APPENDIX 7
GENERIC ISSUES IN THE COMPARISON OF PIPE AND OPEN CHANNEL IRRIGATION DISTRIBUTION NETWORKS - LESSONS LEARNED FROM CASE STUDIES

Contents

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1.0 Purpose

The purpose of this Appendix is to provide the generic understandings gained from the case studies on the technical issues that need to be considered, when completing a comparison of open channel and pipe distribution systems in distributing irrigation water for the purposes of spray irrigating the land.

The technical issues that are broadly discussed are design criteria, hydraulic design and estimating quantities and costs

2.0 Lessons Learned From Case Studies -- General

2.1 Cost Estimation

- The accuracy of cost estimation and reliance put on values should be reflective of the level of investigation or design the scheme is at.
- In early stage investigations scheme costs are underestimated. Often hidden costs and requirements are only considered at later stages.
- A number of unexpected costs often become exposed in detailed design.
- Effort to complete several design iterations is recommended to optimise schemes as significant savings can be made with efficient designs.
- The method of ‘contract’ with contractors affects scheme cost. Contracts are a risk sharing device and the more risk a contractor takes the greater the cost.
- Suppliers and contractors are often willing to assist with pricing components of projects.

2.2 Pipe Schemes

- Pipe scheme cost is generally similar nation wide dependent on pipe material utilized. Alternative pipe types often come with specialized installation systems that have comparable final installed costs.

- For large schemes, often effort is put into sourcing materials from less expensive countries with minimal representation in New Zealand. Experience indicates the cost of pipes made outside New Zealand is not significantly cheaper than local products for comparable material properties. Low quality pipes can be sourced internationally (up to 50% cheaper) but carry a corresponding risk factor.
- Pipe sizes less than 600 mm can often utilize several material types. Above 600 mm the range of materials is more limited including supplier choice. Optimising pipe diameter during design can save significant costs.
- The pipe scheme case studies will provide an approximate scheme cost independent of scheme location in New Zealand. The spreadsheet was developed for gravity water supply at the intake. Pump schemes may alter pipe designs based on transient effects and the velocity versus friction loss design of the pipe.
- For schemes with frequent topographic variation a significant proportional cost will be bends and anchor blocks.
- Contractors for pipe scheme construction are limited when compared to canal construction due to specialist skills often required, such as ticketed welding or installation techniques.
- The layout of the scheme significantly affects costs. Long large diameter primary feeder pipes should be minimized. The two case studies highlighted that the overall scheme layout affects the efficiency of the design.

2.3 Canal Schemes

- Canal scheme design is typically unique to the location and flow requirements, and unit costs are not easily transferred from one scheme to another.
- Local geology, topography and intake locations significantly alter the infrastructure design.
- The acceptance criterion for water losses requires consideration by developers and the appropriate Resource Consenting authority. Where seepage targets are set without regard to the available soil types and construction materials, canal lining may become prohibitively expensive or possible unfeasible from a technical viewpoint. Lining costs are a large portion of canal costs.
- Contractors and equipment for canal scheme construction are readily available and competitive prices can be obtained for construction.
- For larger canal schemes it may be appropriate to pipe smaller sub areas of the scheme rather than constructing tertiary canal systems.
- Water management of canal schemes is often more wasteful than pipe schemes. Utilising modern control systems and equipment such as automated gates for a new scheme will provide significantly improved water usages than a manual system.

3.0 Setting Common Design Criteria

For a fair comparison between the piped distribution and open channel it is important that, as far as possible, both options deliver water to each turnout with the same level of service. Before the outset of designing the piped distribution or open channel network, the design criteria must be clearly outlined.

3.1 Water Source

For an open channel and pipe distribution comparison, the water is likely to be supplied by gravity from a race or a head pond.

- The water may be abstracted from one specific location or from multiple locations.
- There may be opportunity to locate abstraction points at different locations to reduce piping or open channel requirements. This should be considered further as part of the pipe layout optimisation.

