Price Merrett Consulting Pty. Ltd.

Draft Final Report

MID SE IRRIGATORS

INNOVATIONS GRANT

CHANNEL SEEPAGE REMEDIATION TRIAL

REEDY CREEK VIA KINGSTON SE. SOUTH AUSTRALIA

Principal Contact
Philip Price L.S.

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Price Merrett Consulting Pty. Ltd

Soil Survey Report

1. Executive Summary

The aim of the trial was to:

1. Accurately assess Channel seepage rates before and after the application of clay and bentonite.
2. Further assess and evaluate in-field surface irrigation application efficiencies.

Based on the results of the seepage trial a benefit cost analysis was undertaken and the results compared to a pipelining option.

A trial section of channel was selected on three different properties. Properties 1 & 3 were relatively narrow channels on a black clay over limestone base. Property 2 was a channel constructed in sand at least 0.5m deep, although it is expected that clay underlies the sand at not much greater depth.

The result of the bentonite tests was disappointing. In all cases the bentonite application showed no response. There are two likely reasons for this:

1. The channels leaked away so quickly that there was no opportunity for the bentonite to have an affect.

2. The salinity of the groundwater may have had an ameliorating affect on the dispersive nature of Bentonite. This should not have affected its swelling capacity. A later inspection of the channel in property 2 indicated a considerable degree of swelling had occurred.

3. The bentonite was not added at a sufficient rate. Most "recipes" suggest that 50 to 75 tonnes per hectare may be appropriate for sealing dams.

In addition a clay lining trial was conducted on another section of the sandy channel of Property 2. The results indicated a significant reduction in channel seepage.

Existing distribution efficiencies were not as low as expected.

Trial Section	1.	Clay	94%
	2.	Sandy	85%
	3.	Clay	94%

No economic assessment of the Bentonite trial was carried out as there was no benefit. The clay lining trial was assessed and found to have a negative NPV. i.e. there are no benefits.

An economic analysis of conversion to a pipe and riser supply again resulted in a negative NPV, i.e. conversion to pie and riser is totally uneconomic.

Conclusion – channel seepage is not a significant component of total irrigation water usage. Efforts spent in reducing seepage are wasted when considered in the context of a very low application efficiency and low returns from irrigated pasture for lamb production.

2. Background

With the proposed change to volumetric allocation, irrigators in the Reedy Creek Area have been investigating cost effective ways of improving irrigation efficiency. For the purposes of this report, irrigation efficiency is simplified to two components:

1. Application efficiency
2. Distribution efficiency.

$$\text{Application efficiency} = \frac{\text{volume of water beneficially used by a crop}}{\text{volume of water delivered to the field}}$$

$$\text{Distribution uniformity} = \frac{\text{volume of water delivered to the field}}{\text{volume of water delivered to the property}}$$

A previous trial evaluated the surface irrigation application efficiency. This project requires a follow up assessment to review changes to soil hydraulic properties bought about after full wetting of the profile through continuous irrigation. The previous trial was conducted on very dry ground and although normally this can be accounted for by adjusting the target application rate, on the assumption that the continuing infiltration rate would achieve its normal saturated rate, in this case there may be other non soil related issues affecting the rate, skewing the results to abnormally high infiltration. The trial should preferably be conducted on the same bay as previously.

The second part of the project is a channel seepage & remediation trial. The aim of this trial is to accurately assess channel seepage rates before and after the application of various rates of Bentonite.

Trial Set Up. Three channel sections in different soil types will be examined. With very high seepage rates, the quality of data is not so important so shorter monitoring times do not matter (seepage exceeds other affects by a large margin). Soil samples will be taken only to assess texture. Soil permeability testing is a laboratory method of calculating a soils saturated permeability at various soil moisture and compaction rates which is difficult to convert to an actual drop in water level as observed. It is also difficult to replicate the compaction rates in the field so this method is not seen to be practically useful in this situation. The trial will be restricted to measuring actual seepage as a drop in level.

Once the underlying rate is established, Bentonite will be applied to the channel section and the seepage rate measured again. There are three accepted methods of applying Bentonite:

1. Pure Bentonite blanket.

A layer 25mm thick is applied with an overlying protective blanket of soil. This method is not recommended due to cost and practicality. It is potentially overkill in that Bentonite is applied to areas at a constant rate whether they need it or not.

2. Mixed Blanket.
Bentonite is applied at a set rate and incorporated in the soil usually by rotary hoeing. The resultant blanket is then watered and compacted at optimum moisture content. The soil used in the mix should be low in clay content, a sandy loam or sandy clay loam being ideal. This method would suit larger channels constructed in sandy soils. rates of between 50 to 80 tonne per hectare are typical. This may also be a reasonable alternative when constructing new channels.

3. Broadcast Bentonite.
Bentonite is applied to the water surface at selected rates. An ideal method to solve problem spots where the actual location is uncertain. The Bentonite quickly sinks to the bottom of the channel and is drawn into any pathways through the soil with water flow. The Bentonite can be carried many metres into the foundation slowly expanding as it absorbs moisture. Eventually the Bentonite expands to completely block the seepage pathways. Because the Bentonite can be carried well into the foundation this method is ideal for channels. The bed and banks of the channel can be exposed and disturbed with little if any affect on the Bentonite. The unknown in this method is the quantity. Experience has shown that a rate of 50 tonne per hectare can seal a piping failure in a large dam within two days of application.

For this trial we will use the broadcast method. Two rates will be trialled 25 tonnes per hectare and 50 tonnes per hectare. The experimental section will be measured and the equivalent rates in bags per lineal metre will be calculated.

Outcomes:

- An assessment of the benefit of the application of bentonite in reducing seepage in farm channels.

- A benefit /cost analysis will be undertaken and results will be compared with a pipelining option. Pipe and riser systems have become popular in parts of Northern Victoria, however many prominent Irrigation designers have doubts over the economic benefit of such schemes. Higher seepage rates may however make such schemes viable and they must be compared to the bentonite alternative. The steering committee of farmers must decide on the value of water saved as an input into the economic assessment.

3. Field Trials

Three properties in the Reedy Creek area selected for trials were:

1. P & M Andrews
2. A Beggs
3. W Hancock

On each property a short section of existing channel was selected and surveyed to provide an accurate digital terrain model. Gauge boards were placed in each section. The ends were blocked using various combinations of clay, galvanised iron and plastic. All possible leaks were blocked.

The Irrimate seepage monitoring equipment was not required:

1. Channels were very shallow.
2. Seepage rates were sufficiently high that evaporation effects were negligible.

The process was simply to fill the test section, block off all leaks then record water levels against time. The water levels were then correlated to actual volumes from a rating curve developed for each test section (See Appendix A, Rating Curves.)

The seepage rate is expressed as cubic metres / hour / metre channel. As expected, in all cases the rate was initially high but rapidly declined to an almost steady rate. For comparison of results and calculation of total channel seepage the final average seepage rate has been adopted. This is the cumulative drop in water level or volume divided by the total time of measurements

This value is slightly higher than the final measured instantaneous seepage rate. This value was chosen because it took into account the higher initial rates and compensated to some degree for the possible head affect i.e. seepage rates would reduce with lower channel levels, particularly in the sandy channel.

Table 1– Summary of Trial Section

Summary of Trial Section					
	Name	**Soil**	**Length**	**Volume Full**	**Trial Rate**
Trial Section 1	Andrews	Clay	100m	82 m^3	50 tonnes/ha
Trial Section 2	Beggs	Sand	53m	72m^3	50 tonnes/ha
Trial Section 2A	Beggs	Sand	29m	50m^3	150mm clay lining
Trial Section 3	Hancock	Clay	77m	71m^3	25 tonnes/ha

Each section of channel (except for section 2A which was immediately D/S of section 2 and was assumed to have the same seepage) was measured prior to treatment. The channels (sections 1, 2 and 3 only) were then refilled and Bentonite was broadcast from bags at a rate calculated to be equivalent to either 25tonnes/ha or 50 tonnes/ha.

Channel section 2A was treated with an imported clay blanket. Clay was trucked in and dumped alongside the channel, moved into the channel using front end loader and compacted. Approximately 150mm was applied.

Seepage rate tests on Sections 2 and 3 were repeated some days later (no further bentonite was added) to give the bentonite time to react. Unfortunately the landholder accidently lost the results from section 3.

4. Results

The addition of Bentonite showed no improvement in seepage rates. If anything, the Bentonite appeared to increase seepage. This is an inexplicable result and can only be put down to a possible combination of measurement inaccuracy and drier antecedent soil moisture conditions.

The failure of the Bentonite to react sufficiently, or even at all, may be explained in part by the higher salinity of the water. The initial lack of response was thought to be a function of high seepage and rapid draw down of water, leaving no time for the Bentonite to react and swell. Subsequent trials would suggest that this had little effect.

The bentonite was delivered in 25kg bags at a cost of $177 per tonne ($4.42/bag)

The application rates in bags per lineal metre depended on the wetted area of the channel. Wetted area is the length of bank that is wetted up and includes batters and bed. Estimates of wetted area in the field were less than the actual final wetted area. This resulted in slightly less than design application rate being applied.

