Site assessment guide

PLT
(PLT-Cube coming soon)

TRG

LH-Pro, LH and LH-mini

This is one of a series of documents available for free download from the PowerSpout document index.

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Introduction

This document will help you assess your site and choose a suitable PowerSpout turbine type and pipe to suit your desired application.

Scope of application

PowerSpout turbines are efficient, economical and reliable converters of naturally occurring hydraulic energy to electricity. To use a PowerSpout, **you need a source of water flow under pressure**. This should be a naturally occurring source. It must not be a source provided by a pump driven by the electrical output of the PowerSpout turbine itself. We do not supply customers who intend to use our product in this way, because the outcome will be unsatisfactory. We look for the best outcome for our customers.

PowerSpout turbines can only produce electrical energy by converting energy from another source (falling water). If you do not have an independent energy source in that form, then it will not be possible for the turbine to generate any net surplus of energy.

Elements of a microhydro system

Starting from the top you need to divert some flowing water into an intake that filters out any waterborne debris and feeds it into a penstock or flume leading to the turbine itself. See our document **PS all intake guide** in the **PowerSpout document index**.

The "penstock" is the technical name given to the pipeline from the intake to the turbine, which we will also often refer to as the "pipe". In the case of LH turbines you may not need a penstock/pipe as an elevated channel or flume will often work better. See later in this document for advice about penstocks.

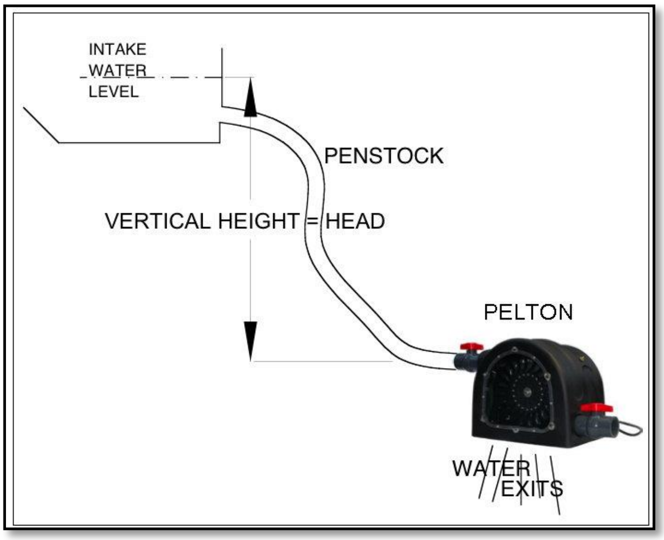
When the penstock reaches the PLT or TRG turbine, the water is fed into "jets" (or "nozzles") that direct water into the spinning runner. The pipework that does this, along with the valves to control flow and the gauge to measure pressure is collectively called the "manifold" and we have a document about that too, the **PS manifold guide** in the index.

Site parameters

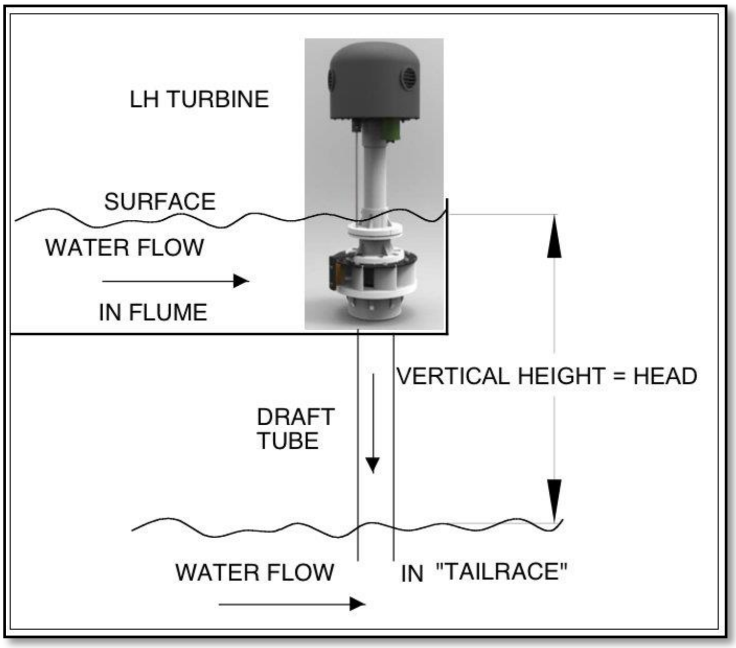
Head and Flow

The generation capacity of your site is determined by the water supply, primarily by the vertical distance the water falls (head) and how much water flows in a given time (flow rate).