3.2 Irrigated Area and Turnouts

- Generally the total irrigated area would be divided up into smaller areas, usually properties or farms. The number of turnouts on the scheme and the flow to be supplied by each turnout will need to be quantified.
- Typically, one turnout supplies one property. Where the properties are small in area, one turnout may supply multiple properties. Large properties may require multiple turnouts. Some properties within the command area of the scheme may not wish to be included within the scheme.
- Within each property, the area used to determine turnout flows may need to be adjusted to represent the actual area on the property that will the irrigated, after taking into account buildings, roads and other non-irrigable areas. Typically a factor of 90% is applied.

The function of turnouts needs to be established. Whether they will provide pressure control, flow control and metering or other functions has to be considered.

3.3 Pressure Control

When designing a pipe network, it is important to consider dynamic, static and transient (surge and water hammer) pressures and appropriate methods for pressure control. Where there are significant elevation changes throughout the network, the scheme may be subjected to high static pressures. If so, static pressure could be significantly higher than dynamic pressure and will be the main focus regarding pressure control.

- Typically lower pressure rated pipes and a lower standard of installation occurs on on-farm irrigation systems than used on municipal or scheme distribution systems, so it is important to protect on-farm systems from the risk of high pressures that may occur in the network.
- Two main options to provide pressure control are: (i) Design the scheme pipeline without pressure control to withstand full static, dynamic and transient pressures and to provide pressure control on-farm as part of the turnout. This will require higher pressure class pipe for the scheme but enable lower pressure class pipe to be used on-farm; and (ii) Provide pressure control within the scheme network in the form of pressure reducing valves or break pressure tanks. This allows lower class pipe to be used throughout the scheme but requires expensive pressure control within the scheme.
- Option 1 is preferred as the complexity of the scheme operation is reduced, lower cost control at turnouts can be used and maximum pressure is delivered to turnouts, reducing on-farm pumping. However, pipe costs are higher.
- Option 2 is more complex, has a higher risk of failure and reduces pressure delivered to the turnouts meaning more on-farm pumping requirements. In general, pressure control within the scheme should be avoided if possible.

Transient modelling is required to minimise the risk of transient pressures throughout the network. Typically transient pressures do not limit design options and usually can be mitigated through appropriate operation and management of the scheme. Therefore at the pre-feasibility stage, transient pressures should be modelled, but it is not necessary to consider transient pressure in detail.

3.4 System Capacity

- The flow delivered to each turnout is usually based on a scheme system capacity, which is defined in litres/second/hectare and related to irrigation demand in the region.
- Based on the peak flow rate to be delivered to each turnout and physical or operational scheme losses in the system, the total peak flow rate for the network can be calculated.
- Whether the scheme design is to provide on-demand water to all water users at all times or whether the water is to be supplied on a roster system has to be considered.

3.5 Pipe and Open Channel Layout

- Whether the pipeline or open channel layout is constrained to following road corridors and property boundaries, taking into account property owners will not be involved in scheme must be considered. Services or existing infrastructure or features that need to be avoided when determining pipe layout options must also be taken into account.
- Because pipelines will probably be buried, property owners are likely to be more amenable to pipes passing through their properties. Open races, due to their nature, will have a larger impact on property owners and will most likely be constrained to property boundaries and road corridors.
- To ensure that piped distribution and open channel networks can be properly compared, they must deliver the same level of service to each turnout. Additional pipeline (or similar) may be required on an open channel network to achieve this.

3.6 Turnout Delivery Pressure – Piped Option Only

- The system needs to be designed to supply positive pressure (say a minimum of 5 m) to all turnouts, ideally without the need for in-scheme pumping. This reduces the risk of negative pressures developing.
- Whether the minimum pressure is set higher than 5 m, for example, where the pressure delivered (if possible) to the turnouts is sufficient for irrigation systems to operate effectively without on-farm pumping, depends on the trade-off between scheme pipe capital cost and on-farm pumping cost. An effective way of examining this is to calculate a net present value (NPV) for the scheme and on-farm pumping and choose the option with the lowest NPV.

