FARM IRRIGATION FACT SHEETS

SET 1: PIPES & PUMPS

Pipe Size, Water Hammer, Friction Loss, Pressure, & Pump Sizing

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Living Lands Agroecology, 2023

Pipe Size

MAXIMUM FLOW

Pipe *inner* diameter sets the max flow limit.

When "max flow" is exceeded (here in ***gpm, gallons per minute***), water travels faster than ***5 feet per second***.

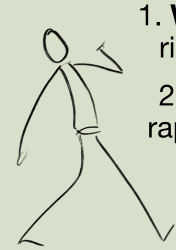
Use this table as a rough guide, but make your pipe choices with a professional.

Pipe Inner Diameter	Max Flow (5 ft/s)
0.5"	3 gpm
0.75"	7 gpm
1"	12 gpm
1.25"	20 gpm
1.5"	30 gpm
2"	50 gpm
2.5"	80 gpm
3"	110 gpm
4"	200 gpm
6"	440 gpm
8"	780 gpm
10"	1230 gpm
12"	1760 gpm

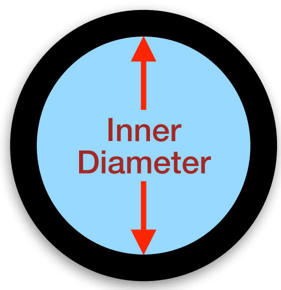
WATER SPEED LIMIT

Don't exceed 5 feet per second.

If water flows faster than 5 ft/s (a brisk walk) then…



1. **Water hammer** risks rise.
2. Friction losses rapidly increase.
3. Pipes and fittings wear out faster.



A pipe's ***actual inner diameter*** differs from the "nominal" (named) diameter. ***Check the specs for your pipe***.

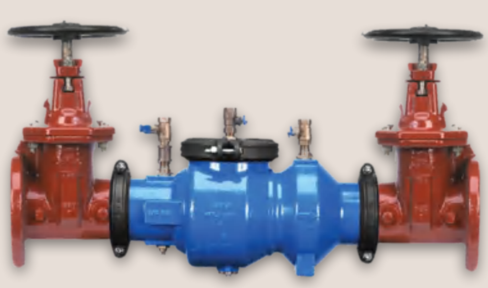
SPEED LIMIT EXCEPTIONS

Some fittings can break the 5 ft/s water speed limit.

Some fittings handle higher water speeds. If the additional pressure loss is acceptable, save money by choosing these fittings ***"one size down"***.

Examples:

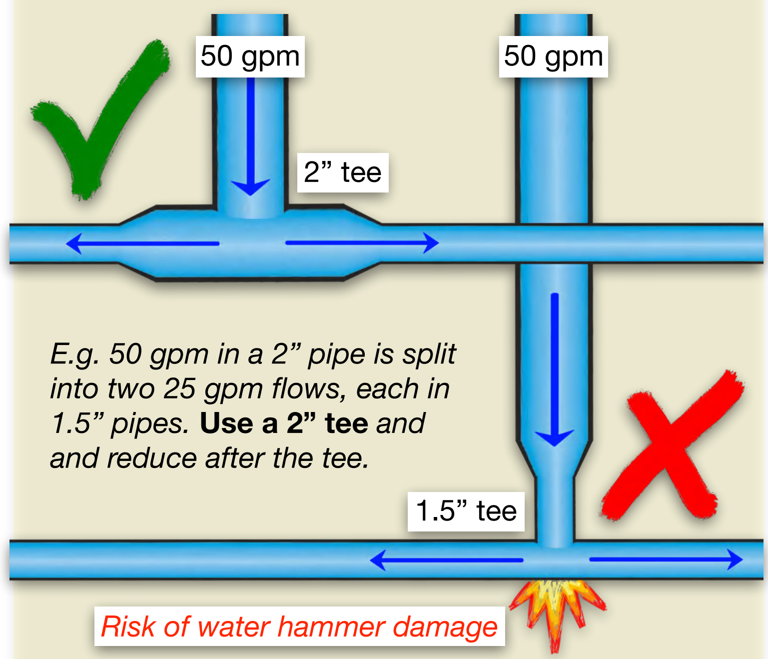
- *2" mainline can use 1.5"* ***automatic valves****.*
- *4" mainline can use a 3"* ***pressure reducer****.*
- *8" mainline can use a 6"* ***backflow preventer*** *(pictured here).*



THE "TEE TOTAL"

Undersized tees get hammered.