Table 2 Application rates

	Application Rate equivalent to 25 tonnes per hectare	Actual bag rate calculated in field and applied (25t/ha equiv)	Actual application Rate	Approx. Cost $ per lineal metre
Section 1	31 x 25 kg bags	26 x 25 kg bags	42 tonnes per ha.	$2.30 / metre
Section 2	28 x 25 kg bags	25 x 25 kg bags	44 tonnes per ha.	$4.17 / metre
Section 3	32 x 25 kg bags	39 x 25 kg bags	31 tonnes per ha.	$2.24 / metre

Note: Application costs did not include labour.

The clay treatment resulted in a significant reduction in seepage. Clay was delivered by truck and dumped beside the channel. It was applied to the channel and rolled using a front end loader. The cost of delivery alone was equivalent to $77 per lineal metre. No estimate of the cost of installation has been made. This was approximately equivalent to a 150mm clay liner. (pers comms A. Beggs).

Table 3 Results of Remedial trial

Results of Remedial Trial			
		Seepage Rate m^3 / hour / m	**Equivalent mm / hour**
Section 1	Existing	0.03	10.2 mm / hr
	After bentonite	0.03	10.5 mm / hr
Section 2	Existing	0.12	23.1 mm / hr
	After bentonite 1	0.12	23.1 mm / hr
Section 2A	After bentonite 2	0.21	38.8 mm / hr
	Existing	0.12	23.1 mm / hr
	After clay lining	0.01	2.1 mm / hr
Section 3	Existing	0.03	8.3 mm / hr
	After bentonite	0.04	10.4 mm / hr

Results are tabulated in Appendix B

4.1 Existing Distribution Efficiencies

Distribution efficiencies for each Trial section were assessed. Distribution efficiency is defined as the ratio:

$$\frac{\text{Volume of water delivered to the field}}{\text{Volume of water delivered to system}}$$

For example, on Beggs property the current channel loss per irrigation is assessed as 14.1 ML with a field application of 80 ML. Distribution efficiency is therefore $\frac{80}{80 + 14} = \frac{80}{94} = 85\%$

There are no "target" efficiencies published.

Table 4 Summary of Existing Distribution Efficiency

		Soil	Potential	Realistic
Section 1*	Andrews	Clay	91%	94%
Section 2	Beggs	Sand	78%	85%
Section 3	Hancock	Clay	90%	94%

* based on 1000m of channel irrigating 70ha

Potential Efficiency assumes that all channel is wetted for the entire irrigation cycle. In reality channel checks are used to keep sections dry for as long as possible. There is a practical limit of about 4 to 5 sections in any length of channel, after this incremental savings in seepage losses decline.

See Appendix C for Summary of efficiency calculations.

5. Economic Analysis

An economic analysis of Bentonite treatment has not been undertaken as there was no benefit. A benefit / cost analysis of clay lining has been undertaken.

A benefit cost analysis of converting to a pipe and riser system has also been carried out.

5.1 Benefit Cost Analysis of Clay Lining Channel Section 2A

5.1.1 Criteria 1: Reduced Pumping Cost of Water Saved

Base Case	
Channel Length	29m
Bed Width	2.46m
Welted Perimeter	5.30m
Base Seepage Rate	0.12 m3 / hour / lineal m
Area irrigated	40ha
Length of Channel	1500m
Flow Rate	15.6 ML / day
Time required to irrigate	40ha = 5.1 days (200 mm application)
Water applied to paddock	80 ML
Potential water lost in seepage	22.6 ML
Reduction factor	62.5% (assume 4 sections in channel)
Actual water loss in seepage	14.1 ML (current)

Distribution Efficiency = $\frac{\text{Water applied to bay}}{\text{Water supplied to farm gate}}$

$= \frac{80}{80 + 14.1} = 85\%$

Seepage loss rate after applying clay	0.02 m3/hr/m
Potential water lost in seepage	2.09 ML
Actual water lost in seepage	1.31 ML (apply factor)
Distribution Efficiency	98%

Benefits

1.	Reduced water pumped.	12.8 ML/ irrigation (94.1 – 81.3)
	(assume 14 waterings per year)	179 ML/ year
	Cost of water saved	
	Current Pumping cost	~ $7 / hour (report by land owner)
	Pump Rate	15.6 ML/day
	Hours of pumping saved p.a.	= 275 hours
	Cost of Fuel	= $1925 p.a.

Costs

2. Clay lining @ $70 / lineal metre = 70 x 1500
= $105,000

Clay lining of channel may have a relatively short life span due to weathering, erosion & stock damage. Assume that 50% of the cost of clay lining incurred again after 10 years.

Net Present Value

Over 20 years NPV @ 8% =($110,851)
Conclusion: *Clay Lining is uneconomic based on reduced pumping costs alone.*

5.1.2 Criteria 2: Opportunity value of Water Saved i.e. grow more pasture

Benefits

Extra water available per year	179 ML/ year
Water use per hectare	28 ML/ha
Extra hectares watered	6.4 ha
Productivity (Gross Margin)	$300/hectare (20DSE/ha @$15/DSE)
Return from Extra pasture	$1920 per year

Costs

Clay lining @ $70 / lineal metre = 70 x 1500
= $105,000

Clay lining of channel may have a relatively short life span due to weathering, erosion & stock damage. Assume that 50% of the cost of clay lining incurred after 10 years.

Net Present Value

Over 20 years NPV @ 8% =($110,904)
i.e. *Clay Lining is uneconomic based on increased productivity from saved water.*

5.1.3 Sensitivity Test : Gross margin required to make clay lining Economical.

Gross margin required per hectare = $1937/ha.
These are dairy industry level of returns.

5.2 Pipe & Riser Calculations

Channell Section 2 (Beggs) has been used for this example. This sandy section had the greatest potential savings and would therefore offer the best benefit cost ratio. If this site fails any test then all sites fail.

Benefit cost ratio analysis.

Based on example above, water saving = 179 ML / p.a.
Assume water application rate 28 ML / ha / year
Extra hectares that could be watered 6.4 ha

Benefits –

Productivity from extra 6.4 ha
Gross Margin Prime Lamb, say 20 DSE / ha @ $15/DSE = $300 / ha
Annual Return from production = $1920

Note: Return from extra production only paying pumping cost.

Conclusion: Irrigation at current costs would appear to be uneconomic. This is a simplistic analysis and does not consider the added value of drought proofing a grazing property.

Pipe and Riser Design Assumptions

1. Current flow rate 15.6 ML/day is maintained. High permeability soils need the highest flow rate possible.

2. Based on current reported figures:
   Flow rate 15.6 ML/day
   Fuel consumption 7 L diesel per hour

   Pump efficiency = 60%
   Drive efficiency = 95%
   Motor efficiency = 60%
   then pumping head currently = 4m

3. Pipe lengths are as per sketch.

4. Costs: a) Capital cost of pipe and riser system
   b) Increased pumping costs
   c) Maintenance costs on extra pumping

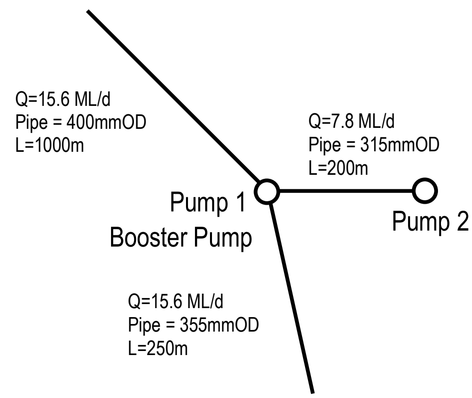
5. Benefits: a) Assume there is no market for water saved and that extra land could not be developed with water saved. Gross margin $300 per ha.
   b) Water saved from seepage only

6. Area Irrigated 40h
   Annual water use 28ML / ha = 1120 ML
   Water lost to seepage = 14.1 ML/ha x 14 irrigators = 198 ML/year

7. Productivity Gain – Assume a 10% increase in productivity from more timely irrigations.

8. No work is done on existing channel.

Design & Layout



Pumps

Increase head on pumps by 6m (4m to 10m).
Increase speed of current pump. 29%
Increase power of current pump 115%
Existing pumps & motors most likely unsuitable.
Cheaper to install booster pump.

Costs (Capital)

Channel Construction	Nil	(no works required)
New Pump station	$16,328	
Pipe and Riser System	$160,380	
Automation of Pipe and Riser	$35,405	

Costs (Maintenance - annual)

Channel maintenance	$540	(spraying and desilting)
Pump maintenance	$1260	
Pipe and riser maintenance	$3534	
Automation maintenance	$708	

Costs (Operating – annual)

Pumping Cost	$16340	(cost to pump extra 6 m head)

Benefits

Savings in labour	$7875	(labour saved on fully automated system)
More ground to irrigate	$2119	(return from extra land irrigated at enterprise Gross Margin)
10% improvement in productivity	$1200	

Conclusion

Net Present Value at 8% after 20 years = ($344,386) for manual pipe and riser
Net Present Value at 8% after 20 years = ($317,434) for automated pipe and riser

There are no benefits from pipe & riser systems.

1. Water use is too high.
2. Seepage losses are not valuable at high water use
3. Enterprise Gross Margins are too low.

See Appendix D for detailed breakdown & analysis

6. Surface Evaluation

These soils are shallow clays over limestone (Rendzina soil type). This farm was written up in the original report. That report recommended a follow up audit to measure the affect of a season of irrigating. The first assessment was made after an abnormally long gap between irrigations. See previous report for methodology.

