GOULBURN-MURRAY WATER

Evaporation Mitigation Project

Final Report to NPSI

Final

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Executive Summary

Goulburn-Murray Water is undertaking a research project (in partnership with the CRC Irrigation Futures and the National Program for Sustainable Irrigation) into the application of monolayers on irrigation channels in order to determine if this is a feasible water savings measure.

This report presents a summary of all work undertaken as a part of this project.

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1 Introduction

Water in open channels is subject to high evaporative losses. Some 70[1] gigalitres of water is lost annually through evaporation from channels in Northern Victoria. Research and field trials carried out by many workers over the last 50 years[2,3] has shown that applying small quantities of chemicals to form a monolayer, or surface film, on the water surface is a cost effective method of suppressing evaporation on bodies of water such as dams. The potential water saving from the use of such monolayers on G-MW irrigation channels is approximately 11GL/year.

Through the CRC Irrigation Futures (CRCIF), G-MW is collaborating with the University of Southern Queensland (USQ) to understand how this technology can be applied to channels.

This project expands the scope of previous commercial trials, which have focused on large water storages and farm dams, to consider evaporation suppression on irrigation channels. There are researchable questions regarding the efficacy, cost and application methodologies that relate specifically to evaporation suppression in channels.

This report summarises all work undertaken as part on this project into the various sections:

- Field Trial Site
- Static Trials
- Flowing Trials
- Laboratory Trials
- Application Equipment Investigations
- Economic Analysis
- Best Management Practice – Preliminary Guidelines

The full suite of G-MW reports related to this project are:

- G-MW Document # 2981714 Evaporation Mitigation Project: Application Equipment Report
- G-MW Document # 2990192 Evaporation Mitigation Project: Closed Channel Trials
- G-MW Document # 3022588 Evaporation Mitigation Project: Best Management Practice – Research Bulletin
- G-MW Document # 3025919 Evaporation Mitigation Project: Closed & Flowing Channel Trials
- G-MW Document # 3030313 Evaporation Mitigation Project: Economic Assessment

[1] G-MW Document # 2828686 Baseline Year Water Balance - Draft
[2] La Mer, V. K. (Ed.). 1962. *Retardation of evaporation by monolayers: transport processes*. New York and London, academic Press.
[3] Barnes, G. T. *The potential for monolayers to reduce the evaporation of water from large water storages*. Agricultural Water Management 95 (2008) 339-353

2 Results & Discussion

2.1 Field Trial Site

The test site chosen for the G-MW trials was the second last pool of the East Goulburn 30 Channel in the Shepparton Irrigation District (Figure 2.1)

Figure 2.1 Location of trial site within Irrigation Region

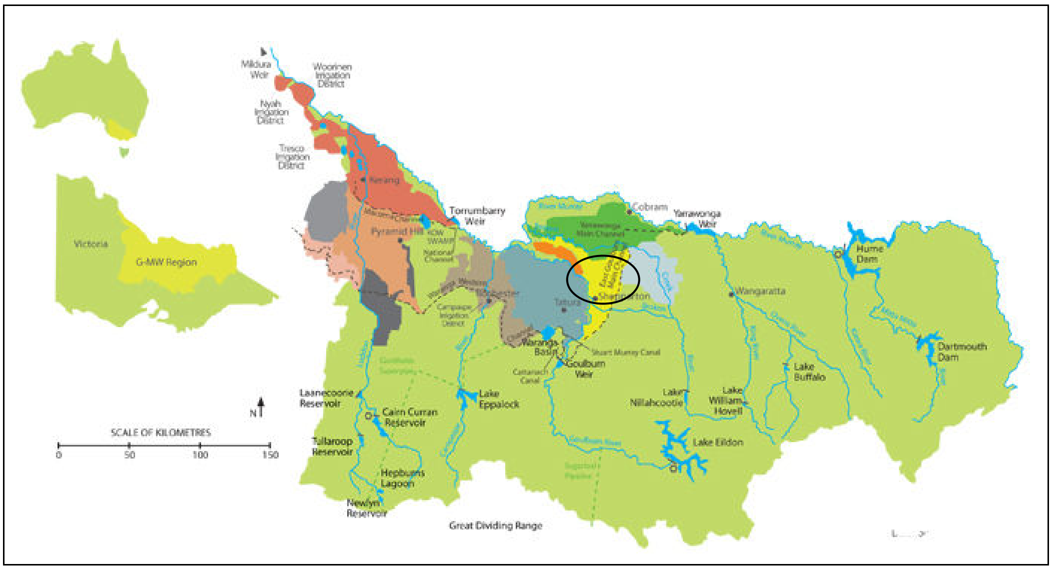
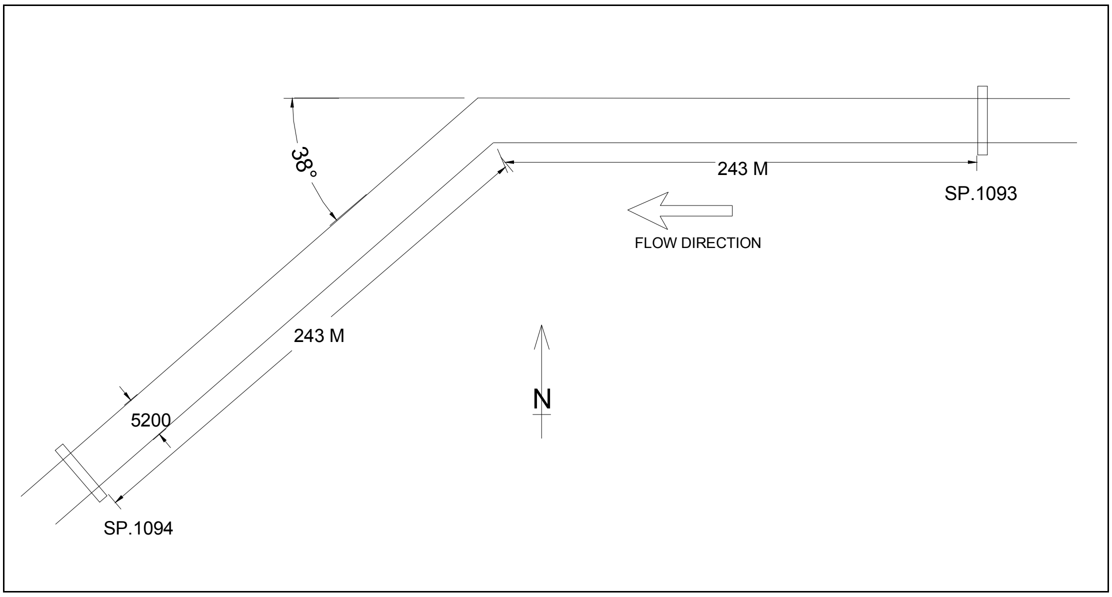


Figure 2.2 shows a schematic of the test channel pool. The pool is approximately 500m long, 5.2m wide and up to 600mm deep and is bounded by regulators SP.1093 and SP.1094 .

Figure 2.2 Schematic of test-channel pool



A number of different instruments were used to measure water depth, water temperature, wind speed, wind direction and rain. Water depth was measured at different locations in order to estimate the channel "wedge effect". Channel wedge can be due to either water flow or due to wind blowing along the channel pool and pushing the water to one end of the pool, and can create variation in water level measurements which is not due to water losses.

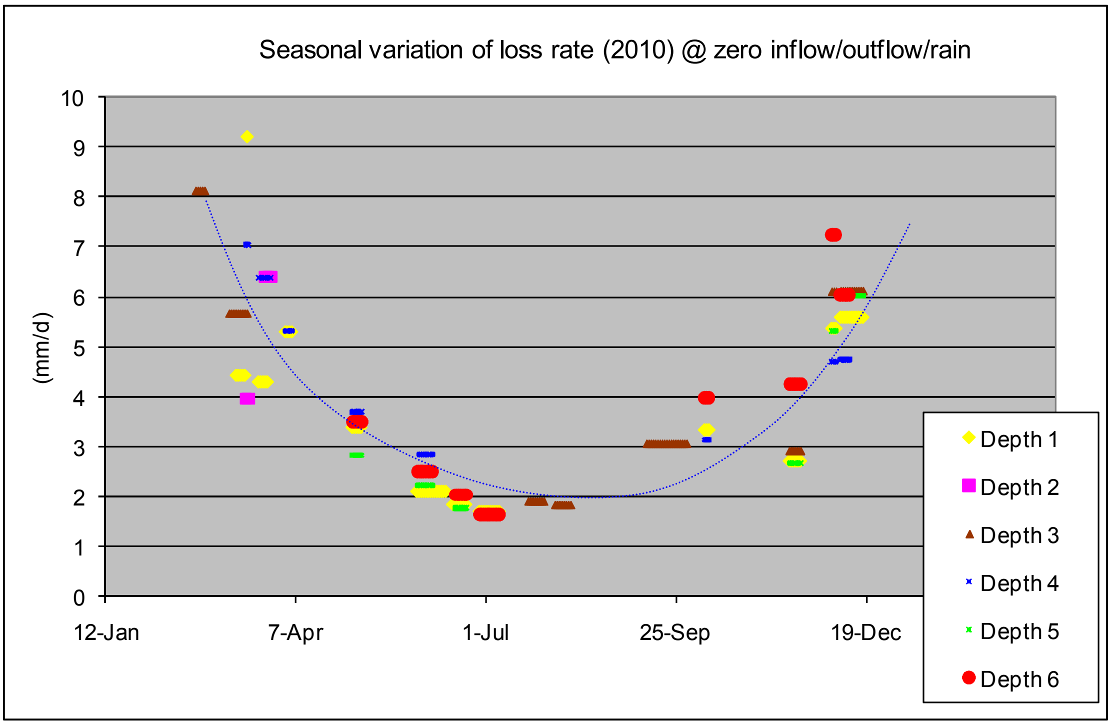
2.1.1 Calculating Base Seepage & Leakage

Before the effect of any treatment could be evaluated, it was necessary to establish the baseline loss rate of the test channel which consists of seepage and leakage.

For ranges of data for which there was no rain, and no inflow or outflow, depth vs time was plotted and the gradient of each linear trendline was obtained. The trendline represents the rate of loss of water from all causes: evaporation, seepage & leakage, and is given in units of mm/day.