If the flow is split into (or combined from) two smaller flows, ***size the tee for the total flow.***



E.g. 50 gpm in a 2" pipe is split into two 25 gpm flows, each in 1.5" pipes. **Use a 2" tee** *and reduce after the tee.*

Water Hammer

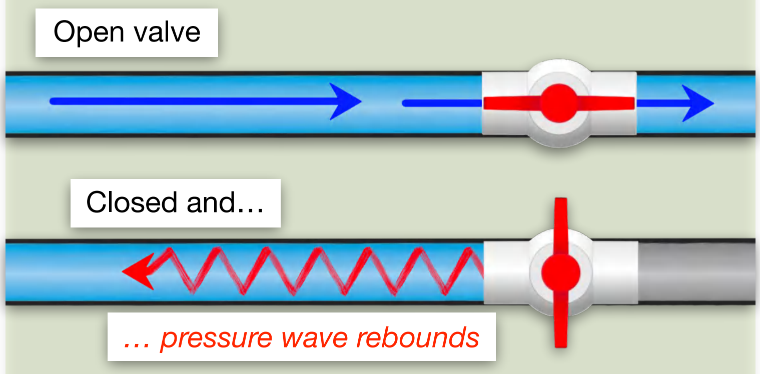
AVOID WATER HAMMER

Faster water hammers harder.

When water flow changes abruptly, “water hammer” pressure waves surge back up the pipe.

Hammer happens when a ***valve is opened or closed***, a pump starts or stops, or there’s a sudden release of air from a pipe.

The faster the water, and the faster the change in flow, the more energy in the hammer.

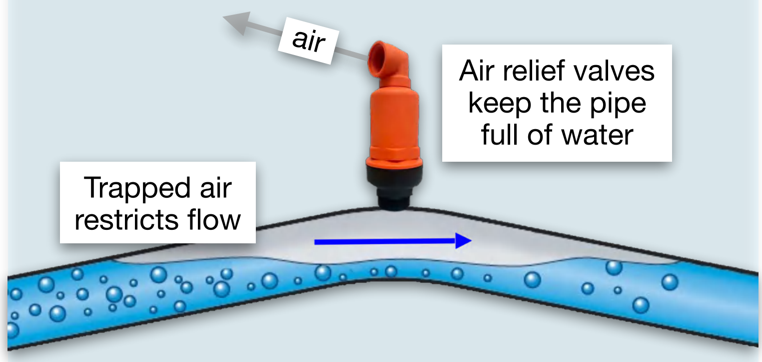


E.g. A valve closed “instantaneously” (in theory) when water is travelling at 5 ft/s, will rebound a pressure wave at 1000 to 4000 km/h and deliver a bang between 100 and 300 psi.

AIR RELIEF VALVES

Air pockets cause problems.

Trapped air forces water to squeeze through a smaller gap, so water either travels faster — increasing turbulence, friction loss, and water hammer — or the flow is reduced. Air pockets that shift also cause water hammer.



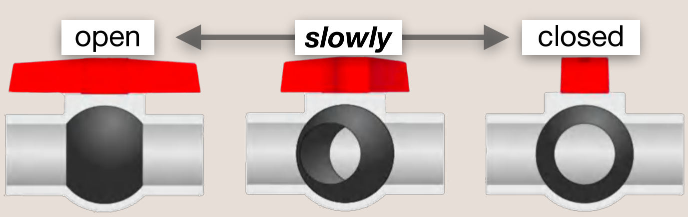
Put air relief valves along mainlines at every high point and at least every 1000 feet.

An expert can help you choose: Some air relief valves simply release air pockets, others also let air in to relieve vacuums, others operate even under water hammer surges, and some can do it all.

