APPENDIX 4
ALIS CASE STUDY

Contents

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1.0 Introduction

1.1 Background

The Ashburton Lyndhurst Irrigation Scheme (ALIS) currently supplies water from the Rangitata Diversion Race (RDR) to the properties within the scheme via an open channel network.

A case study on the preliminary pipeline layout design and costing of a piped distribution system has been completed for part of the Ashburton Lyndhurst Irrigation Scheme (ALIS) to assess the economics of replacing part of the open channel network with a piped supply. This has been completed to provide the basis for establishing a generic method for comparing the costs of converting an open channel scheme to a piped distribution system. The methodology described hereunder will be a useful guide to similar conversion proposals.

It is proposed that part of the irrigated area currently taking water from Laterals 1, 2 and 3 of the ALIS be supplied water with pipes rather than open races. The main supply will continue to come from the RDR Race.

ALIS provided a plan showing the following details of the ALIS (refer to Figure 1):

- Location of RDR main supply race
- Properties to be irrigated under proposal
- Property boundaries and property area
- Preferred turnout location

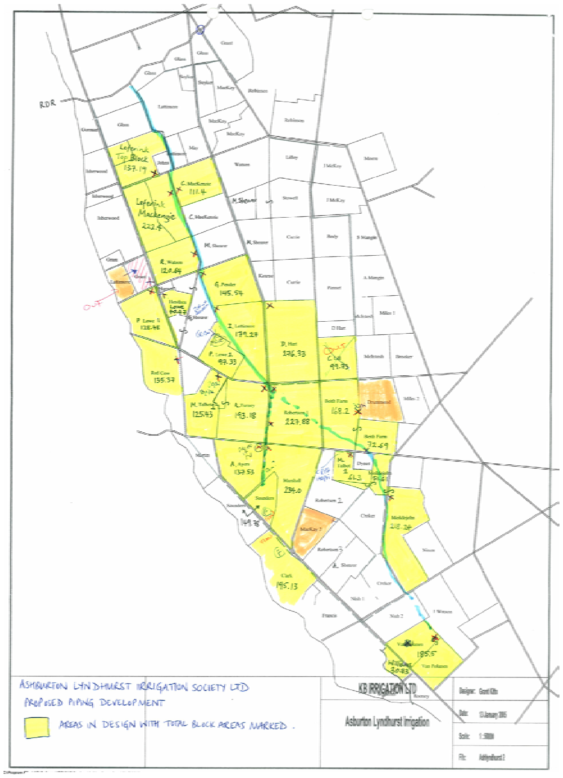

Figure 1: Part of ALIS Scheme

A summary of the method for designing the piped distribution network for the ALIS case study is provided below.

2.0 Design Details

Water is to be abstracted from the RDR main race, and will be delivered to the proposed irrigable area via a pipe network. The water will be delivered to each property using an off-take point (turnout).

Table 1, supplied by ALIS, summarises the total area, contracted area and the design flow for each property.

Table 1: Ashburton Lyndhurst Proposed Piping Area – Contracts and Flow rates (updated 18th December 2006).

Property Number	Block Area (ha)	Total Contract Area (ha)	Uncontracted Area (ha)	Contract Flow (l/s)	Design Flow (l/s)
1	137.19	137.19	0	56.3	67.6
2	222.4	222.4	0	91.3	109.6
3	111.4	52.54	58.86	21.6	25.9
4	120.64	100	20.64	41.1	49.3
5	47.74	16.32	31.42	6.7	8.0
6	145.54	145.53	0.01	59.8	71.7
7	128.48	55.49	72.99	22.8	27.3
8	97.33	97.33	0	40.0	48.0
9	40.47	40	0.47	16.4	19.7
10	135.37	66.5	68.87	27.3	32.8
11	179.27	60	119.27	24.6	29.6
12	276.33	225.52	50.81	92.6	111.1
13	144.07	144.06	0.01	59.2	71.0
14	125.43	125.43	0	51.5	61.8
15	193.18	189.82	3.36	78.0	93.6
16	227.88	165.1	62.78	67.8	81.4
17	137.53	137.52	0.01	56.5	67.8
18	234	234	0	96.1	115.3
19	149.78	60	89.78	24.6	29.6
20	117.14	117.13	0.01	48.1	57.7
21	195.13	70.3	124.83	28.9	34.6
22	240.89	240.89	0	98.9	118.7
23	61.3	35	26.3	14.4	17.2
24	129.17	73.05	56.12	30.0	36.0
25	269.85	269.85	0	110.8	133.0
26	185.5	185.5	0	76.2	91.4
27	30.83	30.83	0	12.7	15.2
Total	**4083.84**	**3297.3**	**786.54**	**1354.2**	**1625.0**

The total area of the properties within the area to be irrigated is 4,084 ha, of which only 3,297 ha is contracted for irrigation. The design flow is based on irrigating the contract area using a system capacity of 0.49 l/s/ha (4.25 mm/d). The total flow to supply this area is approximately 1.625 m^3/s, assuming no losses. There are a total of 27 turnouts.