The crop is permanent pasture, irrigated regularly through summer and autumn for forage for sheep.

Bay width	22.7 m	
Bay length	692 m	
Bay area	1.571 hectares	
Bay slope	0-279	0.022%
	279-692	0.087%

<u>Trial 1 (Soil dry)</u>

Results from previous report.

<u>Calibration Exercise</u>

Flow Rate	7.1 ML/day
Total Irrigation Time	960 minutes
Advance Time	864 minutes
Target Application	75 mm
Application Efficiency	25%
Requirement Efficiency	100% (target demand met everywhere)
Distribution Uniformity	81%
Volume onto bay	4.73 ML
Volume Runoff	0.451 ML (9.6% of delivered volume)
Infiltrated Volume	4.27 ML
Average infiltrated depth	272 mm
Maximum ponding time	19 hours – excessive and destructive of pasture!

Double Flow rate

Flow Rate	14.2 Ml/day
Total Irrigation Time	320 minutes
Advance Time	385 minutes
Application Efficiency	37% - still not acceptable
Requirement Efficiency	100% (target demand met everywhere)
Distribution Uniformity	81%
Volume onto bay	3.16 ML
Volume Runoff	0.15 ML (5% of delivered volume)
Infiltrated Volume	2.99 ML
Average infiltrated depth	190 mm
Maximum ponding time	8.4 hours – acceptable for pasture!
Water Saving	= 4.27 – 2.99 = 1.28 Ml/1.5 ha
	= 85 ML per irrigation over 100 hectares
	= 1200 ML per annum (14 irrigations)

Same Flow rate, halve bay length (346m)

Flow Rate	7.1 Ml/day
Total Irrigation Time	320 minutes
Advance Time	331 minutes
Application Efficiency	37% - still not acceptable
Requirement Efficiency	100% (target demand met everywhere)
Distribution Uniformity	81%
Volume onto bay	1.58 ML
Volume Runoff	0.10 ML (6% of delivered volume)
Infiltrated Volume	1.48 ML
Average infiltrated depth	94 mm
Water Saving	= 4.27 – 1.48 = 2.79 Ml/1.5 ha
	= 186 ML per irrigation over 100 hectares
	= 2604 ML per annum (14 irrigations)

Trial 2

Previously irrigated 8 days ago.
Date 21/02/06
Based on long term historical data – late February (25° days) average daily pan evaporation 5mm.
Crop Water Use = 8 x 5 x 0.8 = 32 mm.
Target application @ say 70% efficiency 46 mm.

Calibration Results

Bay Area	1.571 ha
Bay Width	22.7 m

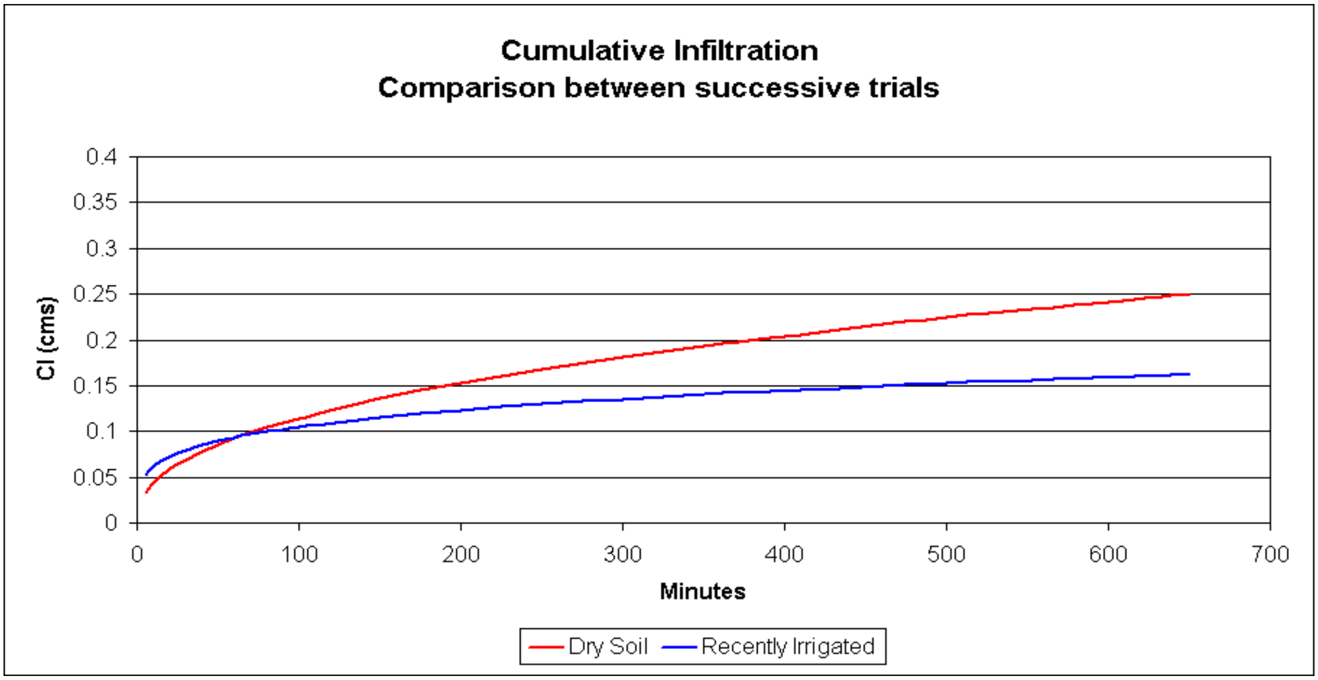
Bay Length	692 m
Target Application	46 mm

Flow rate	7.7 ML/day
Cut off time	890 minutes
Advance time	662 minutes
Inflow	4.76 ML
Infiltrated Volume	3.18 ML
Run off	1.58 ML (33% of applied volume - farmer flooded the area)
Average Infiltration	203 mm
Application efficiency	15%
Distribution uniformity	94%

Modelled Event – to reduce runoff to nil, no other changes.

Flow rate	7.7 ML/day
Cut off time	495 minutes
Advance time	815 minutes
Inflow	2.65 ML
Infiltrated Volume	2.58 ML
Average Infiltration	165mm
Application Efficiency	27%
Distribution Uniformity	77%
Comment:	The reduced volume infiltrated is a result of the difference in antecedent soil moisture levels. The application efficiencies for both the dryer (1st trial) and wetter (2nd trial) soil moisture levels were about the same. The cumulative infiltration curves were compared. It would be expected that the crack fill component of the second trial would be lower (i.e. the soil is not as dry and cracked) and that the slope of the continuing infiltration curve would be similar (i.e. the soil is irrigated for such a long time that it reaches saturation during each irrigation event).

The explanation for this apparent difference may be due to the relatively shallow soil cover. The local farmers believe that the shallow perched water table builds up over the irrigation season. As a non slaking, non dispersive sub plastic clay soil the term “crack fill” may be misleading. We may in fact be seeing an initial consistent intake rate that fills the shallow profile. With the difference in continuing irrigation being due to saturation and creation of a perched watertable slowing the continuing infiltration rate as the hydraulic gradient through the soil decreases.



In any event the second trial can be used for modelling as it truly reflects the majority of the irrigation season.

As with the first trial a number of different optimisation models were applied.

<u>Optimisation Event 1. – Double the flow rate.</u>

Flow rate	15.0 ML/day (7.65 l/S/m)
Time to cut off	235 minutes
Advance time	514 minutes
Inflow	2.45 ML
Infiltrated volume	2.41 ML
Average Infiltration	153 mm
Distribution Uniformity	85%
Application efficiency	30%
Water saving	Minimal.

<u>Optimisation Event 2. – Same flow rate – halve the bay length to 346 m.</u>

Flow rate	7.7 ML/day
Time to cut off	220 minutes
Advance time	370 minutes
Inflow	1.18 ML
Infiltrated volume	1.15 ML
Average Infiltration	146 mm
Distribution Uniformity	86%
Application efficiency	31%
Water saving	Small - 11% (may be significant with reduced allocations)

165mm – 146 mm = 19mm per irrigation
= 19 ML per irrigation per 100 hectares
= 266 ML per season (14 irrigations)

Discussion

The target application rate can never be met with these soils due to a high initial crack fill. Early season irrigation after a dry winter would benefit from the suggested changes but as the irrigation season progresses the savings are less but still valid. With shorter bays the paddock ponding time is much shorter which results in more growing time and potentially a vast improvement in productivity. The potential water saving from reduced bay lengths ay be greater in the spring and autumn when there is a greater chance of drier antecedent soil moisture levels.

Conclusion

These soils are not really suitable for surface irrigation from a purely application efficiency point of view. Changing irrigation frequency, flow rate or changing bay length a small effect on efficiency and water savings but potentially a large effect on producrivity. We have seen that channel seepage losses are small compared to paddock losses.

Recommendations:

Bay lengths should be kept short (<300m) to reduce ponding times.
Flow rates should be maximised to reduce field intake opportunity time, reduce irrigation times and minimise seepage losses.

7. Conclusions

Seepage losses from channels are not significant compared with the very low field application efficiency.

