Construction and Operating Costs of Groundwater Pumps for Irrigation in the Riverine Plain

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Cover Photograph:

Where Bore on Ray Zanatta's Denimein farm
Photograph by Liz Humphreys

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Executive Summary

The use of groundwater as a water source for irrigation is increasing as surface water supplies are becoming fully utilised and increasing in value which has made the pumping of groundwater an attractive alternative. This report provides a summary of the installation, capital and operating costs of groundwater pumping systems for irrigation and salinity control.

Essentially there are two types of groundwater pumping systems used for the purpose of irrigation - bores and spearpoint. Bores are used to pump groundwater from aquifers to supplement surface water supplies whereas spearpoint systems pump groundwater from shallow watertables and are mainly used for salinity and waterlogging control but can also supplement irrigation supply depending on the quality of the groundwater.

The implementation of a groundwater pumping system by farmers will ultimately depend on its financial viability. The cost of setting up a pumping system can vary significantly between farms depending on the bore's intended purpose, hydrological conditions, groundwater quality, location to electrical power and disposal options. The siting, design, materials and construction method used in installing a bore are other factors that also influence cost but also have an impact on the quantity and quality of water obtained.

The capital cost of purchasing and installing a spearpoint system to pump a shallow watertable can vary from approximately $18,000 to $70,000. The high range can be attributed to the variability of spearpoint design, pumping capacity, depth of wellpoints, engine type, proximity to electric power and water discharge area and the cost of a geo-technical investigation.

The capital cost of purchasing and installing a shallow bore is variable with a range similar to spearpoint systems. A deep bore will range from approximately $90,000 to $320,000. The capital cost of purchasing and installing a bore will vary depending on pumping capacity, bore depth, system design, materials used, engine type, proximity to electric power and water discharge area. The major cost components of a bore are drilling (including test hole), bore casing and screens, bore development, pump, motor, power connection and installation costs.

The variable or running costs of groundwater pumping systems includes power costs, maintenance costs on the pump and motor and depreciation. The running costs of an electric powered pumping system is less than a diesel powered system because of lower power and maintenance costs. Power line extension is expensive therefore if power connection costs are relatively low compared to the total capital cost of the pumping system, an electric powered pumping system is more cost efficient than a diesel powered system to pump groundwater.

Before installing a groundwater pumping system it is advisable that a financial feasibility study is undertaken to assess whether a groundwater pump is a viable and worthy investment over a time frame equivalent to the effective life of the investment. The analysis should include a comparison of the different pumping system designs and alternative power sources available to determine which pumping design is the most cost efficient over its effective life.

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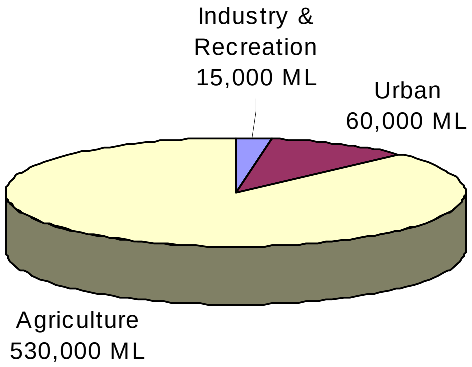
1 Introduction

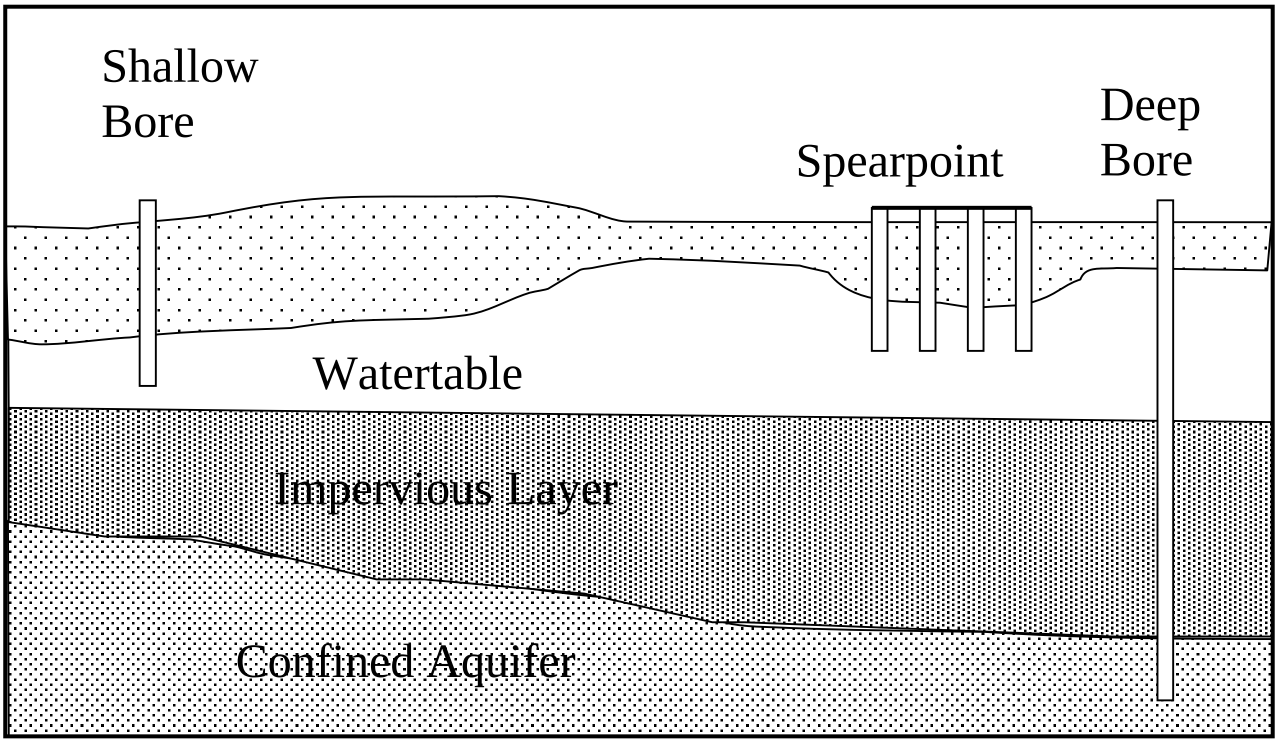
Some twenty per cent of Australia's water use is from groundwater sources (Agriculture and Resource Management Council of Australia and New Zealand, 1997). Agriculture is the main use of groundwater, which accounts for 88% of total groundwater use in NSW (Figure 1) (University of NSW Groundwater Centre, 2001). The use of groundwater as a water source is increasing as surface water supplies are becoming fully utilised and increasing in value which has made the pumping of groundwater an attractive alternative.

Figure 1 Groundwater Usage in NSW



Essentially there are two types of groundwater pumping systems used for the purpose of irrigation - bores and spearpoint. Bores are used to pump groundwater from aquifers to supplement surface water supplies whereas spearpoint systems pump groundwater from shallow watertables and are mainly used for salinity and waterlogging control but can also supplement irrigation supply depending on the quality of the groundwater (Figure 2).

Figure 2 Schematic of Groundwater Pumping Systems



Groundwater is generally of lower quality than surface water i.e. groundwater has higher salinity and dissolved minerals. Depending on the quality of the groundwater and the salt tolerance level of crops, the groundwater may have to be shandied with low-salinity surface water before it is safe to be used as an irrigation supply (i.e. the 'conjunctive use' of groundwater with surface supplies). If the groundwater is of poor quality and the level of conjunctive use is limited, it will need to be disposed of. The main methods of disposal include on-farm or off-farm evaporation basins, drainage to rivers or to low-lying depressions that act as discharge areas. However, due to increasing concerns about river water quality and the riverine environment, disposal to rivers is becoming less acceptable and is preferably done during high river flows.

There are many factors to consider before deciding on an appropriate groundwater pumping system (Figure 3). The implementation of a groundwater pumping system by farmers however, will ultimately depend on its financial viability. The cost of setting up a pumping system can vary significantly between farms depending on the pumping system's intended purpose, hydrological conditions, groundwater quality, location to electrical power and disposal options. The siting, design, materials and construction method used in installing a bore are other factors that also influence cost but also have an impact on the quantity and quality of water obtained. This report will outline and provide estimates of the various costs associated with installing a groundwater pumping system and their associated running cost to aid in the decision making process of deciding which system will be the most cost efficient.

