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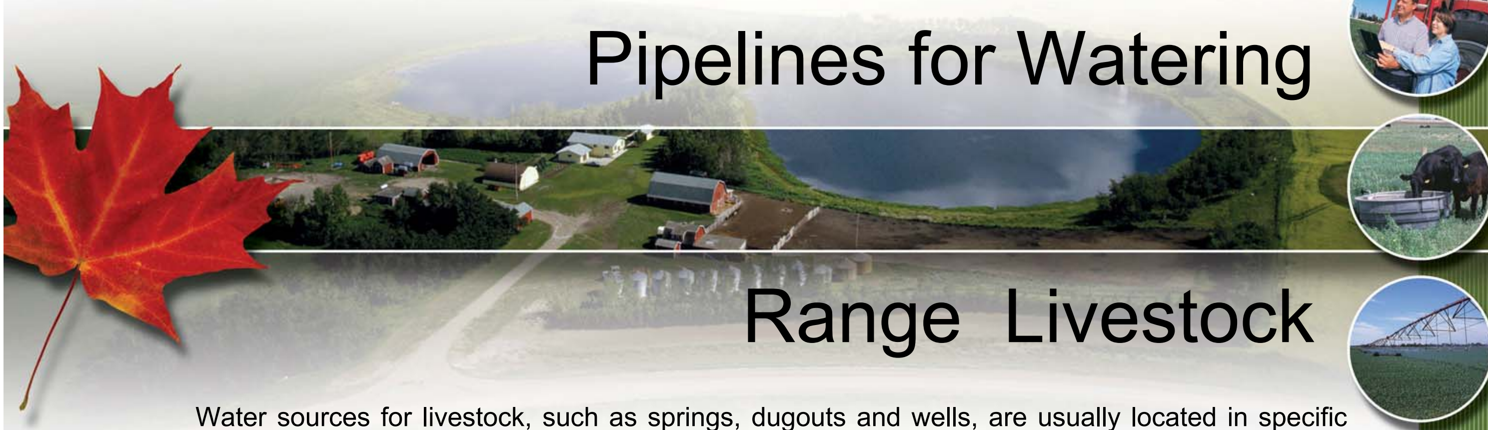
Pipelines for Watering Range Livestock



Water sources for livestock, such as springs, dugouts and wells, are usually located in specific geographic locations which often do not coincide with the locations where the water is needed. This constraint can be relieved by transporting the water from the source to the point of consumption. Pipelines are ideal tools for water conveyance on farming and ranching operations which employ intensive rotational grazing systems, if the grazing area is within about 1.5 to 2 km of a source of water and/or power.

What should be considered in planning a pasture pipeline system?

The following items should be considered in planning a pasture pipeline system:

- discharge (flow) requirements
- the size of pipe and the material comprising it
- distance from the source to the point of consumption
- elevation difference between the source and the point of consumption, as well as the variation in elevation along the pipeline route
- permanence of the installation (i.e. year-round vs. seasonal use; the need for portability)

Other considerations, such as pressure requirements for delivering the desired amount of water, and the amount of pressure the pipe must be able to withstand, are considered implicitly in the preceding list, because they are functions of discharge requirements, elevation differences and the size and material composition of the pipe.

Assistance in determining the first item (discharge requirements) can be obtained by consulting the fact sheets on Pastured Livestock Water Requirements and Troughs for Watering Range Livestock in this series.

What types of pipe are commonly used in stock watering systems?

Pasture pipelines usually consist primarily of plastic piping material, with steel sometimes being used for fittings or in locations that are susceptible to damage. Plastic piping material can be either polyvinyl chloride (PVC) or polyethylene (PE).

PVC — PVC is a rigid plastic and PVC pipe is usually available in 20-foot (6.1 m) lengths. Lengths of pipe can be joined with a variety of joining methods, but solvent-welded joints are the most common for pasture pipeline applications. Although PVC pipe is available in pressure ratings varying from between 50 pounds-per-square-inch (psi) to 315 psi, the minimum recommended pressure rating for pasture pipeline applications is 125 psi for handling considerations. Because PVC deteriorates when exposed to ultraviolet radiation (sunlight), it should always be buried or painted.

