NATIONAL PROGRAM FOR
Sustainable Irrigation

# Open Hydroponics: Risks and Opportunities

## Stage 1

## Final Report

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## Acknowledgements

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# 1.0 Abstract

Open Hydroponics (OH) is an innovative horticultural management program with over 2700ha currently being adopted in Australia and presents an opportunity for more sustainable production (economic and environmental). Conventional drip irrigation growers are also adopting selected Open Hydroponic principles, which use similar practices and carry the same possible benefits and environmental risks.

OH aims to increase productivity by continuously applying a balanced nutrient mixture (fertigation), limiting the root zone and maintaining the soil moisture near field capacity. The combination of these practices is claimed to provide a greater control and manipulation of nutrient and water uptake. Since very little scientific data on OH is published, the basis and environmental risks of these claims are unknown.

Private diverters have good access to a reliable water supply to conduct OH. Similarly, the adoption of advanced water ordering strategies will ensure a reasonably reliable water supply from a high number of pressurised pipe delivery systems and the majority of channel delivery systems to meet the needs of OH. However, this reliability is variable and highly dependant upon individual circumstances. On-farm water storage was identified as an important risk management strategy and may need to be implemented in some pressurised pipe delivery situations and a significant number of channel delivery situations. A poorly designed and constructed on-farm water storage supply system can have major negative environmental impacts.

A desktop water, nutrient and salt balance study identified that irrigation and nutrition management principles used by OH can be efficient. The level of efficiency was directly linked to the implementation of good management. Poor management significantly reduces efficiency and increases the risk of adverse environmental impacts. Management skill and associated training is a key factor to the success of OH.

A preliminary ecological risk assessment resulted in the identification of several major risks from irrigation to sensitive catchments. These include:

1) Leaching of nutrients into waterways, resulting in eutrophication and toxicity to aquatic organisms. Leaching could be exacerbated by increases in hydraulic loading through irrigation management practices or episodic rainfall events.
2) Increased levels of boron in the soil.
3) Increased salinity and sodicity of soils from salt accumulation, which may be less of a problem in sandy soils, but could be a serious issue in heavier soils.
4) The various compounds often associated with irrigation/horticulture such as pesticides and cleaning agents, whose identity and pathways remain unknown.

# 2.0 Background

Open Hydroponics (OH) is an intensive horticultural management program that is increasing in adoption. Over 2700ha of horticultural land is currently using OH and conventional drip irrigation growers are adopting selected OH practices.

The program is being extended to industry through the use of consultants. The program involves the use of innovative and intensive nutrition and irrigation management practices. The practices include the use of drip irrigation, the maintenance of soil moisture near to field capacity, specialised nutrient mixes to meet crop needs and a good level of irrigation management.

OH is still new to Australia and little is known about the program and its risks to the Australian environment. Stage 1 of the project aimed to conduct a desk-top scoping study of the risks and opportunities posed by OH.

# 3.0 Project Objectives

The objectives of Stage 1 are to:

1. Review the current knowledge and status of Open Hydroponics (OH) including grey and published literature;
2. Evaluate the impact of OH on water supply infrastructure;
3. Examine the potential impact of OH on the environment.

# 4.0 Methods

The methods and results of these objectives are summarised here, but more detailed information can be found in the following reports:

- Stage 1 – General Principles and Literature review report
- Stage 1 – Water, Salt and Nutrient Balance report
- Stage 1 - Ecological Risk Assessment Report
- Stage 1 – Water Supply Impact Assessment report
- Stage 1 – OH Workshop Report

## *4.1 Literature Review*

Only two published papers were sourced that dealt with OH. Due to this lack of published information, the literature review focused on the grey literature and non-refereed publications that assisted in explaining concepts of OH. The investigation included personal communication with OH consultants, growers using OH, farm visits, OH field day and seminar notes, commercial hydroponic books and manuals, and selected books on scientific principles of soil, water, and nutrient interactions. This review was written in an extension publication style to enable its use as an introductory document for the horticultural industry. A number of new concepts and theories of soil, water and nutrient interactions were presented in the document, although the review did not attempt to validate these theories. Validation of these theories requires a separate study to investigate and comment on their application to Australian conditions.

In December 2004 an OH workshop was conducted in Mildura. The first part of the workshop presented the major findings of stage one of the project. The second part of the workshop conducted a S.W.O.T. analysis and developed a number of recommended strategies for the development of a stage-two proposal for the project.