Figure 3 Summary of considerations when selecting a pump type

TECHNICAL

- Maximum groundwater yield
- Required groundwater yield
- Required pumping period

PRACTICAL

- Accessibility
- Proximity to power supplies
- Corrosive nature of water
- Maintenance period

FINANCIAL

- Capital cost of pumps
- Capital cost of power supply
- Pump life expectancy
- Pumping and operational costs
- Repairs and maintenance costs

Source: Sinclair Knight Mertz (2001)

2 Types of Groundwater Pumps

There are several different types of groundwater pumps that consist of specific configurations, some of which limit their use in certain situations:

(i) Centrifugal - a suction lift pump which only has a practical suction head capacity of up to 7 metres (depending on the pump selection) and therefore can only be used for shallow groundwater pumping. Pumping capacity of surface centrifugal pumps range from 1L/s to 10L/s.

(ii) Submersible - are mainly used in shallow bores where a vertical centrifugal pump coupled with an electric motor is submerged below the water level within the bore casing and is powered by an electric cable running from the surface. The pumping capacity of submersible pumps has a high range from less than 1L/s to over 100L/s.

(iii) Well turbine - a submerged vertical centrifugal pump driven through a rotating shaft connected to a motor at the surface. They are best for extracting large amounts of water and are used in shallow and deep bores. The pumping capacity of turbine pumps has a high range from 1L/s to over 100L/s.

(iv) Air lift - two pipes lie below the groundwater inside a well where one pipe delivers compressed air which forces groundwater up the other pipe, delivering it to the land surface. Air lift pumps can be useful when power is remote from the well, as the compressed air can be delivered to the well through plastic piping and where the groundwater is corrosive to pump parts. Air lifting is inefficient and is generally limited to shallow pumping. The pumping capacity of air lift pumps has a low range from 0.05L/s to 2L/s.

Air lift pumping systems are not widely used and therefore their associated costs have not been included in this report, however with increasing diesel costs an air lift pump maybe a viable alternative for salinity control in areas where the pumping requirement is low.

3 Groundwater Pumping Systems

3.1 Spearpoint

Within the irrigation districts of Australia, rising watertables and increasing soil salinity are undermining the sustainability of irrigated agriculture. When the watertable is shallow[1], capillary flows from the watertable accumulate salts in the restricted root zone which increases soil salinity and causes yield declines to salt sensitive crops. Shallow groundwater pumping using spearpoint systems is an on-farm subsurface drainage option to help alleviate these problems and can possibly reclaim salt affected soils.

A spearpoint system is a series of screened bores (spears) connected to either a centrifugal or airlift pump by an interconnecting header line. A battery of spears spread over a small area has the potential to provide larger supplies of groundwater. The screen is fitted with a spear point which is conical in shape to help the spear arrangement penetrate the soil and sand. The spear assembly can be installed by:

- Using high pressure water jetting to remove material while the spear assembly is lowered into the hole
- Placing the spear assembly down a drilled hole
- Driving the spear assembly into the water bearing material with a pile driver

A spearpoint system is used to pump shallow groundwater from subsurface formations that have adequate permeability within the Upper Shepparton layer, such as shallow alluvial sands and old prior streams. Most spearpoint systems use centrifugal pumps which have a maximum pumping head of 7 metres. The depth to the spearpoint screens will vary between farms depending on the depth of the permeable formation but will generally be between 5 to 10 metres from the soil surface. A spearpoint system has a direct influence on the watertable level where these permeable formations exist and therefore assist in the protection of farms from rising watertables and the effects of waterlogging and salinity. The area of influence of the groundwater pump is determined by the hydraulic conductivity of the permeable formations. For example, within the Coleambally Irrigation Area (CIA) the Shepparton layer consists of variable proportions of sands, silts and clay with an average hydraulic conductivity of 1.4 to 1.8m/day (Khan et al, 2000). Pumping volume will depend on the size and conductivity of the permeable formations and spearpoint design but will generally range from 0.5 to 4 ML/day.

Groundwater pumping is required during the irrigation season to lower the shallow watertable, and coupled with irrigating, the process of leaching salts past the root zone into the deeper soil profile is enhanced. Due to the better drainage and leaching processes, waterlogging and soil salinity declines and therefore crop yields which are sensitive to waterlogging and salinity will improve[2].

If the groundwater is of reasonable quality, there is the potential for this water to be shandied with channel water and used for irrigation. The level of conjunctive use of groundwater on each farm will depend on the quality and quantity of groundwater, farm allocation (surface water), rainfall and the capability of the farm's recycling system.

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[1] A shallow watertable is defined as one that is less than 2 metres from soil surface.

[2] Crops become sensitive to waterlogging and salinity at different threshold levels

If the level of conjunctive use is limited due to the poor quality of the groundwater, the saline groundwater will need to disposed of in either an on-farm evaporation basin or through a district disposal method via the use of district drains.

3.2 Bore

A typical bore pump arrangement consists of a pump assembly suspended from the bottom of a pipe column, which is attached to a discharge head at the top of the bore (Figure 3). The pipe column becomes the water delivery line and the only thing that varies with each facility is the type of pump, the position of the motor and the drive mechanism.

Bore depths will vary depending on the intended function of the bore. Shallow bores are generally used for pumping from shallow watertables for salinity control purposes and may also supplement irrigation supply depending on the salinity of the groundwater whereas deep bores are mainly installed for irrigation supply.

3.2.1 Shallow bore

Primarily, a shallow bore[3] is used to pump groundwater from the watertable within the Shepparton layer (10 to 30 metres). Where a spearpoint system is not possible, a bore can be installed to pump from shallow watertables that exist in permeable formations that have high conductivity and therefore can aid in controlling watertable depth and consequently soil salinity. Shallow bores that screen deep watertables (i.e. greater than 5m from soil surface) are usually installed to supplement irrigation supply.

If an area affected by salinisation is large, a multiple bore arrangement can be implemented. This is where several bores are spaced close enough to pump the required amount of groundwater to provide a reasonably even drawdown of the watertable over a certain area. A good example of this is the Wakool Scheme which has 54 pumps connected to over 100 shallow bores (with average pumping depth of 12 metres) that aid in controlling the watertable below 1.5 metres over an area of 52,000 hectares of farming land. The average pumping rate is 1.25 ML/day and have an average area of influence of 1.5 kilometres from each pump (Christen et al., 2000).

Shallow bores are low yielding bores compared to deep bores (ie less than 10 ML/day). Pump configurations on shallow bores include turbine or shaft driven, submersible and air lift.

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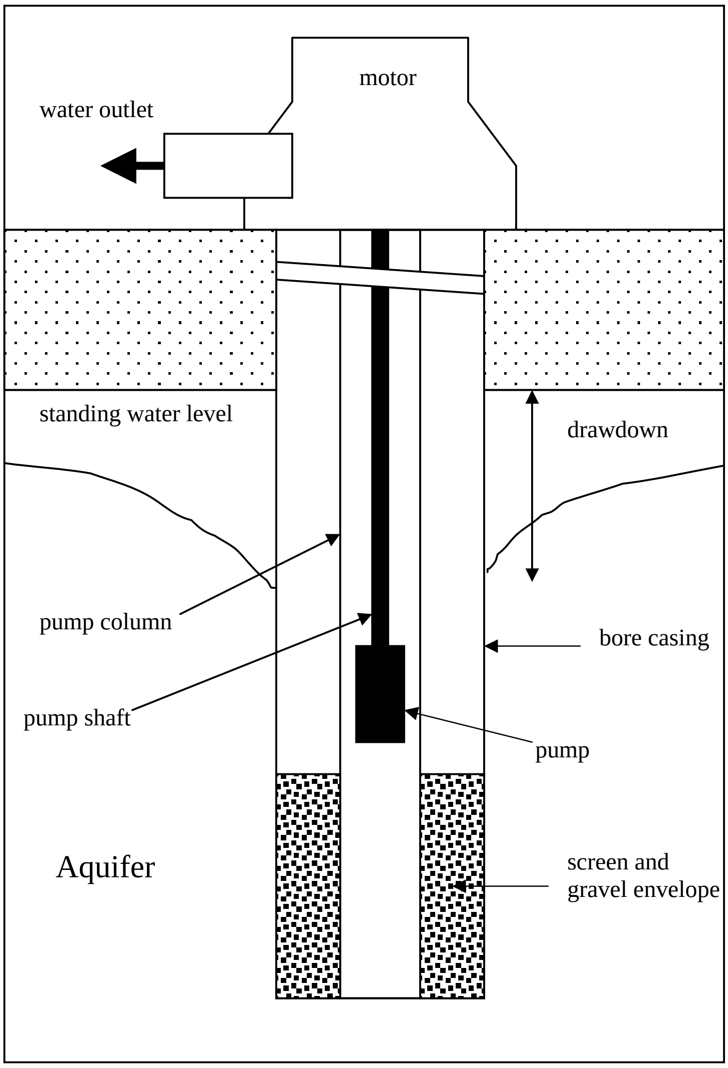
[3] In some literature a shallow bore is referred to as a tubewell however, all pumping configurations that encompass a pump and suction pipes are tubewells (i.e. bores and spearpoints).

