Information Sheet

5.19 The negative effects of modifying irrigation systems outside of design specifications

Introduction

The design of an irrigation system is a specialist activity. Sophisticated design methods are used to select appropriate hardware according to site-specific requirements and end-user preferences. This information sheet, highlights the negative effects of modifying the irrigation system hardware beyond the design specifications.

An irrigation system typically consists of:

- Pumping system: pump house, pump, electrical motor, electrical switch gear, suction and delivery pipes, valves, pressure gauges and/or flow meter;
- Pipe network: delivery main and sub-main lines plus permanent or moveable infield lateral pipes;
- Discharge emitters: sprinklers, micro sprinklers, drip emitters or siphons, and
- Control equipment: valves for flow control, pressure regulation, air release and/or anti-vacuum control.

Additional components such as filters, fertigation units, automation and telemetry are also commonly included.

Design documentation checklist

The South African Irrigation Institute (Suid Afrikaanse Besproeiings Instituut - SABI) recommends the use of suitably qualified professionals and provides a list of SABI accredited designers and their contract details for each province on their website: www.sabi.co.za.

SABI also specifies that the professional irrigation designer should provide the farmer with a design report for new irrigation systems and/or upgrades. The report should contain a layout plan, list of quantities, detailed drawings, pump curve, maintenance and management manual, SABI peak design form and a cost estimation. More details about the design report are provided in an annexure at the end of this information sheet.

Fundamental design principles

To appreciate the negative effects of modifying irrigation hardware away from the design specifications, basic design principles are presented first. An essential aspect of irrigation design is to select the correct pump to meet the pressure and flow requirements for the specific site (e.g. topography) and context (e.g. climate, soil, choice of crop and irrigation system, and preferred operating rules).

Water Pressure

The pump must provide enough water pressure to meet the needs of the irrigation system.

As shown in Figure 1, the pump must deliver enough pressure to:

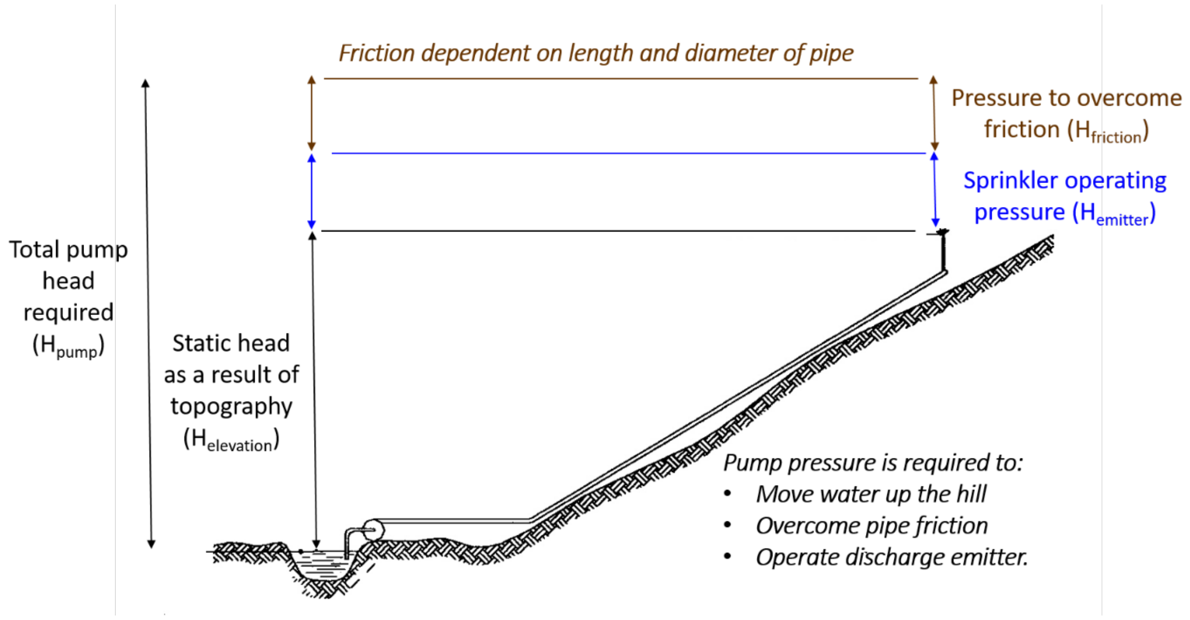
(1) overcome the change in elevation,

(2) overcome the frictional resistance in the pipelines; and

(3) meet the operating requirements of the discharge emitter.