The design is to be capable of supplying water to each property ‘on demand’ at all times.

ALIS has specified a minimum pressure of 60 psi (42 m) to be delivered to the on-farm irrigation system

2.1 Elevations

The highest elevation is at the RDR headrace at 340 m amsl and the lowest elevation is 170 m amsl. The total elevation change over the length of the network is 170 m.

It is considered appropriate to use 10 m contours as interpolation between these contours gives a reasonable estimation of the lie of the land between the contours.

2.2 On Farm Delivery Pressures

The elevation change over the length of the pipe network provides additional pressure within the scheme, which means that properties can be delivered with water under pressure. This additional pressure in the system also enables smaller diameter pipes to be selected, as the elevation gain largely offsets the additional friction losses within the smaller diameter pipes. However, this will increase on farm pumping and a balance between reducing pipe capital costs and on farm pumping costs needs to be reached.

The approach taken was to minimise pipe diameters while maintaining a minimum delivered pressure to the turnout under full demand. In practice, due to the diversity of land use and management practices it is anticipated that the scheme will only operate under full flow demand for short periods of time. For most of the time, particularly at the shoulders of the season, the flow demand will be less than 100% and at these times pressures delivered to the turnout will be higher, thus reducing pumping requirements. Many of the turnouts may not require pumping at all. The trade-off with this approach is that slightly more on-farm pumping is likely to be required than if the pipe diameters were selected based on a lower velocity. Therefore it is important to consider both capital and operational costs when considering the final costs of the scheme[1].

2.2.1 Turnout Delivery Pressure

A minimum pressure of 5 m was to be supplied to all turnouts under full flow conditions. This is to minimise issues with pump priming and negative pipeline pressures.

2.3 Pressure Control

Due to the significant elevation change throughout the network, the scheme may be subjected to high static pressures. In the ALIS case, static pressure will be higher than dynamic pressure and was the main focus regarding pressure control.

The scheme distribution pipelines were designed to withstand static pressures. Pressure control on farm as part of the turnout was assumed, which enabled lower pressure class pipe to be used on-farm. Typically lower specification pipes and construction occurs on on-farm irrigation systems, therefore it is important to isolate the risk of high pressure from the network.

Transient pressures should be modelled at the pre-feasibility stage of any design.

2.4 Pipe Layout and Sizing

The pipe layout and pipe sizing was optimised to minimise the capital cost of the distribution pipeline to deliver a minimum of 5 m pressure to the turnouts.

It was assumed that there were no pipe layout constraints, that the pipeline was not restricted to roads and property boundaries, and that disruption to existing services would not be an issue.

2.5 Turnouts

Turnouts from the scheme distribution system will contain some or all of the following basic components:

- Pressure reducing valve and pressure relief valves to control excess pressures

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[1] In the ALIS situation, it is possible – because of topography -- to obviate the need for any on-farm pumping with increases in some pipe sizes with capital cost increase.

- Flow control
- Flow meter

2.5.1 Turnout Location

The preferred turnout location has been shown on the plan provided by ALIS (Figure 1).

For the purposes of cost comparison, two options are to be considered; one comparing the pipe layout costs for a scheme designed to deliver water to the turnouts at the specified location and the other option based on a pipe layout whereby the turnout location is flexible.

2.6 Pipe Materials

Although any pipe type could be considered, fibre reinforced pipe (FRP) has been used for the design, one of the reasons being it has the ability to withstand high pressures. Also, the risk of the pipe deteriorating with age is low, so that the pipe roughness is unlikely to increase, thus scheme performance should be maintained throughout the pipes life. Nominal diameters have been used within the design.

2.7 On Farm Pumping

Water is to be supplied to each turnout under pressure. However, due to friction losses or changes in elevation along the pipe network, a reduced amount of on-farm pumping may be required. To operate the on-farm irrigation system effectively, a minimum pressure of 42 m (60 psi) has been specified by ALIS. Where less than 42 m pressure is delivered under gravity, small on farm booster pumps will be required.

To aid in the assessment of on-farm pumping requirements, land use projections and monthly and seasonal irrigation demand estimates were scaled from irrigation demand modelling undertaken in the Ashburton region. This was the basis for the criteria used for determining the change in irrigation demand through the irrigation season and the operational costs for on-farm pumping.

Due the variation in pumping pressure and flow required throughout the season, pumps fitted with variable speed drives have been assumed.

2.7.1 Irrigation Demand

A water demand scenario for the Ashburton region was modelled in the Canterbury Strategic Water Study (2002), to determine the average and peak monthly irrigation demand. A daily time series of potential irrigation demand was calculated in the Ashburton region using daily rainfall and climate data from June 1972 to May 2000 based on the land-use assumptions summarised in Table 2. Both the monthly peak flow demand and average monthly flow demand were calculated.