Figure 4 Turbine pump installation



3.2.2 Deep bore

A deep bore is used to pump groundwater from deep aquifers within the Calivil and Renmark layers (approximately 150 to 300 metres). Most deep bore are equipped with turbine pumps due to the high pumping head (30 to 50 metres) and high pumping capacity requirements (up to 30ML/day). The pumping capacity from deep bores depends on the hydraulic conductivity of these aquifers and is generally higher than in the Shepparton layer. For example, within the CIA, the Calivil layer consists of 50 to 70% sands, with an average hydraulic conductivity of 12 m/day and the Renmark layer consists of 30 to 50% sands, with an average hydraulic conductivity of 7 m/day (Khan et al, 2000). As these aquifers generally have better quality (less saline) water than the shallow aquifers and are high yielding, a deep bore becomes an attractive option for farmers who want to supplement their existing irrigation allocation, even though the capital cost is high.

4 Capital Cost of Groundwater Pumps

4.1 Spearpoint Systems

The capital cost of purchasing and installing a spearpoint system can vary from $18,000 to $70,000 (Appendix 1 to 3). This range can be attributed to the variability of spearpoint design, pumping capacity, depth of wellpoints, engine type, proximity to electric power[4] and water discharge area and the cost of a geo-technical investigation.

Before a spearpoint system can be installed, a geo-technical investigation is required to determine the most appropriate site for the pump. This may involve an EM 34 survey of the farm to identify where the permeable formations are below the soil surface. This is usually followed up by the installation of some test and observation wells in which pump tests are performed to identify the distance to standing water level, the level of drawdown and therefore the area serviced by the pump, potential yield of the wells and the quality of the groundwater. When pumping takes place, water is drawn down from the standing water level in a conical motion towards the well. The shape of the cone will vary with the permeability, porosity and the thickness of the water bearing zone.

The preferred site is then selected based on the geo-technical investigation, taking into account other location factors such as proximity to power supply, ease of connection to existing on-farm supply channel system, access to the pump site and the irrigation area that can be commanded from the site. The cost of the geo-technical investigation will vary depending on what existing hydrological information is available for the farm. For example, the site investigation cost in the Murray Valley are approximately $500 per farm which incorporates an EM survey and a pump test (Appendix 3) however, the site investigation costs for a farm in the Shepparton Irrigation Region (SIR) where minimal hydrological information exists can be as high as $14,000 (Table 1).

The major components that make up a spearpoint system include a number of suction pipes or "spears" which have a mesh screen attached to filter the water from the permeable layer. These are attached to the pump via a header line. Boundary constraints to the aquifer or prior stream will the influence the shape of the spearpoint network. For convenience they are usually spaced at 6 or 12 metres intervals to coincide with the standard length of PVC. The most efficient shapes are the circular or H patterns, which reduce overall frictional losses while pumping (Robertson, 1992). An outline on designing, constructing and equipping a spearpoint system is given in Robertson (1992).

The capital costs of the spearpoint system will vary depending on its design; the number and depth of spears, length of headerline, type of pump and motor. An example of capital and installation costs for an electric powered spearpoint system with a centrifugal pump in the SIR is illustrated in Table 2. The total cost for this spearpoint system was approximately $35,000. If this system was diesel powered, the total cost would be approximately $31,000 as the pump and motor cost on a diesel powered spearpoint system that has a pumping capacity up to 4 ML/day are approximately $5,000 to $10,000.

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[4] An electric powered pump will incur a power connection fee and may incur a cost of power line extensions, metering equipment and possibly a sub-station while a diesel pump will only requires a fuel tank.

Table 1. Example of Investigation Costs for a Private Salinity Control Pump in SIR

Activity	Notes	No.	Unit	Rate	Cost	Sub - Total
Stage 1 - EM 34						
EM34 survey	200m spacing	8	km	135	1080	1080
Assessment of first stage data		8	km	65	520	520
Stage 2 - more targeted drilling						
Planning drilling		2	hour	75	150	150
Specification of drilling		4	hour	65	260	260
Drilling	6 holes @ 12.5m	75	m	43	3225	3225
Gamma logging (determines sand layers)	staff	4	hour	65	260	
	vechicles	400	km	0.72	288	
	equipment	6	each	12.5	75	623
Water salinity analysis		6	each	8	48	48
Assessment of second stage data		2	hour	75	150	
		4	hour	65	260	410
Installation of wellpoints and monitoring bores						
Specification of wellpoints & additional monitoring bores		4	hour	65	260	260
	vechicles	100	km	0.72	72	72
Installation of wellpoints (class 9 - 100mm PVC pipe)	2 bores @ 12.5m	25	m	73	1825	1825
Pumptest						
3 day pumptest & monitoring	staff	24	hour	65	1560	
	vechicles	400	km	0.72	288	
	equipment	72	hour	12.5	900	2748
Water salinity analysis		20	each	8	160	160
Pumptest analysis for design yield		4	hour	65	260	260
Assessment of salinity and economic impacts						
Project report-agreed volume and salinity levels		8	hour	65	520	520
Project management		24	hour	46	1104	
		12	hour	75	900	2004
TOTAL PROJECT INVESTIGATION COSTS (2000 prices)						**$ 14,165**

Source: Goulburn Murray Water, December 2000

The total amount that the farmer pays to install a shallow groundwater pump to control the salinisation of agricultural land will depend on the type of subsidies available. For example, in the SIR, a landholder only has to pay $750 for the geo-technical investigation for a private shallow groundwater pump when the actual cost is approximately $14,000 and up to a maximum of 65% of the pump's total capital costs.

The SIR also has public pumps, which control soil salinity on several farms and generally pump groundwater that exceeds the conjunctive water use threshold limit of 5000 EC. This water is pumped into district drains where it is disposed of off-farm.

The cost of geo-technical investigation for public pumps increases significantly from a private pump to a cost of approximately $60,000 (Appendix 7) as a more thorough investigation is required to determine more accurately the area serviced by the pump and consequently which landholders are going to benefit from it and by how much. The total cost of a public groundwater pump usually exceeds $100,000 but is variable (Appendix 6). This is mainly attributed to the highly variable cost of geo-technical investigations and power connection between sites. Farmers who are serviced by the public pump do not pay for any of the pump's capital cost but pay for the operational costs (power, maintenance and depreciation) on a pro rata basis based on area of the farm that is serviced by the pump. The capital cost of public pumps in the SIR are fully subsidised by government grants.

Table 2 Example of Installation Costs for a Private Salinity Control Pump in SIR

Assumptions:

Rateable area	55.87 ha
Yield	0.7 ML per day
Suction head	7m
Wellpoints	4
Wellpoint diameter	100mm
Wellpoint depth	7.73 - 9.23 m
Depth to top of screen	3.7 - 5.0m
Header line (approx)	64.37m
Discharge line	20m

Activity	Notes	No.	Unit	Rate	Cost	Sub - Total
Prefabrication (shed, slab, fence etc)	shed & slab (6 x 2.4m)	1			2400	
	fencing	1			1000	
	conduits, other	1			500	3900
Pump and motor	8.1 L/s					3850
Water meter						407
Pump installation and miscellaneous						4613
Additional wellpoints	10 bores @ 12.5m	125	m	53	6625	6625
Header line fittings						885
Header line pipes	80mm class 12 uPVC	5	length	40	200	
	100mm class 12 uPVC	12	length	65	780	980
Header line bedding sand		20	m3	10	200	200
Header line installation	excavator	24	hour	65	1560	
	labour	48	hour	35	1680	
	vechicles	240	km	0.35	84	3324
Discharge line fittings						554
Discharge line pipes	50mm class 6 uPVC	1	length	25	25	
	80mm class 6 uPVC	3	length	40	120	145
Discharge line - other	Bedding sand	7	m3	10	70	
	Beaching	1			100	
	Slab	1			100	270
Discharge installation	excavator	5	hour	65	325	
	labour	5	hour	35	175	
	vechicles	160	km	0.35	56	556
Power connection	3 phase				5000	
Electrical cabinets, switching etc					2000	
Undergroud connection at site					1000	8000
Total Construction Cost						**$ 34,309**
Investigation and design						500
Construction support						500
Site commissioning						200
Total Spearpoint Installation Cost						**$ 35,509**
TOTAL PROJECT COST (includes investigation costs)						**$ 49,674**
Investigation Costs Paid by Farmer						$750
Spearpoint Installation Cost Paid by Farmer	65 % of total					$23,081
Spearpoint Subsidy						$25,843

Source: Goulbourn Murray Water, December 2000

4.2 Bores

The capital cost of purchasing and installing a bore will vary depending on pumping capacity, bore depth, system design, materials used, engine type, proximity to electric power and water discharge area. The major cost components of a bore are drilling (including test hole), bore casing and screens, bore development, pump, motor, motor protection gear, power connection and installation costs.