After a detailed topographical survey, layout drawings and design calculations, the designer will determine the maximum pressure requirement as follows:

$$H_{pump} = H_{elevation} + H_{friction} + H_{emitter}$$



▲ Figure 1: An Illustration of the factors used to determine the pump pressure requirement.

Pump Flow

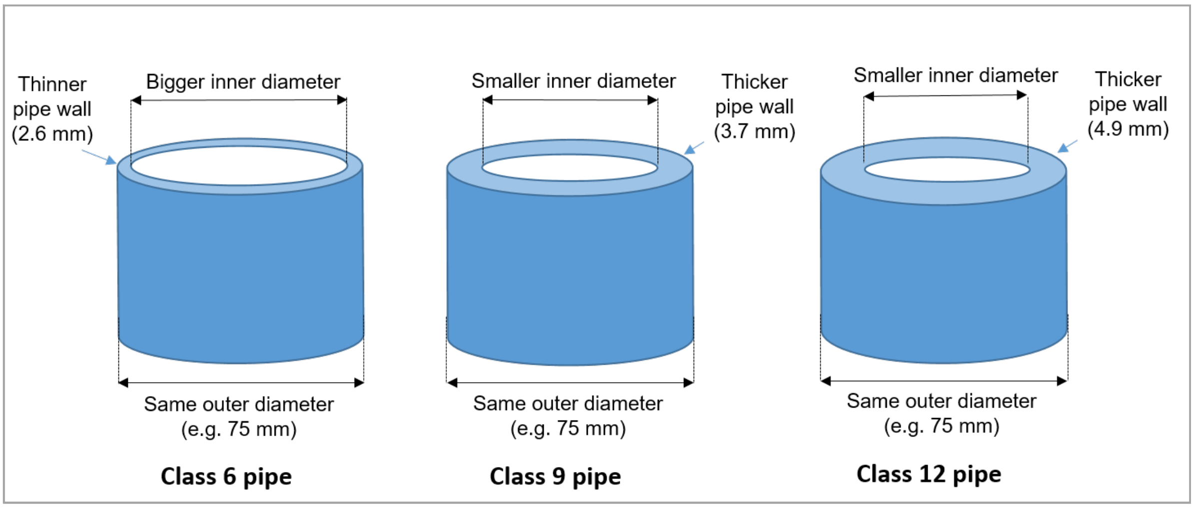
The designer makes use of climate, soils and crop information to determine the irrigation requirement. An appropriate emitter, with a specific flow rate, and an accompanying set of operating rules is then selected to match the irrigation requirement.

The pump flow rate is determined by multiplying the individual flow rate of the discharge emitter to the total number of emitters required per shift. Depending on the type of irrigation system, a designer will typically divide a farm into equal/similar sized irrigation blocks and calculate the number of emitters required to cover each block for a given set of operating rules (stand times and cycle length). Therefore, the flow rate is directly dependent on the size of the area to be irrigated. A larger area has more discharge emitters and therefore requires a larger flow rate and *vice versa*.

Pipe Design

Pipe diameters are selected to minimise friction between the flowing water and the inner pipe wall. Friction is a resistance force that hinders the flow of water. Pipe diameters are chosen to reduce the velocity of the water and the resultant frictional loss to within acceptable norms. A larger pipe diameter results in lower friction and lower pumping and electricity costs, and *vice versa*. Larger pipe diameter, however, comes at a higher capital cost. Therefore, the designer applies economic principles to find the optimal pipe diameter that renders the lowest cost combination, i.e. capital + operating cost.

In addition to pipe diameters, the designer also must select an appropriate pipe class. As illustrated in Figure 2, the pipe class is related to the thickness of the pipe walls and specifies how much pressure a pipe can withstand. For example, a class 6 pipe can withstand a pressure of 60 m (6 bar or 600 kPa), while a class 9 or class 12 pipe can withstand a pressure of 90 m (9 bar or 900 kPa) or 120 m (12 bar or 1200 kPa), for the same outer diameter. If a class 6 pipe is exposed to a pressure higher than 60 m, the pipe is likely to burst.