Loss rates plotted against time (Figure 2.3) show a trend corresponding to the expected seasonal variation, i.e. lower losses in Winter than Summer. The minimum loss rate observed (June to mid August) was less than 2 mm/day. During the same period, the evaporation rate (Bureau of Meteorology data) varied between 2-3 mm/day. From this it is concluded that evaporation accounts for the whole of the observed loss rate of the test pool therefore seepage and leakage is zero. This is consistent with the heavy, impervious soil in the area of the test pool.

Figure 2.3 Loss Rate of Test Pool – No Monolayer



2.2 Static Trials

Static trials were undertaken to determine the effectiveness of monolayers on suppressing channel evaporation without having to account for channel flow (which can potentially have an error in measurement greater than the evaporation). The monolayer materials used were WaterSavr™, the G-MW emulsions of cetyl and stearyl alcohols and ES300.

The percentage savings in evaporation is given by the equation:

$$\%\ \text{savings} = \frac{\text{loss rate without monolayer} - \text{loss rate with monolayer}}{\text{loss rate without monolayer}} \tag{2.1}$$

Where the loss rate is the gradient of the graph of water depth vs time. The loss rate with monolayer is the loss rate during the test period. The loss rate without monolayer is obtained from reviewing the change in depth just prior to application of the monolayer and comparing to BOM data during the test period.

Savings of between 10 and 30% seem possible but need confirming because G-MW has been unable to show definite and consistent water savings from static tests.

2.3 Flowing Trials

Two flowing tests were conducted to test the ability of the CRC Polymers monolayer, ES300, to withstand turbulence created by regulating structures and to determine whether the monolayer was capable of reforming and attaining pressure.

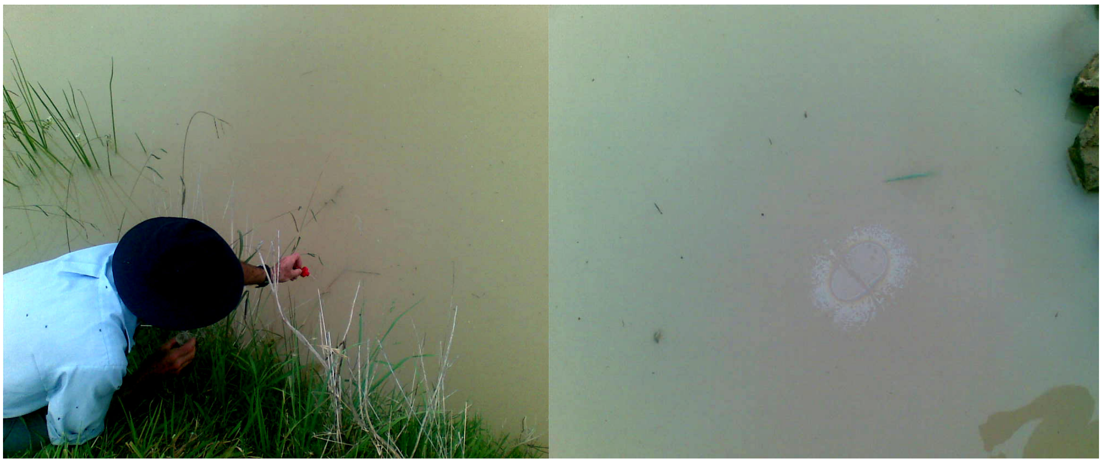
The tests involved pumping emulsion into the segment of channel upstream of a regulator while the channel flow was approximately 20 ML/day. The emulsion flowed over the regulator and indicator oils were used to test the surface pressure at regular intervals downstream.

Within both tests, coverage of the pool was achieved and waves dampened (refer to Figure 2.4). The indicator oils demonstrated that the layer was compressed to > 30 mN/m except for a 100 m stretch directly downstream of the regulator (refer to Figure 2.5).

The tests indicate that the monolayer material ES300 is capable of passing through a regulating structure and reforming downstream. They also highlight that it takes time for the product to attain adequate pressure to retard evaporation.

Figure 2.4 Wave damping due to monolayer application

Figure 2.5 Testing for monolayer presence using indicator oils



The rainbow dispersion in the bottom photo indicates that monolayer is not present or has not achieved the required pressure of the indicator oil. If it had achieved pressure, the indicator oil would not disperse and only a very small "bubble" would be visible.

2.4 Laboratory Trials

Various laboratory trials were undertaken by G-MW including testing the effectiveness of the various products within a laboratory situation. The most important of the observations from the G-MW laboratory work is the potential the monolayer products may be able to withstand turbulence caused by channel regulating structures:

2.4.1 Watersavr Turbulance Resiliance

Goulburn Murray Water undertook laboratory testing of WaterSavr™ (cetyl and stearyl alcohols combined with lime). Preliminary results indicate that shaking, to emulate the turbulence of going over a regulator structure, **does not** inhibit its ability to reduce evaporation. Figure 2.6 shows the loss rate of water before and after the monolayer material is added. Red points and blue points are duplicates. The gradient of both sets of results has reduced following addition of WaterSavr™ indicating reduction in the loss rate. Figure 2.7 gives the loss rate with shaken monolayer material. Red points and blue points are duplicates. The loss rate, given by the gradient, in both instances is less that the loss rate given in Figure 2.6 before monolayer material was added, indicating that the shaken monolayer material still has the ability to reduce evaporation.

Figure 2.6 WaterSavr™ laboratory tests conducted by G-MW (no shaking)

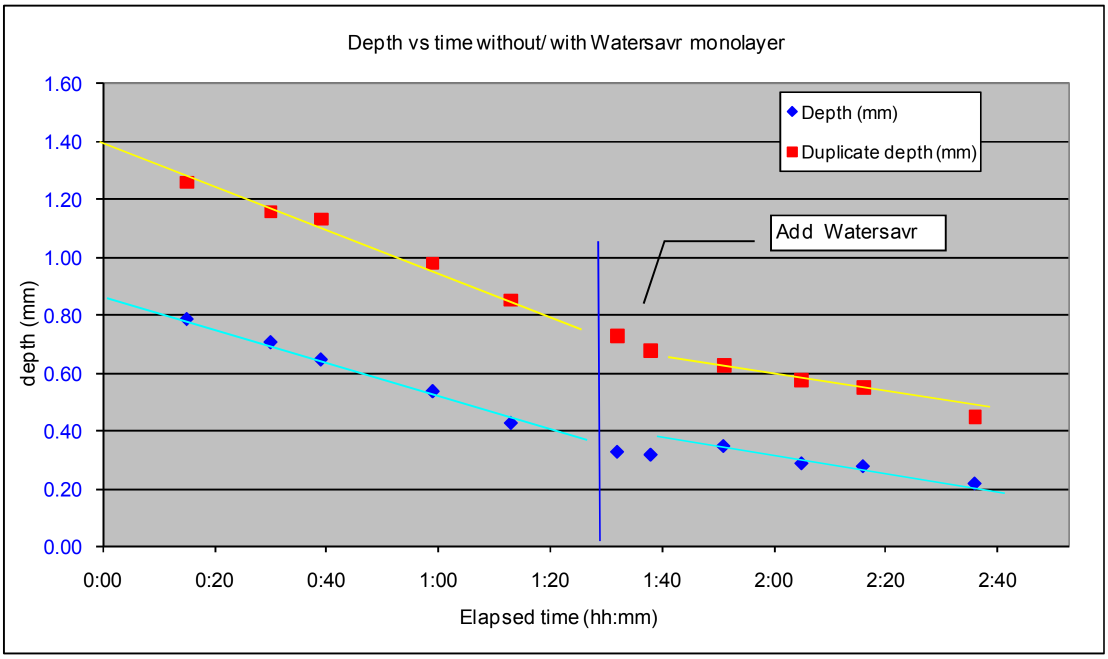
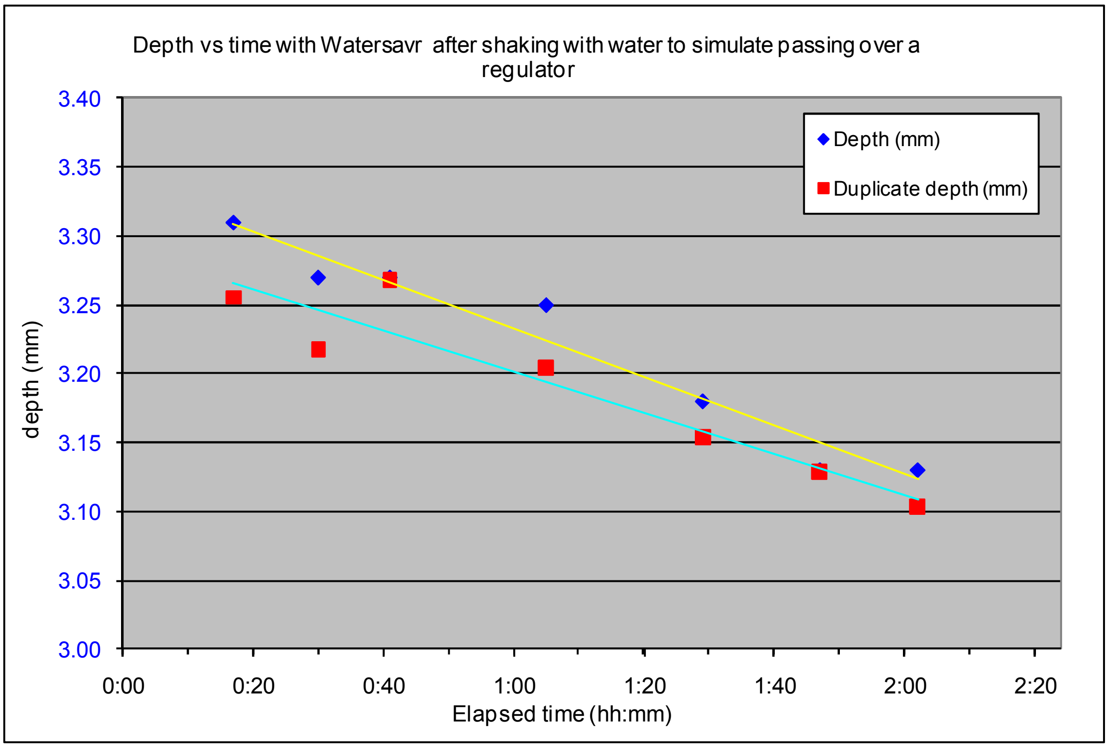


