regard to current knowledge of impacts of climate change presented is vague. Were the participants presented with findings from local and international impact studies, (Nemani et al. 2001; Jones et al. 2005; Webb 2006; White et al. 2006) (I am not aware of any studies relating to oliveculture) or just climate projections? It does not matter to the results, but knowledge of the extent of information given, and then perhaps dismissed as unimportant, could actually be informative.

4. Regional description

When discussing regional characteristics, again there is an emphasis on water and salinity. For this type of report where both rainfall and temperature change impacts are being discussed it is important to also describe the temperature of a region and how that influences viticultural or oliveculture practices, product expectations, and what gives this region its identity. For example:

The McLaren Vale region is renowned for production of shiraz wine. Vines are spur pruned and yields of XXt/ha ripened to XX Baumé is typical for this region. In cool years the wines can be described as … while in hot years flavours can … Notable climate stressors are *northerly winds, and spells of Xdays over X°C. In some of the hotter years, or in cases of extreme events the impacts have been… and management strategies that alleviated these problems were … Budburst can be uneven after particularly mild winters.*

It is instructive to the reader to know how the vines are managed with regard to inter-annual climate variability. It will be in extrapolating some of these management treatments that we begin to evolve an adaptation response. It must be articulated even if it seems obvious.

5. Climate projections

Presentation of the projected changes to climate (at least in the written report) are selective and in some cases misleading. For instance, while it is true some models show increasing summer rainfall projections, it is advisable to present the entire range of results (this may have been done) which include projected rainfall reductions for summer so as not to possibly mislead the participants.

By its very nature, the process of projecting into an unchartered and uncertain climatic territory is both complex and confronting. In the case of this project, stakeholders have been informed, and provided with ownership of the issue, allowing the way forward to become accessible and achievable. I believe this structure of assessment reporting is productive, but again stress the importance of providing the stakeholders with realistic and balanced climate outlooks if the outcomes are to be as beneficial as possible. It is important that this background is included in the final report, because this will become the reference document for the region.

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EXPERT REVIEW (6) — OLIVECULTURE

Comments by: Leandro Ravetti (Technical Director, Modern Olives)

Assumptions

The following considerations have been included in the climate scenario used in the risk assessment:

Rainfall:

- reduced winter/spring rainfall
- increased summer rainfall
- higher frequency of extreme events
- extreme rainfall lows are likely to occur more frequently.

Temperature:

- increased number of days with temperatures above 35ºC.

Water supply:

- groundwater supply and salinity not impacted significantly
- groundwater allocation as percentage of resource rather than volumetric
- surface water supply allocation can be expected to fluctuate on a season–to-season basis.

Salinity:

- winter/spring rainfall may not be sufficient to flush salinity from soils
- soil salinity has the potential to accumulate across seasons.

According to my experience, the following impacts to oliveculture are likely to occur under those climate scenario assumptions:

Lower water availability leading to less growth and lower fruit and oil yields

As an evergreen tree, olives use water year-round. As a direct consequence, vegetative growth and consequently production are affected by low soil moisture during the entire growing season. However, there are two extremely critical periods that must be considered separately.

The most important one extends between August and December. During these months we find flower bud development, full blooming, fruit set and stage one of fruit growth due to cell division. Any moisture stress during this period will reduce the number of fruit per tree and also the potential size of the fruit because of the lesser number of cells per fruit as well as new growth to support the following season’s crop. Lower rainfall during winter and spring will directly affect this period.

The other relatively critical moment is between middle February and a month before harvest time. During this period oil accumulation and cell expansion take place at its peak. Consequently, low soil moisture levels will lead to smaller fruit and less oil content. Increased summer rainfall may help to minimise the risks at this level.

Finally, it is extremely important to underline that, once the crop reaches final canopy size, maximum vegetative growth or even maximum yields, do not always mean the highest profit. This is a crucial concept, which must be studied locally due to different water costs from area to area and different selling prices of olive products between groves and years. In theory, each grower must apply an amount of irrigation water to reach the point where yield increments do not compensate additional irrigation costs. The following table analyses the impact of water restrictions on oil yields and fruit yields based on long-term data from Spain, Italy and Greece research (Barranco, Fernandez-Escobar & Rallo 2004; Fontanazza 1996; Muñoz Cobo & Macías 2005). Our current data (two years) from central and northern Victoria seems to confirm the trends presented in the table in order to estimate the possible impact of water restrictions on crop potential.

Oil and fruit yields vs. water supply in olives

Etc	Irrigation	Yields	Oil Content
100.0%	100.0%	100.0%	100.0%
85.8%	77.0%	84.1%	98.3%
71.3%	53.0%	68.5%	93.7%
57.2%	30.0%	48.0%	90.8%
38.9%	0.0%	25.3%	87.0%

Utilising these data and knowing the real maximum cropping potential of a certain olive grove, a comparative analysis of the economic benefits per megalitre of water applied for the different irrigation scenarios could be estimated.