Shallow bore pumps have a similar range and variability in cost as spearpoint systems. A good example of the cost of installing a sub-surface drainage scheme for salinity control using a series of shallow bores is the proposed design and costing of Stage III of the Wakool Subsurface Drainage Scheme. The proposed scheme is designed to drain an area of 3,000-6,000 hectares from 12 bores (with an average depth of approximately 20 metres and equipped with submersible pumps) at a cost of approximately $4.2 million[5] over 30 years (Australian Water Environments, 2001). Each bore site's capital cost was approximately $89,000 which included $54,500 for bore construction, pump test, flowmeter, pump, motor and $34,500 for power connection.

Deep bore pumps can vary tremendously in price, from approximately $90,000 for a low volume and relatively shallow bore (i.e. 10 ML/day pumping capacity and bore depth of 140 metres) up to $320,000 for a high volume deep bore (i.e. 25 ML/day pumping capacity and bore depth of 300 metres)(Figure 4).

Drilling costs vary according to drilling method and the size of the bore and usually incorporate the cost of the initial test hole for deep bores. If the test hole was unsuccessful in finding a suitable aquifer, subsequent test holes will cost approximately $50 per metre.

Bores must be lined with an adequate length of casing to prevent the collapse of the strata penetrated and acts as a safe housing for any pump installed in the hole. The selection of the casing material is based on the following:-

- nature of strata
- water quality
- bore depth
- cost
- regulatory requirements

Bore casing costs will also vary depending on the bore depth and the material used i.e. steel, UPVC, ABS[6] and the amount of screen required. Steel casing is stronger and generally cheaper than the other materials but its effective life can be reduced in a corrosive environment. The UPVC and ABS bore casing is approximately twice the cost of steel, mainly due to the cost of fittings. The screens have an effective life in excess of 30 years, steel bore casing has an effective life in excess of 70 years while PVC and ABS is theoretically, indefinite (pers. comm. Rex Watson, 2001). There is technology available to be able to repair damaged screens but little can be done for damaged bore casing.

The pump and motor selection will vary depending on pumping capacity, power source and cost. Electric powered motors are generally cheaper than the diesel equivalents however they can incur a high cost of power line extension (Table 3).

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[5] The costs include capital and operational costs discounted at 7%

[6] Unplasticised Polyvinyl Chloride (PVC), Acrylonitrile Butadiene Styrene (ABS).

Table 3 Approximate Costs of Power Line Extension

Pump Power Requirements	< 90 kW	> 90 kW
High voltage power line per km	$15,000 - $20,000	$20,000 -$25,000
Sub-station (transformer)	$8,000	$15,000

Source: Great Southern Energy, 2001

A comparison of two deep bore construction and running costs with different design (due to production capacity) and power source is illustrated in Table 2. The diesel powered bores have a more expensive pump because they require a right angle gear box to drive the turbine pump and more expensive motors than the electric powered bores. The total capital cost of electric powered bores will depend on the cost of connecting the power to the motor. If power line extensions are required the total capital cost can increase significantly. In this example, the cost of power connection (1 km power line extension plus the installation of a 3 phase sub-station) has made the total capital cost of electric powered bores more expensive than diesel powered bores. The sensitivity of the bore's total capital cost to bore depth[7] and power connection costs is illustrated in Figure 4.

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[7] Assumes that the bore configuration remains unchanged except for the depth of the bore between the pump and the screens.

Table 4 Examples of Deep Bore Construction and Running Costs

Bore Type	20" x 16" bore	20" x 16" bore	12" x 9" bore	12" x 9" bore
Bore Depth (m)	220	220	140	140
Pumping Head (m)	45	45	30	30
Bore Yield (ML/day)	25	25	10	10
Pumping Days	70	70	70	70
Engine Type	Electric - 185kW	Diesel - Mitsibishi 190kw	Electric - 75 kW	Diesel - Perkins 70kw
Pump Type	Everflow Vertical Turbine Pump 350 FHH - 3 stage	Everflow Vertical Turbine Pump 350 FHH - 3 stage	Everflow Vertical Turbine Pump 250 FHH - 3 stage	Everflow Vertical Turbine Pump 250 FHH - 3 stage
Capital Costs				
Pump (gear box, fittings, meter, installation)	52064	57432	25176	28684
Motor (protection and fittings)	12500	31646	4000	21452
Electricity Connection (1km line + sub-station)	40000		28000	
Fuel tank (10000 litres)		2500		2500
Bore drilling	51170	51170	22398	22398
Bore casing (steel) and development	80096	80096	31697	31697
TOTAL	**$235,830**	**$222,844**	**$111,271**	**$106,731**

VARIABLE COSTS						
Diesel Engine ($/hr)	**litre/hr**	**$/litre**	**($/hr)**	**($/hr)**	**($/hr)**	**($/hr)**
*Diesel: 25 Ml/day bore	57.63	0.682		39.30		
*Diesel: 10 Ml/day bore	15.4	0.682				10.48
Major overhaul (% motor value / 15 years)		20%		0.17		0.11
Minor overhaul (% motor value / 5 years)		5%		0.13		0.08
Oil (litres/year)	119	3		0.21		0.21
Filters (no./year)	14	10		0.08		0.08
Pump maintenance (% pump value / 30 years)		5%		0.04		0.02
Total Variable costs				39.94		10.99
Electric Engine ($/hr)	**kWh**	**c/kWh^**				
**Electricity: 25 Ml/day bore	216.12	13.3	28.74			
**Electricity: 10 Ml/day bore	57.63	13.3			7.66	
Maintenance - switchgear and bearing ($/yr)		300	0.18		0.18	
Maintenance - rewind allowance ($/yr)		200	0.12		0.12	
Pump maintenance (% pump value / 30 years)		5%	0.04		0.02	
Total Variable costs			29.08		7.96	