GO SLOW ON VALVES

Opening or closing valves fast hammers hard.

The ***longer and bigger*** the pipe, the higher the ***pressure and flow***, the ***slower*** you need to go.

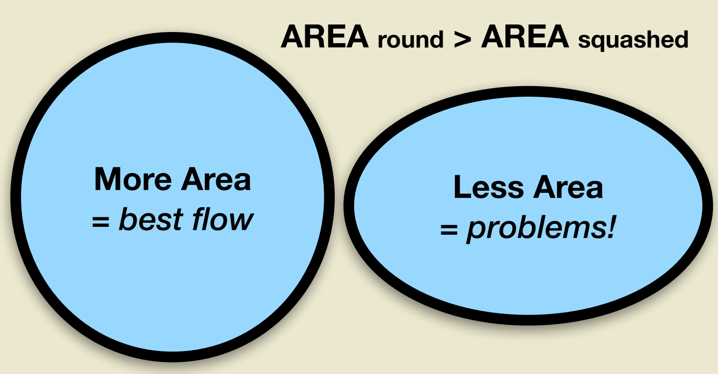


*E.g. A valve at the end of **1000 feet** of Class-160 (160 psi rated) PVC pipe operating at **110 psi** should be opened or closed over **6 seconds**.*

SQUASHED PIPES

Flattened pipes are smaller.

Out-of-round pipes have ***less cross-sectional area***, so ***water has to speed up***, increasing the risk of water hammer, wear and tear, and friction.

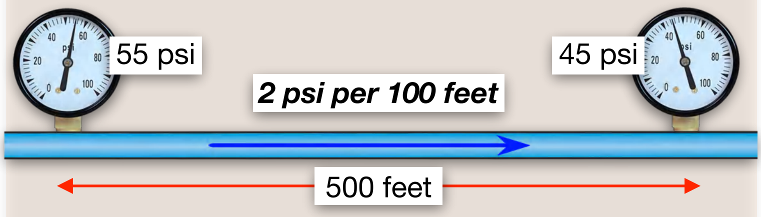


Friction Losses

PIPE LENGTH

Longer pipes and higher flows lose more pressure to friction.

As water rubs along pipe walls, friction reduces pressure, measured in ***psi lost per 100 feet of pipe.*** As the flow increases, so do these loses.



*E.g. A **1" PVC** pipe with a **9 gpm** flow loses pressure at a rate of **2 psi per 100 feet**, so a 500-foot length loses 10 psi in total.*

PIPE MATERIAL

Rough pipes lose more pressure.

Friction losses are greater in pipes made of rougher material, or that have rust, calcification, or algae.

These ***build-ups also reduce inner diameter***, increasing water speed and so adding even more friction loss.

	Flow	Speed	2" PVC	2" Old Steel
	30 gpm	3 ft/s	0.7 psi/100'	1.4 psi/100'
	40 gpm	4 ft/s	1.1 psi/100'	2.4 psi/100'
	50 gpm	**5 ft/s**	**1.7 psi/100'**	**3.7 psi/100'**
Too fast!	*60 gpm*	*6 ft/s*	*2.4 psi/100'*	*5.1 psi/100'*
	70 gpm	*7 ft/s*	*3.2 psi/100'*	*6.8 psi/100'*

*E.g. **Friction losses in old steel pipe** are double the losses for the same size (Sch. 40) plastic pipe.*

FRICTION LOSS TABLES

Use spec sheets to add it up.

Every type of pipe and fitting has a table or graph provided by the manufacturer to show water ***flow***, water ***speed***, and friction ***pressure loss***.