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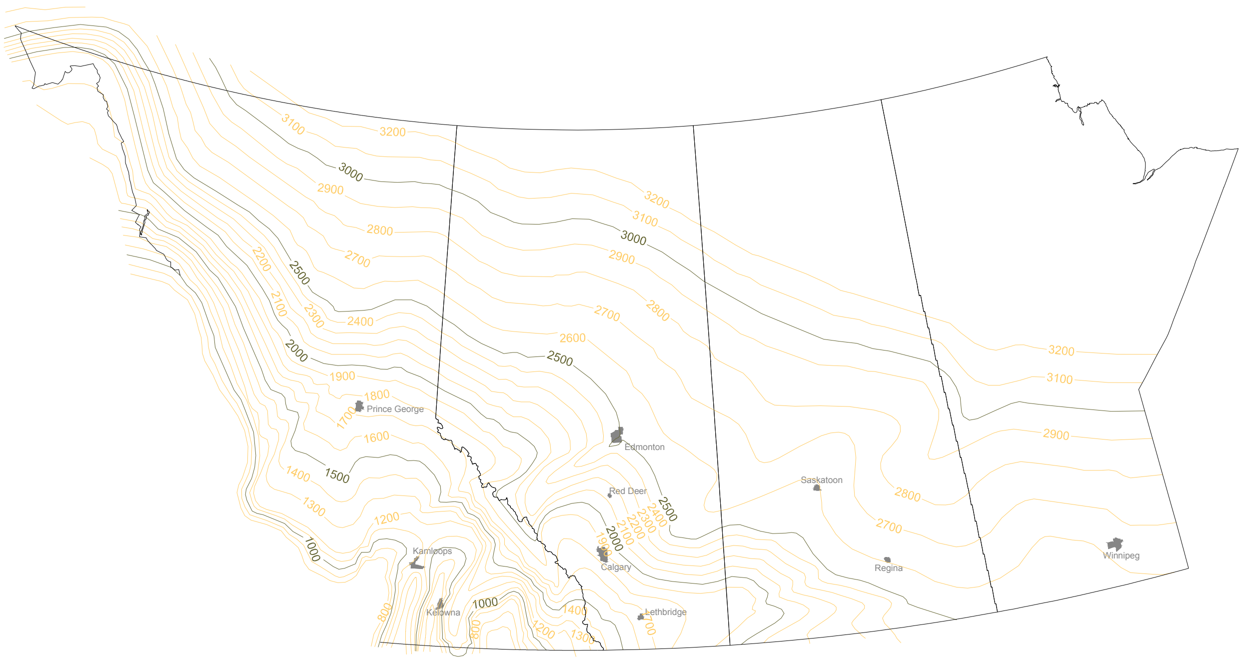
PE Polyethylene used in the manufacture of PE pipe is available as high, medium or low density material. High-density PE has greater strength than low or medium density material, and is less permeable to contaminants like hydrocarbons (oil and gas). However, high-density material is more rigid than low or medium density PE, and as a result, it is more difficult to handle and individual segments must be joined by a thermal fusion method. Most pasture pipeline applications using PE pipe use low-density polyethylene. Depending on the size of pipe, PE pipe is available in coils up to 300 m long. Individual lengths of low-density PE pipe are usually joined with insert fittings and screw clamps.

How should a pasture pipeline be installed?

Installation of pasture pipelines is governed by how they are intended to be used. If the system is intended to be portable and mobile, then the pipe should be strung out and laid on the ground surface. Because PVC deteriorates when exposed to ultraviolet radiation, and because it is relatively brittle, only PE pipe should be used for surface installation.

If the installation is to be permanent or long-term, then the pipe should be buried. Seasonal use of the system requires that the pipe only be buried a minimum distance beneath the ground surface. If the pipeline is intended for year-round use, it will have to be buried below frost level.



Depth of Frost Penetration (mm) in Western Canada

(Adapted from the Canadian Foundation Engineering Manual, Canadian Geotechnical Society, 1985)

Graphic Text to Translate: Depth of Frost Penetration (mm) in Western Canada (Adapted from the Canadian Foundation Engineering Manual, Canadian Geotechnical Society, 1985);

Pasture Pipeline Installation Methods

Surface Installation	Surface-laid pipe will require protection in areas where animals or vehicles regularly pass over the pipe, but unprotected pipe can usually tolerate limited crossings. Exposed pipe is susceptible to chewing damage by some animals. Surface-laid pipe should be anchored at intervals with stakes or rocks. Due to susceptibility to frost damage, surface-laid pipelines should not be considered for early spring or late fall use. Water conveyed through surface-laid pipe can sometimes get warm enough through heating from the sun to discourage cattle from drinking.

Shallow Burial

Plough for Shallow Burial of Pipe
Source: Special Areas Board, Alberta Government, http://www.specialareas.ab.ca/shallow.html

"Shallow" burial usually means burial to a depth of between 0.3 and 0.5 m. Shallow burial of pipe can be accomplished through ripping or ploughing, which can significantly reduce installation costs. Because PE pipe can sometimes be stretched during installation, individual rolls should be ploughed in separately, with overlap at the joints. Joints can be made later, with excess material "snaked" around the joint to allow the stretched pipe to relax without pulling the joint apart. Rigid PVC pipe can also be ploughed into the ground. PVC pipe should be laid out on the surface and assembled 48 hours prior to installation to allow the solvent-welded joints to set.

Deep Burial

Pipe intended for year-round use should be buried below the depth of frost penetration (see preceding figure). While it may be possible to plough pipe to such depths in some circumstances, the requirement for heavy equipment may make it cost-prohibitive on small jobs. Therefore, some deep-burial installations are trenched and backfilled. Small-diameter pipe does not usually require special bedding, but care should be taken to ensure that the initial backfill does not contain rocks or hard lumps that could damage the pipe.