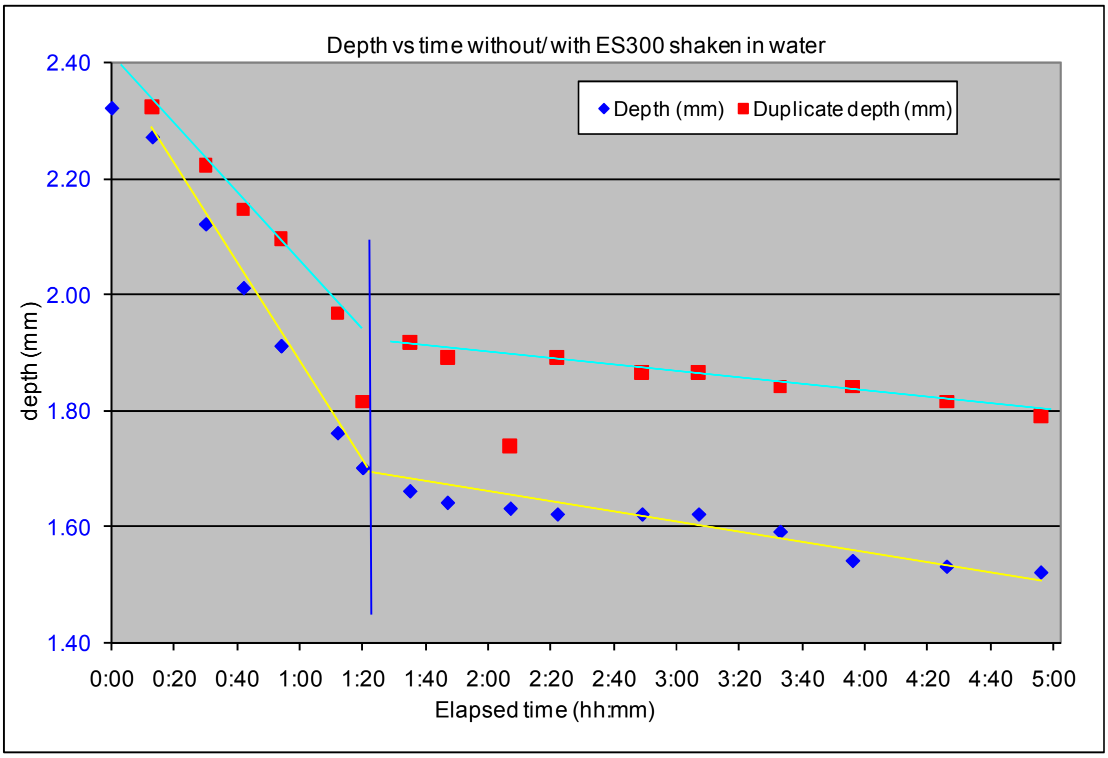
Figure 2.7 WaterSavr™ laboratory tests conducted by G-MW (shaken)



The result of this shaking test for WaterSavr™ which indicates continued evaporative resistance following shaking, conflicts with current knowledge of the resilience of WaterSavr™. Further testing is required to determine the validity of the results.

Tests have been undertaken by G-MW into the evaporative resistance of ES300. Following shaking to emulate the turbulence of going over a regulator structure, the efficiency appears to be 80 - 90% (in comparison to the loss rate of the unshaken ES300 which was 60 – 70%). This indicates that the monolayer has sufficient stability to withstand turbulence in the field. This will greatly improve the cost effectiveness of the product as it will not need to be reapplied at every regulating structure. Figure 2.8 shows the loss rate of water before and after the shaken monolayer material is added. Red points and blue points are duplicates. The loss rate, given by the gradient, has reduced following the application of shaken monolayer.

Figure 2.8 ES300 laboratory tests conducted by G-MW (shaken)



This preliminary testing indicates that ES300 may be more resilient and capable of passing regulating structures, however further testing should be conducted to substantiate this result.

2.5 Application Equipment Investigations

Application equipment required to apply evaporation suppressant monolayers to a water surface (dam, lake or channel) is dependent on the formulation of the monolayer itself.

Monolayers may be different formulations as detailed below:

- Liquid / Emulsion

  A liquid formulation is called an emulsion and consists of chemical monolayer material combined with another agent such as an organic solvent or water with an emulsifying agent. Organic solvents are undesirable when the product is to be applied on a large scale because of pollution, toxicity and cost.

  Aquatain is a liquid formulation which consists of a mixture of polydimethylsiloxane (a liquid silicone polymer) and a surfactant (detergent).

  E100 is being developed by the CRC Polymers and is currently undergoing trials and soon to be released commercially. It is a solid material but available as an emulsion or solution in an organic solvent.

  Products investigated by G-MW were in an emulsion form.

- Solid

A solid formulation of a chemical monolayer may or may not include added agents to enhance spreading properties or provide bulking, and can be in various forms including: solid blocks, flakes and powdered. Each of these forms potentially requires a different means of applying.

Watersavr is a powdered formulation and consists of a mixture of cetyl alcohol (C16H33OH), stearyl alcohol (C18H37OH) and hydrated lime (Ca(OH)2). The two alcohols make up approx. 10% of the mixture, with the rest being lime.

- Slurry

  A slurry is a suspension of the powdered substance in water. Some means of providing continuous mixing is required to prevent the solid from settling to the bottom of the container.

2.5.1 Application Equipment Investigations

Monolayer application equipment generally consists of a storage compartment for the product and a pump to dispense the product. Various forms of “programming” or automating the application of the monolayer exist.

G-MW reviewed the available application equipment for use in the field trials:

- Commercial applicators are available for both Aquatain and Watersavr, however these were not investigated or trialed by G-MW.
- The USQ application equipment has not been trialled by G-MW because the scale of our trials so far has not required automatic control.
- The Acrolien Dosing Unit has not been trialled for the application of chemical monolayers to irrigation channels because it was too expensive and difficult to handle:
- Goulburn-Murray Water utilised a perilstatic pump for the field trials which is detailed further in the following section.

2.5.2 Field Trial Application Equipment

Goulburn-Murray Water used a peristaltic pump to deliver emulsified cetyl and/or stearyl alcohol to the test channel. The pump was powered by 12V lead-acid batteries. Two speeds were available: selected by switching the batteries to provide 12V (low speed) or 24V (high speed). The corresponding delivery rates were 2.4 L/min or 5.0 L/min.

Where finer control of delivery rate was required and this was achieved by plumbing changes whereby some of the output was diverted back to the storage tank.

Figure 2.9 – Peristaltic pump installation on an irrigation channel by G-MW

The benefits of this application method are:

- Relatively inexpensive
- Simple and reliable
- Accurate delivery

Potential enhancements and recommendations:

- remote control or automation

2.5.3 Automation of Application Equipment

If undertaking monolayer application on a larger scale it would be desirable to incorporate a number of automatic features to correspond with the output of the Decision Support System model that decides the optimal time to apply monolayer.

There is the potential to tap into existing knowledge of control systems currently used for herbicide delivery.

2.6 Economic Assessment

2.6.1 Potential Costs associated with Water Savings

Table 2.1 details the cost per megalitre of water savings of systems addressing evaporation losses from dams as reported in the literature (for those systems where the cost and efficiency data is available). Note: only capital costs have been allowed for, because minimal information is available on the maintenance costs of the different techniques.

Table 2.1 Dam evaporation mitigation systems

Method	Potential evaporation savings	Installation Cost / m²	Cost / ML saved (NPV @ 6% over 30 years – capital only)	Product Life
Floating Covers				
E-VapCap	90%	$7[4]	$390	12 years[5]
REVOC	95%	$30[3]	$1,060	30 years[3]
Defined Sump	95%	$30[2]	$1,110	25 years[2]
Evap-Mat	90%	$3.50[2]	$130	30 years [2]
Fabtech	95%	$7[2] (excludes earthworks)	$340	15 years[2]
Floating Objects				
AquaCaps	85%	$17[3]	$750	20 years
Agfloats	80%	$10[6]	$440	25 years[4]
Raftex	95%	~$4.50[2]	$470	5 years[2]
HexDome TM	90%	~$6.50[2]	$260	25 years[2]
QUIT Evap Cover	87.5%	$7[3]	$490	~9 years[3]
Other Methods				
Shade cloth	70%	$7 - $10[7]	$410	30 years[8]
Chemical monolayer	5% - 30%	$0.00 - $0.38[2]	$130 - $1200[5]	

2.6.2 Decision Support System Modelling

A decision support system (DSS) has been developed to predict the optimum times, environmental conditions and locations for G-MW to apply monolayers to irrigation channels. The DSS ustilised the results of field work and modelling of the G-MW channel network.

[4] NCEA Evaporation Control n.d., *Product Review,* NCEA Evaporation Control, University of Southern Queensland, Toowoomba, Qld, viewed 6 October 2010, <http://evaporationcontrol.ncea.biz/Downloads/Product%20Review.pdf>

[5] Craig, I.P 2008, *Loss of storage water through evaporation with particular reference to arid and semi-arid zone pastoralism in Australia*, DKCRC Working Paper 19, The WaterSmart™ Literature Reviews, Desert Knowledge CRC, Alice Springs

[6] Reclaim Industries Ltd n.d., *Agfloat,* Reclaim Industries Ltd, Hallam, Vic, viewed 5 October 2009, <http://www.reclaim.com.au/index.php/products/agfloat/>

[7] Craig, I, Green, A, Scobie, M and Schmidt, E 2005, *Controlling Evaporation Loss from Water Storages,* NCEA publication, University of Southern Queensland, Toowoomba, Qld

[8] National Program for Sustainable Irrigation 2005, Controlling evaporation losses from farm dams, Land & Water Australia, Australia, viewed 5 October 2009, <http://lwa.gov.au/files/products/national-program-sustainable-irrigation/pf050873/pf050873.pdf>

The decision support system provides an estimate of $/ML of water saved (by extrapolating the mm/day results to “average” pool dimensions) when applying monolayers to irrigation channels under a given set of input conditions.