Table 2: Assumed land-use for potentially irrigable land

Region	Dairying	Intensive Livestock and Dairy Support	Arable
Ashburton	52 %	30 %	18 %

To estimate the potential irrigation demand for the Rakaia/Selwyn scheme, the data from the Ashburton region has been scaled based on the peak flow difference between the Ashburton data and ALIS, thus enabling the monthly flow demand to be calculated. The average flow demand as a percentage of the peak flow for each month is shown in Figure 2.

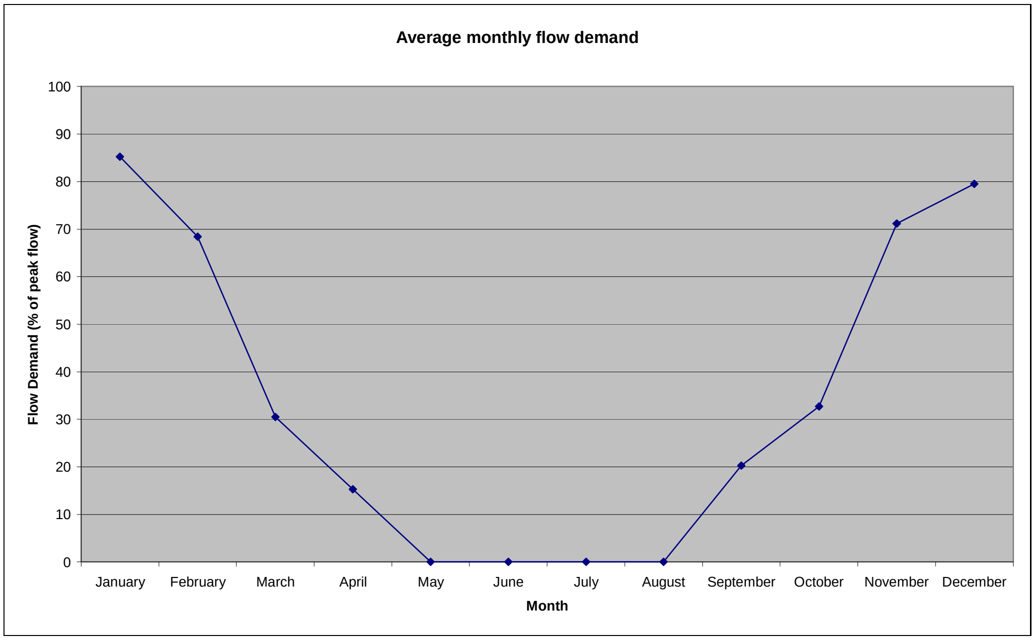

Figure 2: Average monthly flow demand

3.0 Hydraulic Design

The plans showing the property boundaries and scheme layout, supplied by ALIS, was imported into Irricad^{TM} irrigation design software.

Firstly, the pipe layout was optimised based on reducing pipe capital cost.

Secondly, a detailed hydraulic analysis was completed, to finalise the pipe diameters of the network to ensure all design requirements and appropriate design limits were met.

Thirdly, based on the finalised pipe layout and pipe diameters, on-farm pumping costs were estimated.

Finally, an assessment on the trade-off between pipe capital cost and on-farm pumping was completed based on considering the NPV for the network.

3.1 Pipe Layout

3.1.1 Design Options

During the pipe layout optimisation process, two design options for designing the pipe layout to deliver water to the turnouts were considered:

1. Pipeline based on supplying water to the turnout location as specified by ALIS (Figure 1)
2. Pipeline based on supplying water to a turnout location that is flexible within the property (Figure 2).

For each pipe layout options, the following method was followed.

3.1.2 Method

Entering data into Irricad
Based on the plans supplied by ALIS, the following information was entered into Irricad^{TM} irrigation design software

- Scheme boundary
- RDR head race
- Property boundaries
- Contour information

All turnouts were entered into the modelling software based on supplying each property at the required flow rate determined from the scheme system capacity (0.49 l/s/ha) multiplied by area of the property. Then the main distribution pipeline for Options 1 and 2 were entered taking the most direct route possible to minimise the length of larger diameter pipe. Lateral pipelines branching off from the main distribution pipe were used to supply the turnouts.

Pipe layout optimisation
To optimise the pipe layout, changes were made to the layout while comparing pipe capital costs to assess whether the revised layout was more cost effective.

To effectively compare capital costs between each scenario, a quick assessment of the pipe diameters required throughout the network for different layouts is required. The method needs to be repeatable and provide for a consistent and comparative approach for assessing the different layouts

To quickly assess the pipe sizes for each pipe layout iteration, the pipe diameters throughout the entire network were sized based on a maximum velocity. The maximum velocity was selected so that a positive (essentially greater than 1 m) pressure was delivered to the majority of turnouts and to ensure that the pressure within the main distribution pipe was gaining down the network. This approach meant that typically only pipe diameters on the laterals needed to be adjusted to ensure all turnouts received positive pressure when finalising pipe diameters (see below). The maximum velocity was set to 3 m/s.

Cost savings were made by directing the flow from the main pipeline into smaller branch mains as high as possible in the system, thus allowing a smaller diameter main pipe to be selected. Generally, the cost saving gained by reducing the larger diameter pipe was more than offset by the cost in the increased length of smaller pipe.