Nutritional issues

Lower water availability will determine nutritional issues particularly associated to those nutrients, such as potassium, that require good soil moisture levels for their uptake. These problems will tend to be worse after a year with good soil moisture levels, when the trees reached good growth and cropping potential. If a water shortage occurs then, the tree nutrition to support the large cropping potential will be clearly deficient. Foliar spray strategies are normally applied in the Mediterranean to minimise these nutritional issues.

Increased frost risks

It is difficult to define precisely the minimal temperatures that the olive tree is able to tolerate. It is important to remember that the olive tree does not have a true dormant period. Even in the suitable coldest climates for olive growing, the tree shows an instable dormant period.

Consequently, frost tolerance varies greatly according to:

- the physiological moment when we have the frost
- the length of the frosts (how many hours?)
- the intensity of the phenomena (what was the lowest temperature?)
- the age of the tree (old productive trees are more tolerant than young ones)
- the variety
- the position in the grove (lower areas, slopes, facing north or south, etc.)
- nutritional levels in the tree
- pest and diseases.

Furthermore, it has been demonstrated that low humidity levels in the air and low levels of soil moisture are significant contributing factors to increase the incidence of frosts. Extensive areas of South Australia and Victoria have suffered some of their worst frost events in history during the recent drought years. Consequently, a higher incidence of frost damage reducing crop levels and value can be expected in drier winter and spring conditions.

More water needed from irrigation

Drier winters and springs as well as higher summer temperatures will certainly increase the water demand from irrigation in order to compensate for the reduced rainfall and higher evaporation rates. As the drier periods are likely to affect catchment areas as well, an increasing pressure on the water resources with a highly likely increment on water prices should be expected. The analysis of the cost effectiveness of additional water should be evaluated following some of the considerations presented in previous paragraphs.

Pests and diseases

More humid summers could increase the threat of more suitable conditions for the development of certain pests and diseases such as black scale (Saissetia oleae) and peacock spot (Spilocaea oleagina). Both of them can be controlled if accurate monitoring and timely chemical treatments are carried out. Nonetheless, it will determine an increment on growing costs.

Tree damage and fruit losses

The higher frequency of extreme events involving high rainfall in short periods of time, gale winds and/or hail could determine a higher incidence of tree and fruit losses associated with these events. It is very difficult to provide an accurate estimation of the likely level of damage but they need to be considered as some of those damages could be minimised by taking appropriate insurance cover.

Olives will survive extremely dry periods, but at a cost

Olives are probably one of the species best adapted to survive extreme rainfall lows. Nonetheless, as has been analysed in previous paragraphs, both fruit and oil yields will be affected and under extreme circumstances, and particularly with young trees, tree losses may occur.

Lower oil content

A larger number of days with summer temperatures above 35ºC could be of some concern. Photosynthesis is generally inhibited by temperatures higher than 35ºC (Bongi & Palliotti 1994). However, olive cultivars acclimatised to high temperatures maintain 70-80% of their photosynthetic rate at 40ºC (Bongi & Long 1987). High temperatures are frequently associated with high vapour pressure deficits between leaf and air, water stress and high light influence that could compromise the oil accumulation potential of the olives.

Higher polyphenols

Olive oils produced under more severe water and temperature stressing conditions tend to have higher levels of polyphenols and other antioxidant substances associated with the pungency and bitterness of those oils. Extremely high levels of pungency and bitterness could lead to imbalanced oils.

Salinity affects yields

Olives are moderately salt tolerant, although salinity may be a problem, due to the potential high salt concentration in the soils and irrigation water. Olive orchards growing along the coast must also cope with salt deposited by sea winds.

Fruit yields could be reduced by up to 10% when the electrical conductivity (EC) in the soil saturated extract reaches 4dS/m, up to 25% with values of 5dS/m and as much as 50% with values of 8dS/m (Navarro Garcia 2004). Specific toxicities could also be an issue even with lower levels of salinity, e.g. moderate yield reductions could be expected with percentages of interchangeable sodium reaching 20–40% (Navarro Garcia 2004).

Identify any gaps in the oliveculture risk assessment survey (agronomic or business aspects)

In general terms, I agree with most of the elements identified in the risk analysis presented in the project, with some minor discrepancies as regards the likelihood or consequences that do not change the final result significantly.

The following risks could also be included or expanded in the analysis.

Frost

As it was explained before, the drier winter and spring conditions can lead to a higher than normal frequency and intensity of frost events. More frequent or severe frost events can determine crop losses from the quantity and/or quality point of view. This situation is more likely to affect those groves planted further from the temperate effect of the sea. L(likelihood): Moderate to likely & C(consequence): Moderate.

Extreme events

Once more, higher frequency of extreme events involving high rainfall in short periods of time, gale winds and/or hail, could determine a higher incidence of tree and fruit losses associated to these events. It is very difficult to provide an accurate estimation of the likely level of damage. L: Moderate & C: Minor to Moderate.