The literature review and workshop reports have been published as separate reports and available through Land and Water Australia.

### *4.2 Water Nutrient and Salt Balance*

A water balance model was employed to provide baseline data on crop water requirements and potential drainage from OH. Estimates of nutrient leakage were made from the combination of a daily nutrition program and the water balance model. The daily nutrition program was developed from the literature review and was subsequently reviewed by Open Hydroponic consultants. It was not possible to use current recommended Open Hydroponic fertiliser mixes due to commercial sensitivity.

The effects of (i) fixed and (ii) flexible irrigation on soil water content, drainage and nutrient leakage were investigated over a 12-month period from 1st January 2004 in a hypothetical OH citrus orchard in Sunraysia, by using a soil water balance model. These Open Hydroponic irrigation scenarios were examined for their impact on water supply infrastructure and ecological risk. Diurnal crop evapotranspiration was estimated from a radiation interception model and local meteorological data from the Sunraysia region. Fixed irrigation was operated during the daytime for a set duration that was adjusted each month. Irrigation duration was calculated to replace 120 % of average daily $ET_c$ for each month. Irrigation commenced when the midpoint of the required run time coincided with average maximum hourly rate of $ET_c$. Flexible irrigation was automatically operated for one-hour duration. Irrigation was triggered when hourly estimates of the wetted root-zone soil water content exceeded 10 % of RAW. This scenario is equivalent to scheduling irrigation based on hourly measurements of soil water content.

Potential nutrient leakage was estimated from the daily fertigation program. Accumulation of salt in the root-zone was estimated from salts in the water supply and fertiliser. The accumulation of salts and nitrate in the wetted zone and hence salt toxicity was examined for 40, 60, 80, 90 and 100 % nitrate uptake efficiencies. Leaching irrigations were simulated to maintain root-zone salinity below the threshold for yield decline.

### *4.3 Water Supply Infrastructure*

Four water supply authorities were selected to assess their ability to supply water to meet OH needs during peak demands. The water authorities selected were Lower Murray Urban and Rural Water Authority ; Western Murray Irrigation Limited, Dareton, New South Wales; Goulburn-Murray Water, Tatura, Victoria and Murrumbidgee Irrigation, Leeton, New South Wales. These areas represent a large cross section of the potential locations for the adoption of OH in a broad range of horticultural crops. A daily peak water requirement of 6.5 mm/day was assumed for this study.

Separate meetings were arranged with representatives from each of the water supply authorities. At the meetings they were asked a series of questions about their ability to meet OH water supply needs and any related issues.

## 4.4 Ecological Risk Assessment

Ecological Risk Assessment (ERA) is the process of **defining and assessing the risks to ecological resources** from hazards that result from human activity and determining the acceptability of those risks. The ERA process as described by Hart *et al*. (2004), was used to develop a method to begin identifying and quantifying the risks associated with OH in the Mallee catchment area. The components of a ERA are described in detail in the Stage 1 ERA report. Following is a short summary of the process.

During Stage 1 of the project, a workshop on Ecological Risk Assessment was held (October 20th 2004) to explore the benefits of ERA to OH decision-making (in conjunction with Professor Barry Hart, Monash University and Dr Terry Walshe, the University of Western Australia). Workshop participants included natural resource managers, irrigation scientists, Catchment Management Authority (CMA) and viticulture and citrus industry representatives, as well as members of the community.

Participants developed a generic conceptual diagram, in which an OH orchard was placed in a delicate Mallee catchment area. This diagram was used to facilitate the identification of 1) ecological values to be protected within affected catchments, and 2) direct and indirect effects of OH that have the potential to harm local ecosystems. A more comprehensive analysis of ecological values for the Mallee region was contained within the Mallee CMAs Regional Catchment Strategy.

Four key endpoints (or ecological values) were identified at the workshop: waterways, groundwater, flora and fauna, soil. Using the conceptual diagram and these endpoints, the workshop participants identified a number of hazards posed by OH to an ecological system, as well as factors contributing to the risk of those hazards impacting on the system.

The information generated at the workshop was used to develop a single conceptual model, which was further refined by the ERA project team (Faggian, Boland, Goodwin) with the assistance of Prof Barry Hart and Dr Carmel Pollino at the Water Studies Centre, Monash University. The Hazards were classified according to likelihood (rare through to certain) and consequence (insignificant through to catastrophic) and combined to produce a risk rating (Low, Moderate, High, Very High).