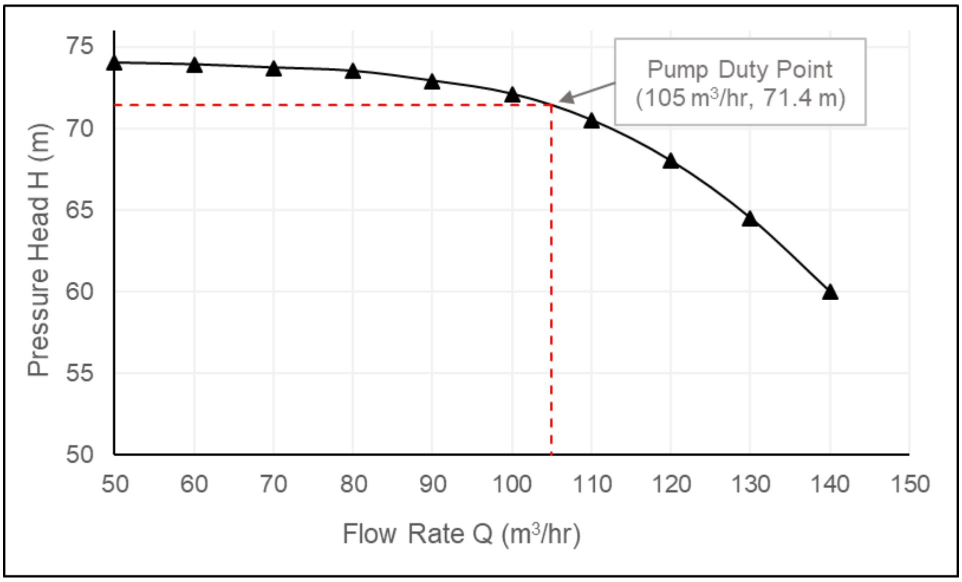


▲ Figure 2: Illustrating the difference in wall thickness for different pipe classes (but, same outer diameter).

Pump selection and associated pump curve (pressure-flow relationship)

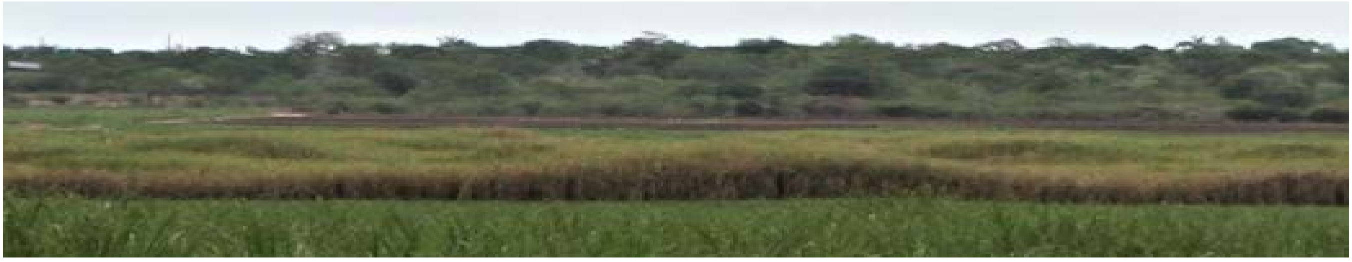
As described above, the pressure and flow rate requirements are calculated for the specific site, crop, climate, soil and irrigation system. Thereafter, the irrigation designer will select a pump that can deliver the flow rate and pressure at the highest efficiency.

Figure 3 provides an example of a simplified pump curve. Every pump has its own curve, which relates the different flow rates (Q) on the x axis to a corresponding pressure head (H) on the y axis, for the specific pump at a fixed speed in revolutions per minute (rpm). Every pump curve is also associated with a duty point. The pump duty point reflects the flow rate and pressure that the pump can deliver when operating at its best efficiency point. If the pump operates to the left or right of the duty point, it will be operating below its optimal efficiency. Hence, a pump is selected when the duty point best matches the site and context-specific system (pressure and flow) requirements.