Currently only product costs are included within the DSS. There is not enough information available at this point to accurately estimate the capital and maintenance costs associated with monolayers, however it is expected that the product cost will form the bulk of the cost.

2.6.2.1 Decision Support System – Flow Chart

The following flow charts detail the channel characterisation process (which sits behind the DSS) and the DSS process.

Figure 2.10 – Channel Characterisation

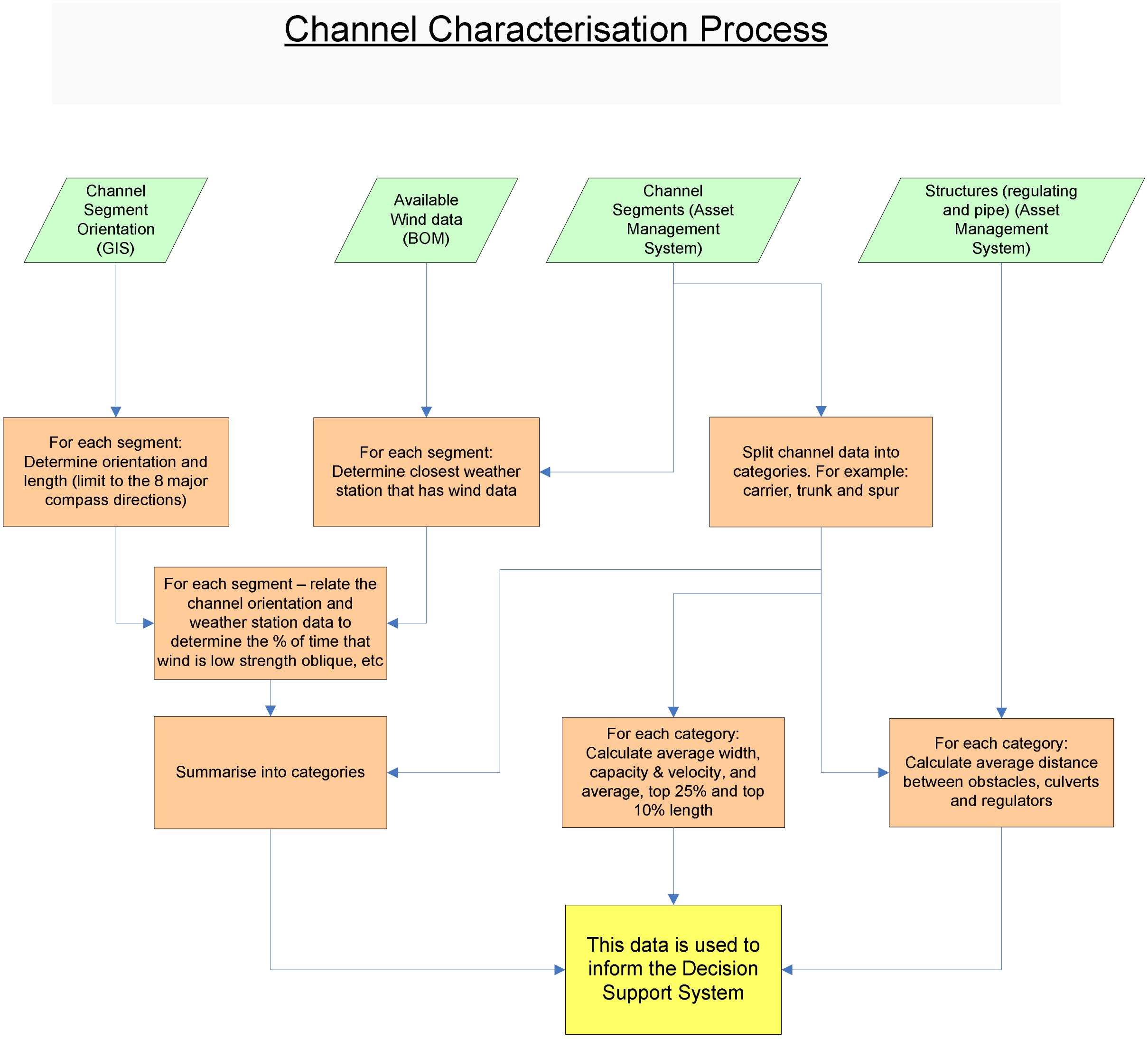
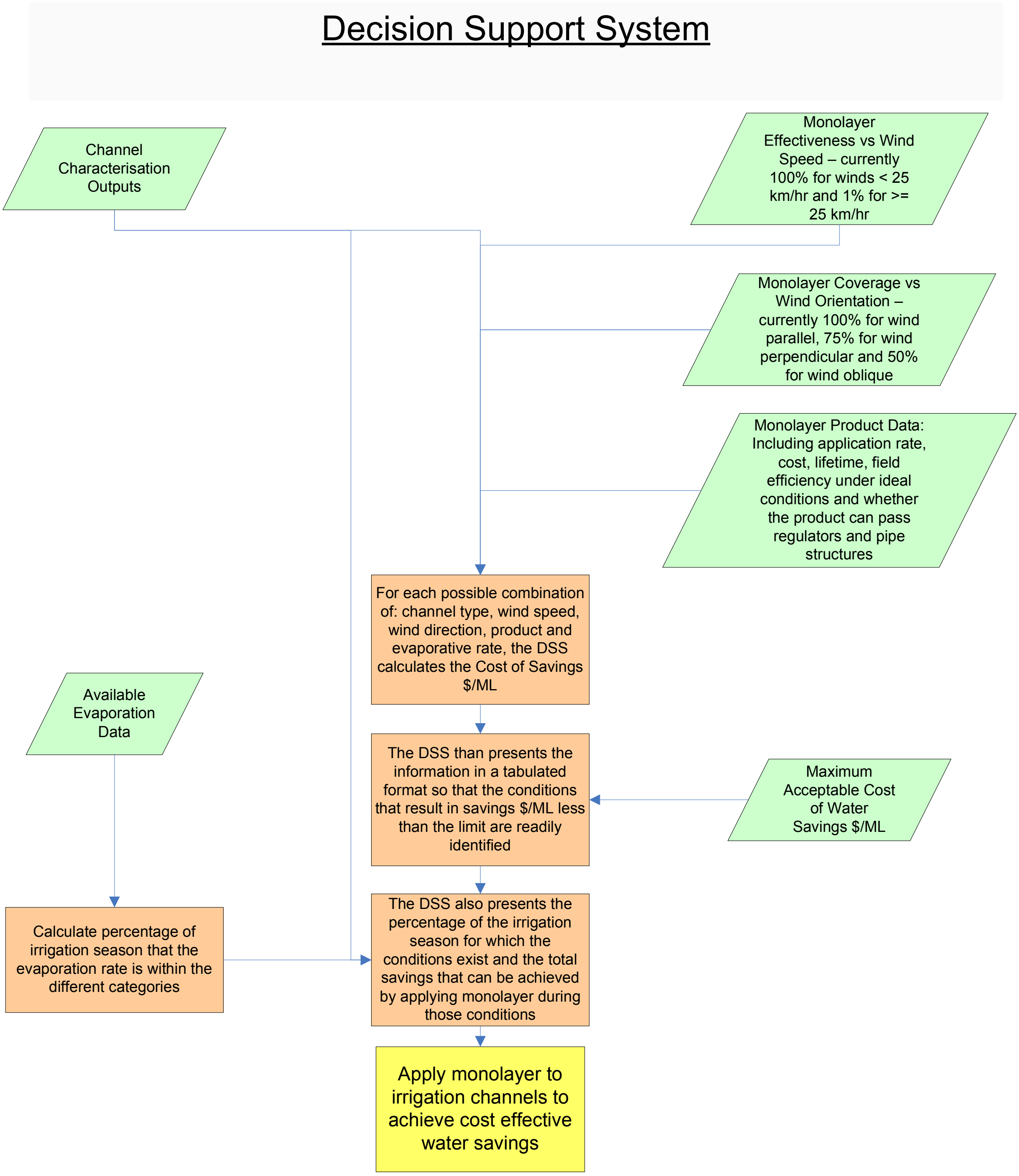


Figure 2.11 – Decision Support System



2.6.3 Summary of Results

A summary of the results of the DSS (based on the modelling of the G-MW channel network, and the field and laboratory trials undertaken by G-MW) is presented in Figure 2.12 to Figure 2.23.

Figure 2.12 shows the cost per megalitre of savings achieved by different monolayers applied to average carrier channels within the GMID.

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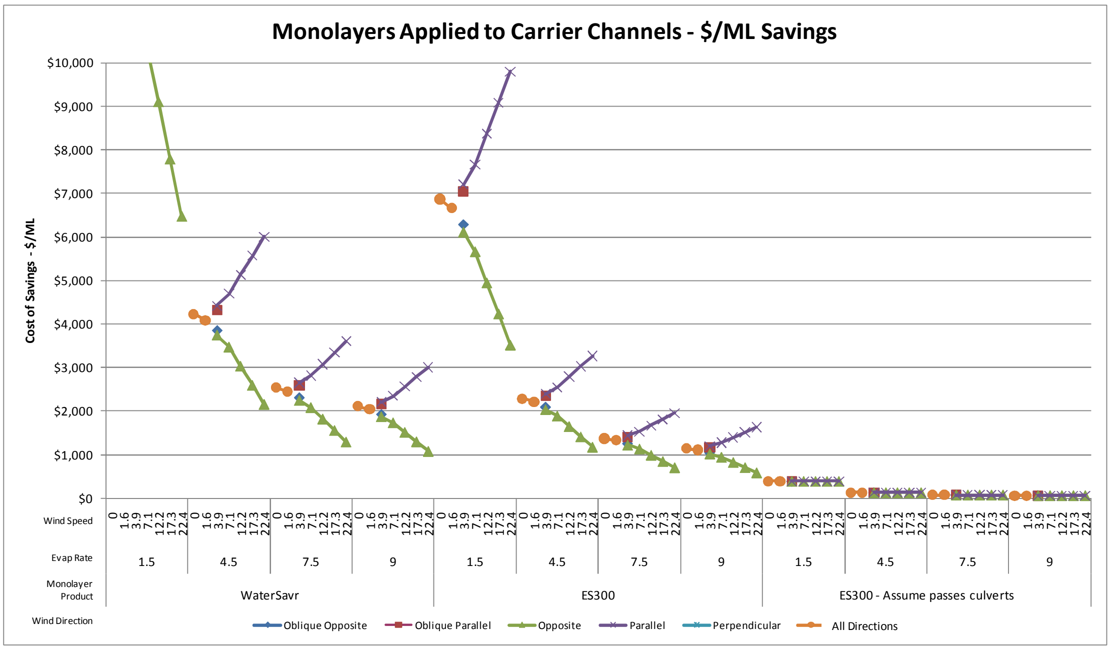
Figure 2.12 Cost per ML savings – Carrier Channels



[1] At the lower wind speeds, the wind direction has minimal impact

Figure 2.13 shows the cost per megalitre of savings achieved by different monolayers applied to average trunk channels within the GMID.