Salinity worse than anticipated

It is my belief that the salinity problem can be much worse than anticipated by the participants of the forums. It has been my experience that, even without water restrictions in place, it is not uncommon that olive growers in Australia under-irrigate their trees, building up dangerous levels of salinity in the soil profile by not following appropriate salt leaching techniques. Higher water prices and increased restrictions can exacerbate this problem. Let us consider that a poorly managed grove irrigating with water showing a salt content of 2,000 ppm can push the percentage of interchangeable sodium (PIS) *[i.e. exchangeable sodium percentage]* levels above the concerning 20% limit in just a couple of years. L: Likely to almost certain 7 C: Moderate to Major.

Grove no longer economic

I do believe that it is necessary to further analyse the different scenarios that can follow a grove that is not longer economically viable. Special attention has been dedicated to its potential as an invasive risk. Equally important will be its potential as a source of pests and diseases for other groves in the area. The social impact of abandoned groves should also be considered not only for the growers themselves but also for service providers, local business, suppliers, casual labour in the area, etc.

Review of the adaptation strategies

Comments and additional suggestions as regards the adaptation strategies are presented in ***bold italics.***

Irrigation:

- Ensure water use is at maximum efficiency across the industry. ***OK. Particular emphasis should be give to infrastructure and systems inefficiencies.***
- ***Educate growers as regards deficit irrigation strategies. Learning how to make the most of the available resources.***
- Establish working relationships with forecasters specific to the needs of the industry. ***OK***
- Where possible encourage at-risk growers to seek greater water security. ***OK***
- Monitor water allocation trends and alert growers to anticipated reductions. ***OK***
- ***Work with water authorities for specific water allocation schemes catering for the needs of perennial crops and olives in particular.***
- Develop business strategies for remaining viable through periods of drought. ***OK***
- ***Determine the maximum crop potential of the different groves identifying limiting factors and calculate the breakeven price for purchasing additional water. Is the additional expense justifiable?***
- Advocate for industry access to drought relief. ***OK***

Salinity:

- Advocate for targeted salinity avoidance research. ***OK***
- Develop appropriate salinity avoidance practices. ***OK***
- Ensure growers are informed regarding salinity avoidance practices. ***OK***
- Monitor salinity build-up in high risk areas. ***OK. We should remember that any grove that is not managed accurately is at risk of developing a salinity problem.***
- Review long-term salinity and natural resources impact risk with key stakeholders. ***OK***
- Promote salinity management as a key pillar of industry environmental management. ***OK***
- ***Let us not only look at the salinity problem but also specific toxicity issues such as sodium, chloride or boron toxicities.***

Changing summer climate:

- Advocate for research into olive industry pest and disease management. ***OK***
- ***Educate growers as regards the most efficient integrated pest management (IPM) practices to prevent and control the key pests and diseases.***
- Investigate effective management of increased pest and disease pressure. ***OK***
- Increased grower capacity to manage pest and disease pressures. ***OK***

- Improve margins per kg of fruit. ***OK. Very complex point. Several aspects will need to be considered: real crop potential of the grove as a combination of genetics, environment and management; marketing strategies; economies of scale; etc.***
- Increase plant resilience to pest and heat pressure. ***OK. Very difficult to achieve. There is some information as regards the behaviour of different varieties under stressing conditions but it is not easy to change.***

Business:

- Review sustainability of current olive product pricing practices. ***OK. I would review the sustainability of the olive industry in the area as a whole. Answering the question if the industry is currently profitable is critical before entering into more detailed analysis of the future.***
- Identify ongoing need (quantity, cost and timing) for salinity flushing irrigation applications. ***OK***
- Identify and monitor high risk commercial olive groves. ***OK***

Provide any other comments or suggestions for improvement

Considering that most of the critical impacts of the estimated climate change scenarios are linked to water availability and sustainability of the olive industry, I would suggest that those two components need to be studied in depth for the current Fleurieu Peninsula olive industry.

Different methods could be utilised, but an average consideration of most growers as well as specific case groves should be measured. The most important aspects to determine as starting points of this work are:

- current fruit yields per year of age of the grove
- current oil yields
- current oil prices
- current net margins with and without considering depreciation and interests
- current water availability per hectare.

All these aspects will be critical to evaluate the current condition of the local olive industry before analysing the eventual impact of climate change. It is important to try to avoid pointing at possible climate changes as the main cause of a situation that could have been quite precarious to start with. It will present growers with realistic scenarios of where they are now and where they could be with or without climate changes in the future.