▲ Figure 3: Simplified pump curve operating at 1450 rpm.

When a pump delivers a higher flow rate than the design specification, it operates to the right of the pump duty point on the pump curve and delivers lower pressure. This can result in under- and non-uniform irrigation (Figure 4). The pump also operates at a lower efficiency, drawing more power and increases the electricity costs of the system. In addition, the pump can experience cavitation, increasing the maintenance needs or decreasing the lifespan of the pump.



▲ Figure 4: Uneven height of sugarcane crop (wavy cane) due to non-uniform irrigation.

When the pump delivers lower flow rates, it operates to the left of the duty point on the pump curve. Lower flows can cause pump recirculation of water, which drastically reduces efficiency. Very low flows can also result in cavitation and unhealthy increases in temperature. Simultaneously, lower flow rates result in the delivery of higher pressure. This can result in non-uniform irrigation and crop stress. In addition, higher pressure increases the wear of pump impellers, bearings and seals. If the pump delivery pressure exceeds the design specifications, pipelines can burst or start leaking at joints.

As described in this section, the irrigation system and its individual components such as the pump, pipe network, irrigation block layout, emitter and operating rules are carefully designed/selected for each specific context and site. The irrigation hardware should be installed as per the design specifications.

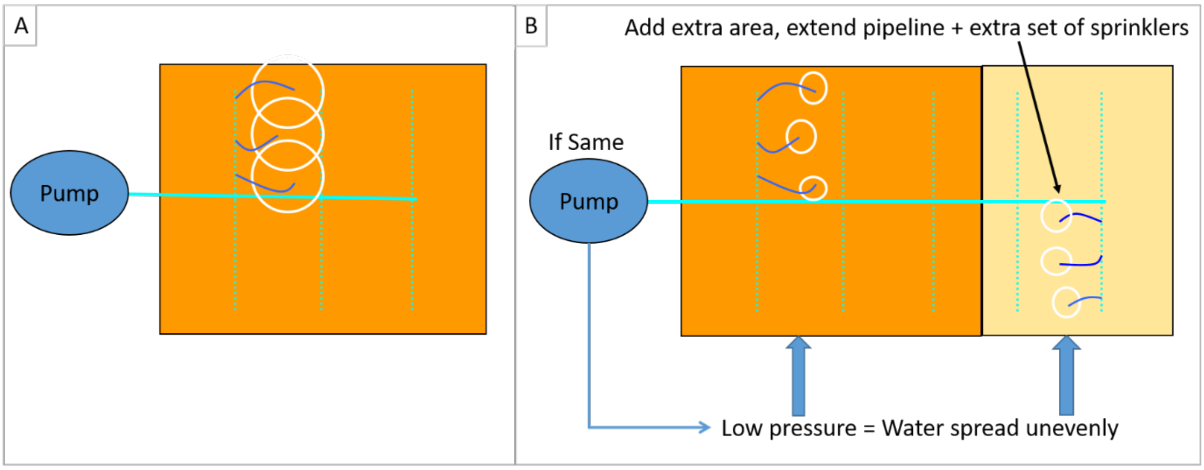
Typical modifications of irrigation systems and the associated negative impacts

Modifications of irrigation systems will lead to either one, or a combination, of the following: increase in cost, uneven irrigation, over- or in most cases under-irrigation, increase in maintenance cost and reduction of the "life" of the irrigation system. In this section, typical scenarios of irrigation system modifications are presented to illustrate the detrimental impacts of deviating from design specifications.

a. *Expanding the area under irrigation (Drip or Sprinkler systems)*

Often, the main or sub-main lines are extended with additional lengths of pipe to irrigate an additional patch of land, which was not included in the original design. The extra length of pipe implies more pressure is required to overcome the additional friction. Also, when the new patch of land is higher up on the hill, the pump must overcome a greater static head (increased pressure due to elevation). Sometimes, more emitters are added to the system to irrigate the new piece of land. As a result, the existing pump is not able to meet the additional pressure and/or flow requirements and the total system operates at a reduced pressure.