As part of the ERA process the project team decided to test the application of the National Guidelines risk assessment framework. The assessment of risk using the national guidelines framework was undertaken for all major hazards previously identified (i.e. nutrients, salts, hydraulic loading and unknowns), allowing the risks to be characterised and ranked.

# 5.0 Results and Discussion

The results and discussion deal with each of the three project objectives separately

## *5.1 Current Knowledge and Status of Open Hydroponics*

OH is a management practice originally developed by Professor Rafael Martinez (Spain) and recently introduced into Australian tree crop production. Over 2700 hectares of perennial horticulture is currently using Open Hydroponic management programs. Also, conventional drip irrigation orchardists are implementing some of the principles of OH into their irrigation and nutrition management by what is known as intensive fertigation. The combination of OH and conventional growers using intensive fertigation is having a significant impact on management practices and skill levels in perennial horticulture.

The aim of OH is to increase productivity by continuously applying a balanced nutrient mixture through the irrigation system, limiting the root zone by restricting the amount of drippers per tree, and maintaining the soil moisture near field capacity. The combination of these practices is claimed to provide a greater control and manipulation of nutrient uptake at specific physiological stages and improved water uptake.

Early indications are that growers are achieving a 20 % increase in productivity. Similar improvements in productivity are also being reported by conventional drip irrigation growers adopting intensive fertigation. Improvement in tree growth, especially for young trees, has been a common observation by growers using OH principles. The positive comments from growers already using Open Hydroponic principles is fuelling interest and an increasing adoption rate.

OH can increase orchard productivity but also increases management risks. Risks identified include the ability to maintain water supply to the orchard and nutrition and irrigation management skill levels. These risks will be further discussed in the Water Supply Infrastructure and Environmental impact section of this report.

A number of theories of water, soil and nutrient interactions have been claimed to explain the increases in productivity and water use efficiency of OH. These claims include:

1. Maintaining soil water content at field capacity improves water and nutrient uptake, and the movement of nutrients through the soil to the root surface.
2. An ionically balanced nutrient solution requires less energy for nutrient uptake.

The OH workshop conducted in December 2004 indicated that there was a significant knowledge gap in validating these claims. There was concern that despite rapid adoption, there is little public knowledge or scientific evaluation of the principles of OH and its environmental impact. Research that has been conducted on OH is predominantly confidential. Private consultants transfer a considerable amount of information on OH. The reliability and scientific foundation of this information is unknown.

OH can produce many benefits to the Australian horticulture industry. Early indications are that improvement in productivity is occurring. A core part of the OH management program is the use of best management practices and monitoring to ensure that the system is operating at peak performance. Monitoring includes soil moisture, weather conditions ($ET_o$), soil nutrient levels, crop nutrient status, water application and productivity. This is a major step forward in improving general growing practices.

### *5.2 Impact of Open Hydroponics on Water Supply Infrastructure*

The investigation highlighted that the majority (over 90%) of irrigated horticultural districts are able to supply water to meet the water needs of OH, however in some situations on-farm water storage maybe required.

Private diverters with pumps on a river generally have the lowest risk with all year-round access to water and would probably not require on-farm water storage.

Water supply authorities that manage pressurised pipe and channel delivery systems indicated that all growers, whether drip, spray or furrow irrigation, are treated equally when ordering water. No special considerations are given to drip irrigators requiring a daily water supply regardless of system efficiency. It is the grower's responsibility to manage their water supply needs and to ensure that they have access to water when they require it. Growers and channel attendants often develop suitable localised arrangements, ensuring all supply needs are met in a way that is satisfactory to all parties.

Pressurised pipe delivery systems have a very high capability of meeting OH water supply needs. OH require a supply flow rate of approximately 1.5L/sec/ha during peak demand (6.5mm/day, 0.5mm/h application rate, 12 h daily irrigation). Some recently built pressurised pipe delivery systems are designed to supply up to 1.4L/sec/hr at the farm gate for all customers. It is feasible that these systems would be able to supply water if 93% of the district was irrigated to OH requirements during daylight leaving 7% of capacity for irrigation of non OH crops at night. A small on-farm water storage might be a consideration in some circumstances. The need is highly variable and dependant upon the individual situation and its associated risk assessment.