Bentonite application trials were unsuccessful. The base seepage rates suggest that any amelioration is unlikely to yield an economic return:

1. Field application efficiencies are too low, therefore small savings in water through seepage is almost “wasted” on inefficient surface irrigation.

2. Gross margins are too low to raise the benefits side of the benefit cost ratio.

Clay lining gave excellent results in reducing seepage, however there is no economic benefit.

Limiting seepage from channels provides no benefit given the current irrigation method and returns from grazing pasture.

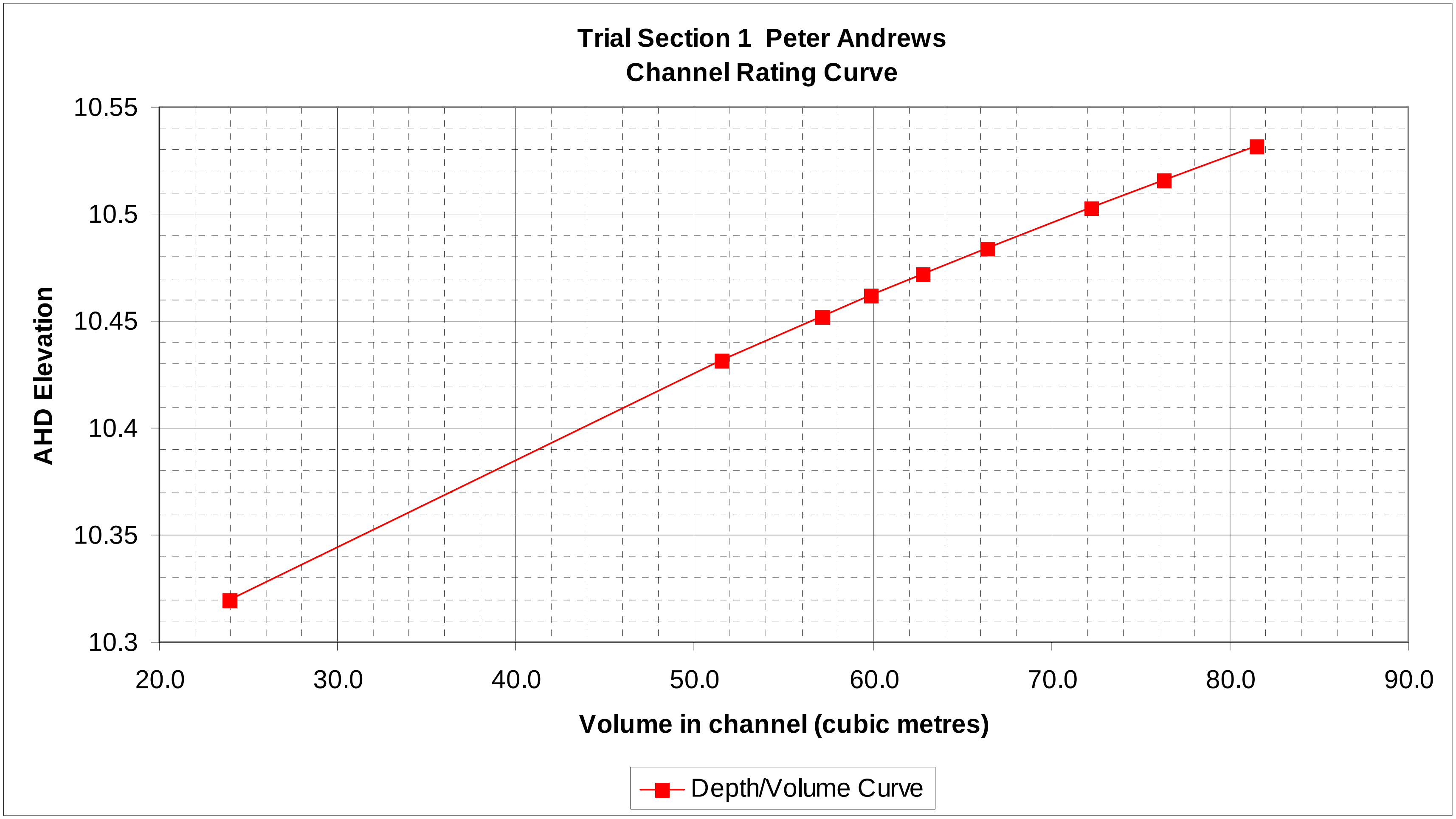
Seepage losses are insignificant in relation to potential reduction in irrigated area due to conversion to volumetric allocation. However there are simple measures available to reduce seepage losses. Reduce seepage losses by:

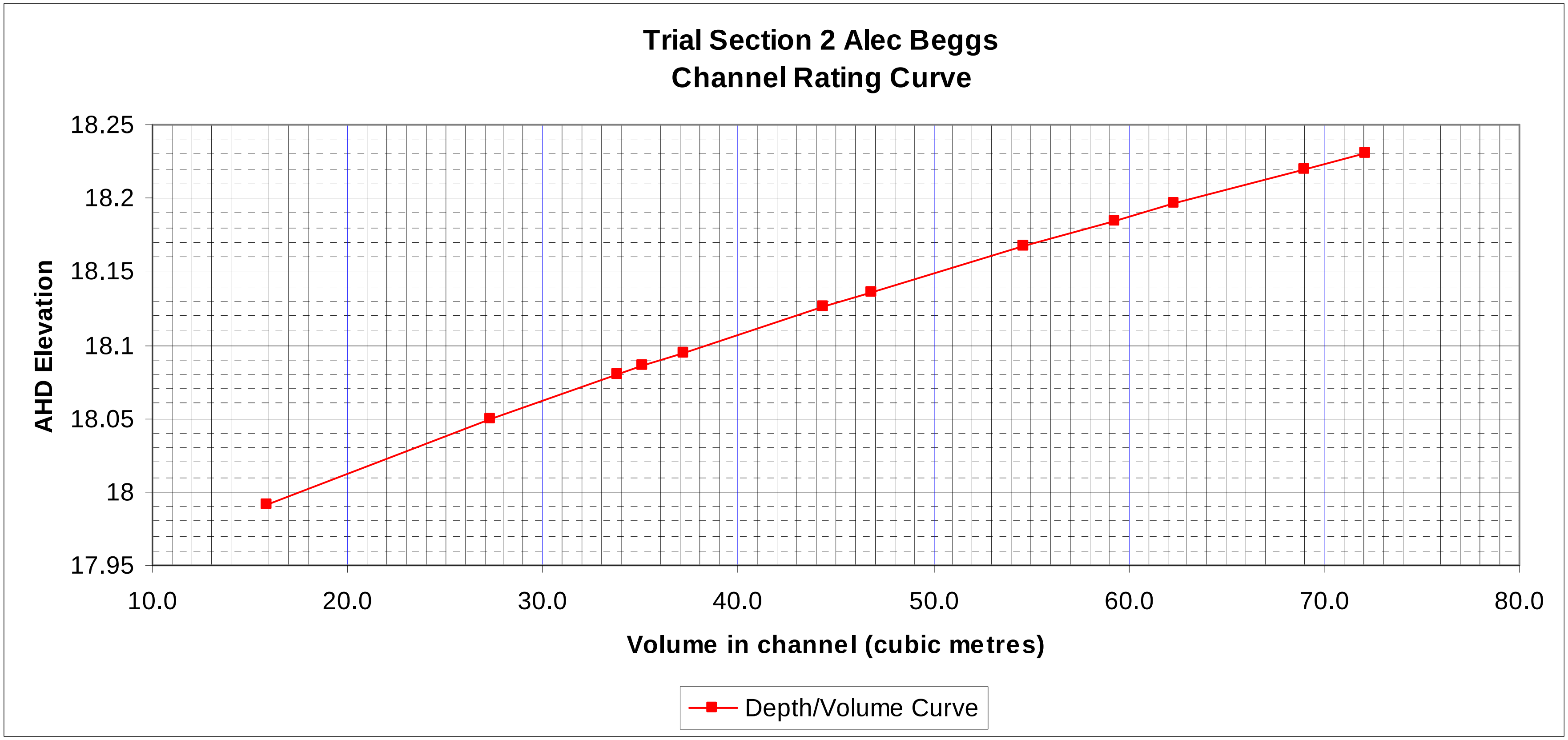
1. keep wetted perimeter small
2. do not wet up long channel sections
3. maintain highest possible flow rates
4. keep channels clean
5. keep bays small to reduce inflow hence total irrigation time and seepage opportunity time.