Also, for Option 2, the length of laterals was reduced by relocating the turnouts. Turnouts were positioned as close as possible to the main delivery pipe to reduce the incidence of two pipes bordering one property. In some cases, this resulted in some turnouts being positioned near the bottom, rather than the top of the property.

3.2 Pipe Diameter

Once the pipe layout was optimised, the pipe diameters were finalised.

Firstly, the turnouts were identified where the delivered pressure was less than the minimum pressure of 5 m. Then pressure loss was checked along the lateral pipes. Where small diameter pipes had high friction losses over a short distance (particularly at the ends of the lateral), these pipes were upsized. Following that, pipes along the lateral which had the highest velocity were upsized until the minimum of 5 m pressure was delivered to all turnouts on that lateral.

The velocity in all pipes was checked to ensure that they were within acceptable velocity limits to reduce the risk of water hammer. Also, static and dynamic pressures were assessed throughout the scheme and selected pipe classes checked to ensure that the pipe pressure limits were not exceeded.

3.3 On Farm Pumping

3.3.1 Pump Size

Using the final pipe layout and pipe diameter, the pressure delivered to each turnout at 100% flow demand, i.e. when all turnouts were operating, was determined. Based on a minimum pressure of 42 m to operate the on farm irrigation system, the turnouts that required on-farm pumping and the pump head required was identified.

Assuming a pump efficiency of 75% and a motor efficiency of 90%, the pump size required at each turnout was calculated.

Using pump capital costs (supplied by Flowserve) and electrics cost data (supplied by Nairn Electrical) a relationship between capital cost and pump size was derived for a variable speed drive pump, as follows.

Pump capital cost ($) = 571.5 x Pump size (kW) + 15,196

Based on this data total pump costs were calculated.

3.3.2 Pump Energy Cost

To enable calculation of the seasonal pump energy cost the pressure delivered to each turnout for the average monthly flow demand was modelled (described above). This allowed average monthly pumping requirements to be calculated.

The number of hours that the turnout would have been operating at maximum flow within that month has been calculated based on the flow demand. For each month within the irrigation season, the on-farm pumping requirement has been calculated and then combined to give total season pumping requirements.

Based on the following energy charges within the region (supplied by Meridian), the annual energy costs were calculated:

- Daily charge $2.82/day = $1029/yr
- Energy charge 0.13c/kWh
- Capacity charge 0.32c/kVA/day = $123/kW/year (assuming a power factor correction of 0.95)

4.0 Results

4.1 Pipe Layout and Sizing

The greatest cost savings could be made when the route was not constrained to property boundaries and road corridors, which allowed the most direct pipeline route to be chosen. This reduced the length of larger diameter pipe, which is where the majority of the cost savings could be made.

The pipe diameter and pipe class was selected to meet velocity and pressure requirements. The pipeline bill of materials for Options 1 and 2 are summarised in Table 3 and Table 4.

Table 3: Option 1 - bill of materials - pipe length

	Pipe Class						**Total pipe length (m)**
FRP	**PN3**	**PN6**	**PN9**	**PN12**	**PN15**	**PN18**	
100mm	0	0	130	0	330	0	460
150mm	0	0	780	0	2,220	1,170	4,170
200mm	330	0	1,900	0	320	0	2,550
250mm	0	0	2,170	2,520	2,400	1,400	8,490
300mm	0	0	0	0	0	0	0
350mm	0	0	0	1,210	1,340	0	2,550
450mm	0	0	0	400	400	0	800
500mm	0	0	0	1,770	0	0	1,770
600mm	0	0	0	490	0	0	490
650mm	0	0	1,040	890	0	0	1,930
750mm	0	0	1,680	0	0	0	1,680
900 mm	2,400	2,540	190	0	0	0	5,130
Total pipe length (m)							**30,020**

Table 4: Option 2 - bill of materials - pipe length

	Pipe Class						**Total pipe length (m)**
FRP	**PN3**	**PN6**	**PN9**	**PN12**	**PN15**	**PN18**	
100mm	0	0	350	0	0	0	350
150mm	0	0	1,270	0	1,060	310	2,640
200mm	0	0	1,160	940	120	0	2,220
250mm	0	0	870	1,110	4,700	1,040	7,720
300mm	0	0	0	0	460	0	460
350mm	0	0	0	1,990	0	0	1,990
450mm	0	0	0	1,190	350	0	1,540
500mm	0	0	0	330	0	0	330
600mm	0	0	0	640	0	0	640
650mm	0	0	0	250	0	0	250
750mm	0	0	2,660	700	0	0	3,360
900 mm	2,400	2,540	200	0	0	0	51,40
Total pipe length (m)							**26,640**

Table 3 and Table 4 shows that the total pipe length required for Option 1 is approximately 13% more than for Option 2 and consequently the pipe capital cost for Option 1, was approximately 4% more expensive that the Option 2, thus showing the savings made by having a flexible water supply location.