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EXPERT REVIEW (7) — OLIVECULTURE

Comments by: Paul James (Senior Horticultural Consultant — Temperate Fruits, Rural Solutions SA)

Impacts to oliveculture under the climate scenario used in the risk assessment

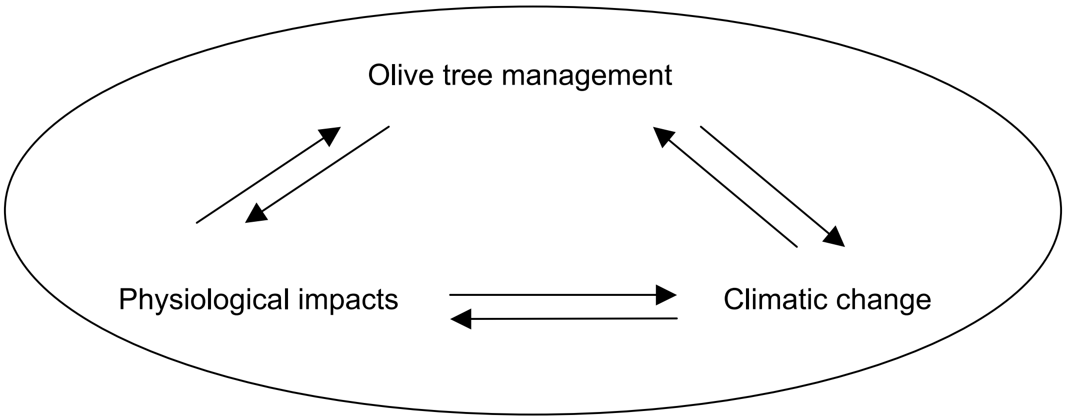
Overall I found the methodology used in the project to be extremely good at achieving its stated objectives, however I believe there are some areas that need further consideration.

Olives are a temperate/Mediterranean tree fruit and therefore their annual vegetative growth and fruiting characteristics is very specifically linked to a number of climatic requirements and seasonal climatic influences. These climatic requirements and influences have a direct impact on the olive trees growth throughout the year and are not restricted to the influence of summer temperatures and annual rainfall.

The project structure, particularly the initial workshop and information provided to the participants, primarily focused on management practices and a subset of the environmental factors influencing olive trees, i.e. those structured around rainfall and summer temperatures. It has not fully investigated (or minimised) the plant physiological impacts of climate change. These physiological impacts are more substantial than those identified in the workshop structure. In simplistic terms there is a three-way interaction between olive tree management, climatic influences and physiological responses (shown in Diagram 1).

The climate influences the physiological response which in turn influences the growers' management responses.

Diagram 1. Climatic and physiological interactions on olive tree management



Spring weather conditions, particularly during the critical flowering period, have a very significant impact on the fruit set of olive trees. Any conditions at this stage, i.e. frost, cold temperatures, wet weather and/or excessive wind will adversely affect fruit set. A poor fruit set then subsequently influences how the tree grows for that season and potentially the following year. The crop loads in turn influence the seasonal management responses of the grower and their subsequent use of natural resources such as water. Poor fruit set can lead to biennial bearing which itself has a big influence on grower management practices and economic viability.

Drier spring weather conditions increase the risk of frost. In extreme situations frost can lead to total crop failure. Increase the frost risk and growers will by necessity need to consider various frost mitigation strategies, the most important being the use of irrigation to produce latent heat to minimise the frost impact. This would necessitate the use of larger quantities of water in the spring risk period. Water used for frost control is <u>separate</u> to the irrigation requirements of the crop.

I believe if a plant physiologist or crop technical specialist was involved in the very early planning stages, that the information used to structure and conduct the first information workshop and the subsequent group discussions in the second workshop would have resulted in a wider perspective of climatic influences.

In summary, the project's major focus on changes to annual rainfall levels, water issues (irrigation and salinity) and predominately summer temperatures does not fully encompass the full impact of possible climate change impacts on oliveculture. In particular, I believe neither the implications of changes in the spring weather conditions, nor the implications of extreme weather events on fruit yields <u>and</u> quality have been fully investigated. A commercial grower's economic viability is directly linked to their marketable yields—not total yields produced.

Identify gaps in the oliveculture risk assessment survey (agronomic or business aspects)

The report states that an 'assumed climate scenario was used to reduce uncertainty and provide a common set of assumptions'. Unfortunately, this assumed climate scenario did not fully encompass the full range of potential climate impacts. In particular, it did not encompass the impacts over the full year and is lacking in the areas of spring weather, autumn and winter temperatures.

The assumed climate scenario focuses on broad categories and not the specific crop physiological timings and requirements.

The potential risks associated with poor or extreme weather conditions during spring have been briefly discussed. Olives, although an evergreen and therefore not considered deciduous, still have a requirement for chilling to enhance flower development. This chilling requirement is influenced by autumn and winter temperatures, any increase in the average temperatures during this period may have detrimental effects on the olive trees cropping potential.

Table 14 in the report is a summary of the oliveculture risk assessment.

Based on this table my view is that the risk assessment has gaps in the following areas:

Irrigation — no provision for specific frost protection — severe spring frosts

Impacts of changing summer climate:

- too narrow focus—temperature only
- summary only comments on increased pest and disease pressures
- no reference is made of impacts on:

  - marketable yields
  - fruit quality
  - tree stress — with associated effects on following season performance.