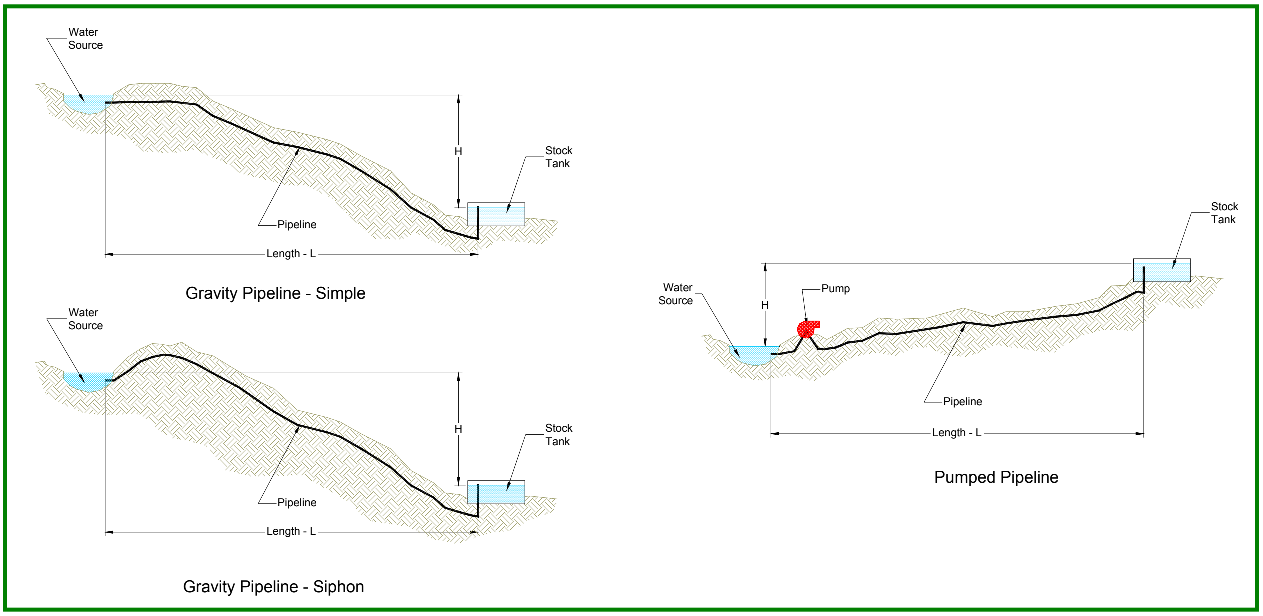
How should a pipe be selected?

The size and strength required for a pasture pipeline will depend on the flow it is required to convey, the distance from the source to the point of consumption, and the elevation difference between the source and the point of consumption.

Water flowing through a pipeline loses energy due to frictional resistance. For a given kind of pipe, the amount of energy or pressure that is lost to friction will depend on the size and length of pipe, and the rate at which water flows through the pipe. As a general rule, pasture pipeline systems should operate under conditions where the velocity of the water moving through the pipe is less than about 1.5 m/s (4.9 ft/s). Water flowing faster than this will result in unacceptably-high friction losses, and may result in the pipeline being subjected to water hammer problems if valves or pumps are operated improperly. Also note that if systems regularly operate at velocities less than about 0.5 m/s, sediment and sludge may accumulate in the line.

If the elevation of the source is higher than the point of consumption, it may be possible for sufficient water to flow under the influence of gravity; otherwise, a pump will be required. A special case of a gravity-driven pipeline system is a siphon. In this kind of application, the point of consumption is lower than the water source, but at one or more locations between the source and the point of consumption, the elevation of the pipeline is higher than the source.

The sketch on the following page illustrates various possible pipeline layouts, and the chart that follows the sketch provides information to enable the friction loss to be determined for various pipe sizes and flows.



Graphic Text to Translate: Water Source; Pipeline; Stock Tank; Length – L; H (height); Gravity Pipeline – Simple; Gravity Pipeline – Syphon; Pumped Pipeline; pump

The bold diagonal lines on the chart correspond to pipes of various diameters, whereas the dashed diagonal lines correspond to various flow velocities. For example, consider the case where a 25 mm (1 inch) diameter pipe is carrying water flowing at a velocity of 1.5 m/s (4.9 ft/s).

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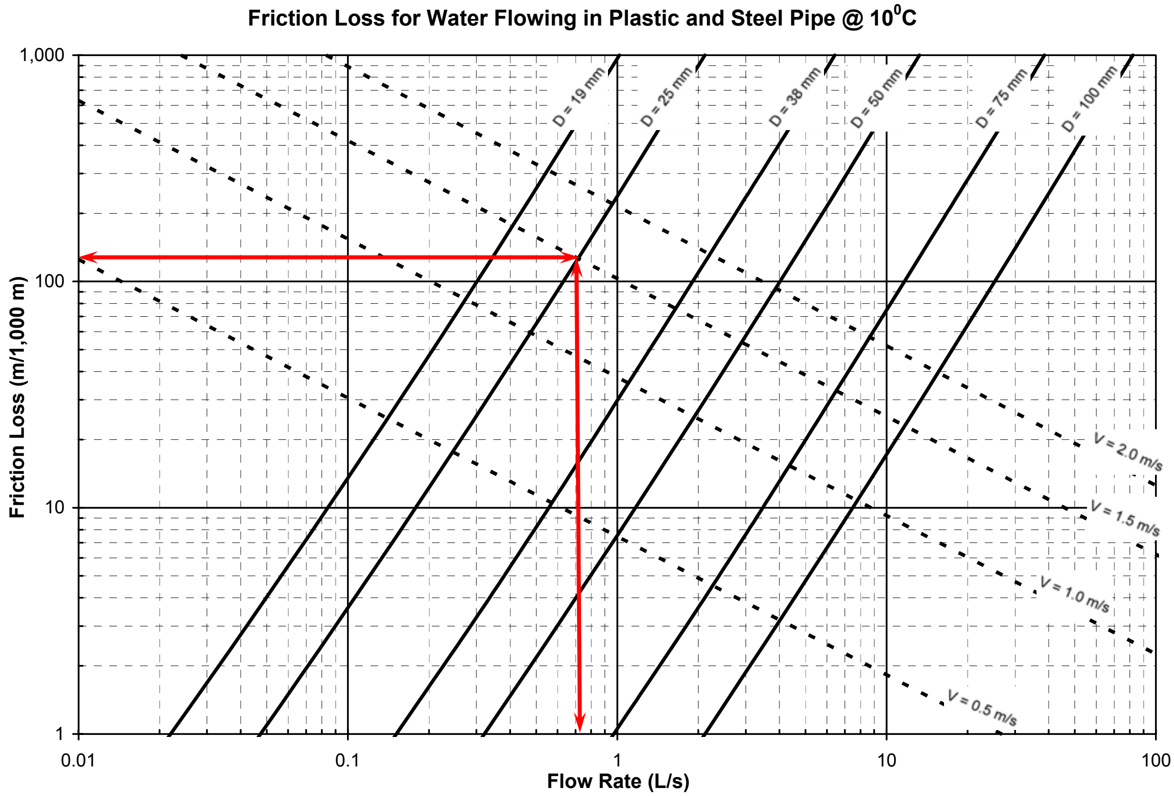