Once a main layout had been chosen, it was found that minor changes in the layout actually resulted in only small percentage changes the overall pipe capital cost. It was not considered necessary to perform numerous iterations for the purpose of the study.

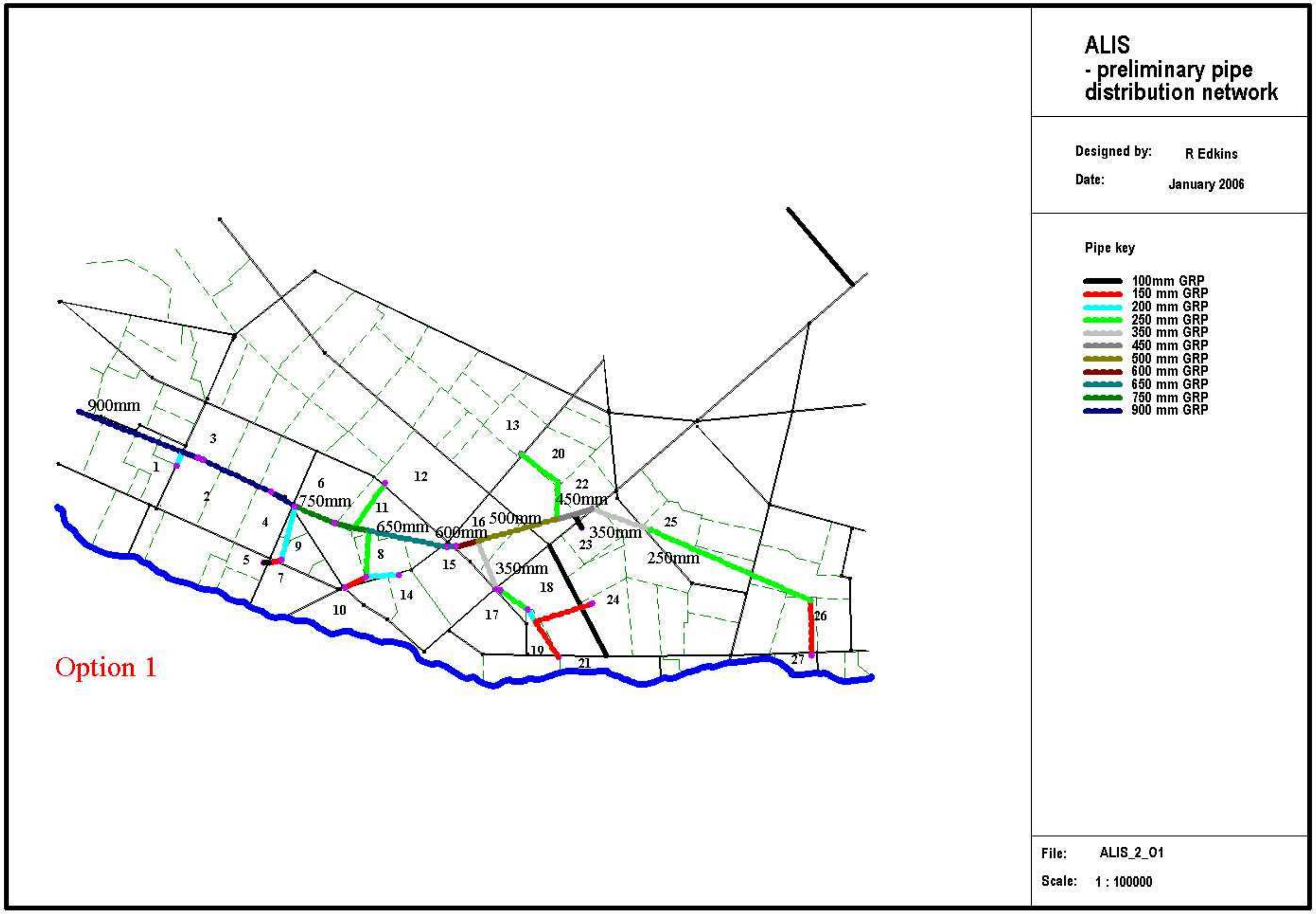

Figure 3: Option 1 proposed pipe layout

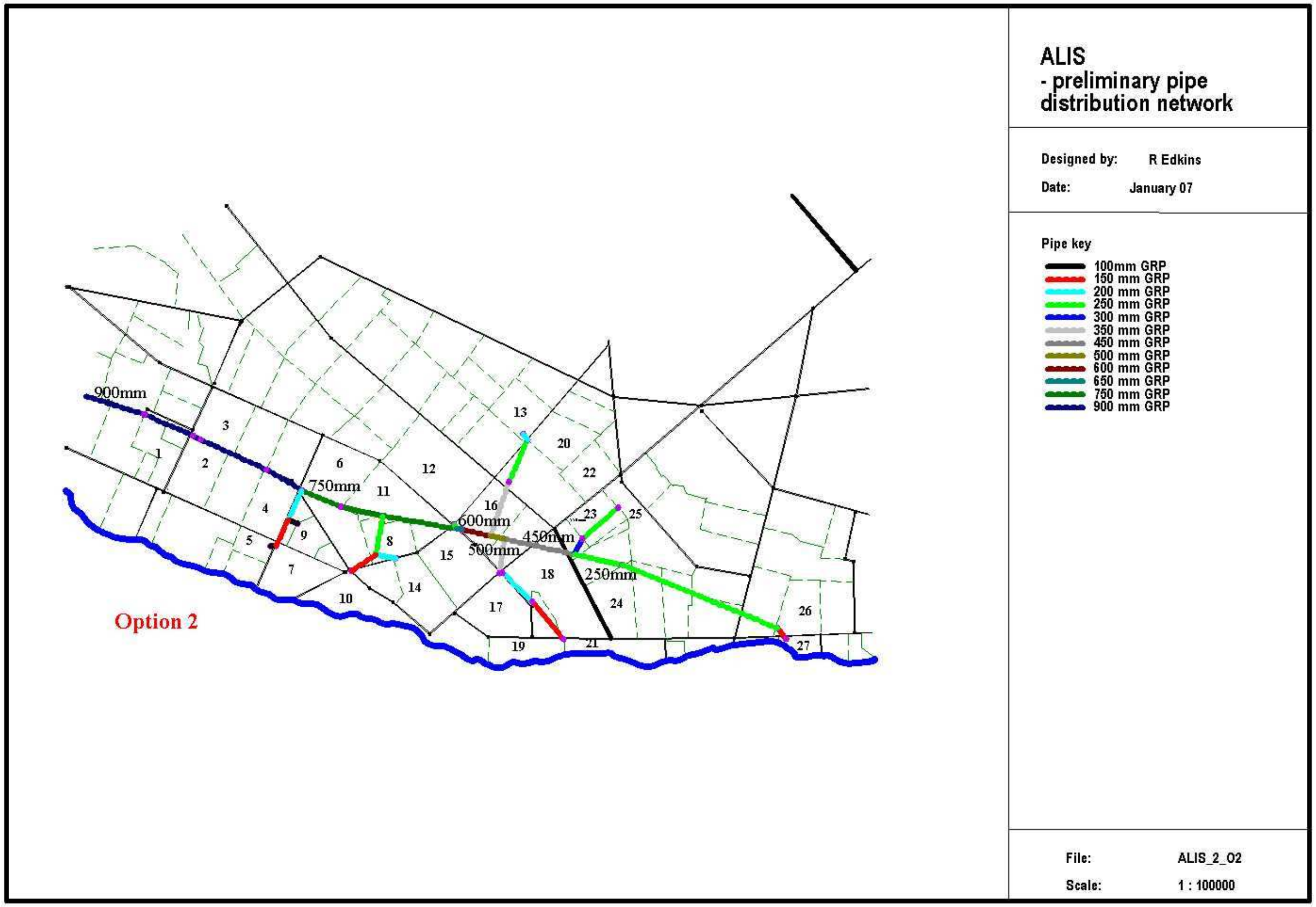

Figure 4: Option 2 - proposed pipe layout

4.2 On Farm Pumping

4.2.1 Pump Capital Cost

The preliminary on-farm pump size and pump capital costs for the two piped distribution system options are summarised in Table 5.

Table 5: Preliminary on-farm pump size and pump capital cost

Option	Total pump kW	Pump capital Costs
Option 1	285	$ 512,244
Option 2	214	$ 410,880
Open channel	893	$ 760,571

4.2.2 Annual Energy Cost

Table 6: Preliminary on-farm annual operational costs

Option	Annual on-farm pumping cost
Option 1	$ 57,013
Option 2	$ 48,350
Open channel	$ 359,311

Table 5 and Table 6 show that the Option 1 requires more pumping than for Option 2. This is likely to be related to the additional pipe length required to supply the turnouts at the specified locations which would be increasing friction losses within the scheme.

4.2.3 Trade-Off Between on Farm Pumping and Pipe Capital Costs

It was found that when sizing the pipe diameters for a lower velocity, pipe capital costs increased due to larger diameters being used. However, the reduction in pump capital cost and annual pumping did not offset the increase in pipe capital. The assumption of supplying minimal pressure to the turnouts under full load is justified.

4.2.4 Pressure Delivered Under Different Flow Demands

The delivery pressure to each turnout changes under different flow demands. To demonstrate this, the pressure delivered to four turnouts (one located near the top, two near the middle and one near the bottom of the scheme) under different flow demands for Option 2 are shown in Figure 4. The location of these turnouts is shown in Figure 3.

The turnout located near the top of the scheme only has a minor variation in pressure under different flow demands. The turnouts located near the middle and bottom of the scheme, some pumping may be required at 100% flow demand (assuming 50 m head is required), but when the flow demand reduces to around 80%, pumping requirements for these turnouts would be minimal.

Figure 5 demonstrates the number of turnouts that would require pumping throughout the season.