Business:

- only has a focus on increased costs
- does not consider the impacts of poor crop levels and subsequent potential biennial bearing issues
- fruit quality issues are not highlighted—significant economic risks.

Other issues:

- overall the report fails to identify the significant risks associated with:
  - spring weather changes
  - autumn weather conditions
  - winter temperatures
  - impact of extreme weather conditions.

Adaptation strategies, roles and responsibilities

In my opinion, the limited range of climate risks identified limits the strategies identified.

The scenario presented regarding the FPOA — described as being 'comparatively small and having limited resources' and consisting of 'around 30 members, funded through membership fees rather than a levy and relies entirely on volunteer effort'—suggests the association has limited capability to provide active leadership. Given the small size of the industry, I believe more responsibility will need to be carried by individual business units than has been identified in the summary.

In relation to specific strategies listed I believe the following comments apply:

Risk area	Potential strategy	Comments
Irrigation	Maximum water-use efficiency	Agree — need more enterprise involvement
	Working relationships with BoM	Agree
	At-risk growers — seek greater water security	Agree — need more enterprise involvement — they carry the financial responsibility not the FPOA
	Monitor water allocation trends	Needs active partnership between FPOA and water allocators
	Business strategies for drought	Agree
	Advocate for drought relief	Agree — business survival
Frost risk	Strategy not identified	
Salinity	Targeted research	Agree — extension of existing information should also be considered
	Salinity avoidance practices	Role for FPOA and growers as well as agencies
	Extension of avoidance practices	Agree
	Monitor long-term salinity in high risk areas	Agree — individual businesses should be using monitoring techniques as part of irrigation best practices
	Review long-term salinity and natural resources risks	Needs active partnership between FPOA and various agencies

	Promotion of salinity management as part of environmental management	Strongly agree
Impacts of changing summer climate	Advocate research into pest and disease (P&D) management	Agree — need to widen focus
	Investigate effective P&D management strategies	Agree — individual businesses should be using monitoring techniques as part of best management practices
	Increase grower capacity	Agree
	Improve fruit returns	
	Reduced crop load management	Not identified
	Management of weather damaged or reduced quality fruit	Not identified
	Increase plant resilience to pest and heat pressure	Agree — wide scope for involvement
Business	Review sustainability of current pricing practices	Advocacy role for FPOA
	Salinity flushing management	Agree — individual business requirement
	Identify and monitor high risk olive groves	Role for FPOA as well as agencies – What is technical expertise of NRM Board to make decision in this area?
	Crop load management	No strategies identified
Spring weather	No strategies identified	
Autumn weather	No strategies identified	
Winter weather	No strategies identified	
Extreme weather	No strategies identified	

Overall, the way in which this risk assessment has been reported it appears that there has been limited ‘thinking outside the square’ beyond the existing organisations and agencies as potential partner organisations, for example the use of peer leaders to lead change from within the industry.

Other comments or suggestions

Introduction:

Whilst climate change may be ‘disruptive to the fundamental factors that have enabled the target industry groups to become established in this region’, it does not necessarily mean that it will lead to their relocation out of the region. Climate change modelling undertaken with the apple and pear industry in the AMLR shows that they are currently growing in the most desirable areas and that will not change with the current climate change predictions. What will change is the industry’s management strategies to handle the changed environment.

Methodology:

- The outcomes are only as good as the inputs — overall the project has demonstrated excellent process and outcomes. Further benefits and outcomes could have been obtained with the use of a plant physiologist and/or crop technical specialists in the initial project development and workshop stages.
- Olive group representation — focused on regional representation, not necessarily appropriate knowledge needed to achieve desired outcomes.

- Group discussion — the strategy to get discussion started was very effective, but then some of the assumed climate scenario assumptions restrict active exploration of options, particularly when only 'current' irrigation and crop management practices can be considered. The methodology used requires the growers to view the situation from a wide perspective, which then if not facilitated adequately restricts their ability to focus down on specifics i.e. risk strategies.
- Be careful on using the 'broad' workshop of grower responses to drought to extrapolate too far — the report's own data indicates a considerable variation in individuals practices and the growers are relatively inexperienced. To explore these questions further more information is required.
- Assuming current oliveculture practices (this is a restrictive view) practices are always changing and not likely to be 'static' — efficiencies are always being sought.
- There is a focus on planning based at the industry level rather than the enterprise level. I believe the two are intertwined and you need to 'plan globally but act locally'.

Irrigation considerations:

Long held 'view' that only in the case of very high value intensive horticultural crops, i.e. cut flowers and nurseries, is using mains water for irrigation ever going to be economic.

Extreme events:

Not adequately covered.

Key findings:

Oliveculture comments are very disconcerting, and lead to question: what is the industries' likely ability and capability to be able to adapt anyway?

Where to from here:

I strongly agree with the comments expressed, if NRM boards and other organisations want to engage primary producers it needs to be in a constructive manner using collaborative models as demonstrated by this project.