	4" Sch. 40 PVC		6" Sch. 40 PVC	
Flow (gpm)	**Speed** (ft/s)	**Friction** (psi/100')	**Speed** (ft/s)	**Friction** (psi/100')
150	3.8	0.51	1.7	0.07
200	**5.0**	**0.87**	2.2	0.12
250	*6.3*	*1.32*	2.8	0.18
300	*7.6*	*1.85*	3.3	0.25
350	*8.8*	*2.46*	3.9	0.33

*E.g. With a **200 gpm** flow, 4" Schedule-40 PVC is at the **5 ft/s** limit and loses **0.9 psi per 100 feet**.*

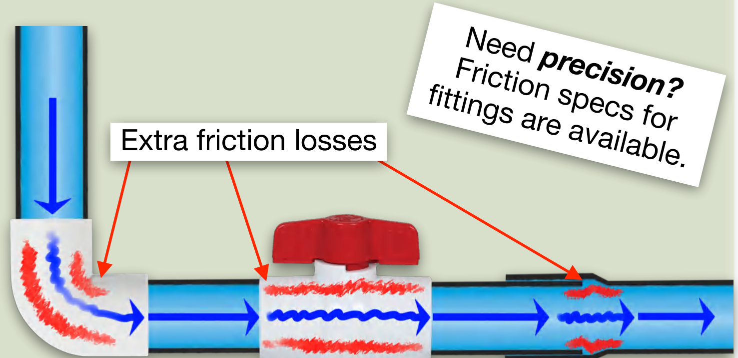
FITTINGS & CORNERS

Redirected flows lose pressure.

Every time water turns a corner or changes speed — e.g. to squeeze through a fitting, or tumble around at a widening — friction reduces pressure.

Add 10% to 20% to the pipe's total (full length) friction loss to ***roughly account*** for fitting friction.

Need **precision?** Friction specs for fittings are available.

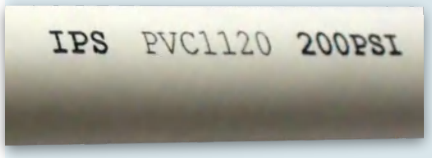


Pressure & Pipe Quality

PLAY IT SAFE

Operating pressures should not exceed 70% of the pipe's rating.

Even below the 5 ft/s limit, we still need a ***pressure rating buffer*** to handle water hammer surges.



E.g. Class 200 ***PVC*** *(200 psi rated) should not exceed 140 psi in operation.*

Some materials are more resilient. ***Polyethylene*** pipe (***PE, HDPE***) can run at 80% of its rating.

E.g. PE rated to 75 psi should not exceed 60 psi.

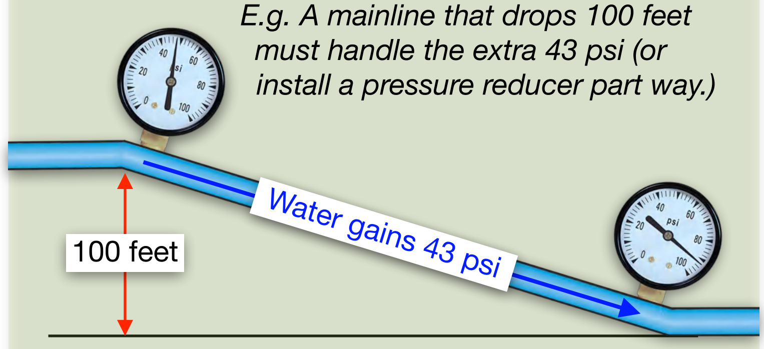
ELEVATION

Pressure increases downhill.

Every 1 foot drop of elevation adds 0.43 psi pressure to the water in a pipe.

1 foot head = 0.43 psi <u>OR</u> ***1 psi = 2.31 feet head***

E.g. A mainline that drops 100 feet must handle the extra 43 psi (or install a pressure reducer part way.)

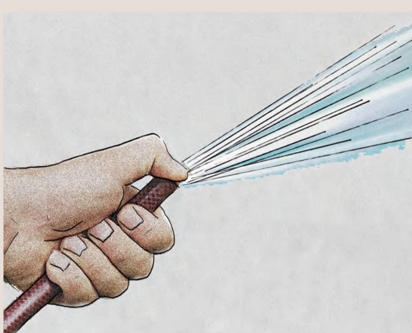


PIPE SIZE & PRESSURE

Thumb on a garden hose…

"Reducing pipe size increases pressure, right? Like spraying water with my thumb on a garden hose?"

Your thumb ***reduces flow***, which decreases friction losses and, yes, that increases pressure (which is traded for speed as it sprays out the end.)