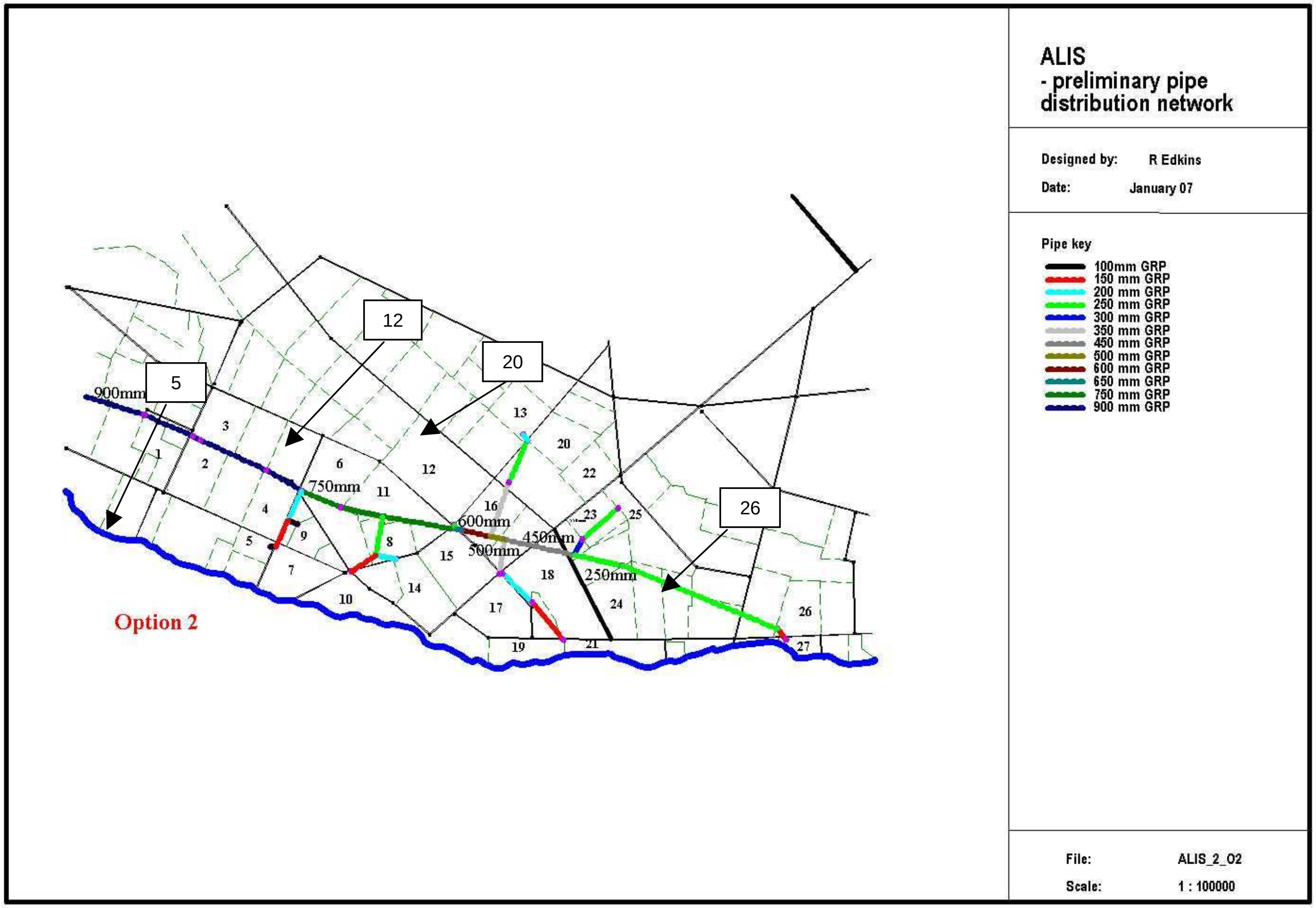

Figure 5: Location of turnouts to show pressure change dependent on load

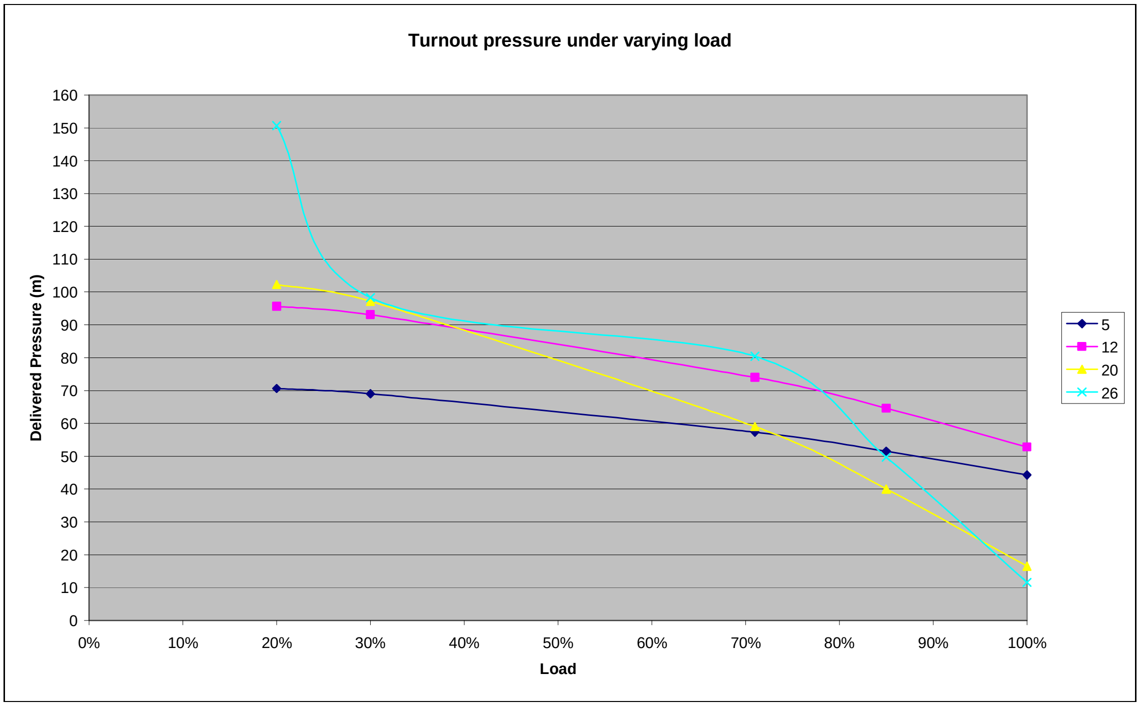

Figure 6: Turnout pressure for different