EXPERT REVIEW (8)—OLIVECULTURE

Comments by: John Fennell (Principal Industry Coordinator — Horticulture, PIRSA)

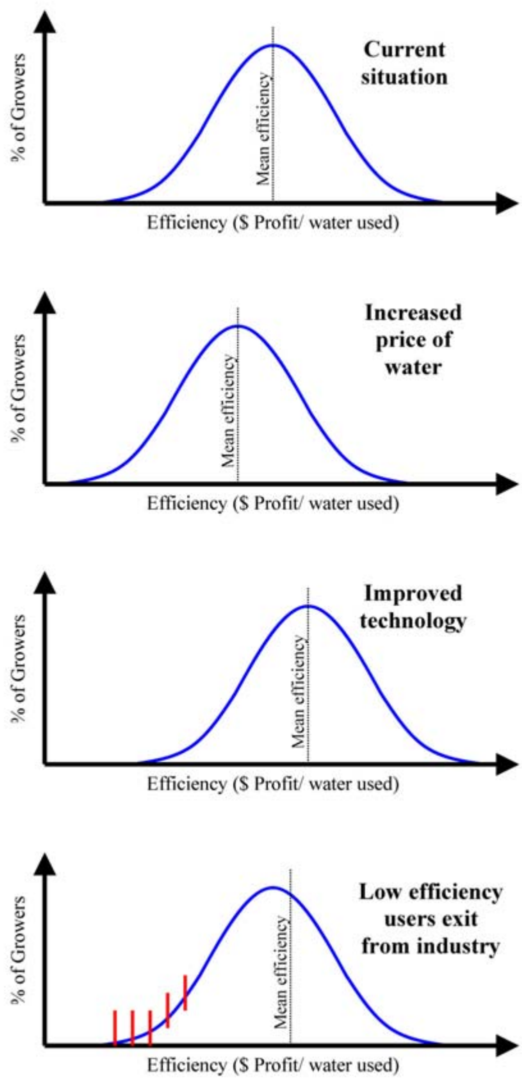
Water/industry sustainability

Across the olive industry there will be a range of business models, ranging from small operations with supplementary off-farm income, to medium scale and large scale full-time commercial growers. Likewise, different enterprises will vary in their production efficiency (defined as $profit/quantity water used), degree of mechanisation, economies of scale and profitability.

Water resources are likely to have been over-allocated to begin with, in the context of our variable climate. Therefore it is widely recognised that we should be encouraging producers and the horticultural industry to use water more efficiently. However, from a business perspective the emphasis should be on optimising profits from the available water, not just using less water.

From an industry perspective, it would be beneficial to:

- firstly, understand the range of production efficiencies ($profit/quantity water used) that are being achieved by growers across the industry; and
- secondly, undertake an economic analysis to determine the impacts of any strategies on the best (most efficient) producers.



When scarcities occur, to cut back water on an equal basis across all producers makes everyone inefficient (see diagram).

It is feared that ‘blunt’ market based instruments such as increasing the price of water will decrease profits for all producers and make the whole industry less sustainable. The greatest impacts of rising input costs may be felt by the key producers in the industry (i.e. large full-time growers who operate without any form of supplementary income).

Growers should be rewarded with incentives to move toward greater water-use and production efficiencies. This type of targeted approach (rewarding the most efficient producers) may provide the best chances of strengthening industry viability in the face of climate change.

A strategy for low efficiency growers, in the face of climate change challenges, may be to exit the industry.

Economic analyses typically show that profits are maximised when inputs (water, nutrients) are at optimum levels. Running an olive grove on low water levels and with minimal inputs will not be viable in the long-term.

We should not be growing any more olive groves than we have water available to irrigate them at profitable rates.

It could be argued that there are values in keeping a range of business models in the olive industry:

- In terms of economic viability and achieving NRM objectives (e.g. controlling weed, pest, disease risks) greater industry consolidation will lead to bigger operators who are more profitable and efficient.
- In terms of social objectives (e.g. maintaining rural communities), smaller family-owned operations may be desirable. And smaller farms with some off-farm income will assist with climate change induced financial challenges.

Role of government and industry

The climate change imperative has forced us to look at long-term (50–100 year) objectives that will represent a fundamental shift in the way we do things. Business operates on five-year plans, usually based on short-term economic goals. It is probably going to be up to government to help industry to shift towards the long-term objectives associated with climate change. Plans or solutions that are not politically or socially acceptable at the present time may be justified in order to match the long-term and imposing challenges of climate change.

Potential weed risk

In my view the issue of weed risk from abandoned groves has been overstated, as a solution (NRM Act 2004) to control abandoned groves already exists. This type of legislation to control weed risk from abandoned olives does not exist for other crops, which may also cause problems (e.g. abandoned vines can be a source of disease, such as downy mildew).

However, the temporary abandonment of groves is still an issue. This is more likely to be a problem where enterprises have off-farm supplementary income and could afford to temporarily abandon the grove.