Graphic Text to Translate: Friction Loss for Water Flowing in Plastic and Steel Pipe @ 10 degrees Celcius; Friction Loss (m/1,000m); Flow Rate (L/s); D =19mm; V=0.5m/s

As shown by the red arrows, for this situation, the flow will be about 0.73 Litres per second (11.6 US gpm), and the friction loss will be about 125 m (410 ft) for every 1,000 m (3,280 ft) of pipe length. Other ways to use the chart, and further explanation of the units, are presented in the following sections.

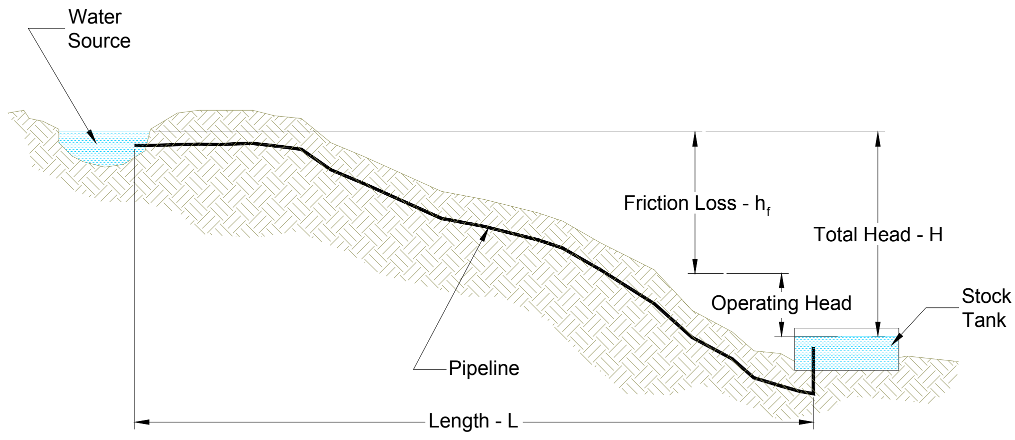
The pipe selected should have a pressure rating that exceeds the total pressure that might be exerted on the system. This total pressure is often expressed in units of length, rather than pressure, and it consists of the following elements:

1) Operating pressure - the pressure that is required immediately upstream of the point of discharge. Usually about 15 psi (100 kilopascals - kPa), which can be expressed as about 35 feet (10.6 m).
2) Elevation difference - 1 psi (6.9 kPa) = 2.31feet (0.71 m) of elevation.
3) Pipe friction - pressure lost as water flows through the pipe.
4) Transient pressures - pressure waves caused by rapid valve operation or start-up or shut-down of a pump.

Determination of transient pressures is very complicated, but fortunately, for most pasture pipeline situations, they are not a significant concern; the pipelines are relatively long, the pipe material is fairly elastic, and they operate at relatively low velocities. If flow velocities are kept below about 1.5 m/s, and if the maximum pressure determined by adding items 1 to 3 in the preceding list is less than about 70% of the pressure rating for the pipe, it is very unlikely that transient pressures will cause problems.

Example - Gravity Pipeline

A rancher/farmer intends to develop a pasture pipeline that can convey water to a watering point at a rate of about 40 litres per minute (0.67 L/s or 10.6 US gpm). The source of water is a spring located about 1.2 km (0.75 mi) from the proposed location of the stock tank, at an elevation about 40 m (131 ft) higher. A minimum pressure of about 100 kPa (15 psi) is required at the waterer, which can be expressed as 10.6 m (35 ft.) of head. What pipe size and pressure rating is required?



Gravity Pipeline - Example

Graphic Text to Translate: Gravity Pipeline – Example; Water Source; Pipeline; Friction Loss h subscript f; Operating Head; Total Head – H; Stock Tank; Length - L

1) *Determine the maximum system pressure*
   The maximum pressure exerted on the pipe will be when no water is flowing and will equal the Total Head, which in this case, is 40 m (131 ft.), or 57 psi (390 kPa).