3.7 On-Farm Pumping

- To operate an on-farm irrigation system effectively, a minimum pressure will need to be supplied, which for pre-feasibility studies, should be based on typical irrigation system pressure requirements. For example, a typical spray irrigator requires approximately 40 m pressure at the hydrant to operate effectively. Assuming there is 10 m pressure loss due to friction within the on-farm pipeline, then the turnout pressure would need to be 50 m.
- With an open channel network, delivery pressure is effectively zero and pumping from the open channel will be required to deliver the necessary turnout pressure to the irrigation system.
- With a piped gravity system, water will be supplied to each turnout under pressure. However, due to friction losses or changes in elevation along the pipe network, some on-farm pumping may be required at times in some locations.
- To aid in the assessment of on-farm pumping requirements for both open channel and pipes systems, land use projections and monthly and seasonal irrigation demand estimates are required. These will form the basis for the change in irrigation demand through the irrigation season and will be the criteria used for determining the operational costs for on-farm pumping.

4.0 Hydraulic Design

4.1 Pipe Layout and Sizing

The pipe layout is determined by completing a preliminary hydraulic analysis under various options to maintain positive turnout pressures if possible and to provide approximate pipe diameters and cost for each option. Cost is usually used to rank layout options. Once an acceptable layout is determined, a detailed hydraulic analysis is completed to finalise the pipe diameters of the network to ensure all design criteria and appropriate design limits are met.

4.2 Pipe Layout

4.2.1 Contour Information

The level of detail for the contour information entered into the modelling software needs to be appropriate for the region. For example, on gradually sloping plains (e.g. Canterbury Plains) 10 m contours may be acceptable as the interpolation between these contours is going to give a reasonable estimation of the lie of the land between the contours. However, in North Otago on the rolling downlands, a higher level of contour information may be required as interpolation between the contours may not be representative of the lie of the land.

4.2.2 Water Source

When the scheme water source is from a main race, multiple water supply takes from the water source should be considered. This may have the advantage of allowing some properties near the top of the scheme to be supplied directly from the water source. Also the main water supply location point may adjust so that it is closer to the majority of turnouts, which will reduce the length of larger diameter pipe required.

4.3 Turnouts

Laterals branching off from the main supply pipe should be used to supply the turnouts. The number of laterals to supply water to the turnouts can be reduced by relocation of the turnouts. For example, to deliver water to four adjacent properties if the turnout is located at the high point on the properties then two lateral pipes are likely to be required, whereas if the turnouts can be repositioned it may be possible to deliver all four properties by one larger pipe which is likely to be more cost effective. This is possible only if there is flexibility in the turnout location.

4.4 Pipe Layout

To optimise the pipe layout various pipe layouts need to be modelled. In doing this approximate pipe diameters should be determined, thus enabling the total pipe capital cost to be estimated.

Using pipe network modelling software, pipe diameters throughout the entire network can be initially sized based on water flows not exceeding a specified velocity. This is considered an appropriate method for selecting a pipe layout, as it provides a quick assessment of the pipe diameters and costs required throughout the network for different layouts. Using software, this method is repeatable and should provide for a consistent and comparative approach for assessing the different layouts. A full hydraulic analysis is required to finalise pipe diameters within the network (see Section 4.6). This is not considered necessary for comparative assessments of the different layouts in the initial stages.

4.5 Using Gravity for Maximum Benefit - Maximum Velocity

For schemes with significant fall from top to bottom of the scheme, the elevation change over the length of the pipe network may allow higher velocities to be used, as the change in elevation supplies pressure in the system. This enables smaller diameter pipes to be selected, as the elevation gain largely offsets the additional friction losses within the smaller diameter pipes.