Figure 2.13 Cost per ML savings – Trunk Channels

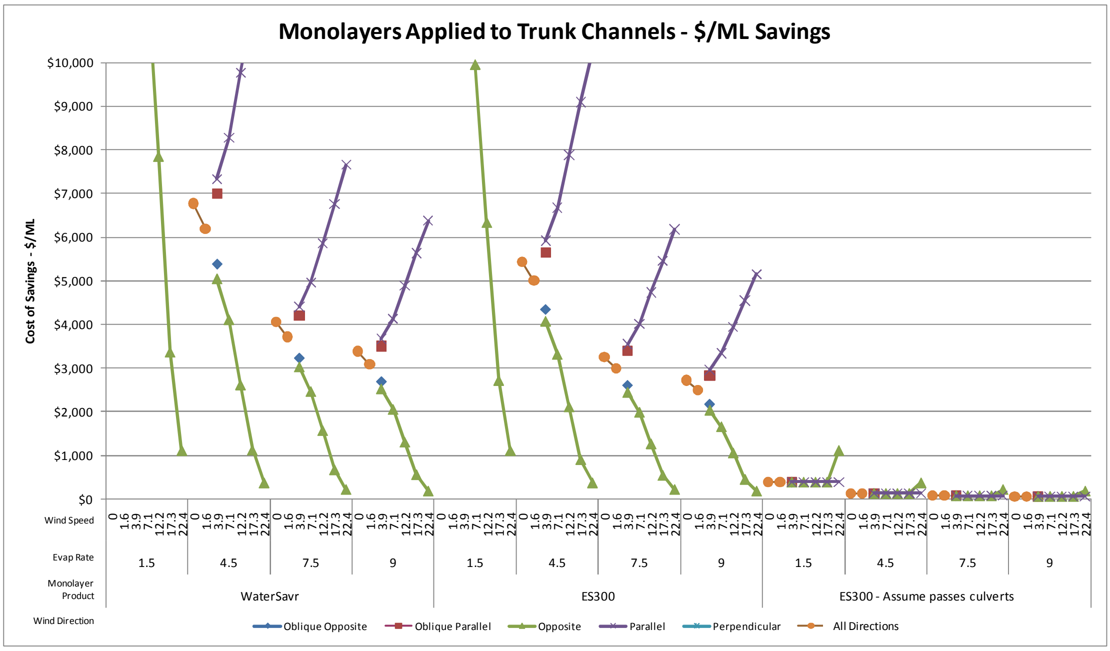


Figure 2.14 shows the cost per megalitre of savings achieved by different monolayers applied to average spur channels within the GMID.

Figure 2.14 Cost per ML savings – Spur Channels

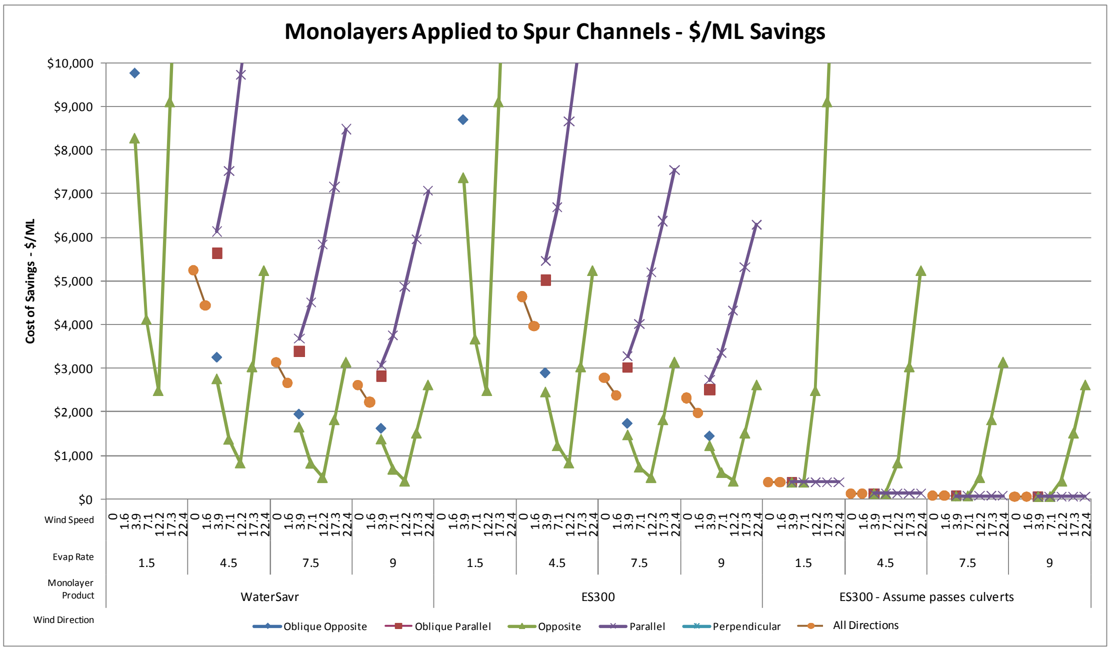
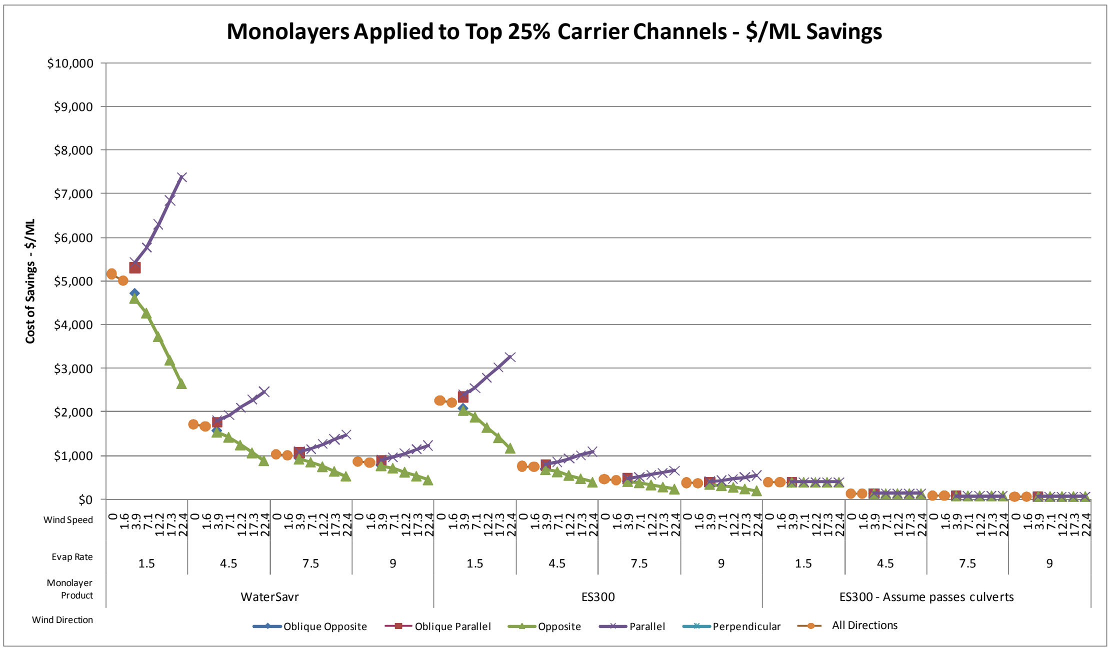


Figure 2.15 shows the cost per megalitre of savings achieved by different monolayers applied to the 25% longest carrier channels within the GMID.

Figure 2.15 Cost per ML savings – Top 25% Carrier Channels



[1] Top 25% of carrier channels means the 25% longest carrier channels

Figure 2.16 shows the cost per megalitre of savings achieved by different monolayers applied to the 25% longest trunk channels within the GMID.

Figure 2.16 Cost per ML savings – Top 25% Trunk Channels

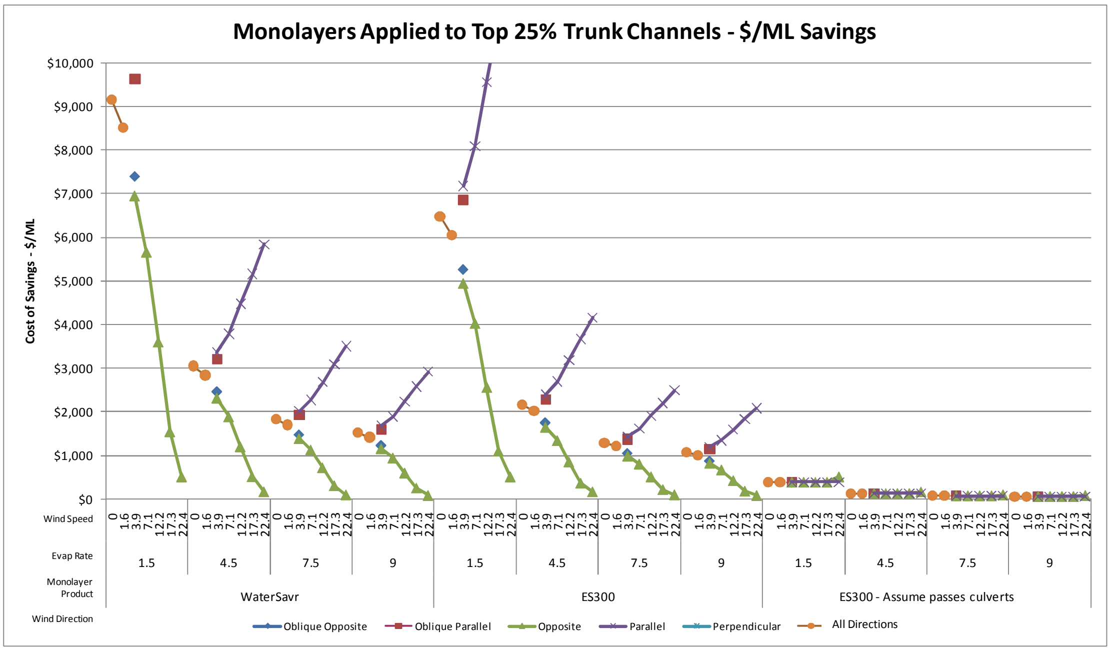


Figure 2.17 shows the cost per megalitre of savings achieved by different monolayers applied to the 25% longest spur channels within the GMID.