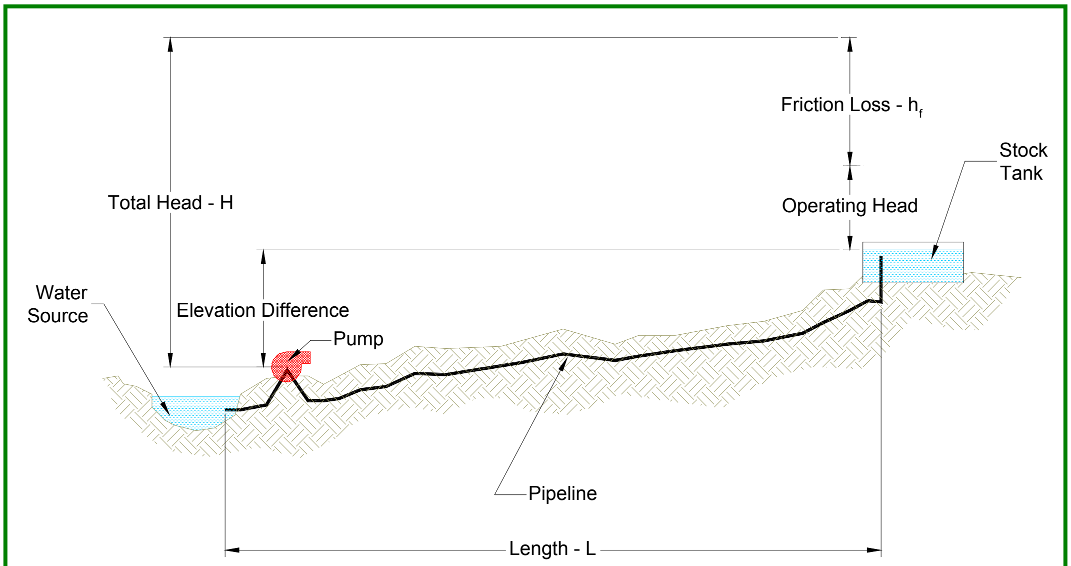
2) *Select a suitable pressure rating for the pipe*
   The maximum pressure determined in step 1 should be about 70% of the pressure rating of the pipe. So, the pipe should have a minimum pressure rating of about 57÷0.70=80 psi (550 kPa).

3) *Determine the required pipe size*
   The total head available is about 40 m, and of that, 10.6 m is required to operate the waterer. This means that there is about 29.4 m of head that can be used to overcome friction losses over the 1,200 m distance that the water has to travel. Expressed as the head loss per 1,000 m, this would be 29.4÷1.2, or 24.5 m/1,000m. Referring to the chart, by drawing a horizontal line across at a level indicating a friction loss of 24.5 m/1,000 m, and a vertical line up from a location indicating a flow of 0.67 L/s, the two lines intersect between the bold lines defined by 25 mm diameter pipe and 38 mm diameter pipe. The larger of the two pipe sizes should be chosen. It should also be noted that the two lines drawn for this problem intersect at a location below the dashed line indicating a velocity of 1.5 m/s (actually, between the dashed lines defining velocities of 0.5 and 1 m/s), so transient pressures are unlikely to be a concern.

Therefore, a 38 mm (1½ inch) diameter pipe with a pressure rating of 80 psi (550 kPa) can satisfy the rancher's needs.

Example - Pumped Pipeline

A rancher intends to develop a pasture pipeline that can convey water to a watering point at a rate of about 24 USGPM, or 90 litres per minute (1.5 L/s).The source of water is a dugout located about 600 m (1,960 ft) from the proposed location of the stock tank, which is about 15 m (49.2 ft) higher than the dugout. A minimum pressure of about 100 kPa (15 psi) is required at the waterer, which can be expressed as 10.6 m (35 ft.) of head. What pipe size and pressure rating is required?



Pumped Pipeline - Example

Graphic Text to Translate: Pumped Pipeline – Example; Total Head – H; Water Source; Elevation Difference; Pump; Pipeline: Friction Loss – h subscript f; Operating Head; Stock Tank; Length - L

1) *Determine the required pipe size and pump characteristics*
Referring to the chart, the smallest pipe that can carry a flow of 1.5 L/s at a velocity less than 1.5 m/s would be a 38 mm (1½ inch) diameter pipe, which would have a friction loss of about 60 m per 1,000 m (refer to chart). Larger pipes could be selected which would have lower friction losses, but if we assume that we want to minimize pipe cost, then the smallest pipe size governs. In this case, the friction loss would be about 36 m (ie. if such a system would lose 60 m of head over a distance of 1,000 m, it would lose 36 m over a distance of 600 m). Therefore, the maximum pressure that would exist while the system was operating would be 15+36+10.6 or 61.6 m (202 ft.), or 88 psi (600 kPa). The rancher would ask his pump supplier for a pump that could deliver a flow of 24 US gpm against a head of 202 feet.

2) *Determine the maximum system pressure and required pressure rating for the pipe*
The maximum pressure that the system would experience would be when the pump was still running, but the valve at the stock tank was closed. In such a case, the Total Head would be the pump "shut-off" head, which could be obtained from the pump supplier.
For the purposes of this example, we will assume that the shut-off head for the pump is about 230 ft (70 m) or 100 psi (690 kPa). Therefore, 100 psi should be about 70% of the pressure rating for the pipe, so the pressure rating for the pipe should be greater than about 140 psi (965 kPa).

Therefore, a 38 mm (1½ inch) diameter pipe with a pressure rating greater than 140 psi (965 kPa) can satisfy the rancher's needs. There are many combinations that could be used, and the lowest total system cost, rather than the lowest pipe cost, should be used in decision-making. For example, using a larger pipe would enable the rancher to use a smaller pump with lower energy costs, as well as a pipe with a lower pressure rating.