This is depicted in Figure 5A and 5B, where 5A is the original design with adequate pressure and flow for a dragline sprinkler system, resulting in good irrigation uniformity. Figure 5B illustrates a modification to the system with an added area, extended pipelines and an extra set of sprinklers, but with the same pump, resulting in low pressure and poor irrigation coverage. This leads to poor irrigation uniformity, under-irrigation, crop stress, additional operating costs and increased wear and tear when the pump is not operating at the best efficiency point.



▲ Figure 5A: Original design with good sprinkler coverage.

▲ Figure 5B: Modified design with extra area, extended pipes and extra sprinklers causing low pressure across the system and poor sprinkler coverage.

In Figure 5B, if a new pump capable of meeting the new pressure and flow requirements of the additional area is installed, care is still required to evaluate the pipe diameters and pipe classes (strength of the pipe to deal with the additional pressure) in the existing main line. A designer will need to ensure that the frictional losses, relating to pipe diameters, are still within the acceptable norms for economical pumping and that the pipe wall thickness, relating to pipe classes, can withstand any increase in pressure delivered by the new pump.

b. *Adding on extra sprinklers (dragline or semi-permanent sprinkler systems)*
Sometimes, to shorten the cycle length or to avoid irrigating at night, extra sprinklers are added to the system to irrigate the same area over a shorter period. Adding extra sprinklers, however, increases the flow rate requirements, causing the pump to operate to the right of the pump duty point on the pump curve (i.e. higher flow and lower pressure). The reduction in pressure delivered by the pump can lead to non-uniform irrigation and/or under application of water on higher portions of land.

c. *Replacing sprinklers, nozzles or emitters with wrong specifications*
Water and suspended sediments flowing at high pressure are abrasive and cause the nozzles in sprinklers to wear out over time. As a result, nozzles need to be replaced periodically, as part of the preventative maintenance programme. Similarly, sprinklers on centre pivot systems can also get damaged and malfunction over time, while drip emitters can become clogged. Replacement of sprinklers, nozzles or drip lines with emitters that differ from the original design specifications can significantly alter the pumping requirements. For example, a 5% increase of the nozzle area (opening) can result in a 10% increase of flow and power demand. Hence, if the new discharge emitters require increased flow or pressure, the existing pump will operate outside of the best efficiency point, resulting in increased operating and maintenance costs, as well as non-uniform, under- or over-irrigation and crop stress.

Modifying irrigation systems, without consulting a professional irrigation designer, or replacing irrigation hardware with components that deviate from the original design can have serious and detrimental impacts on crop yield, as well as the lifespan, and operating and maintenance costs of irrigation systems. Contact your SASRI Extension Specialist or a suitably qualified irrigation designer for assistance if your irrigation system needs to be modified.

Items to be included in an irrigation design report

A professional irrigation designer should hand over a design report to the client with the following contents:

Layout plan

This should comprise the layout of the blocks and detailed plans of each block. Two copies are required, one for installation purposes and one for the grower's records.

List of quantities

A list of the materials, with size and other specifications, required for each block or system is needed so that quotations can be obtained from irrigation equipment suppliers. The list of quantities can also be used as a checklist for the equipment that is delivered by the irrigation equipment supplier.

Detailed drawings

Detailed drawings of equipment are required to make installation easier, and should include:

- Valve connections: drawings of the valves with the desired accessories.
- Filter banks: drawings of the complete filter installation with manifolds and valves.
- Pumps: drawings of the pump with necessary equipment.

Pump curve

The irrigation designer issues the pump manufacturers pump curve indicating:

- the design flow rate and pressure at the pump duty point,
- the pump operating efficiency and power requirement, and
- at what suction height the system is designed for, so that the user knows what the minimum water level requirements are. This is often overlooked and is the cause of suction pressure problems and high operation and maintenance costs.

Maintenance and management manual

A comprehensive maintenance and management manual is required to ensure that the performance of the installed irrigation system is not adversely affected by incorrect maintenance and management practices.

SABI peak design form

The SABI peak design form contains technical specifications that should be evident in the design. The required operating flow rate and pressure for the irrigation system at critical points, as well as many other parameters are included to help the irrigator manage the system.

Cost estimation

A cost estimate must be made for the whole project and, if applicable, for each phase.

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