Figure 2.17 Cost per ML savings – Top 25% Spur Channels

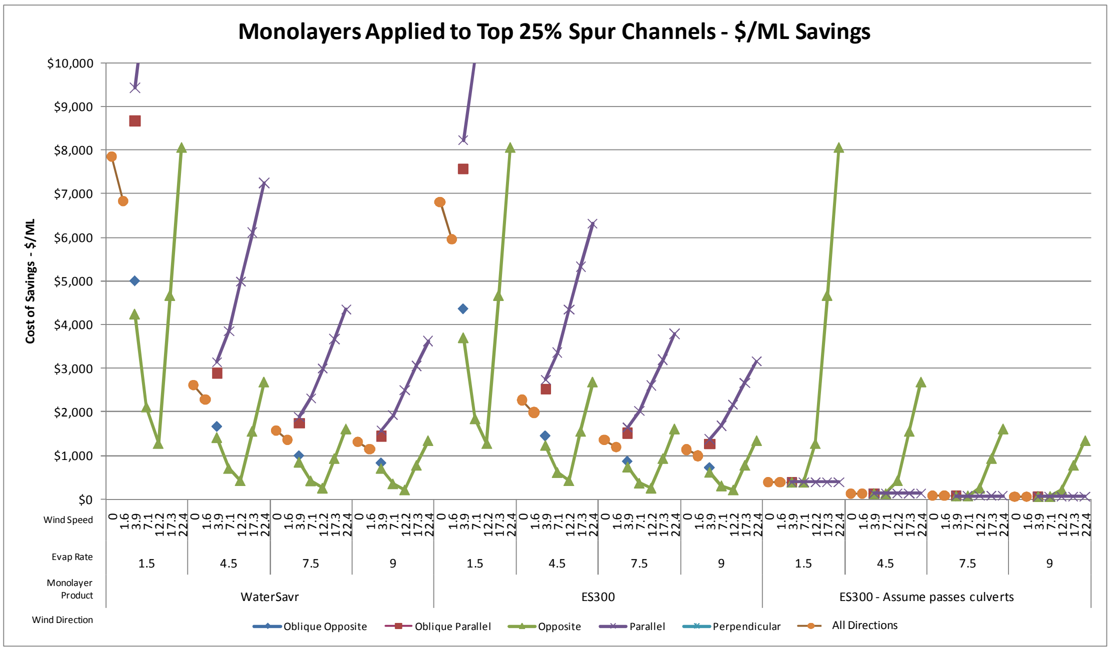
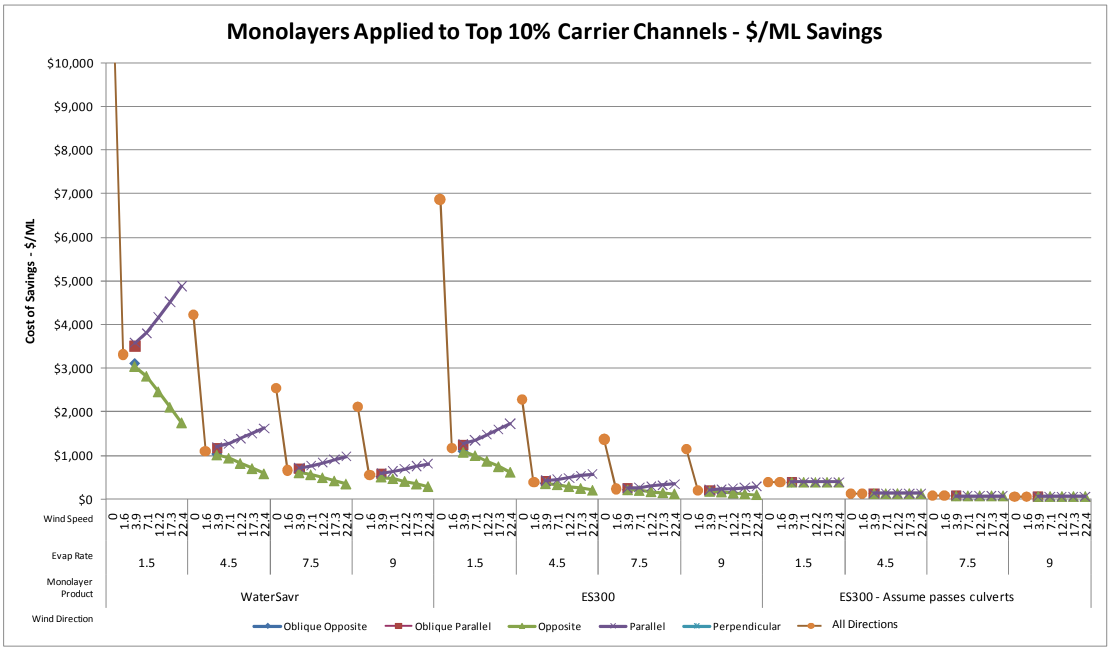


Figure 2.18 shows the cost per megalitre of savings achieved by different monolayers applied to the 10% longest carrier channels within the GMID.

Figure 2.18 Cost per ML savings – Top 10% Carrier Channels



[1] Top 10% of carrier channels means the 10% longest carrier channels

Figure 2.19 shows the cost per megalitre of savings achieved by different monolayers applied to the 10% longest trunk channels within the GMID.

Figure 2.19 Cost per ML savings – Top 10% Trunk Channels

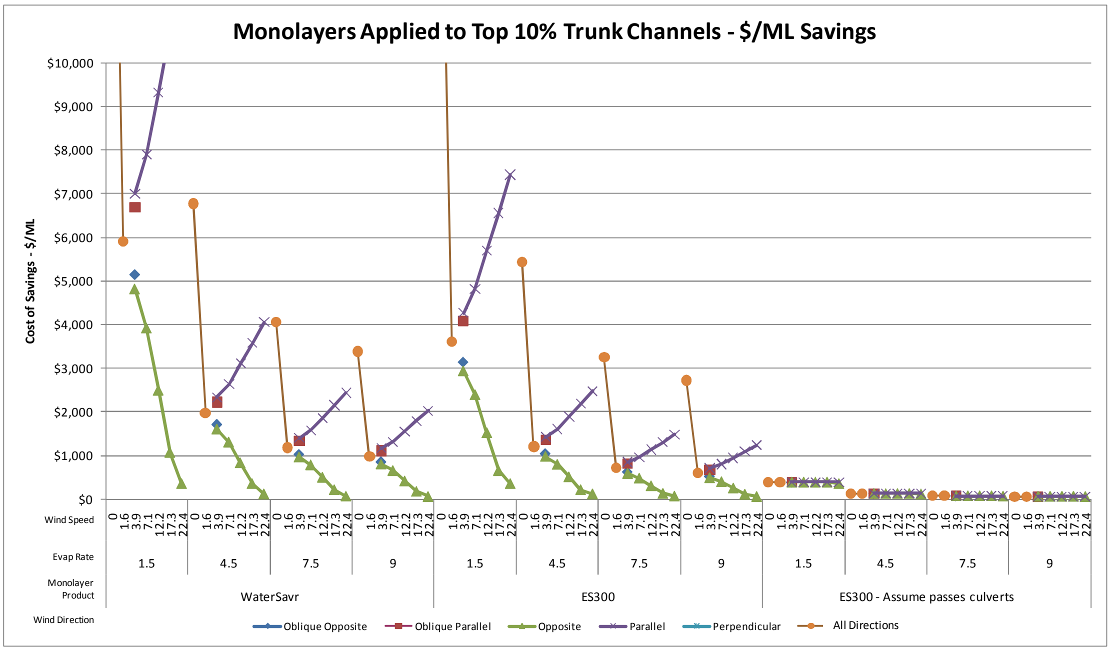


Figure 2.20 shows the cost per megalitre of savings achieved by different monolayers applied to the 10% longest spur channels within the GMID.