If the velocity is too high, pipe friction losses will exceed pressure gains due to gravity, meaning that the pressure within the pipeline could become negative or zero, or the cost of on-farm pumping may become excessive. Also, the risk of water hammer and problems with transient pressures increases significantly at high velocities.

If the allowable maximum velocity is too low, pipe diameters and hence pipe cost will increase significantly. Further, minimal reductions in on-farm pumping costs are often achieved, ultimately increasing the total NPV of the network.

When setting a maximum velocity, trial a couple of scenarios, bearing in mind that a maximum velocity may need to be set to reduce the risk of water hammer (e.g. 3 m/s). Aim on basing the velocity on supplying positive pressure to the majority of turnouts and on pressure increasing down the network within the main supply pipe. This approach means that typically no further adjustment will be needed to the main supply pipes and only pipe diameters on the laterals need to be adjusted to ensure all turnouts receive positive pressure (described in Section 4.6).

The trade-off with this approach is that 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 a scheme.

This is investigated further in Section 4.10 where the NPV for the entire network is considered to determine the trade-off between pipe capital cost and on-farm pumping cost.

4.6 Pipe Diameter

Once the layout is finalised, diameters of the pipes can be determined.

- Check that velocity within pipes is within acceptable velocity limits to reduce the risk of water hammer.
- Check that the dynamic and static pressure within the pipelines are within pipe pressure class limits.
- Check that the minimum pressure is supplied to all turnouts.

4.7 On Farm Pumping

- The turnouts that require on-farm pumping need to be identified and the pump size determined based on supplying the agreed turnout pressure at peak load. In areas of high irrigation demand and on smaller schemes with low numbers of turnouts, peak load may be based on 100% demand.
- In schemes with lower irrigation demand, with high numbers of turnouts and a wide variation of crop types, a lower figure such as 90% scheme demand or 80% scheme demand may be preferred.
- The network is then modelled under different loading to calculate the energy costs related to on-farm pumping.

4.8 Pump Size

From the modelled scheme delivery pressure data under peak load conditions, the turnouts that require on-farm pumping can be identified by comparing the minimum on-farm pressure specified to operate the irrigation system with the scheme delivery pressure. The additional pressure required to supply the on-farm pressure is calculated. This data is used to size the pump for each turnout.

For the open channel option, a standard soft-start surface pump should be sufficient as pumping pressure requirements are generally fixed. Either the system is running or it is not and there is little variation in the pump power required throughout the season.

For the piped option, variable speed drive pumps should be considered due to the large variation in pump pressure requirements experienced at the turnouts throughout the season.

4.9 Pump Operational Costs

To enable seasonal pumping costs to be calculated, model the pressure delivered to each turnout using the average monthly flow demand for each month. Based on the average monthly flow demand, calculate the number of hours that the turnout would have been operating at maximum flow within that month.

Using the maximum flow and operating hours per month, the monthly on-farm pumping requirement can be calculated, thus giving the total season pumping energy use.

4.10 NPV

When designing the scheme and finalising the pipe diameters, it is important to consider both capital and operational costs, to establish a relative total cost of the scheme. This can be done by calculating the NPV.
Based on the pipe diameters determined in the design process, the pipe lengths and pipe class are known and pipe capital costs can be calculated.

Using the total seasonal energy use and energy price to determine energy costs and adding in other annual costs such as maintenance and operational costs, calculate the net present value of the annual costs based on a representative discount rate over an appropriate period of time.

Add the pipe capital cost and other capital costs to the net present value of the annual costs to determine the total cost of the scheme. Note that it is not necessary to include all scheme costs for this assessment if they are the same for all options. Only differences should be included.

Adjust the pipe diameters based on a lower or higher velocity, or manually following the steps described above and recalculate the capital costs and annual costs and compare. Continue performing these iterations until the lowest NPV is established.