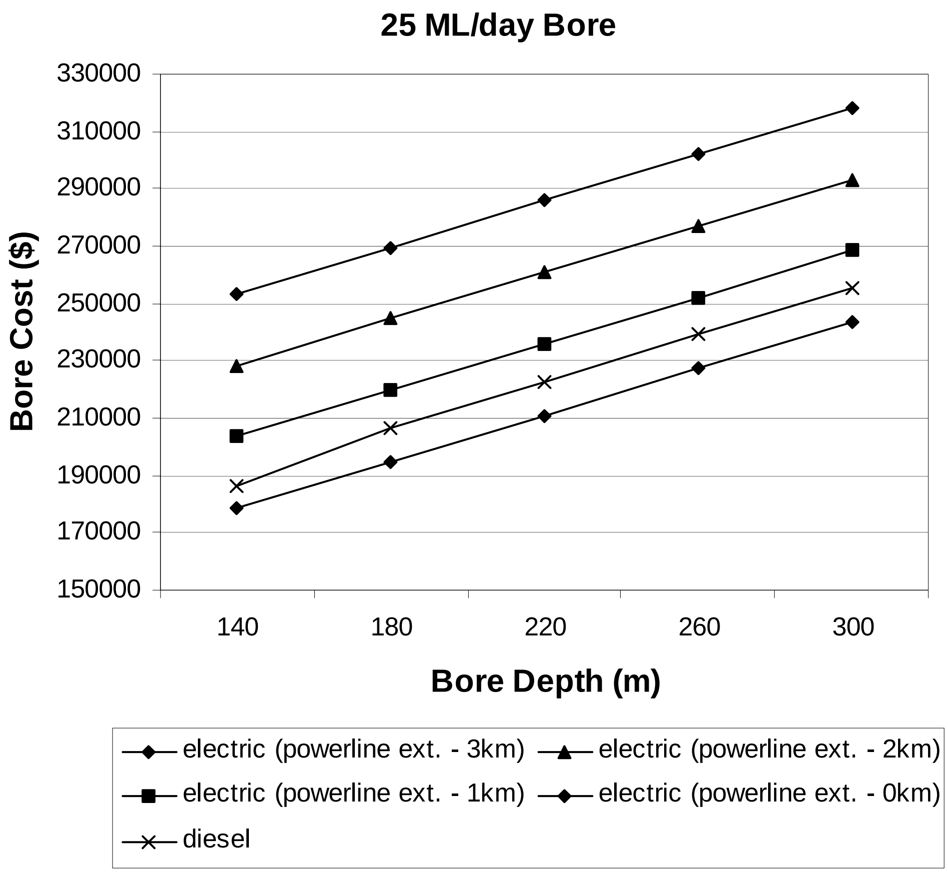
* Pump efficiency = 74%, Derating = 80%

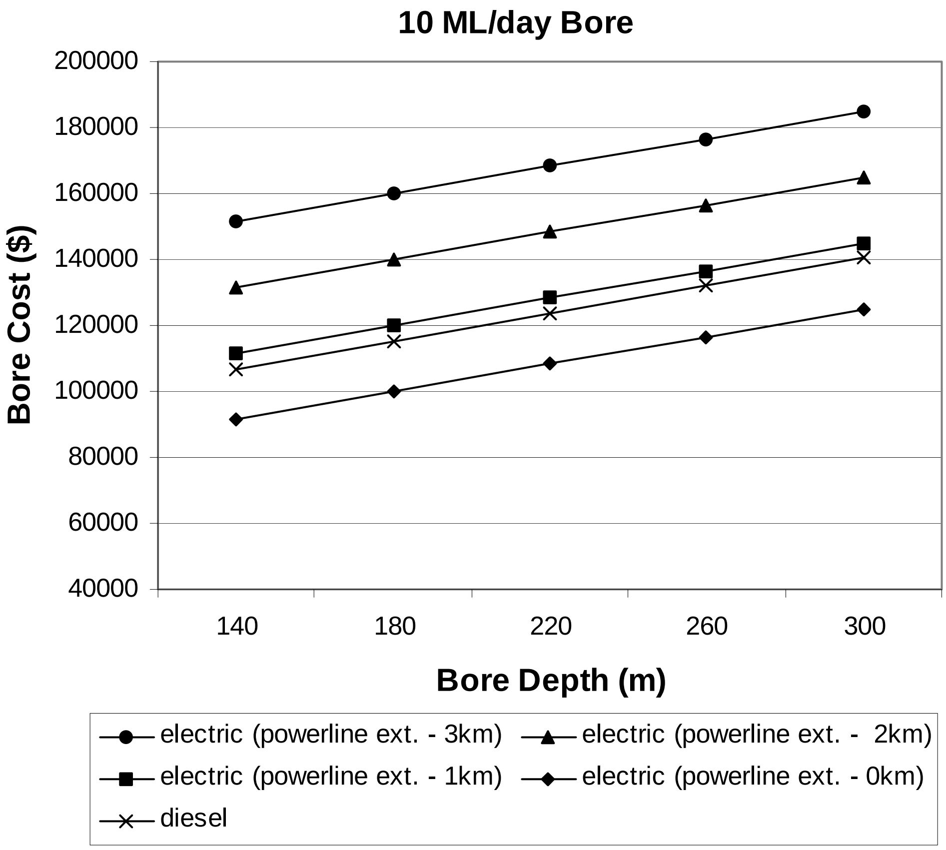
** Pump efficiency = 74%, Derating = 80% (electric), Derating = 75% (diesel)

^ 38% peak rate and 62% off-peak rate

Source: Bore costs - Watsons Drilling, Deniliquin, NSW
Variable costs - Murrumbidgee Groundwater Pumpers Association
Motor costs - Brian Cockayne, Combined Agricultural Machinery, Deniliquin
Joe Catanzariti, Quiprite, Griffith

Figure 5 Sensitivity of Bore Costs





5 Variable Costs of Groundwater Pumps

The variable or running costs of groundwater pumping systems include power costs (electricity, diesel, LPG gas, natural gas), maintenance costs on pump and motor and depreciation. As most bore casing and pipe construction comprises of non-corrosive material such as PVC[8], there is no foreseen maintenance expenditure required on these items.

This report only outlines the variable costs associated with the two main power sources for pumps; diesel and electricity. Currently there are not many users of LPG or natural gas however, gas conversion is increasingly looking attractive in the current climate of high diesel prices. For example, in the Darlington Point area there is opportunity for gas conversion if there is enough demand by farmers with bores to warrant the cost of gas companies installing the supply pipes (pers. comm., G. Toskin, 2000).

The variable costs of a diesel powered motor are more expensive than electric powered motors due to higher energy and maintenance costs.

5.1 Electric Powered Pumps

Electricity rates will depend on the company supplying the power. Table 3 is the electricity rates for Great Southern Energy.

Table 5 Great Southern Energy Rural Electricity Plans, December 2000.

Power Costs - Electricity Plans		
Business - Rural		c/kWh
Peak (first 3.28 kWh)		25.56
Peak (balance)		12.78
Access charge per day	78.48 cents	3.27
Average Cost Over a 24 Hour Period		
Weekday & weekend		17.80
Bislink - Rural (need special meter)		c/kWh
Peak (7-9am & 5-8pm weekdays)		13.58
Shoulder (9am-5pm & 8-10pm weekdays)		12.63
Off-peak Charge (10pm - 7am plus weekends)		5.91
Access charge per day	137.35 cents	5.72
Average Cost Over a 24 Hour Period		
Weekday		16.03
Weekend		11.63

The average electricity cost per kilowatt hour will depend on the pumping time during peak and off-peak periods. For example, a farmer who uses the Bislink Plan and pumps at peak rates 38% of the time and off-peak 62% of the time, the average electricity cost per kilowatt hour is:

$$(0.38 \times 16.03) + (0.62 \times 11.63)$$
$$= 13.3 \text{ cents/kWh}$$

---

[8] Steel bore casing and some screens will corrode depending on the quality of groundwater however, they are expected to last in excess of 30 years to 100 years.

Maintenance costs are minimal on electric motors. Costs will include the replacement of the motor bearing once in the engine's effective life of approximately 25 years (cost is estimated as 10% of the motor value), maintenance of switch gear and rewind allowance (see Variable Costs in Table 4). Maintenance costs on the pump is estimated at 5% of the pump value.

5.2 Diesel Powered Pumps

Diesel fuel costs are approximately 105 cents/litre on farm (May 2001), however farmers are eligible for a Federal Government rebate for diesel fuel of 38.12 cents/litre (pers. comm., Customs Diesel). It is assumed that 0.25 litres of fuel will be consumed per kilowatt hour (Murrumbidgee Groundwater Pumpers Association, 1992). Therefore, if a pump requires 150 kilowatts to pump 1 ML/hr, the motor would need 37.5 litres per hour at a cost of approximately $25/ML.

A diesel motor will require approximately three top overhauls and one major overhaul during the 15 year life of the motor (Murrumbidgee Groundwater Pumpers Association, 1992). The cost of the top overhaul is estimated at 5% of the cost of the engine and the major overhaul is estimated at 20% of the cost of the engine. An oil and fuel filter change is required every 250 hours (see Variable Costs in Table 4). Maintenance costs on the pump is estimated at 5% of the pump value.

5.3 Calculation of a Pump's Energy Requirements

A pump's energy requirement depends on the flow or pumping rate, the depth from which to pump or total head, pump and motor efficiency losses (Appendix 7).

The power required by a pump can be calculated by the following formula (Faour, 2001).

$$\begin{array}{l} \text{Gross power} \\ \text{Required (kW)} \end{array} = \frac{\text{Flow rate (litres/sec) x Total Pumping Head (metres)}}{\text{102 x Pump Efficiency (\%) x Derating (\%)}}$$

Total head is not the distance between static water level and discharge level. Total head needs to incorporate the level of sustainable drawdown and friction losses due to pumping. A sustainable drawdown level is where the pumping rate does not exceed the conductivity of the screened aquifers. Therefore total pumping head at the pump is the sum of:

(i) The vertical height from the pumping level at the water source to the point of discharge (suction lift plus static lift)
(ii) The pressure head at the point of discharge
(iii) The friction head or losses due to water flowing in the pipes and fittings.