Channel delivery systems are highly variable in their ability to supply water at peak demand periods. The ability to supply water varies considerably depending upon the distance from the main channel and associated laterals. If using an advanced ordering strategy, it is estimated that the majority of channel systems should be able to meet OH water supply demands. This is an approximate estimation and a more precise estimation would require a more detailed study on flow rates and peak supply demands on a number of channel systems.

There are a number of risks that can affect the probability of supply. This includes human error in miscalculating on advanced orders and where some channel systems shut down for up to two months during the winter period for maintenance. Winter shut down may not pose a major threat for deciduous perennials (i.e. stone fruit, vines etc) but will pose some problems for evergreen perennials (i.e. citrus, avocados etc).

This risk is highly variable depending upon the regularity of winter rainfall and on agronomic crop needs.

In consideration of the numerous risks involved with a channel water supply system, a correctly sited and constructed on-farm water storage would become a major consideration as a part of a risk management strategy. The need and size of an on-farm water storage will be highly variable depending upon individual circumstances. The correct size and construction is a critical factor both economically and environmentally. An undersized storage system will cause irrigation scheduling problems and a poorly constructed storage system will have considerable environmental impacts and valuable water losses. No enforceable standards exist on the correct construction of an on-farm water storage supply, however there are voluntary guidelines for the siting, construction and management of on-farm water storages available.

Water supply authorities have indicated that channel systems are gradually being converted to pressurised pipe delivery systems. This change is driven by the need to eliminate supply system losses, improvements in water supply efficiencies and the ability to meet the water supply needs of more efficient irrigation systems such as drip irrigation.

This study raised a number of issues including the siting of an OH enterprise, funding for the conversion of channel systems to pressurised delivery systems, the ability of growers to make special arrangements with water authorities to improve their guarantee of supply and the environmental risks and water losses associated with on-farm water storage.

The choice of location for an Open Hydroponics enterprise in relation to a reliable water supply is a crucial decision. A private diverter has the most reliable access whilst a pressurised pipe delivery system would have good reliability. A channel delivery system would in some cases be an unfavourable choice for an OH enterprise. However many channel systems are planning to convert to pressurised pipe and much of the risk could be reduced by the use of an appropriate on-farm water storage.

The opportunity exists to develop a water supply system that is more aligned with the demands of modern and innovative drip irrigation techniques such as OH. Growers using Open Hydroponic irrigation management principles require a daily water supply. Incorporating a daily prediction of water requirements into a more long term rostering system would greatly improve the guarantee of supply to drip irrigated enterprises and OH.

### *5.3 Potential Impact of Open Hydroponics on the Environment*

The water nutrient and salt balance study indicated that a flexible pulse irrigation system scheduled on a soil water deficit and operated to refill the root-zone with water had (by definition) no leakage. OH aims to achieve such a scenario. However, in practice this is difficult to implement. Sufficient soil moisture sensors need to be installed to account for the spatial variation (both in the root-zone of individual trees and across the paddock) in soil texture, wetting pattern and root distribution. Alternatively, estimates of tree water use could be used to trigger irrigations. Real time estimates of tree water use, calculated from an automated weather station, could be used to turn on irrigation when tree water use had reached a defined limit. A simpler approach is to schedule irrigation based on historical climatic data and incorporate a feedback for rainfall and soil water content that alarms a manager to temporarily turn off the irrigation.

The water balance study highlighted a considerable environmental risk of nutrient build up in the wetted zone (if nutrient uptake is less than 100 %) that is susceptible to leakage from rainfall events. Similarly, salinity levels will increase and even at 100 % uptake of nutrients, there is likely to be a salinity problem if there is no leaching. Good management skill is therefore a key factor to successfully maintaining soil moisture and salinity levels within optimal and acceptable levels. Good management skill includes irrigation scheduling to match water application rates to crop water use, the application of a suitable leaching fraction (~5-10 %) to wash salts out of the root zone and the application of nutrients, namely nitrogen, to match crop removal rates. Excessive application of nitrogen and other nutrients at defined periods could cause short term soil salinity issues and increase the risk of nitrate leaching from rainfall events. The model showed that at 90 % nutrient uptake efficiency the concentration of nitrate after 12-months reached 29 mg/l. This is equivalent to potential loss of 35 kg/ha of nitrate below the root-zone.