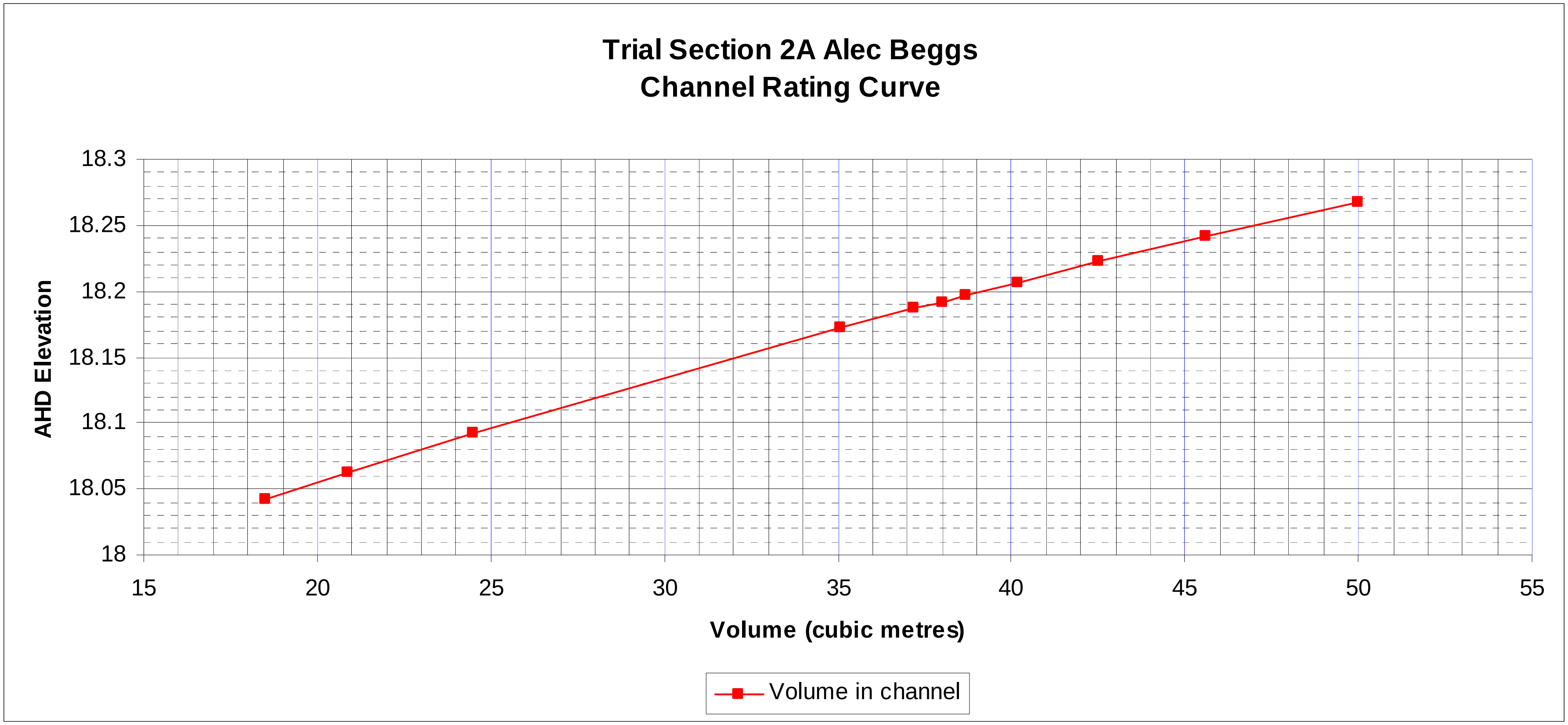
The second surface evaluation trial indicated that there are only modest gains (upto 11%) in water savings by changing layout. Early season irrigations would benefit from shorter bays and higher flow rates. The greatest effect will be in shorter ponding times due to reduced lengths of bays.

Appendix A

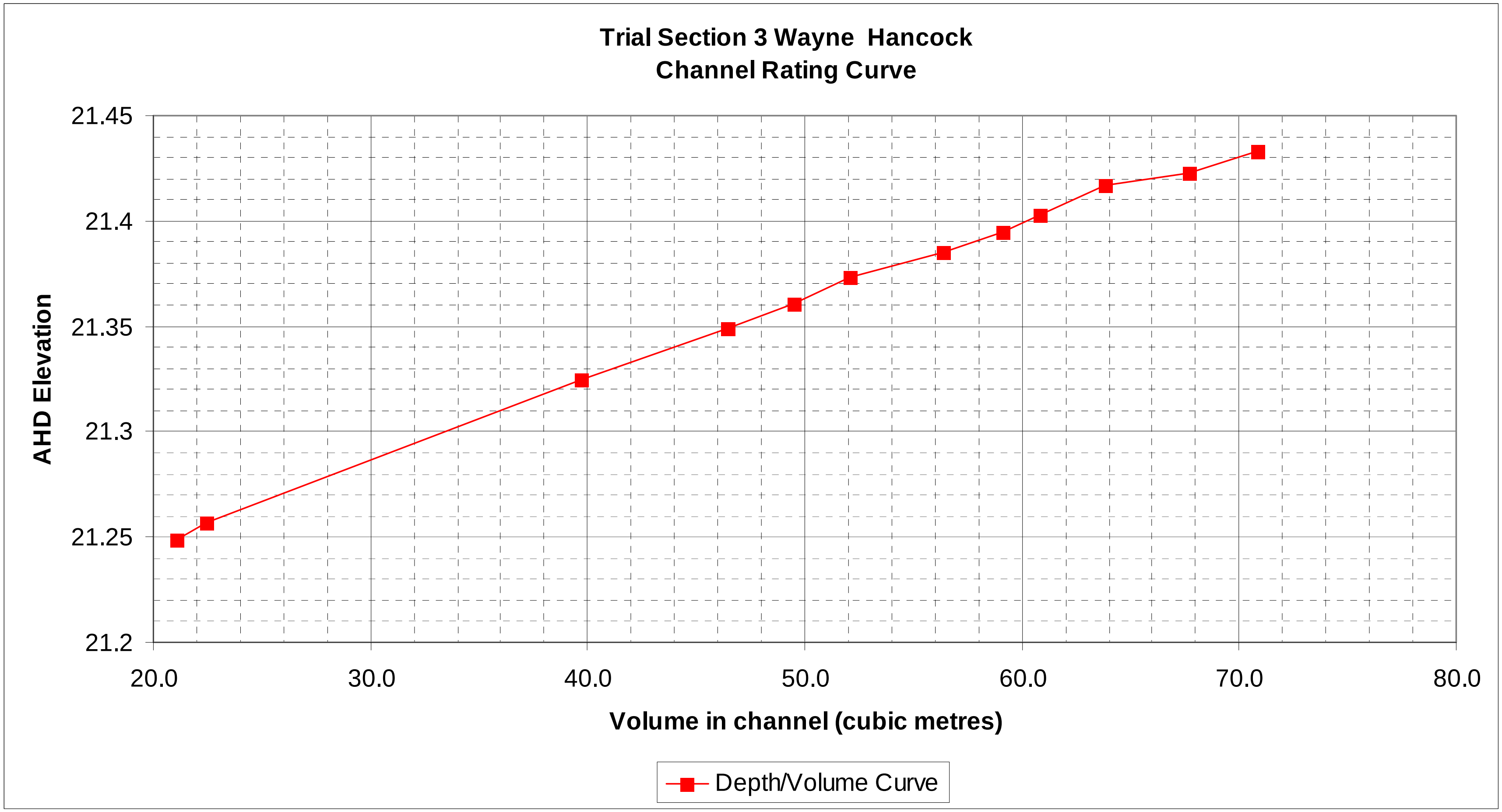
Channel Rating Curves


Trial Section 1 Peter Andrews
Channel Rating Curve
AHD Elevation
10.55
10.5
10.45
10.4
10.35
10.3
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
Volume in channel (cubic metres)
Depth/Volume Curve


Trial Section 2 Alec Beggs
Channel Rating Curve
AHD Elevation
18.25
18.2
18.15
18.1
18.05
18
17.95
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Volume in channel (cubic metres)
Depth/Volume Curve



Trial Section 2A Alec Beggs
Channel Rating Curve
AHD Elevation
18.3
18.25
18.2
18.15
18.1
18.05
18
15
20
25
30
35
40
45
50
55
Volume (cubic metres)
Volume in channel


Trial Section 3 Wayne Hancock
Channel Rating Curve
21.45
21.4
21.35
21.3
21.25
21.2
AHD Elevation
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Volume in channel (cubic metres)
Depth/Volume Curve

Appendix B

Trial Results – Channel Seepage

Trial Section 1 Andrews

Base case - No bentonite Added										
Time (hr)		Gauge Elevation (m)	AHD (m)	W/L drop (mm)	Inst. Seepage Rate (mm per hour)	Ave seepage loss (mm/hr)	Volume in channel m^3	Cum. volume Lost m^3	Inst. Rate of water loss m^3/hr	Average water loss rate m^3/hr
Top of gauge		11.615	11.039							
13.30	13.50	11.108	10.532				81.5			
14.13	14.22	11.092	10.516	-16	22.3	22.3	76.3	5.2	7.3	7.3
15.15	15.25	11.079	10.503	-13	12.6	16.6	72.2	9.3	4.0	5.3
16.25	16.42	11.06	10.484	-19	16.3	16.5	66.4	15.1	5.0	5.2
17.22	17.37	11.048	10.472	-12	12.6	15.5	62.8	18.7	3.8	4.8
18.09	18.15	11.038	10.462	-10	12.8	15.1	59.9	21.6	3.7	4.6
18.47	18.78	11.028	10.452	-10	15.8	15.1	57.1	24.4	4.4	4.6
20.40	20.67	11.008	10.432	-20	10.6	14.0	51.5	30.0	3.0	4.2
32.04	32.07	10.896	10.32	-112	9.8	11.4	23.9	57.6	2.4	3.1