Olives only pose a weed risk in areas where:

- olives cannot be harvested or controlled (e.g. due to inaccessible terrain)
- vectors are present (e.g. starlings, foxes)
- soil and moisture conditions are suitable.

Greater role in addressing climate change(?)

In my view, the potential opportunities for olives to help address climate change should be investigated further. Olives have a reasonable salinity tolerance and thousands of hectares of groves would represent a substantial carbon sink. From an industry point of view, it would be good if large scale plantings, supporting mechanised harvesting, could be established in areas where feral spread is not an issue (e.g. in marginal cropping land where groundwater is available).

EXPERT REVIEW (9) — OLIVECULTURE

Comments by: Jim Rowntree (Rowntree Management)

I agree with most of the conclusions if this is how the climate plays out in reality.

From the risk assessment survey, critical and potential issues include:
- water availability under reduced allocations, and particularly under drought conditions
- emerging soil salinity issues towards 2030
- tree damage and yield reductions due to defoliation, heat stress and sunburn
- climate change induced increases in production costs leading to the reduced financial viability of businesses.

My opinion differs in the area of pests and diseases in that I think the pest and diseases pressure is likely to be less in a drier environment as the orchards I know of in drier climates have few pests and diseases, certainly no more than wetter areas.

Many of these orchards are in the rainfall range indicated in the reports projections.

I also think that no matter what happens in regards to climate change, salinity and irrigation efficiency are of great importance.

EXPERT REVIEW (10) — OVERALL ADAPTATION PLANNING PROCESS

Comments by: Dr Douglas Bardsley (University of Queensland)

The key points raised during the workshops with key industry stakeholders seem valid and are clearly immediate concerns for stakeholders as they manage their seasonal activities. In just one recent example, the extended hot spell in summer-autumn 2008 has raised important issues with the timeliness of wine grape harvesting. There are however, further significant longer term implications for the wine and olive industries that will need to be examined in significantly greater depth (see for examples: Jones GV, White MA, Cooper OR & Storchmann K, 2005, 'Climate change and global wine quality,' in *Climatic Change* 73(33), pp. 319–343; and Rosenzweig C & Tubiello FN, 1997, 'Impacts of global climate change on Mediterranean agriculture: current methodologies and future directions,' in *Mitigation and Adaptation Strategies for Global Change*, 1(3), pp. 218–232).

The risk assessment framework appears to struggle to guide the required broader examination of industry needs and associated NRM over the longer term issues. For example, the multiple criteria associated with the 'Consequence descriptors' for risk assessment, would make it difficult for stakeholders to perceive of or articulate the level of future risk.

The presentation of more detail on the local industries themselves and some further referencing would assist future comparisons with other industries or the same sectors in different regions.

Clearly many assumptions have been made about the information presented to stakeholders on climate change and the outcomes to 2030 remain speculative and imprecise. More research needs to be undertaken to better understand the implications of projected climate change on local resources management systems. Yet, it is exactly because of the uncertain nature of future climate change that the work has justifiably focused on the importance of engagement and the development of future co-learning through strengthening partnerships. This is the importance of this work and as a consequence, a major recommendation would be that such risk assessments are seen only as the initial step in a longer process of reorganising industries to allow for both short-term and longer-term impacts of climate change.

GLOSSARY

Act (the) — In this document, refers to the *Natural Resources Management (SA) Act 2004,* which supercedes the *Water Resources (SA) Act 1997.*

Adaptation — Action in response to, or anticipation of, climate change to reduce or avoid adverse consequences or to take advantage of beneficial changes. Adaptation is usually distinct from actions to reduce greenhouse gas emissions.

Adaptive management — A systematic process for continually improving management policies and practices by learning from the outcomes of operational programs.

AGO — Australian Greenhouse Office.

AMLR — Adelaide and Mount Lofty Ranges.

AMLR NRM Board — Adelaide and Mount Lofty Ranges Natural Resources Management Board.

ASRIS — Australian Soil Resource Information System.

AWS — Automatic weather station.

Biodiversity — (1) The number and variety of organisms found within a specified geographic region. (2) The variability among living organisms on the earth, including the variability within and between species and within and between ecosystems.

Biological diversity — See 'biodiversity'.

BoM — Bureau of Meteorology, Australia.

Catchment — A catchment is that area of land determined by topographic features within which rainfall will contribute to runoff at a particular point.

Climate change — A change in climate, which is attributed directly or indirectly to human activity, which alters the composition of the global atmosphere, and is in addition to natural climate variability observed over comparable time periods.

Climate projection — A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models. Climate projections are distinguished from climate predictions by the more substantial degree of uncertainty in the underlying assumptions e.g. regarding how future technological and economic trends may affect emissions.

CO_2 — Carbon dioxide.

Community — All South Australians including institutions and organisations.

Council, the — City of Onkaparinga.

CPI — Consumer price index.

CSIRO — Commonwealth Scientific and Industrial Research Organisation, Australia.