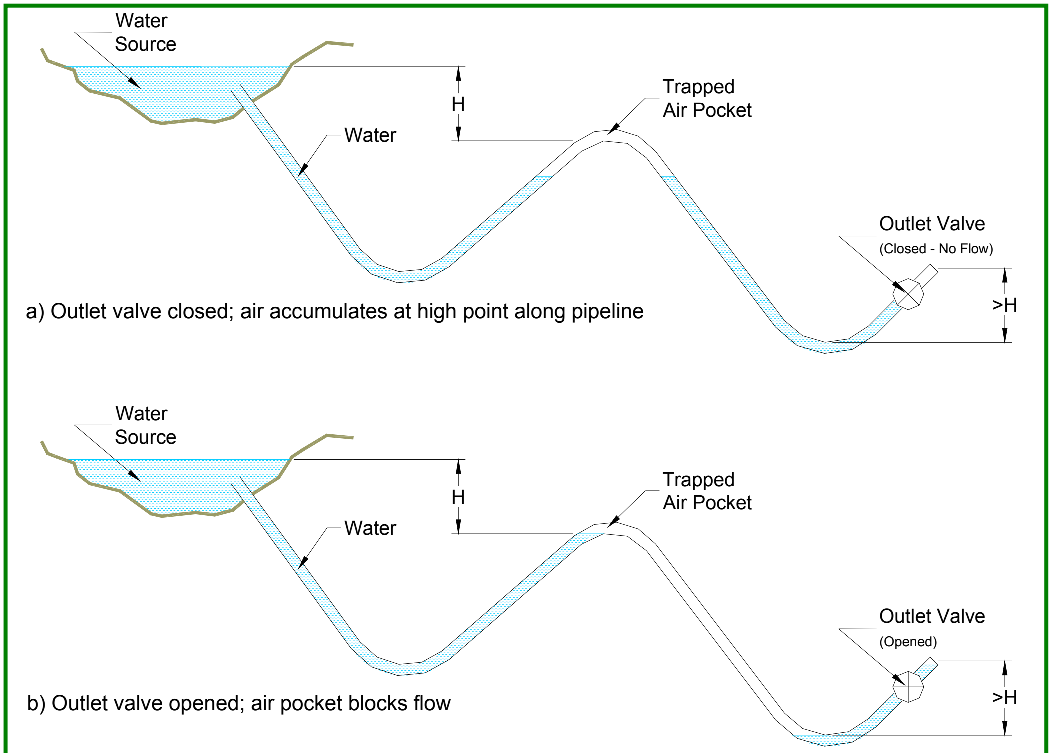
What other considerations are there for developing pasture pipelines?

One of the major considerations in pipelines, especially gravity pipelines, is air-locking, or a partial or complete blockage of flow by air pockets trapped at high points along the pipeline. Air can enter pipelines in a number of ways:

- Initial filling of the line in the spring - the line will be full of air and the air will have to be expelled before the system can operate

- "Gulping" at the inlet - if the inlet is not far enough below the surface of the water, a vortex can form allowing air to enter the pipe
- Dissolved air released from the water - at high points along the pipeline the pressure may be reduced enough that air dissolved in the water bubbles out of solution - this is of concern especially with siphons
- Entry to the line at a stock tank that is installed as a flow-through trough

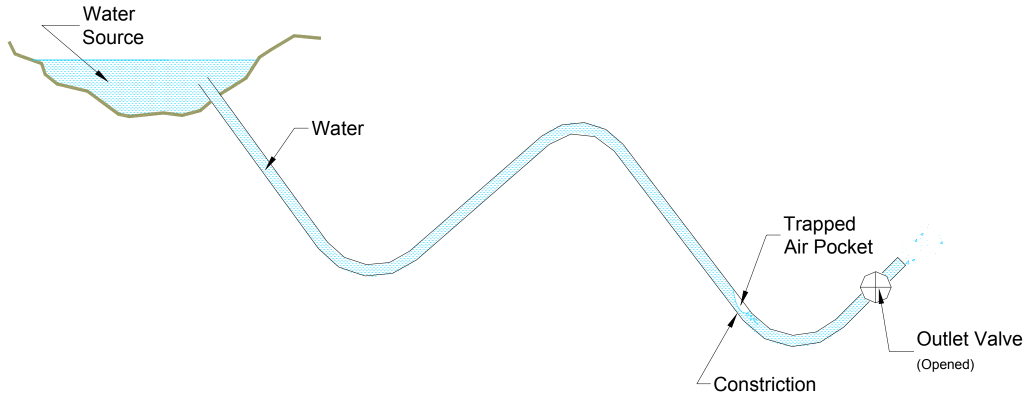
Air locks can be partial or total; that is, they can either completely block flow, or they can partially block the flow, reducing the desired flow rate. The following sketches illustrate total and partial air locks:



Total Air Lock

Graphic Text to Translate: Total Air Lock; Water Source; Water; Trapped Air Pocket; Outlet Valve (Closed – No Flow); a) Outlet valve closed; air accumulates at high point along pipeline; b) Outlet valve opened; air pocket blocks flow; Outlet Valve (opened)

Graphic Text to Translate: Partial Air Lock; Trapped Air Pocket; Constriction; Outlet Valve (opened)



Partial Air Lock

For the total air lock, the figure shows how air gathers at a high point when an outlet valve is closed. If the layout of the pipeline is such that the vertical distance from the outlet to the low point is greater than or equal to the vertical distance between the surface of the water supply and the crown of the high point (H), then no water can flow even if the outlet valve is subsequently opened.