For a more detailed explanation on how total pumping head is calculated, see Kondidin Group, (1998), p96.

Pump efficiency depends on pump design and will vary with pump speed, output pressure and flow rate. Most large pumps usually operate at efficiencies within the range 74 to 85% (Faour, 2001).

Derating accounts for efficiency losses between the energy required at the pump shaft and the total energy required. Approximate derating factor for electric motors is 80% and for diesel motors is 75% (Faour, 2001).

The pumping rate and pumping depth of the bore have a major impact on pumping costs. For example, a deep bore with a total pumping head of 30 metres and yields 25 ML/day (290 L/sec) will have the following power requirements and fuel costs.

1. Electric motor: power = $\frac{290 \text{ L/sec} \times 30 \text{ m}}{102 \times 0.74 \times 0.8}$

   = 144 kW

Cost per hour is 13.3 ¢/kW x 144kW = $19.15/hr
Cost per ML is $19.15/hr ÷ 1.044 ML/hr = $18.34/ML

2. Diesel Motor: power = $\frac{290 \text{ L/sec} \times 30 \text{ m}}{102 \times 0.74 \times 0.75}$

   = 153.7 kW

Hourly fuel use is 153.7 kW x 0.25 L/hr/kW = 38.43 L/hr
Cost per hour is 66.88 ¢/L x 38.43L/hr = $25.70/hr
Cost per ML is $25.70/hr ÷ 1.044ML/hr = $24.62/ML

A concentration of deep bores within a certain area may increase the drawdown in the aquifers during the peak irrigation season, as is the case for bore pumpers in the Darlington Point district. With increased drawdown of aquifers, the pumping head can increase and pumping capacity can decrease which will increase the cost of pumping. For example, if the total pumping head increases to 45 metres and pumping capacity becomes 21.6 ML/day (250 L/sec), diesel consumption increases to 50 L/hr and the water cost becomes $36.92/ML (for electric powered motors the water cost becomes $27.54/ML). To minimise pumping costs in peak season, some farmers use a temporary storage in conjunction with the bore (pers. comm., G. Toskin, Murrumbidgee Groundwater Pumpers Association, December 2000).

As illustrated in the above example, the power cost to operate a diesel powered pump is much higher than an electric powered pump (34% in this example). In the above example, the on-farm diesel cost would have to be below 50 cents per litre to be cost competitive with electric motors. The sensitivity of fuel costs to total head in cost per megalitre is illustrated in Figure 4 and fuel costs to pumping capacity and total head in cost per hour in Table 7.

Figure 6 Estimate of Energy Costs

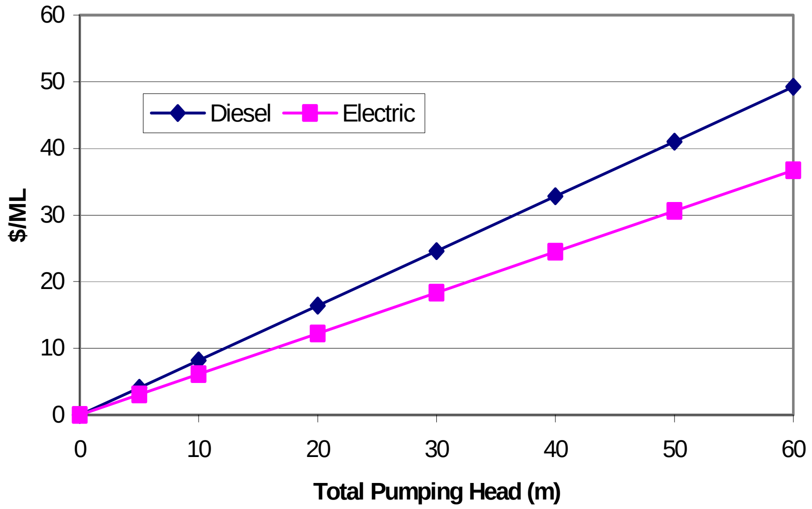


Table 6 Sensitivity of Pumping Costs to Pumping Head and Pumping Capacity

Sensitivity - Diesel Cost ($/hour)

Assumptions:

Net diesel price	66.88	c/L
Fuel consumption	0.25	L/kWhr
Pump efficiency	74%	
Derating	75%	

Pumping Rate		Pumping Head (m)						
(ML/day)	L/sec	5	10	20	30	40	50	60
1	12	0.17	0.34	0.68	1.03	1.37	1.71	2.05
2	23	0.34	0.68	1.37	2.05	2.73	3.42	4.10
5	58	0.85	1.71	3.42	5.13	6.84	8.55	10.26
10	116	1.71	3.42	6.84	10.26	13.67	17.09	20.51
20	231	3.42	6.84	13.67	20.51	27.35	34.18	41.02
30	347	5.13	10.26	20.51	30.77	41.02	51.28	61.53
40	463	6.84	13.67	27.35	41.02	54.70	68.37	82.04
	$/ML	4.10	8.20	16.41	24.61	32.82	41.02	49.23

Sensitivity - Electricity Cost ($/hour)

Assumptions:

Net electricity price	13.30	c/kWhr
Pump efficiency	74%	
Derating	80%	

Pumping Rate		Pumping Head (m)						
(ML/day)	L/sec	5	10	20	30	40	50	60
1	12	0.13	0.26	0.51	0.77	1.02	1.28	1.53
2	23	0.26	0.51	1.02	1.53	2.04	2.55	3.06
5	58	0.64	1.28	2.55	3.83	5.10	6.38	7.65
10	116	1.28	2.55	5.10	7.65	10.20	12.75	15.30
20	231	2.55	5.10	10.20	15.30	20.40	25.50	30.60
30	347	3.83	7.65	15.30	22.95	30.60	38.25	45.90
40	463	5.10	10.20	20.40	30.60	40.80	51.00	61.20
	$/ML	3.06	6.12	12.24	18.36	24.48	30.60	36.72

If the on-farm net diesel price remains at 67 cents per litre, the electric pump efficiency would have to be less than 55% or the derating would have to be less than 60% for diesel to be more cost efficient. It must be noted that these sensitivities only include energy costs and therefore do not include the other variable costs of repairs and maintenance.

6 Comparing the Capital and Running Costs of a Pumping System

Due to the different capital costs of pumping systems and associated operating expenses over time, it is difficult to determine which design has the least cost. This is overcome by doing a cost analysis. This is a process of valuing all the costs of each pumping system (capital and variable) over the life of the investment in today's monetary terms and then discounting future costs to take into account the opportunity cost of alternative investments. All discounted costs are summed to obtain the net present cost (NPC). The pumping design with the smallest NPC is the most cost efficient. The NPC is calculated by:

$$NPC = \sum_{j=1}^{n} \frac{C_j}{(1+i)^j}$$

where NPC = the sum of the discounted future annual cash costs
Cj = costs in year j
n = number of years
i = discount rate

The NPC of each design can only be compared when the investment life of each design is the same. Most components on a pumping system have an effective life in excess of 30 years except for the motor (electric = 25 years, diesel = 15 years). If we assume that the investment life of a pumping system is equivalent to the effective life of the motors, the NPC criteria cannot be used. Instead, a calculation of the annuity cost over the effective life of each motor is needed. An annuity is the equal annual cash flow amount, when discounted and summed, will equal the NPC of the unequal cash flow amounts. An annuity is calculated by (Makeham et al, 1993):

$$Annuity = NPC\left(\frac{i(1+i)^n}{(1+i)^n - 1}\right)$$

For example, the annuity value for the electric and diesel powered bores (outlined in Table 4) are illustrated in Table 7. The underlying assumptions are that the average number of pumping days are 70 days per year and the discount rate is 10%. The reason for the large difference in annuity values is due to the difference in power costs i.e. for the 25 ML/day bore the difference is $16,400 per year (electricity costs were $48,280 per year and diesel costs were $64,680 per year) and for the 10 ML/day bore the difference is $4,380 per year (electricity costs were $12,870 per year and diesel costs were $17,250 per year).

Table 7 Bore Annuity Values

	Electric Powered	Diesel Powered
25 ML/day bore	$72,481	$92,314
10 ML/day bore	$24,521	$28,757

In this example, due to the significant difference in power costs, an electric powered bore has a lower annuity value and therefore is more cost efficient than a diesel powered bore. For the diesel powered bore to be more cost efficient, the power line extension would have to be greater than 9 kilometres for the 25 ML/day bore and 3.5 kilometres for the 10 ML/day bore.