Figure 2.20 Cost per ML savings – Top 10% Spur Channels

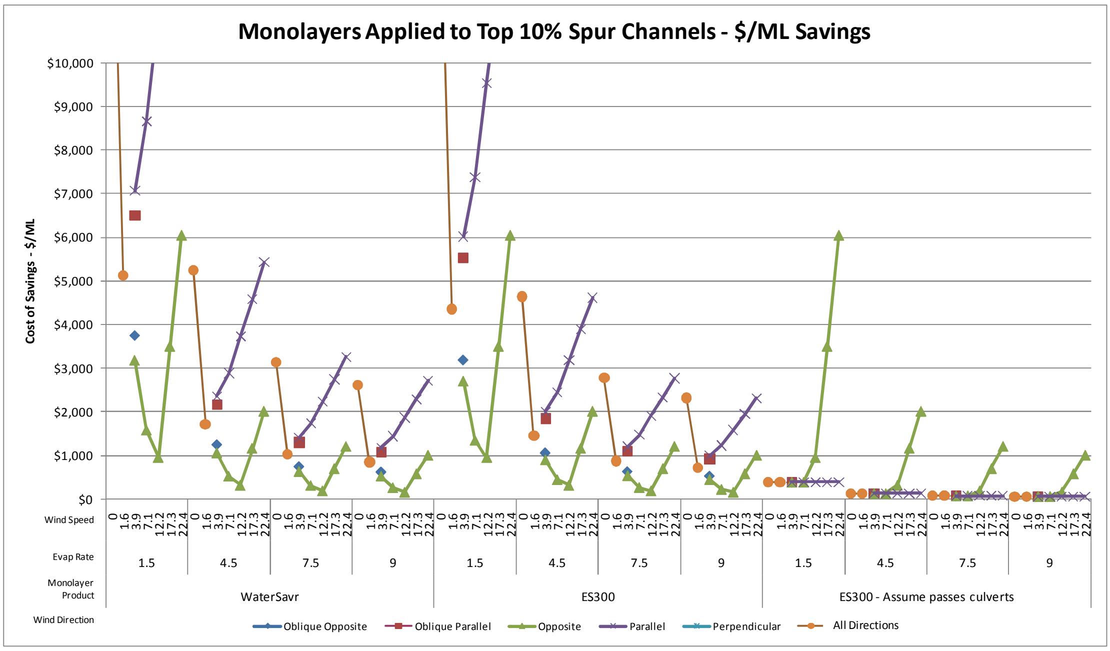
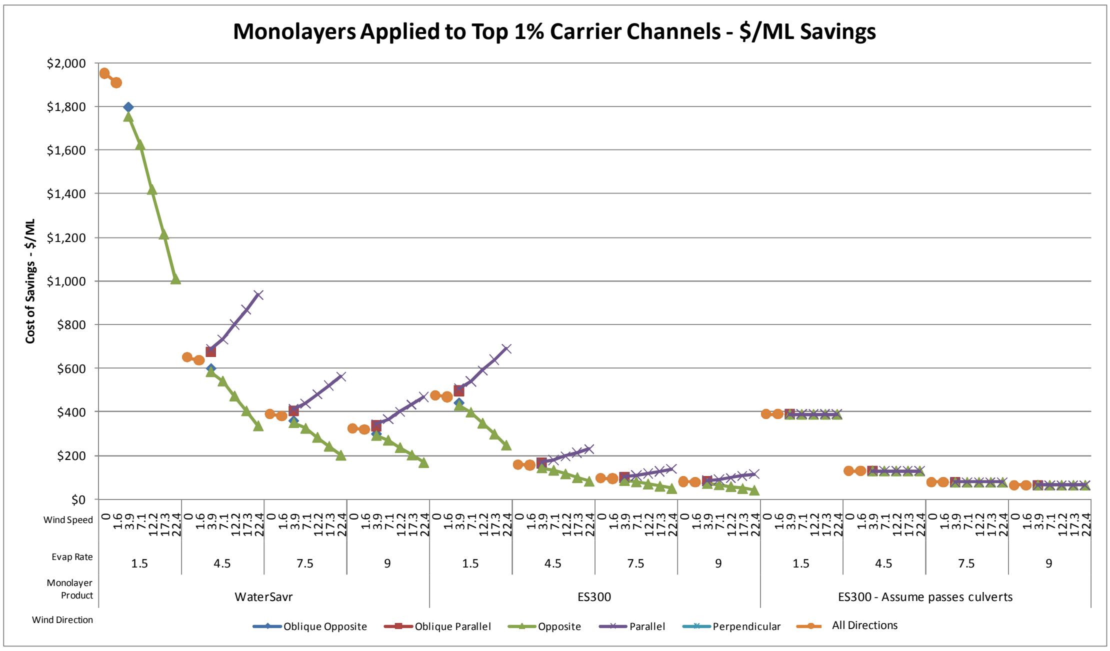


Figure 2.21 shows the cost per megalitre of savings achieved by different monolayers applied to the 1% longest carrier channels within the GMID.

Figure 2.21 Cost per ML savings – Top 1% Carrier Channels



[1] Top 1% of carrier channels means the 1% longest carrier channels

Figure 2.22 shows the cost per megalitre of savings achieved by different monolayers applied to the 1% longest trunk channels within the GMID.

Figure 2.22 Cost per ML savings – Top 1% Trunk Channels

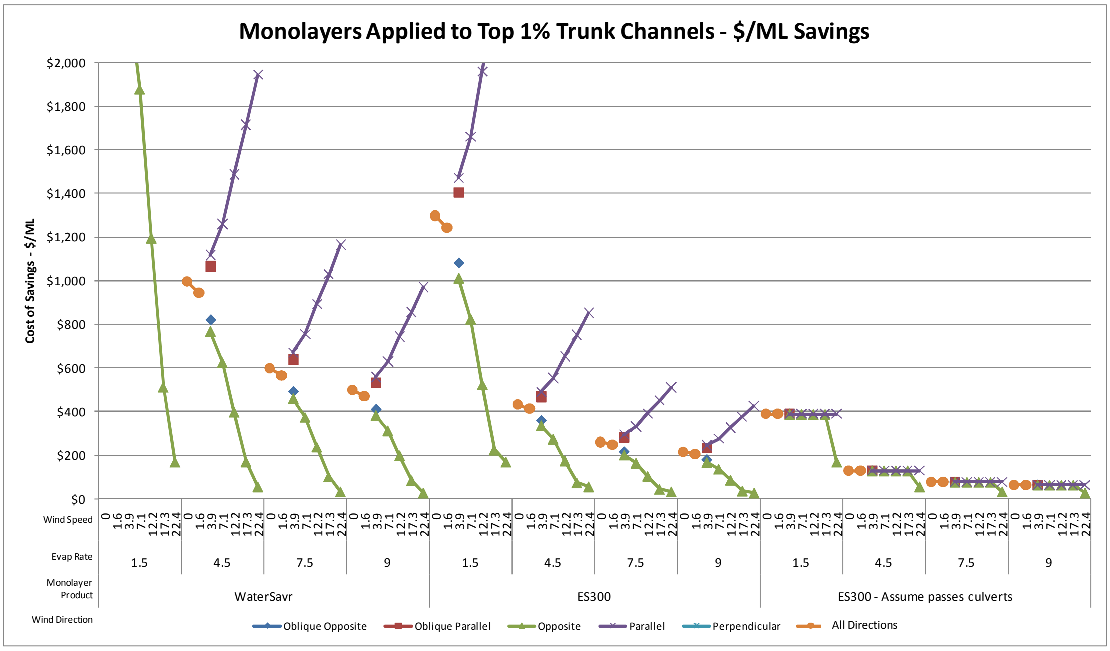
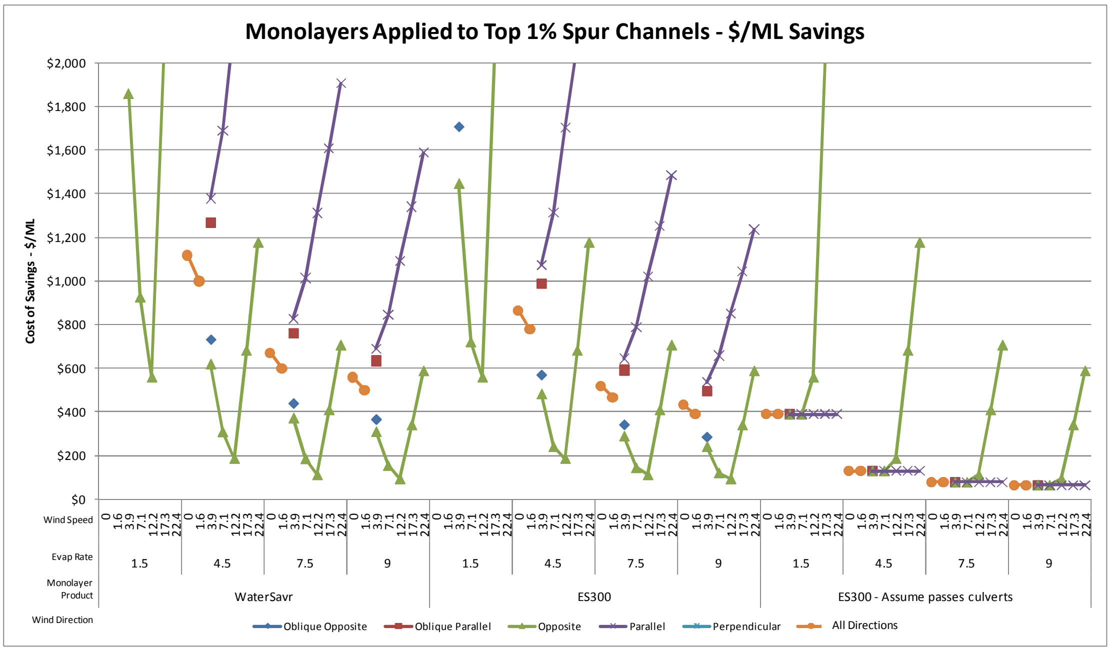


Figure 2.23 shows the cost per megalitre of savings achieved by different monolayers applied to the 1% longest spur channels within the GMID.

Figure 2.23 Cost per ML savings – Top 1% Spur Channels



In summary, the series of graphs display the following trends:

- Longer channel pools result in the most cost effective savings (decreasing $/ML)
- Increased evaporative rates result in increased cost effectiveness (decreasing $/ML)
- From least cost effective to most cost effective, the products are: Aquatain (not shown on the graphs), WaterSavr and ES300 (Melbourne University formulation). The assumptions behind this are:
    - Aquatain and WaterSavr assumed incapable of passing regulating structures
    - ES300 assumed capable of passing regulating structures
    - Cost of ES300 assumed equivalent to WaterSavr
- If a method can be devised to allow ES300 to pass culverts (eg a siphon), it will further increase in cost effectiveness
- For carrier and trunk channels, when wind opposes channel flow, increasing wind speed results in increased cost effectiveness (decreasing $/ML)
- For carrier and trunk channels, when wind is in the same direction as channel flow, increasing wind speed results in decreased cost effectiveness (increasing $/ML)
- For spur channels, the above two observations hold true up to a wind speed of 14 km/hr. Above this increasing wind speed results in decreased cost effectiveness (increasing $/ML), regardless of wind direction.