Trial Section 1 Andrews After Addition of Bentonite

Trial 1 Bentonite Added										
Time (hrs)		Gauge Elevation (m)	AHD (m)	W/L drop (mm)	Inst. Seepage Rate (mm per hour)	Ave seepage loss (mm/hr)	Volume in channel cub m	Cum. volume Lost m^3	Inst. Rate of water loss m^3/hr	Average water loss rate m^3/hr
9.30	9.50	11.1	10.524				79.2			
11.15	11.25	11.079	10.503	-21	12.0	12.0	72.2	7.0	4.0	4.0
13.23	13.38	11.05	10.474	-29	13.6	12.9	63.0	16.2	4.3	4.2
14.47	14.78	11.038	10.462	-12	8.6	11.7	59.9	19.3	2.5	3.7
17.27	17.45	11.01	10.434	-28	10.5	11.3	52.0	27.2	2.8	3.4
31.16	31.27	10.84	10.264	-170	12.3	11.9	10.1	69.1	3.0	3.2

Trial Section 2 Beggs

Base case - No bentonite Added

Time (hrs)		Gauge Elevation (m)	AHD (m)	W/L drop (mm)	Inst. Seepage Rate (mm per hour)	Ave seepage loss mm	Volume in channel m^3	Cum. volume Lost in cub m. m^3	Inst. Rate of water loss m^3/hr	Average water loss rate m^3/hr
Top of gauge		14.015	18.531							
11.36	11.60	13.715	18.231				72.1			
11.48	11.80	13.704	18.220	-11	55.0	55.0	69.0	3.1	15.5	15.5
12.12	12.20	13.680	18.196	-24	60.0	58.3	62.3	9.8	16.8	16.3
12.45	12.75	13.669	18.185	-11	20.0	40.0	59.3	12.8	9.1	11.1
13.25	13.42	13.651	18.167	-18	27.0	35.2	54.6	17.5	5.9	9.6
14.30	14.50	13.620	18.136	-31	28.6	32.8	46.8	25.3	7.4	8.7
15.00	15.00	13.610	18.126	-10	20.0	30.9	44.4	27.7	3.4	8.1
16.05	16.08	13.579	18.095	-31	28.6	30.3	37.2	34.9	6.9	7.8
16.15	16.25	13.570	18.086	-9	54.0	31.2	35.1	37.0	21.0	8.0
16.35	16.58	13.564	18.080	-6	18.0	30.3	33.8	38.3	6.5	7.7
17.45	17.75	13.534	18.050	-30	25.7	29.4	27.3	44.8	5.9	7.3
20.15	20.25	13.475	17.991	-59	23.6	27.7	15.9	56.2	4.2	6.5

Trial 1 50 tonnes per ha. Bentonite Added

Time (hrs)		Gauge Elevation (m)	AHD (m)	W/L drop (mm)	Inst. Seepage Rate (mm per hour)	Ave seepage loss (mm)	Volume in channel m^3	Cum. volume Lost in cub m. m^3	Inst. Rate of water loss m^3/hr	Average water loss rate m^3/hr
8.41	8.68	13.692	18.208				65.6			
8.52	8.87	13.685	18.201	-7	38.2	38.2	63.9	1.7	9.3	9.3
9.07	9.12	13.675	18.191	-10	40.0	39.2	61.0	4.6	11.6	10.6
11.50	11.83	13.59	18.106	-85	31.3	32.4	39.7	25.9	8.8	8.2
13.30	13.50	13.549	18.065	-41	24.6	29.7	30.5	35.1	5.1	7.3
15.55	15.92	13.49	18.006	-59	24.4	27.9	18.7	46.9	5.2	6.5

Trial 2 50 tonnes per ha. Bentonite Added several days later

Time (hrs)		Gauge Elevation (m)	AHD (m)	W/L drop (mm)	Inst. Seepage Rate (mm per hour)	Ave seepage loss (mm)	Volume in channel cub m	Cum. volume Lost in cub m. m^3	Inst. Rate of water loss m^3/hr	Average water loss rate m^3/hr
11.21	11.35	13.719	18.235				73.3			
12.32	12.53	13.64	18.156	-79	66.8	66.8	51.8	21.5	18.2	18.2
14.30	14.50	13.555	18.071	-85	43.2	52.1	31.8	41.5	10.2	13.2
15.30	15.50	13.51	18.026	-45	45.0	50.4	22.5	50.8	9.3	12.2
16.30	16.50	13.47	17.986	-40	40.0	48.3	15.0	58.3	7.5	11.3
17.00	17.00	13.45	17.966	-20	40.0	47.6	11.5	61.8	5.0	10.9

Trial Section 2A Beggs Clay Trial

Trial 3 Clay added equivalent to 150mm layer at $70 per lineal metre

Time (hrs)		Gauge Elevation (m)	AHD (m)	W/L drop (mm)	Inst. Seepage Rate (mm per hour)	Ave seepage loss (mm)	Volume in channel cub m	Cum. volume Lost in cub m. m^3	Inst. Rate of water loss m^3/hr	Average water loss rate m^3/hr
11.21	11.35	12.035	18.267				50			
12.32	12.53	12.01	18.242	-25	21.1	21.1	45.6	4.4	3.7	3.7
14.30	14.50	11.99	18.222	-20	10.2	14.3	42.5	7.5	1.6	2.4
15.30	15.50	11.975	18.207	-15	15.0	14.5	40.2	9.8	2.3	2.4
16.30	16.50	11.965	18.197	-10	10.0	13.6	38.7	11.3	1.5	2.2
17.00	17.00	11.96	18.192	-5	10.0	13.3	38.0	12.0	1.0	2.1
17.30	17.50	11.955	18.187	-5	10.0	13.0	37.2	12.8	2.7	2.1
19.00	19.00	11.94	18.172	-15	10.0	12.4	35.1	14.9	1.2	1.9
33.30	33.50	11.86	18.092	-80	5.5	7.9	24.5	25.5	0.7	1.2
44.00	44.00	11.83	18.062	-30	2.9	6.3	20.9	29.1	0.3	0.9
60.00	60.00	11.81	18.042	-20	1.2	4.6	18.5	31.5	0.2	0.6

Trial Section 3 Hancock

Base case - No bentonite Added

Time		Gauge Elevation	AHD	W/L drop	Inst. Seepage Rate	Ave seepage loss	Volume in channel	Cum. volume Lost in cub m.	Inst. Rate of water loss	Average water loss rate
hrs		m	m	(mm)	(mm per hour)	mm	m^3	m^3	$metres^3/hr$	$metres^3/hr$
Top of gauge		13.31	22.035							
14.27	14.45	12.708	21.433				70.8			
15.13	15.22	12.698	21.423	-10	13.0	13.0	67.7	3.1	4.0	4.0
15.49	15.82	12.692	21.417	-6	10.0	11.7	63.8	7.0	6.5	5.1
17.07	17.12	12.678	21.403	-14	10.8	11.3	60.8	10.0	1.9	3.8
17.55	17.92	12.67	21.395	-8	10.0	11.0	59.1	11.7	3.5	3.4
18.58	18.97	12.66	21.385	-10	9.5	10.6	56.4	14.4	2.6	3.2
20.00	20.00	12.648	21.373	-12	11.6	10.8	52.1	18.7	3.0	3.4
21.18	21.30	12.636	21.361	-12	9.2	10.5	49.5	21.3	2.2	3.1
22.37	22.62	12.624	21.349	-12	9.1	10.3	46.4	24.4	2.6	3.0
24.50	24.83	12.6	21.325	-24	10.8	10.4	39.7	31.1	3.1	3.0
32.00	32.00	12.532	21.257	-68	9.5	10.0	22.4	48.4	2.3	2.8
33.18	33.30	12.524	21.249	-8	6.2	9.8	21.1	49.7	1.1	2.6

Trial 1 Bentonite Added

Time		Gauge Elevation	AHD	W/L drop	Inst. Seepage Rate	Ave seepage loss	Volume in channel	Cum. volume Lost in cub m.	Inst. Rate of water loss	Average water loss rate
hrs		m	m	(mm)	(mm per hour)	mm	m^3	m^3	$metres^3/hr$	$metres^3/hr$
9.56	9.93	12.711	21.436				71			
10.13	10.22	12.702	21.427	-9	31.8	31.8	69.3	1.7	6.0	6.0
11.37	11.62	12.686	21.411	-16	11.4	14.9	62.8	8.2	4.6	4.9
13.30	13.50	12.664	21.389	-22	11.7	13.2	57.3	13.7	2.8	3.8
15.10	15.17	12.648	21.373	-16	9.6	12.0	52.1	18.9	2.9	3.6
16.53	16.88	12.628	21.353	-20	11.7	11.9	47.5	23.5	3.2	3.4
17.35	17.58	12.62	21.345	-8	11.4	11.9	45.3	25.7	2.7	3.4
18.21	18.35	12.61	21.335	-10	13.0	12.0	42.7	28.3	3.0	3.4
22.10	22.17	12.566	21.291	-44	11.5	11.9	31.2	39.8	3.0	3.3