7 Conclusions

1. Shallow groundwater pump (spearpoint) costs can vary dramatically between locations, the main influences being the cost of geo-technical investigations, system design and power connection, consequently the capital cost of purchasing and installing a spearpoint system to pump a shallow watertable can vary from approximately $18,000 to $70,000.

2. Bore costs can vary dramatically depending on and bore depth, bore yield, bore design and power connection costs, consequently the capital cost of purchasing and installing a shallow bore is similar to a spearpoint system and a deep bore from approximately $90,000 to $320,000.

3. Electric motors have less expensive power and maintenance costs than diesel motors.

4. An electric powered pumping system is more cost efficient than a diesel powered system if power connection costs are relatively low.

Before installing a groundwater pumping system it is advisable that a financial feasibility study is undertaken to assess whether a groundwater pump is a viable investment over a time frame equivalent to the effective life of the investment. The analysis should include a comparison of the different pumping system designs and alternative power sources available to determine which pumping design is the most cost efficient over its effective life.

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APPENDIX 1 Spearpoint Systems - Case Studies

Farm		"Calwarra"	"La Vila"	"Ceramic"
Farm type		Dairy	Dairy	Rice, cereals
Farm area	ha	243	103	321
Area landformed	ha	182	73	240
Irrigation allocation	ML	608	422	608
Recycling percentage	%	15	10	5
Watertable	m	2.5	?	?
Groundwater pumped	ML	200	200	200
Spearpoint pumping rate	ML/day	3.5	2.5	1.5
Groundwater salinity	dS/m	2.2	1.9	1.9
Max irrigation water salinity	dS/m	0.8	0.8	0.8
Conjunctive water salinity	dS/m	0.6	0.7	0.6
Average pumping days	day	57	80	133
<u>Capital Invested</u>				
Initial Exploration				1000
Drilling and installation		10000	10000	3800
Spears and header pipe		4000	4000	4000
Pump and motor		6000	6000	4150
Meter		663	663	650
Pump shed		300	300	0
Power connection		2000	2000	5888
Total		$22,963	$22,963	$18,488

Source: Lisa Wall and Graham Marshall (1995), Drainage Reuse and drainage Systems: Financial Case Studies in the Berriquin Irrigation District, NSW Agriculture, Orange.

APPENDIX 2   Private Spearpoint Costs For The SIR

	ITEM	Costs ($)		
		High	Average	Low
Site Assessment				
1.	****FEDS Investigation costs**	12300	12300	12300
2.	**Exploratory Drilling**	3500	3050	2600
	Total	15800	15350	14900
Spearpoint Installation				
3.	**Pumpsite (pump, motor and pump pit)**			
	0-1.0ML/d *Only 1 pump analysed	NA	3425	NA
	1.0-2.0ML/d	10100	8500	6800
	2.0-3.0ML/d	11600	9500	7400
	3.0-4.0Ml/d	11600	10100	8700
	4.0-5.0ML/d	12500	10700	8800
4.	**Pipelines**			
	Wellpoints	7000	4500	3000
	Headerline	6800	5400	4000
	Delivery	12000	6000	600
5.	**Power**			
	Single phase OR	5000	3000	400
	Three Phase	11000	8000	5000
	Contractor	4200	3400	2500
	Total Cost			
	0-1.0ML/d (with 3 phase)	NA	46075	NA
	1.0-2.0ML/d (with 3 phase)	66900	51150	36800
	2.0-3.0ML/d (with 3 phase)	68400	52150	37400
	3.0-4.0Ml/d (with 3 phase)	68400	52750	38700
	4.0-5.0ML/d (with 3 phase)	69300	53350	38800
6.	**Typical Grant of Spearpoint Installation (%)**	49	43.3	37.6
7.	**Landholder Site Assessment Cost**	750	750	750
	Total Landholder Cost			
	0-1.0ML/d (with 3 phase)	NA	12303	NA
	1.0-2.0ML/d (with 3 phase)	25789	14211	8984
	2.0-3.0ML/d (with 3 phase)	26524	14587	9210
	3.0-4.0Ml/d (with 3 phase)	26524	14812	9699
	4.0-5.0ML/d (with 3 phase)	26965	15038	9736

Source: Heinz Kleindienst, Sinclair Knight Mertz, Tatura

*Based on pumps installed since 1/1/98
**Farm Exploratory Drilling Service: Figures Based on TIC analysis

Wellpoint costs determined using the average cost per wellpoint of $50 and 10 metre de
Large wellpoint system contains 14 wellpoints, medium system 10, and small 6 wellpoints

Delivery line costs determined using the average unit cost per metre of $30/m.
Large delivery line was taken at 400 m, a medium at 200 m and a small delivery line at 2

Other figures were averages based upon typical industry cost

APPENDIX 3 Example of Spearpoint Costs from Murray Irrigation

	Farm 1	Farm 2
Spearpoint pumping rate (ML/day)	2	1.5
No. of spears	12	5
Spear depth (m)	8	7
Engine Type	Diesel	Electric
Capital Invested		
Licence	150	150
Water testing	100	100
EM 31/34 investigation	500	300
Drilling, spears and installation	8700	6950
Pump and motor	9900	2600
Meter	1400	1000
Pump shed + other	2500	2000
Power connection	0	9000
Total	$ 23,250	$ 22,100

Source: Adrian Smith, Murray Irrigation, December 2000.

APPENDIX 4 Total Cost of Public Salinity Control Pumps in the SIR

Irrigation Area	Site	Annual Volume (ML)	Salinity (EC)	Annual Salt Loads (tonnes)	SDA (EC)	Rated Area (ha)	Yield (ML/ha)	Total Cost^ ($)
Murray Valley	C101	180	5000	540	0.0563	211	0.85	77533
	C102	186	6650	742	0.0773	118	1.58	101380
	C103	100	3000	180	0.0188	93	1.08	116712
	C104	61	7600	278	0.0290	71	0.86	140000
	Total	527		1740	0.1814	493	1.07	
Central Goulbourn	R102	168	9600	968	0.0903	233	0.72	80000 *
	R103	224	4100	551	0.0574	416	0.54	112586
	R104	47	3300	93	0.0097	47	1.00	123480
	R105	49	9600	282	0.0263	87	0.56	183000
	R106	118	7800	552	0.0575	179	0.66	191435
	R107	86	5100	263	0.0274	148	0.58	87575
	R108	106	8000	509	0.0530	107	0.99	140000 *
	T104	134	4200	338	0.0352	224	0.60	
	T105	108	5200	337	0.0351	204	0.53	90000 *
	T106	158	5900	559	0.0583	140	1.13	149767
	T107	62	6300	234	0.0244	42	1.48	108057
	T108	100	7800	468	0.0488	105	0.95	108663
	T109	120	5200	374	0.0390	153	0.78	124645
	CG1	89	3900	208	0.0217	95	0.94	
	CG2	150	4200	378	0.0394	205	0.73	
	CG3	76	4500	205	0.0214	68	1.12	
	CG4	72	7000	302	0.0315	51	1.41	
	CG7	84	7000	353	0.0368	56	1.50	134000 *
	Total	1951		6975.6	0.7132	2560	0.76	
Rochester	Ro104	60	4100	148	0.0154	93	0.65	99059
	Ro105	70	5300	223	0.0232	39	1.79	103867
	Ro106	72	3900	168	0.0176	89	0.81	168806
	Total	202		539	0.0562	221	0.91	
SIR TOTAL		2680		9254.58		3274	0.82	$122,028 #

^ From period July 1994 - June 1999

Source: T. Hunter, Goulburn Murray Water, Dec. 2000

* estimate

average cost of pump

APPENDIX 5 Geo-technical Investigation Costs for a Public Groundwater Pump in the SIR