flow demands, for turnouts located lower within the scheme.

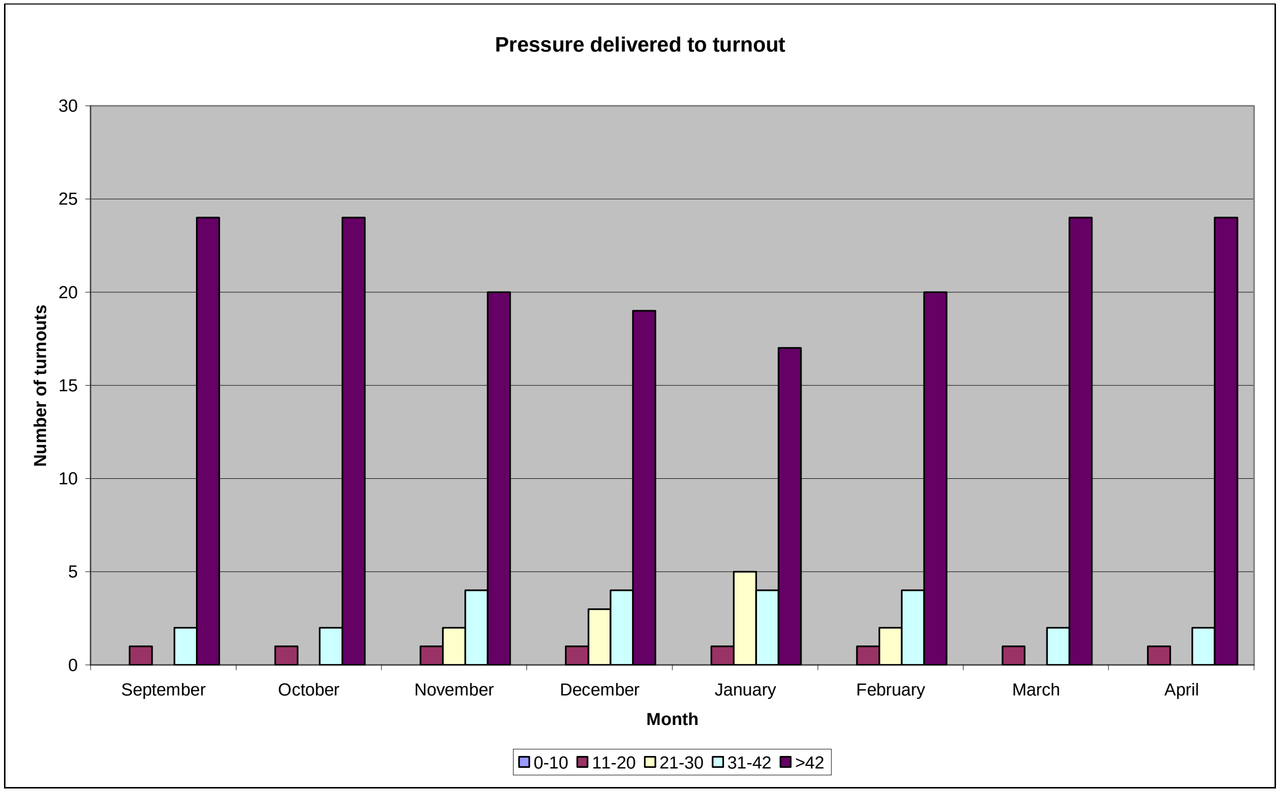

Figure 7: Turnout pressure for different flow demands, for turnouts located lower within the scheme