Appendix C

Distribution Efficiency Calculations

Trial Section 1 – Andrews

Calculations				
Adopted Final Loss Rate		3.1	m3 per hour	
Channel Length		100.0	m	Test section
Final Loss rate per metre		0.03	m3/hour/lineal metre	
Wetted Perimeter		3.1	m	
Adopted final loss rate		10.2	mm/hour	
Channel Length		1000.0	m	
Volume Loss per Irrigation		31.0	m3/hour	
Assumed Water use per irrig.		200.0	mm	
Area Irrigated		34.75	ha	Bays 695m long
Water used per irrig		70	ML	
Flow rate		7.1	ML/day	
Days to water area		9.86	days	
Seepage Loss over irrign. Cycle		7.34	ML	assumes entire channel wet for entire time
Distribution Efficiency		91%		
Real loss	2.00 sections	5.51	93%	Distribution Uniformity
Real Loss	3.00 sections	4.89	94%	Distribution Uniformity
real Loss	4.00 sections	4.59	94%	Distribution Uniformity
Real Loss	5.00 sections	4.08	95%	Distribution Uniformity

Trial Section 2 – Beggs

Calculations				
Adopted Final Loss Rate		6.5	m3 per hour	
Channel Length		53.0	m	
Final Loss rate per metre		0.12	m3/hour/lineal metre	
Wetted Perimeter		5.3	m	
Adopted final loss rate		23.1	mm/hour	
Channel Length		1500.0	m	
Volume Loss per Irrigation		183.9	m3/hour	over entire irrigation area
Assumed Water use per irrig.		200.0	mm	
Area Irrigated		40.0	ha	
Water used per irrig		80	ML	
Flow rate		15.6	ML/day	
Days to water area		5.1	days	
Seepage Loss over irrign. Cycle		22.63	ML	assumes entire channel wet for entire time
Distribution Efficiency		78%		
Real loss	2.00 sections	16.97	82%	Distribution Uniformity
Real Loss	3.00 sections	15.09	84%	Distribution Uniformity
real Loss	4.00 sections	14.14	85%	Distribution Uniformity
Real Loss	5.00 sections	12.57	86%	Distribution Uniformity

Trial Section 3 – Hancock

Calculations					
Adopted Final Loss Rate			2.6	m3 per hour	
Channel Length			77.0	m	test section
Final Loss rate per metre			0.03	m3/hour/lineal metre	
Wetted Perimeter			4.1	m	
Adopted final loss rate			8.3	mm/hour	
Channel Length			1630.0	m	
Volume Loss per Irrigation			55.8	m3/hour	
Assumed Water use per irrig.			200.0	mm	
Area Irrigated			38.0	ha	
Water used per irrig			76	ML	
Flow rate			12.5	ML/day	
Days to water area			6.08	days	
Seepage Loss over irrign. Cycle			8.14	ML	assumes entire channel wet for entire time
Distribution Efficiency			90%		
Real loss	2.00	sections	6.11	93%	Distribution Uniformity
Real Loss	3.00	sections	5.43	93%	Distribution Uniformity
real Loss	4.00	sections	5.09	94%	Distribution Uniformity
Real Loss	5.00	sections	4.52	94%	Distribution Uniformity

Appendix D

Pipe and Riser Trial – Economic Assessment

INPUT DATA			FARM: Alec Beggs		
Farm Enterprise	Sheep		Irrigations		
Gross Margin per hectare	300	$/hectare	Average no of waterings per year	14	
Area irrigated	40	hectares	Water use per irrigation	200	mm
Number of Bays	35		Annual water use	1120	ML
Average Area per bay	1.14	hectares			
System Flow Rate	15.6	ML/day	Channel Dimensions		
			Length of channel/pipe	1500	m.
Ongoing seepage loss rate	23.1	mm/hour	Bed width	3	m.
			Wetted perimeter	5.3	m.
Temporary market value of water	$ 120	$/ML	Overall Width	10	m.
Reduction factor for irrigated area	80	%(assumes not all saved land is used)	Wetted Channel factor	62.5	% (equivalent percent of channel length actually wet for the entire irrigation cycle)
			Channel Construction Cost	0	$/cubic metre
How to value water saved	v	t = temp sale v = gross margin value		0	$/lineal metre

New Channel		
Pad width	9	m
Pad height	0.25	m (ave.)

NOTE:
Assume existing channel with minor upgrade. Minimal construction cost.
Add 2 channel stops to allow for channel to be irrigated in sections. Means that only 68% of potential maximum seepage is lost
Pumping costs not included, only extra cost to cover losses in pipeline

D1: Section 1

New Channel or improved channel (Assumption is that there are no new works)

Channel

Channel capacity	15.6	ML/day
Bed Width	3	
Channel Length	1500	m
Fill per length	2.25	m^3/m
Fill required	1458.6	m^3
Estimated earthworks cost	$ -	

Bay Outlet Sizing and Cost, Channel Checks

	Number	Cost	Installation	Total
Bay outlets	0	$ 400	$ 300	$ -
Channel Stops	0	$ 700	$ 400	$ -
Crossings	0	$ 1,200	$ 800	$ -
Fencing	0	$ 2	$ -	$ -
Other				$ -
Total Structures Cost				0

Channel Construction Cost. **$ -** **[A]**

D2: Section 2

New Channel Ongoing Cost Estimation

Channel Spraying

Channel Spraying (contractor) @	$ 100.00	per km
Channel length	1.5	km
Cost per spraying	$ 150.00	
Sprays per year	3	
Total Annual Spraying Cost	$ 450.00	

Channel Desilting

Estimated Deposition rate	2	cm/year
Channel length	1.5	km
Deposition Volume	60	m^3/km
Excavtion cost	$ 1.50	per m^3
Total Annual desilting Allowance	$ 90.00	
Other Ongoing Channel Costs	$ -	specify here

Total Annual Costs
For Channel System **$ 540.00** **[B]**

D3: Section 3
Pipe and Riser Installation Cost Estimations

Pipeline Cost
(Price per metre will vary with pipeline length. Allow extra for freight)

Size	Length	Laid price $/m	Cost ($)	Risers (No.)	Installed Price ($/m)	($)	Cost
250		38	0		650	0	0
280		47	0		700	0	0
315	200	52	10400	35	800	28000	38400
355	250	65	16250		900	0	16250
400	1000	79	79000		950	0	79000
450		100	0		1000	0	0
TOTAL	1450		105650	35		28000	$133,650
				Contingency Margin		20%	$ 26,730

ESTIMATED TOTAL PIPE AND RISER COST $160,380

D4: Section 4
Pump Station Costs

	Cost per unit	No.	Total
Pump Cost (Axial Flow with turbine impeller)	4000	1	4000
100mm Pump Well, 2.00 m deep			0
630mm inlet pipe with trash guard 6.0m long	2027	1	2027
2 Flanges, 2 backing rings and a breather	900	1	900
Galv. Iron Shed	800	1	800
Diesel Motor	6300	1	6300
Electric Motor	3600		0
Flow Meter	7000		0
2 flanges, 2 backing rings and one way valve			0
(only if outlets above pump)			0
250mm	1230.9	0	0
280mm	1337.6	0	0
315mm	1647.8	0	0
400mm	2301.2	1	2301.2
450mm	3907.8	0	0
Pump Site Total			$ 16,328
include costs additional to those required to set up a reuse pump.			
Any additional Costs (Installation)			
Total Pump Station Costs			16328.2

Pump, Pipe and Riser Installation Costs $176,708 [C]

D5: Section 5
Pipe and Riser Ongoing Cost and Savings Estimation

Annual Pump Replacement Allowance

Allows for replacement every 5 years	Allowance/unit	Number	Pump Replacement Allowance
Diesel Motor	$ 1,260	1	$ 1,260
Electric Motor	$ 960	0	$ -
			$ 1,260

Other maintenance

Estimated Percentage of total Pump, pipe and riser installation cost	2%	%
Total	3,534.16	

Pumping Costs

Irrigated Area	40	ha.
Annual Water use per hectare	28	ML/ha
Annual Water use	1120	ML

Annual Pumping Cost

PUMP OPERATING COSTS

Annual Drainage/Irrigation Pumped

Volume :	**28.00**	ML/Ha per annum
Flow Rate	15.6	ML/day

Pump No.	Pump Type & Size	Catch't Area (Ha)	Head at Pump (m)	Flow Rate (L/s)	Pump Effic'y (%)	Motor Effic'y (%)	Drive Effic'y (%)
Electric		40	6	180.56	80	91	95
Diesel		40	6	180.56	80	50	95

Power supply system used D (enter either E for electricity or D for diesel motor)

Total Annual Ongoing Pipe and Riser Costs	**$ 21,134**	**[D]**	(Replacement, maintenance and power costs)

Joins table below

Joins from table above

Electricity Costs:

Annual Service Charge :	**$ 170.00**	per annum
Off-Peak Charge :	**$ 0.033**	per KWh
Peak Charge :	**$ 0.210**	per KWh

Diesel Fuel Cost	**$ 1.000**	per litre
	(0.35L per kWhr)	

Annual Pumped Volume (ML/Yr)	Annual Pump Operating Time (Hrs)	Power Required (KW)	Annual Power Required (KWh)	Off-Peak Portion (elec) (KWh)	Peak Portion (elec) (KWh)	Total Annual Operating Cost
1120	1723.1	14.9	25651.8	13338.95	12312.9	$ 3,195.89
1120	1723.1	27.1	46686.3			$16,340.21