Activity	Notes	No.	Unit	Rate $	Cost $	Sub - Total $
Preliminary assessment						
Assessment of request & project establishment		4	hour	46	184	184
Assessment of existing data		15	hour	67	1005	1005
Stage 1 - drilling						
Planning drilling		10	hour	67	670	670
Consultation with landholders and pegging d	staff	30	hour	67	2010	
	vehicles	300	km	0.69	207	2217
Specification of drilling		4	hour	67	268	268
Drilling	10 holes @ 12.5m	125	m	43	5375	5375
Gamma logging (determines sand layers)	staff	10	hour	52	520	
	vehicles	100	km	0.69	69	
	equipment	4	hour	47	188	777
Water salinity analysis		10	each	8	80	80
Soil salinity analysis		12	each	15	180	180
Assessment of first stage data		1	hour	46	46	
		4	hour	67	268	314
Stage 2 - more targeted drilling						
Planning drilling		1	hour	46	46	
		4	hour	67	268	314
Consultation with landholders and pegging d	staff	30	hour	67	2010	
	vehicles	300	km	0.69	207	2217
Specification of drilling		4	hour	67	268	268
Drilling	6 holes @ 12.5m	75	m	43	3225	3225
Gamma logging (determines sand layers)	staff	7	hour	52	364	
	vehicles	100	km	0.69	69	
	equipment	3	hour	47	141	574
Water salinity analysis		6	each	8	48	48
Assessment of second stage data		1	hour	46	46	
		4	hour	67	268	314

Installation of wellpoints and monitoring bores						
Preliminary assessment of disposal options		1	hour	46	46	
		3	hour	67	201	247
Consultation with landholders re. Preferred s	staff	35	hour	67	2345	
& pegging drill sites	vehicles	300	km	0.69	207	2552
Specification of wellpoints & additional monitoring bores		4	hour	67	268	268
Installation of wellpoints (class 9 - 100mm P	4 wellpoints @ 12.5m	50	m	73	3650	
Short term testing of wellpoints	staff	8	hour	52	416	
	vehicles	200	km	0.69	138	
	equipment	4	hour	42	168	4372
Drilling additional monitoring bores	4 bores @ 12.5m	50	m	43	2150	2150
Gamma logging additional bores	staff	8	hour	52	416	
	vehicles	100	km	0.69	69	
	equipment	2.5	hour	47	118	603
Water salinity analysis of monitoring bores		4	each	8	32	32
Pumptest						
Specification of 21 day pumptest		8	hour	67	536	536
Consultation with landholders re. disposal		20	hour	67	1340	1340
21 day pumptest & monitoring	staff	100	hour	52	5200	
	vehicles	1200	km	0.69	828	
	equipment	500	hour	11.5	5750	11778
Water salinity analysis		20	each	8	160	160
Pumptest analysis for design yield		4	hour	67	268	268
Analysis of rateable area		15	hour	67	1005	1005
Assessment of salinity and economic impacts						
Assessment of disposal options and impacts		2	hour	46	92	
		15	hour	67	1005	1097
Assessment of salinity losses in rateable area		10	hour	39	390	390
Assessment of land use in rateable area		8	hour	67	536	536
Economic analysis		8	hour	67	536	536
Consultation with landholders re. Project out	staff	15	hour	67	1005	
	vehicles	200	km	0.47	94	1099
Assessment of landholder support for projec	staff	5	hour	67	335	
	vehicles	200	km	0.47	94	429
Project report		8	hour	67	536	536
Project management		8	hour	46	368	
		12	hour	67	804	1172
Review of project report		2	hour	46	92	92
Submission of report to WSC		1	hour	46	46	46
Consideration of WSC input		2	hour	46	92	92
Submission of report to IC		2	hour	46	92	92
TOTAL						**$ 49,458**
Additional Overheads						
Program Management						7000
Drilling Contract Management						900
TOTAL PROJECT INVESTIGATION COSTS						**$ 57,358**

Source: T. Hunter, Goulburn Murray Water

APPENDIX 6 Capital Costs of a Public Pump in SIR

Design Characteristics:

Rateable area	55.87 ha
Yield	1 L/s (0.70 ML/day)
Suction head	7m
Wellpoints	4
Wellpoint diameter	100mm
Wellpoint depth	7.73 - 9.23 m
Depth to top of screen	3.7 - 5.0m
Header line (approx)	64.37
Discharge line	59.6

Activity	Notes	No.	Unit	Rate	Cost	Sub - Total
Prefabrication (shed, slab, fence etc)	shed & slab (6 x 2.4m)	1			2400	
	fencing	1			1000	
	conduits, other	1			500	3900
Pump and motor	8.1 L/s					3850
Water meter						407
Pump installation and miscellaneous						4613
Header line fittings						885
Header line pipes	80mm class 12 uPVC	5	length	40	200	
	100mm class 12 uPVC	12	length	65	780	980
Header line bedding sand		20	m3	10	200	200
Header line installation	excavator	24	hour	65	1560	
	labour	48	hour	35	1680	
	vehicles	240	km	0.35	84	3324
Discharge line fittings						554
Discharge line pipes	50mm class 6 uPVC	3	length	25	75	
	80mm class 6 uPVC	7	length	40	280	
	150mm class 6 uPVC	1	length	100	100	455
Discharge line - other	Bedding sand	20	m3	10	200	
	Beaching	1			200	
	Slab	1			200	600
Discharge installation	excavator	16	hour	65	1040	
	labour	16	hour	35	560	
	vehicles	160	km	0.35	56	1656
Access track		50	m	55	2750	
	culvert				1000	3750
Power connection	3 phase				5900	
Electrical cabinets, switching etc					7000	
Underground connection at site					4500	17400
Construction management						4000
Prime Cost						**$ 46,574**
Contingencies	15% of prime cost					6986
Total Construction Cost						**$ 53,560**
Survey cost						2000
Investigation and design						12000
Construction support						1000
Site commissioning						2000
Post-construction documentation						2000
Land acquisition						2000
Project management						2000
Total Spearpoint Installation Cost						**$ 76,560**
Total Investigation Costs						**$ 57,358**
TOTAL PROJECT COST						**$ 133,918**

Source: T. Hunter, Goulburn Murray Water

APPENDIX 7 Bore Costs

Bore Type			20" x 16" bore	20" x 16" bore	12" x 9" bore	12" x 9" bore
Bore Depth (m)			220	220	140	140
Pumping Head (m)			30	30	30	30
Bore Yield (ML/day)			25	25	10	10
Pumping Days			70	70	70	70
Engine Type			Electric - 185kW	Diesel - Mitsibishi 190kw	Electric - 75kW	Diesel - Perkins 70kw
Pump Type			Everflow Vertical Turbine Pump 350 FHH - 3 stage	Everflow Vertical Turbine Pump 350 FHH - 3 stage	Everflow Vertical Turbine Pump 250 FHH - 3 stage	Everflow Vertical Turbine Pump 250 FHH - 3 stage
CAPITAL COSTS						
Pump and Motor						
Pump			43000	43000	19976	19976
Right angle gear-box				7768		4408
Pump Fittings			2864	2864	500	500
Water Meter			700	700	700	700
Motor			12500	21636	4000	13970
Motor Protection				1227		1350
Motor Fittings				8783		6132
Crane and freight			500	500	500	500
Installation			5000	2600	3500	2600
Energy Connection						
Electricity Connection (1km line + sub-station)			40000		28000	
Fuel tank (10000 litres)				2500		2500
Total			**$104,564**	**$91,578**	**$57,176**	**$52,636**
Bore	**unit**	**$/unit**				
20" drilling (m)	78	240	18720	18720		
16" drilling (m)	142	215	30530	30530		
12" drilling (m)	60	170			10200	10200
9" drilling (m)	80	135			10800	10800
20" PVC casing (m)	78	225	17550	17550		
16" PVC casing (m)	118	182	21476	21476		
12" PVC casing (m)	60	97			5820	5820
9" PVC casing (m)	62	66			4092	4092
Stainless steel screens and fittings						
- 20"-16" reducer	1	950	950	950		
- 12"-9" reducer	1	650			650	650
- 16 " screen (m)	24	1250	30000	30000		
- 9" screen (m)	18	750			13500	13500
- 16" weld rings	10	140	1400	1400		
- 9" weld rings	7	75			525	525
- 16" screen adapters	4	190	760	760		
- 12" screen adapters	4	95			380	380
- 16" end cap	1	60	60	60		
- 12" end cap	1	30			30	30
Drilling fluid-bentonite (bag)		24	1080	1080	768	768
Drilling fluid-Pac R (bag)		210	840	840	630	630
Development ($/hr)		160	6400	6400	5600	5600
Freight			1200	1200	800	800
Consumables			300	300	300	300
Total Bore Costs			**$131,266**	**$131,266**	**$54,095**	**$54,095**
TOTAL PUMP AND BORE COSTS			**$235,830**	**$222,844**	**$111,271**	**$106,731**

Source: Watson Drilling and Quiprite