2.6.4 Monolayers compared to other techniques for saving evaporation

Monolayers differ from other evaporation savings techniques in that they are an ongoing operational activity, rather than one off capital works (although some capital works will be required to install the pumps when/where required). They can be targeted for use at those channels that represent the biggest savings and best conditions for the use of monolayers. They can also be targeted for periods when additional water is highly sought after. However, although monolayers come at a low capital cost, the potential savings is lower, and the cost per megalitre of savings can still be quiet high. The two most important issues that need to be resolved in order to accurately compare monolayer use to other techniques for saving evaporation are: can monolayers pass over regulating structures and remain effective; and can a technique be devised to allow monolayers to pass culvert structures (eg. A siphon)? For monolayers capable of passing regulating structures, the $/ML varies from $100/ML to well over $10,000/ML. However, if the monolayer is also capable of passing a culvert structure, the cost generally remains below $1000/ML, and depending on the conditions can be quiet low, for example when evaporation is 4.5mm/day on the average carrier channel, the cost is approximately $200/ML.

Referring to Table 2.1, the cost of the other techniques ranged from $130/ML for Evap-Mat to $1110/ML for Defined Sump.

Monolayers will be a more attractive options for saving evaporation losses from irrigation channels if a technique can be devised to enable them to pass culvert structures. Further cost effectiveness could then be obtained if the life of the product in the environment could be increased, however the potential environmental implications of a longer life product would need to be investigated.

2.7 Best Management Practice – Preliminary Guidelines

This report summarises the findings from field trials and modelling into a series of guidelines that irrigation authorities can refer to when evaluating or applying monolayers to irrigation channels in order to suppress evaporation.

At this point there is need to continue extensive testing of the technology in field situations prior to launching into full scale application of monolayers to irrigation channels. Of highest importance is the need to devise a method to allow the product to pass submerged irrigation culverts, thus allowing full utilisation of the product life and increasing cost effectiveness.

2.7.1 Using the Decision Support System to Inform When and Where to Apply Monolayers to Irrigation Channels

2.7.1.1 Applicability

This BMG can be applied by any irrigation system operator that wishes to reduce evaporative losses from irrigation channels through the use of monolayers. This BMG is specifically aimed at the application of monolayer technology to the distribution system for irrigation water to the agriculture sector (i.e the network of channels and control structures that delivers water to farms) as distinct from bulk water storages (reservoirs) and farm dams.

The purpose of this BMG is to consider all the variables applicable to the use of monolayers on irrigation channels and serves to inform the most appropriate time to apply monolayers on irrigation channels to achieve cost effective water savings.

2.7.1.2 Description

The Decision Support System (DSS) is a model to inform when and where to apply monolayers to irrigation channels in order to achieve particular outcomes. Those outcomes may be the lowest $/ML water savings, water savings below a required $/ML threshold or a required volume of water savings. The Decision Support System will provide the following boundaries for monolayer application to meet the requirements:

- Channel type: Carrier, Trunk, Spur
- Which channels: all, longest 25% or longest 10%
- Wind conditions: wind speed and wind direction relative to channel flow
- Evaporative rate
- Monolayer Type
- Structure Impediments

For example, within the GMID savings of less than $1000/ML may be achieved by applying ES300 to the 10% longest carrier channels when wind is less than or equal to 25km/hr and evaporation is greater than or equal to 4.5mm/day.

2.7.1.3 Implementation

The current Decision Support System is limited to the GMID, for it to be utilised by another irrigation system operator it will require the appropriate asset, wind and evaporation data to be entered. The steps below describe use of the DSS by G-MW.

- Enter the price limit established in the BMG “The maximum cost of achieving water savings in a given year” into the DSS

- The DSS will show (colour coded) those situations which meet the $/ML criteria.
- The user then decides in which of those situations to apply product, if any.

The following table presents a sample of the output of the DSS, in this instance WaterSavr applied to Trunk channels. Assuming a limit of $1000/ML it can be seen that the only times this can be achieved is when the wind is between 19.6 and 25km/hr and opposing the channel flow, and the evaporative rate is 3-6mm/day or 6-9mm/day.

Table 2.2 Model Output

Product	WaterSavr						
Channel Type	Trunk						
Evaporative Rate	1.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$20.3 K						$20.3 K
1.6	$18.6 K						$18.6 K
3.9		$22.0 K	$15.1 K	$21.0 K	$16.2 K	N/A	$18.6 K
7.1		$24.8 K	$12.3 K	N/A	N/A	N/A	$18.6 K
12.2		$29.3 K	$7.9 K	N/A	N/A	N/A	$18.6 K
17.3		$33.8 K	$3.4 K	N/A	N/A	N/A	$18.6 K
22.4		$38.3 K	$1.1 K	N/A	N/A	N/A	$19.7 K
35	N/A						

Evaporative Rate	4.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$6.8 K						$6.8 K
1.6	$6.2 K						$6.2 K
3.9		$7.3 K	$5.0 K	$7.0 K	$5.4 K	N/A	$6.2 K
7.1		$8.3 K	$4.1 K	N/A	N/A	N/A	$6.2 K
12.2		$9.8 K	$2.6 K	N/A	N/A	N/A	$6.2 K
17.3		$11.3 K	$1.1 K	N/A	N/A	N/A	$6.2 K
22.4		$12.8 K	$0.4 K	N/A	N/A	N/A	$6.6 K
35	N/A						

Evaporative Rate	7.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$4.1 K						$4.1 K
1.6	$3.7 K						$3.7 K
3.9		$4.4 K	$3.0 K	$4.2 K	$3.2 K	N/A	$3.7 K
7.1		$5.0 K	$2.5 K	N/A	N/A	N/A	$3.7 K
12.2		$5.9 K	$1.6 K	N/A	N/A	N/A	$3.7 K
17.3		$6.8 K	$0.7 K	N/A	N/A	N/A	$3.7 K
22.4		$7.7 K	$0.2 K	N/A	N/A	N/A	$3.9 K
35	N/A						

<= $1000/ML
>$1000/ML and <= $5000/ML
> $5000/ML

The general principles of achieving the greatest $/ML water savings are:

- Apply monolayer during periods of high evaporation
- Apply monolayer to longer pools (where the product travel time is increased between obstacles)
- Do not apply monolayer when the wind exceeds 25km/hr

- Apply monolayer when the wind is parallel, opposite or oblique to the channel flow, but not perpendicular to the channel flow (which will reduce coverage on the channel)
- Best results will be achieved by applying monolayer when the wind is opposing the channel flow, but the wind speed does not exceed 3.33 x channel flow (this will ensure the monolayer flows downstream, but very slowly, therefore staying on the channel longer and reducing the product quantity required)
- Ensure that all irrigation customer service points either take water from below the surface or are bunded to ensure the monolayer does not escape the channel

2.7.1.4 Scope

The current Decision Support System is limited to the GMID, for it to be utilised by another irrigation system operator it will require the appropriate asset, wind and evaporation data to be entered.

2.7.1.5 Documentation

To document this BMG, the irrigation system operator shall document the model variables and outputs, the channels chosen to be treated and ultimately the savings achieved and the extent to which they vary from the model prediction.

2.7.2 Monolayer Material – Environmental & Social

Use of monolayers on irrigation channels must consider the environmental and social impacts:

- Within the channel
- On farm
- To downstream users

The basic steps to accomplish the BMG are described below:

- Don't discharge to waterways such as rivers to eliminate the potential for negative public perception regarding the natural environment
- Consult with neighbouring landowners
- Put together a fact sheet
  a. Product makeup
  b. Product life within the natural environment
  c. The benefits of product use – irrigator benefits
  d. Comparison with other commonly used products ie. makeup
  e. Comparison with naturally occurring monolayers
  f. Potential benefits from use and potential for landowners to implement on-farm
- Ensure bunding of overshot outlets (flume gate outlets) so that the monolayer is not discharged to landowner properties

- Establish an acceptable maximum field life for monolayer products that ensures they remain within the channel system and do not enter natural waterways
- Maintain Material Data Sheets for all monolayer products in use

3 Summary

3.1 Works Undertaken

The following works were undertaken:

- Performed closed-channel trials with monolayer applied for several days
- Performed trials on flowing water to determine the conditions that enable a continuous layer to be maintained
- Laboratory trials undertaken to study the "survival" of the monolayer after the agitation that it experiences when passing through a regulator
- Modelling undertaken to develop a Decision Support System model to determine where and when it is cost effective for G-MW to apply monolayers to irrigation channels (a summary of the modelling informed the economic analysis)
- Development of preliminary Best Management Practices

3.2 Conclusions

The following conclusions are made:

- Savings of between 10 and 30% with the different monolayer products seem possible but need confirming. It has not been possible to show definite, consistent water savings from static tests
- The monolayer materials ES300 and WaterSavr appear capable of withstanding the turbulence created by regulator structures, demonstrated by laboratory testing
- The ability of ES300 to withstand regulator turbulence was demonstrated by field testing in which it reformed and obtained pressure adequate to suppress evaporation
- Monolayer materials are incapable of passing submerged pipe culverts.
- Further field testing is required to determine whether the use of monolayer materials on irrigation channels is a feasible method of reducing evaporation.
- There is not a single $/ML associated with the monolayer technique, because there are many variables that affect the cost effectiveness. An acceptable $/ML needs to be established and monolayers only applied during the periods that can achieve the required cost effectiveness.
- Modelling the use of monolayers on irrigation channels has shown that the most critical barrier to the cost effectiveness of monolayers is the ability to pass culvert structures. Therefore, it is imperative that investigations are undertaken to determine whether a technique can be developed to allow monolayers to pass culvert structures.

3.3 Recommendations

The following recommendations are made:

- Perform further closed-channel trials with monolayer applied for periods longer than several days i.e.weeks

- Undertake field trials with other monolayer products such as WaterSavr to determine whether they are capable of passing regulating structures. This will enable further comparison with the performance of ES300.
- Undertaken investigations to determine whether a technique can be developed to allow monolayers to pass culvert structures.
- Further review costs associated with the monolayer technique including: cost of maintenance and filling and actual costs of application equipment including linkage into the SCADA system.