The simulation studies provided a valuable insight into identifying some possible issues with OH irrigation, nutrition and salinity management. Further in-field validation work is required to provide a more detailed assessment of current practices.

The use of soil, nutrient and crop monitoring are important tools for minimising water and nutrient imbalances that can negatively impact on productivity and the environment. Monitoring equipment includes soil moisture monitoring devices (i.e. soil capacitance probes, tensiometer), ceramic soil suction cups to monitor soil solution nutrient content and salinity within and below the root zone, and crop nutrient monitoring (i.e. leaf or fruit tissue tests). Other more technical monitoring tools such as a drainage lysimeter or drainage meter (i.e. full stop) could also be incorporated into the management program. A good level of management skill is required to use these tools effectively.

Management skill is an important factor to the success of OH. Considerable productivity losses from excessive nutrient application in an OH enterprise has already occurred. This could have been averted with grower training. More research and development of OH is required so that reliable and credible training information can be provided. This work should include in-field monitoring of commercial OH orchards and targeted research on key OH irrigation and nutrition management principles.

A preliminary ecological risk assessment resulted in the identification of major risks from irrigation to sensitive catchments:

1) Leaching of nutrients into waterways, resulting in eutrophication and toxicity to aquatic organisms. Leaching could be exacerbated by increases in hydraulic loading through irrigation management practices or episodic rainfall events.

2) Increased levels of boron in the soil.
3) Increased salinity and sodicity of soils from salt accumulation, which may be less of a problem in sandy soils, but could be a serious issue in heavier soils.
4) The various compounds often associated with irrigation/horticulture such as pesticides and cleaning agents, whose identity and pathways remain unknown.

The ERA was a useful process to prioritise risks of irrigation of orchards within the context of sensitive Mallee ecosystems and enabled the identification of key information gaps and data requirements. The ERA process provides a systematic means of characterising a potential environmental hazard (ie irrigation) using a process of scientific and community consultation. The development of conceptual models quickly identifies real pathways where a hazard might reach sensitive ecological systems, and in the process eliminates emotive or anecdotal risks.

The risk analysis step is a rigorous method that relies on quantitative data to assess the likelihood and impact of hazards. In the case of ERA, qualitative and subjective data will always form a component of the data set due to the complex nature of ecological systems. This is dealt with by explicitly stating the uncertainties and assumptions made in all steps of the ERA. The approach taken for the draft national guidelines on recycled water proved to be useful for the application of risk assessment for irrigated horticulture.

1. ERA can provide rigorous assessment at a catchment scale. The process should be undertaken by natural resource managers with the appropriate expertise rather than individual businesses.
2. The ERA process provided clear identification of information gaps when considering the effects of OH. These information gaps should be addressed through appropriate monitoring programs.
3. It is expected that OH will decrease the likelihood of environmental impacts but could potentially increase the consequence (i.e. something going wrong could have a significant impact). The resultant risk will depend upon the skills of the manager and the adoption of sustainable management practices. To assess the severity of these risks it would be possible to conduct scenarios analysing management practices and validating this through monitoring.
4. Given the significant impact of management skills on environmental impacts it is critical that a program defining sustainable management be developed that includes specific management practices and monitoring requirements.

# 6.0 Adoption and Technology Transfer

- Publications and Reports: see section 9.0 for a full list of publications. All publications have been provided to NPSI and CRCIF for appropriate posting on the web, providing public access to the information.
- Presentations: Poster and oral presented at the NPSI 2nd Annual Investors Forum in Tanunda South Australia on the 10th of October. An oral presentation outlining the OH project at the CRCIF conference, 20th September 2004.

- OH Workshop was conducted on the 3rd of December that invited members of industry. The workshop presented project findings and conducted a S.W.O.T. analysis
- Ecological Risk Management Workshop held on 20th October 2004 that discussed the different tools used in an Ecological risk assessment and their application in an OH context. Risk Management workshop notes distributed to project team

# 7.0 Commercial Potential

All tools developed for the project have been identified as public good and have no commercial potential. This included the fertigation model, Water, Salt and Nutrient model and Ecological Risk Assessment Conceptual models.

# 8.0 Conclusion – Risks & Opportunities

OH is a new and innovative management system that is currently being rapidly adopted by innovative and progressive farmers. However a number of significant risks have been identified which include knowledge gaps, management skill, on-farm water storage impacts on the environment.