Increased production from Extra land Available

Channel Length	1500	m	
Channel width	10	m	(area from outside toe to outside toe)
Extra Area for production	1.2	hectares reduced by factor, not all saved area irrigated	
Extra water required to irrigate	33.6	ML per annum	
Extra Revenue from Production			Gross Margin Analysis
Enterprise	Lambs	300	$/ha
Extra Gross margin from area		$ 360	per annum

Value of Water saved (reduced distribution losses)

Permeability rates	23.1	mm/hr				
Wetted width of channel	5.3	m				
Wetted area channel	7950	sq. m				
Total annual volume	1120	ML				
No of irrigations	14					
Flow rate	15.6	Ml/day				
Channel wetted time	5.1	days		Adjusted Figures		
Seepage losses	22.60	ML		14.13	Adjusted Seepage loss by changed management or not all channel wetted for entire cycle	
Annual Seepage Losses	316.43	ML		197.77	Adjusted annual rate as above	
Distribution Efficiency	0.72			0.82		
Extra hectares that could be watered	10.10	ha		5.86	Seepage loss is reduced by the extra water required to irrigate area saved	
Value of water saved			(x)	$ 1,759	$ per year	Area saved at the enterprise gross margin
Value of Water saved on the Temp market			(y)	$ 23,733	$ per year	

If x>y then use water, if y>x then sell water (if allowable)

Option used in NPV, Sale value or gross margin value	$ 1,759

Increased Productivity from Better Irrigation practices

Estimated Increase in production	10	%	Might be justified with variable soil types
Irrigated Area	40	hectares	
Current Gross Margin on area	$ 12,000	$ per year	
Extra GM	$ 1,200	$ per year	

Labour Savings

Number of bays	35		
Time spent per Bay	35	minutes	
Time saved per irrigation	20.42	hours	
Time saved per year	285.8	hours	
Labour and vehicle cost	30	$ per hour	
% Labour Saved	15	% (assume say 30% time saved - less effort to change bays!)	
Total labour savings	$ 1,286	per year	**[L]**

Other Savings

TOTAL ANNUAL SAVINGS

Increased production from Extra land Available	$ 360	
Value of Water saved (reduced distribution losses)	$ 1,759	
Increased Productivity from Better Irrigation practices	$ 1,200	
Labour Savings	$ 1,286	
Other Savings	0	
TOTAL	**$ 4,605**	**[E]**

D6: SECTION 6 AUTOMATION INSTALLATION COSTS

Riser Size	Number	Cost/Unit	Cost
Base Station	1	$ 5,900	$ 5,900
Risers	20	$ 1,252	$ 25,040
Wheels	1	$ 1,765	$ 1,765
Pump (Electric)	0	$ 750	$ -
Pump (Diesel)	1	$ 2,700	$ 2,700

Automation Cost	$ 35,405	**[T]**
Set Up costs for pipe and riser	$176,708	**[C]**
Any additional set up costs		
TOTAL AUTOMATED PIPE AND RISER	**$212,113**	**[F]**

Automation Ongoing Cost Estimation

Suggested 2% of the total automation installation cost as an estimate of ongoing maintenance costs

Allowance	2	%
Automation maintenance Allowance	$ 708	
Pipe and riser ongoing costs	$ 21,134	**[D]**
TOTAL ONGOING COST	**$ 21,842**	**[G]**

Automation Ongoing savings Estimation

As for pipe and riser , but also includes further labour savings

AS for Item L above (Labour Saved) but assume a further time saving. Still allow for say 5 minutes per bay to check system operation occasionally.

Number of bays 35

Time spent per bay	5	minutes
Total time spent per Irrig	100	minutes
Total time spent per year	23.33	Hours
Labour and Vehicle hire rate	$ 30	per hour
Cost of Labour	$ 700	per year
Labour Cost for Open channel	$ 8,575	per year

Labour saving for fully automated system	**$ 7,875**	**per year**	
Labour saving for manual pipe and riser only	**$ 1,286**	**per year**	
Extra saving for automation above P&R	$ 6,589	**per year**	**[X]**
TOTAL ONGOING AUTOMATION SAVING	**$ 11,194**	**[H]=[E]+[X]**	Includes pipe and riser savings plus extra labour savings due to automation

Section 6
Summary and Economic Analysis

System	New Channel		Pipe and riser		Automated Pipe and riser	
Start up Cost	$ -	[A]	$176,708	[C]	$212,113	[F]
Annual Ongoing Costs	$ 540	[B]	$ 21,134	[D]	$ 21,842	[G]
Annual Savings			$ 4,605	[E]	$ 11,194	[H]

<u>Comparison table - Compared to constructing a new channel system</u>

	Pipe and riser		Automated Pipe and riser	
Additional Start up Cost	$176,708	[C-A]	$212,113	[F-A]
Additional Savings less costs	- 15,989	[E+B-D]	- 10,108	[H+B-G]

<u>Economic Analysis</u>

Payback period is determined using net present value analysis(NPV)

Interest rate	8	%	
Inflation rate	2	%	
Discount rate	6	%	(Difference between interest and inflation)
Return Period	20	years	(The life of the project - for farming can be 15 to 20 years)

NPV MANUAL PIPE AND RISER vs CHANNEL	YEAR	CAPITAL COST $	OPERATING COST $	MAINT. COST $	TOTAL COST $	RETURNS or net annual benefit $	NET CASH FLOW	DISCOUNT FACTOR 8%	P.V. @8%	NPV
	1	$176,708			176708	-$ 15,989	-$192,697	1.000	-192697	-192697
	2				0	-$ 15,989	-$ 15,989	0.926	-14805	-207502
	3				0	-$ 15,989	-$ 15,989	0.857	-13708	-221210
	4				0	-$ 15,989	-$ 15,989	0.794	-12693	-233903
	5				0	-$ 15,989	-$ 15,989	0.735	-11752	-245655
	6				0	-$ 15,989	-$ 15,989	0.681	-10882	-256537
	7				0	-$ 15,989	-$ 15,989	0.630	-10076	-266613
	8				0	-$ 15,989	-$ 15,989	0.583	-9330	-275943
	9				0	-$ 15,989	-$ 15,989	0.540	-8638	-284581
	10				0	-$ 15,989	-$ 15,989	0.500	-7999	-292580
	11				0	-$ 15,989	-$ 15,989	0.463	-7406	-299986
	12				0	-$ 15,989	-$ 15,989	0.429	-6857	-306843
	13				0	-$ 15,989	-$ 15,989	0.397	-6350	-313193
	14				0	-$ 15,989	-$ 15,989	0.368	-5879	-319072
	15				0	-$ 15,989	-$ 15,989	0.340	-5444	-324516
	16				0	-$ 15,989	-$ 15,989	0.315	-5040	-329556
	17				0	-$ 15,989	-$ 15,989	0.292	-4667	-334223
	18				0	-$ 15,989	-$ 15,989	0.270	-4321	-338545
	19				0	-$ 15,989	-$ 15,989	0.250	-4001	-342546
	20				0	-$ 15,989	-$ 15,989	0.232	-3705	-346251
	TOTAL	**$176,708**	**$0**	**$0**	**$176,708**	**($319,783)**	**($496,491)**		**($346,251)**	

NPV AUTOMATED PIPE AND RISER vs CHANNEL	YEAR	CAPITAL COST $	OPERATING COST $	MAINT. COST $	TOTAL COST $	RETURNS or net annual benefit $	NET CASH FLOW	DISCOUNT FACTOR 8%	P.V. @8%	NPV
	1	$212,113			212113	-$ 10,108	-$222,222	1.000	-222222	-222222
	2				0	-$ 10,108	-$ 10,108	0.926	-9360	-231581
	3				0	-$ 10,108	-$ 10,108	0.857	-8666	-240248
	4				0	-$ 10,108	-$ 10,108	0.794	-8024	-248272
	5				0	-$ 10,108	-$ 10,108	0.735	-7430	-255702
	6				0	-$ 10,108	-$ 10,108	0.681	-6880	-262582
	7				0	-$ 10,108	-$ 10,108	0.630	-6370	-268952
	8				0	-$ 10,108	-$ 10,108	0.583	-5898	-274850
	9				0	-$ 10,108	-$ 10,108	0.540	-5461	-280312
	10				0	-$ 10,108	-$ 10,108	0.500	-5057	-285368
	11				0	-$ 10,108	-$ 10,108	0.463	-4682	-290051
	12				0	-$ 10,108	-$ 10,108	0.429	-4335	-294386
	13				0	-$ 10,108	-$ 10,108	0.397	-4014	-298400
	14				0	-$ 10,108	-$ 10,108	0.368	-3717	-302117
	15				0	-$ 10,108	-$ 10,108	0.340	-3442	-305559
	16				0	-$ 10,108	-$ 10,108	0.315	-3187	-308745
	17				0	-$ 10,108	-$ 10,108	0.292	-2951	-311696
	18				0	-$ 10,108	-$ 10,108	0.270	-2732	-314428
	19				0	-$ 10,108	-$ 10,108	0.250	-2530	-316957
	20				0	-$ 10,108	-$ 10,108	0.232	-2342	-319300
	TOTAL	**$212,113**	**$0**	**$0**	**$212,113**	**($202,170)**	**($414,283)**		**($319,300)**	