But we <u>need</u> flow to irrigate.

The only way to get higher pressure without losing flow is to reduce friction (e.g. ***<u>bigger</u> pipes***) or use a bigger pump, or more elevation drop.

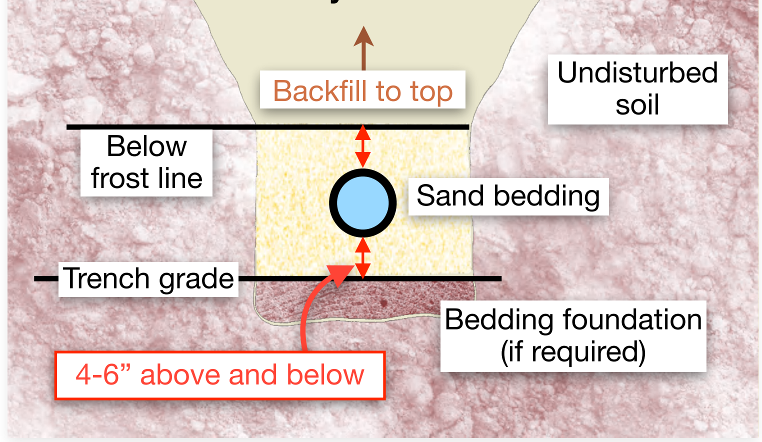
PIPE LONGEVITY

Old pipes are prone to failure.

Depending on material, installation, and operation, pipes eventually need to be replaced.

A **Schedule 40 or Class 200 PVC** mainline that's properly installed in a sand bed below frostline, and operated at water speeds below 5 ft/s, should last more than **40 years**.

An **HDPE** mainline in the same scenario should last **a century or more**.



Pumps

MAXIMUM FLOW

Add up the water flow needed for the "highest-use" scenario.

To choose a pump, first know the maximum flow.

The maximum may be limited by your water license, water purveyor, or a regional limit. Otherwise, the maximum flow is the ***highest flow you need to (or can) run at one time***.

TOTAL DYNAMIC HEAD

Add up the pressure needed for the "worst-case" scenario.

To choose a pump, add up the highest ***total dynamic head (TDH)*** the pump must produce.

TDH (in psi or feet-of-head) is the "push" required to overcome elevation changes and friction losses, and still have enough pressure to run the irrigation.

Add up the Total Dynamic Head:

1. Add the ***pressure lost due to elevation*** gain from the water level at the intake to the highest elevation nozzle or emitter.
2. Add all the ***friction losses at maximum flow*** from the intake to the furthest irrigation.
3. Add the ***pressure required*** to properly operate the ***emitter or nozzle***.

INTAKE SCREEN SIZE

Take a fish-eye view on suction.

For surface water intakes, meet Department of Fisheries screen requirements:

Use ***"8-mesh" screen*** (8x8 holes-per-square-inch) or finer, at 1 square foot of ***open*** area per 45 gpm.

8-mesh is about 60% open area, so expose about ***1 square foot of 8-mesh per 25 gpm.***

PUMP EFFICIENCY

Read the "pump curve".

Pumps have a sweet spot where the combination of flow and head runs at the highest efficiency.

The "pump curve" — a graph of ***flow, head, and efficiency*** — can be complex: Ask an expert.

If flow or head requirements vary a lot, consider a ***variable frequency drive*** to save energy.

No sharp corners on the suction line

HORSEPOWER ESTIMATE

Guess the pump size you need.

With highest flow (***Q in gpm***), total dynamic head (***TDH in feet-of-head***), and an estimate of pump efficiency (***E in %***) calculate ***"brake horsepower".***

$$\text{Horsepower (BHP)} \approx \frac{Q \times TDH}{40 \times E}$$

At 60% efficiency

Total Dynamic Head	100 ft head	200 ft head	400 ft head
Horsepower (BHP)	**Maximum Flow (gpm)**		
1	23	11	5
3	71	35	17
5	110	59	29
7.5	170	89	44
10	230	118	59
20	470	230	118
40	950	470	237
60	1400	710	350
100	2300	1180	590