## *8.1 Risks*

A considerable level of economic and environmental risk is associated with OH. Potential risks included:

- Investment in an OH system where the underlying principles have not been scientifically reviewed.
- Under trained and subsequently under skilled growers adopting OH.
- Inadequate water supply risk management strategies
- The use of poorly designed and constructed on-farm water storages.
- Nutrient leaching, salinity and sodicity

Theories on water, soil and nutrient interactions have been claimed to explain observed increases in productivity. Some of these theories challenge conventional principles but none of them appear to have been scientifically reviewed. There is concern that OH is being adopted without scientific evaluation of its principles and its environmental impact.

A desktop study indicated that irrigation and nutrition management practices used by OH could be efficient. However the level of efficiency is directly linked to the implementation of good management. Poor management will significantly reduce efficiency and increase the risk of adverse environmental impacts. There is also the risk that matching nutrients to the tree's capacity to take up and use those nutrients can lead to a reduction in fruit quality. Careful regulation of nutrient mixes is critical and this requires a high level of management skill to identify any problems at an early stage. It is recognised that the level of management skill amongst the horticultural community is variable. Management skill and associated training is a key factor to the success of OH.

The majority of horticultural areas are able to supply water to meet Open Hydroponic needs if risk management strategies are implemented. Risk management strategies included the initial location of OH enterprise to access reliable water supply, backup power supplies, advanced ordering of water and on-farm water storage. In most situations, advanced ordering of water will be adequate to manage water supply risk, however, higher risk situations will require on-farm water storage. It is difficult to estimate the need for on-farm water storage as it is dependent upon personal risk perceptions and siting of the enterprise in relation to its proximity to the main water supply (main channel or pump station). It is anticipated that on-farm water storage will be an important consideration for OH enterprises on both pressurised pipe and channel delivery systems located on non-ideal sites of water supply. Poorly designed and constructed on-farm water storages have a high risk of environmental damage through water leakage. Further work is required to assess on-farm water storage needs within the irrigation districts and develop guidelines for the correct construction of on-farm water storage.

## *8.2 Opportunities*

OH is a new and innovative management program that incorporates best management practices including the use of monitoring tools to ensure that the orchard is maintained at peak performance. These monitoring tools assist in maximising productivity. An opportunity therefore exists for OH to act as a catalyst to increase the adoption of more efficient and sustainable irrigation and nutrient management programs.

There is also the opportunity to increase knowledge of soil, water and nutrient interactions by research into the theories proposed for increases in productivity associated with OH. If these theories are scientifically validated they will significantly impact on all types of horticultural production systems.

An opportunity exists to support and assist the adoption of OH into the Australian horticulture industry by:

- The scientific validation of OH principles and an assessment of its environmental impacts.
- The provision of appropriate OH information and training, including topics such as economics, irrigation scheduling, fertigation, nutrition, monitoring tools, water supply risk assessment and on-farm water storage issues and considerations.

Stage one of this project conducted desktop studies of OH. To achieve the objectives stated above, further work is required that would include 1) monitoring commercial OH orchards, 2) targeted studies, lab and field research on specific OH issues and principles and 3) conducting a full ERA to assess the impact of more widespread adoption of OH. The proposed work will assist to promote a more economically and environmentally sustainable horticultural industry in Australia

Stage 2 of the project must focus on a comparison of the risks of OH and conventional irrigation, using the full ERA approach. In order to carry out such a comparison, processes need to be established that allow for the collection of quantitative data from field sites. Water, nutrient and chemical application rates would need to be collected to scientifically assess the risks. . In some instances, data collection will be impossible or impractical, in which case theoretical modelling will provide a reliable alternative.

# 9.0 Publications

- Stage 1 – General Principles and Literature review report
- Stage 1 – Water, Salt and Nutrient Balance report
- Stage 1 - Ecological Risk Assessment Report
- Stage 1 – Water Supply Impact Assessment report
- Stage 1 – OH Workshop Report
- Fact sheet – Stage 1 Project Overview - Open Hydroponics : Risks and Opportunities
- Fact Sheets - Introduction to Open Hydroponics
- Fact Sheet - Adopting Open Hydroponics – Factors to Consider
- Fact Sheet – Stage 1 Project Findings Overview - Open Hydroponics : Risks and Opportunities

# 10.0 Further Information

- Soil, Water and Salt Movement Associated with Precision Irrigation Systems - CRCIF
- NPSI Report of Water Use Efficiency