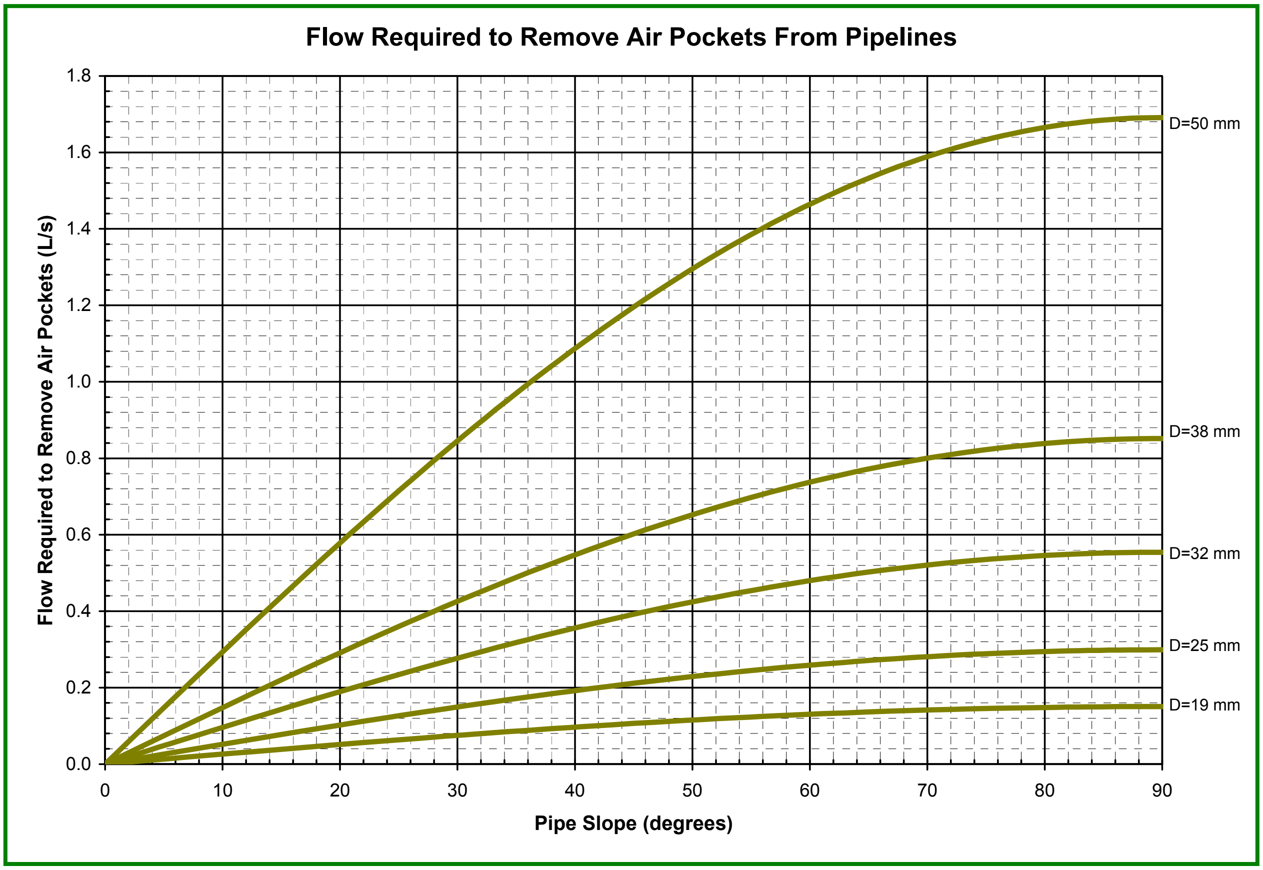
The partial air lock would arise in a situation where the vertical distance between the outlet and the low point is less than H, but not sufficiently low to allow velocities in the pipeline to completely sweep away the trapped air pocket.

Air locks can form regardless of whether water is flowing through the line or not. Air that enters the pipeline while water is flowing must be carried along with the flow to prevent an air lock from forming. When water is not flowing, prevention of the formation of air locks requires that air in the line must be able to rise and exit the pipeline, or the layout of the pipeline is such that any air pockets trapped at high points can be dislodged.

The occurrence of air-binding in pipelines can be prevented in a number of ways:

- Ensure that air does not enter the pipeline - while this is obvious, in a practical sense, it is probably not possible to completely prevent air from entering a pipeline.
- Install the pipe on a continuous grade without undulations or high points - the topography may make such an installation impractical.
- Periodically remove air from high points with stand-pipes or air-release valves - this will work on most systems except siphons.
- Ensure that the flow velocity is sufficient to flush any air out of the line.

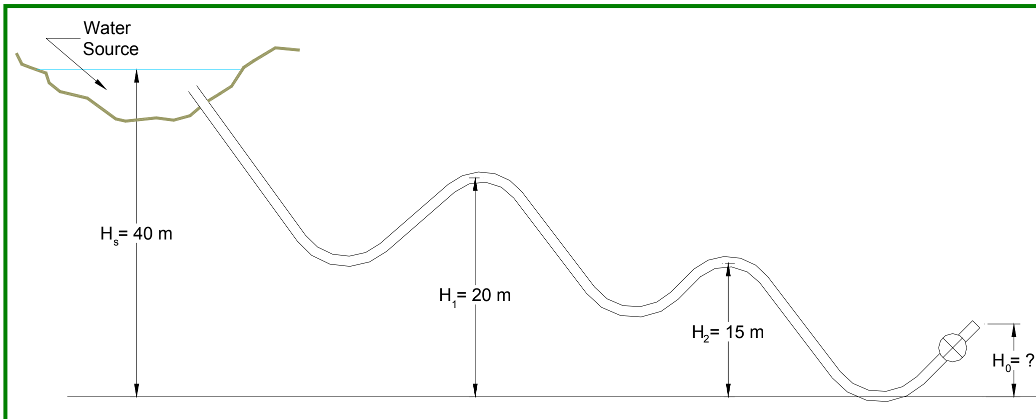
The flow required to ensure that air can always be flushed out of the line depends on the size of pipe and the angle of those portions of the pipe that slope downward in the direction of the flow (for example, the portion of pipe downstream of the local high point in the previous sketches). The following chart indicates what the air-flushing flow should be in various pipe sizes with varying slopes:



Graphic Text to Translate: Flow Required to Remove Air Pockets from Pipelines; Flow Required to Remove Air Pockets (L/s); Pipe Slope (degrees); D=19mm

Example - Air Lock Considerations in a Gravity Pipeline

A gravity-feed watering system is being installed in the Rocky Mountain foothills using 1 in. (25 mm) diameter pipe. The water source is a hillside spring, and the 800 m pipeline route crosses three steep draws and over the ridges between, as shown in the following sketch. The steepest downward sloping portion of pipe is inclined at an angle of about 25 degrees to horizontal. At what height should the outlet be placed to ensure air locks do not form?



Air-Lock Considerations - Example

Graphic Text to Translate: Air-Lock Considerations – Example; H subscript 1; H subscript f;

1) *Determine the flow required to ensure that air pockets can be flushed, and the friction loss at that flow*
   From the chart, for a 25 mm (1 inch) diameter pipe with a slope of 25 degrees, the required discharge would be about 0.125 L/s (2 US gpm). From the friction loss chart, water flowing at 0.125 L/s in a 25 mm diameter pipe would lose about 3.5 m of head per 1,000 m of pipe, so for an 800 m pipe, the friction loss would be about 2.8 m.

2) *Determine the maximum height above the reference datum that the outlet can be to prevent air locks*
   To prevent air locks from forming, the sum of the friction loss (Hf), the height of the outlet (H0), and the height of the two summits (H1 and H2) must be less than the height of the source (Hs). Therefore, the maximum height that the outlet can be above the reference datum would be 40 - 20 - 15 - 2.8 = 2.2 m.

Therefore, if the outlet is placed less than 2.2 m above the reference datum, flow in the pipe will be at least 0.125 L/s and air locking should not occur. Note that no allowance has been made for pressure required at a watering valve. Also note that once any accumulated air is flushed from the line, the total head available would be 40 - 2.2 = 38 m over the 800 m distance, which would mean that the allowable friction loss would be 38 ÷ 0.8 = 47.25 m/1,000 m. From the friction loss chart, for this allowable friction loss, the flow in the pipe could reach about 0.5 L/s (7.9 USgpm) once all the air is expelled.

What should be considered in operating and maintaining a pasture pipeline?

Pipelines themselves are generally very low maintenance items. The primary maintenance considerations are associated with the mechanical components that may comprise part of the pipeline system, such as pumps, valves and inlet screens. These components should be regularly checked (every two or three days) to ensure proper operation and to remove any material that may clog them. Components that may be damaged by livestock or machinery should be protected with suitable barriers and flagging.

Pipelines that are operated seasonally require seasonal start-up and shut-down activities. Shut-down activities prior to freeze-up should include removal of pumps and float valves, opening any in-line valves, and removal of as much water from the pipe as possible. Pipes on undulating terrain should have drain valves installed at low points. Pipes on fairly level or gently undulating terrain can have water blown out with compressed air. Any openings that could allow small animals or debris to enter the pipe should be covered. Start-up activities in the spring should include installation of any components removed in the fall, and gradual filling of the line with water. Slow, gradual filling of the line is important to prevent damage to valves and fittings from being “slammed” by rapid expulsion of air followed by a slug of water.

The Bigger Picture

Pipelines are only one of many options available to producers wishing to manage their land and water resources for improved productivity and environmental protection and enhancement. The information in this fact sheet is intended to give prospective developers of pipeline systems a general idea of what is involved in designing a system, and should not be considered complete. Producers intending to develop a pasture pipeline system should seek additional technical advice for their specific application. For additional information on pasture pipelines, as well as additional information on total livestock watering systems, contact your local AAFC-PFRA office.

Sources of information for this Fact Sheet included: BC Livestock Watering Manual, BC Ministry of Agriculture and Fisheries - Soils and Engineering Branch, 1990; “Pasture Water Systems for Livestock”, Alberta Agriculture, Food and Rural Development, http://www.agric.gov.ab.ca/agdex/400/400_716-3.html; Water Conveyance With Siphons, PFRA Technical Service; October, 1996; Air-Water Flow in Hydraulic Structures, Engineering Monograph No. 41, U.S. Dep’t of the Interior, Water and Power Resources Service.

UNIT ABBREVIATIONS

psi - pounds per square inch	kPa - kilopascal	gpm - gallon per minute
mm - millimetre	m - metre	ft - feet
in - inches	km - kilometre	L/s - litres per second

UNIT CONVERSIONS

1 US gallon = 3.785 litres	1 cubic metre (m^3) = 1,000 litres	1 metre (m) = 3.28 feet
1 Imperial Gallon = 4.546 litres	1 kilometre = 1,000 m = 0.62 miles	1 psi = 6.985 kPa
1 inch = 25.4 mm	1 psi = 2.307 ft. of water	

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