DWLBC — Department of Water, Land and Biodiversity Conservation (Government of South Australia).

EC — Electrical conductivity; 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C; commonly used as a measure of water salinity as it is quicker and easier than measurement by TDS.

Erosion — Natural breakdown and movement of soil and rock by water, wind or ice. The process may be accelerated by human activities.

Evapotranspiration — The total loss of water as a result of transpiration from plants and evaporation from land, and surface water bodies

Extreme event — Weather conditions that are rare for a particular place and/or time such as an intense storm or heatwave.

FPOA — Fleurieu Peninsula Olive Association

GCM — Global climate model.

Greenhouse effect — The balance of incoming and outgoing solar radiation which regulates our climate. Changes to the composition of the atmosphere, such as the addition of carbon dioxide through human activities, have the potential to alter the radiation balance and to effect changes to the climate. Scientists suggest that changes would include global warming, a rise in sea level and shifts in rainfall patterns.

Greenhouse gas emissions — The release of greenhouse gases into the atmosphere. A **greenhouse gas** is an atmospheric gas that absorbs and emits infrared or heat radiation, giving rise to the greenhouse effect (e.g. carbon dioxide, methane, nitrous oxide, etc.).

Groundwater — Water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground.

GWRDC — Grape and Wine Research and Development Corporation.

Hydraulic conductivity (K) — A measure of the ease of flow through aquifer material: high K indicates low resistance, or high flow conditions; measured in metres per day.

IPCC — Intergovernmental Panel on Climate Change.

IPM — Integrated pest management.

Irrigation — Watering land by any means for the purpose of growing plants.

Leach — Removal of material in solution such as minerals, nutrients and salts through soil.

Mesoclimate — the climate of a small area of the earth's surface which may differ from the general climate of the district.

MLR — Mount Lofty Ranges.

Model — A conceptual or mathematical means of understanding elements of the real world that allows for predictions of outcomes given certain conditions. Examples include estimating storm run-off, assessing the impacts of dams or predicting ecological response to environmental change.

MVGWTA — McLaren Vale Grape Wine and Tourism Association.

MVPWA — McLaren Vale Prescribed Wells Area.

Natural resources — Soil, water resources, geological features and landscapes, native vegetation, native animals and other native organisms, ecosystems.

'No regrets' — A measure that has other net benefits (or at least no net costs) besides limiting greenhouse gas emissions or conserving or enhancing greenhouse gas sinks.

NRM — Natural resources management; all activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively.

OSA — Olives South Australia.

P&D — Pest and disease.

Percentile — A way of describing sets of data by ranking the dataset and establishing the value for each percentage of the total number of data records. The 90th percentile of the distribution is the value such that 90% of the observations fall at or below it.

PIRSA — Primary Industries and Resources South Australia (Government of South Australia).

PIS — Percentage of interchangeable sodium (Equivalent to ESP, exchangeable sodium percentage).

POAMA — Predictive Ocean Atmosphere Model for Australia, an extended seasonal forecast dynamic computer model under development by the BoM.

Population — (1) For the purposes of natural resources planning, the set of individuals of the same species that occurs within the natural resource of interest. (2) An aggregate of interbreeding individuals of a biological species within a specified location.

Precautionary principle — Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

Prescribed area, surface water — Part of the State declared to be a surface water prescribed area under the Act.

Prescribed well — A well declared to be a prescribed well under the Act.

Projection — See 'Climate projection'.

PWA — Prescribed wells area.

QLD DNRW — Queensland Department of Natural Resources and Water.

REM — Resource and Environmental Management, a consulting firm.

Resilience — The ability of a system to withstand and recover from stresses and disturbances.

Risk — A probalistic measure of the consequence of a threat acting on an asset, typically expressed as a product of likelihood and consequence. Risk can also be a measure of the probability of management actions not delivering the desired outputs and outcomes.

SA — South Australia.

SAEDP — Southern Adelaide Economic Development Plan.

SAICORP — South Australian Government Captive Insurance Corporation: the trading name for the Insurance Division of the South Australian Government Financing Authority (SAFA).

SARDI — South Australian Research and Development Institute, a division within PIRSA.

SAWIA — South Australian Wine Industry Association.

SA Water — South Australian Water Corporation (Government of South Australia).

SRES — Special Report on Emissions Scenarios, a report of the Intergovernmental Panel on Climate Change (IPCC).

Surface water — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir

Sustainability — The ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time

TDS — Total dissolved solids, a measure of water salinity.

Water allocation — (1) In respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence. (2) In respect of water taken pursuant to an authorisation under s.11 means the maximum quantity of water that can be taken and used pursuant to the authorisation

Watercourse — A river, creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; a lake through which water flows; a channel (but not a channel declared by regulation to be excluded from the this definition) into which the water of a watercourse has been diverted; and part of a watercourse

WBWC — Willunga Basin Water Company (which supplies reclaimed water from treated effluent).

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