For the Pelton and Turgo turbines the **head** is measured between intake water level and the turbine jets below. Water exits the turbine at atmospheric pressure back into the stream.



In the case of the LH turbines, the propeller turbine is close to the surface in an elevated flume. You can measure the head from the intake surface level down to the water surface in the tailrace below.



Estimating the power output

A rough estimate of generation potential can be calculated as follows:

- Generation (Watts) = head (metres) x flow (litres per second) x 5
- Generation (Watts) = head (feet) x flow (gallons per minute) / 10

Standard PowerSpout turbines are rated for up to 1200 W but a special high power (HP) version is available that is capable of 1.6 kW at 1600 rpm, given suitable water pressure and flow conditions. We do approve PLT and TRG applications up to 2kW/turbine in some cases. Contact us if you have a suitable site.

Maximum current that the turbine wiring can carry is 32 amps, as standard. An upgrade to 50 amps is available on request for high power low voltage applications. (A fee applies.)

Worked example

If for example the head is 20 metres and the flow is 10 litres per second then the power generated continuously is about 1000 Watts or 1 kW (20 x 10 x 5 = 1000). The turbine will therefore produce 24 kWh of energy per day and over 700 kWh units of energy per month. This exceeds typical household energy consumption in most countries. If the power output were only 500 watts then you would get half as many units per month, which would still suffice in many cases. (The same arithmetic applies to solar PV although obviously that will only work in daytime hours so that a 1kW PV array is unlikely to produce more than 6 units of energy per day in summer and may average 3-4/day or less over a typical year).

Penstock length and internal diameter

The dimensions of the penstock are important because of the pressure losses that will occur when water flows down it. Our "gross head" described in the previous section will be diminished somewhat by friction loss in the penstock. This headloss will depend on penstock length, internal diameter and flow rate. The calculation is complex and so we rely on our online calculator to tell us the efficiency of the penstock based on these factors. The calculator returns a percentage figure that represents the net head (actual pressure at the turbine in operation) in relation to the gross head (static pressure when there is no flow).

The document **PS all hydro design and calculator manual** in the index will guide you through using this tool. The calculator will then tell you what power output (in Watts) to expect based on the information provided. This will be much more accurate than the above rules of thumb.

If in doubt about how to choose the best pipe then consult with a PowerSpout dealer who will guide you.

Voltage and turbine speed

The voltage produced by your turbine will vary depending on how fast it is running (the RPM) and on how much power it is generating.

You or your dealer must decide a suitable voltage. For battery charging systems this will usually be 40 or 80VDC, feeding an MPPT controller. For grid-tied inverter (GTI) systems it is more likely to be 200V. This voltage is to be entered into the online calculation. Every order must be accompanied by a calculation, plus notification of the make and model of the charge controller or GTI that will be used.

Whatever is chosen, we will design and manufacture your turbine to produce this output voltage at the rotational speed (RPM) that best matches the net head. The calculations will only be as good as the data provided, and the turbine will only work on the site you have surveyed.

Cable length and size

The length of the cable (wire run) from the turbine to the controller or GTI is another item in the calculator. When you enter the cable length and wire size you will be told the efficiency of the cable and given an idea of how much power will reach the input to the controller.

It's important to consider all of these site parameters carefully and review the output power that you can achieve with your system design. No order can be placed without a full system description as outlined above.

Site assessment summary

In order to assess your hydro site potential you can either

- Visit our web site www.powerspout.com and complete the advanced calculator, or
- Complete the table below and email it to questions@powerspout.com or to one of our dealers. We will reply promptly with the best hydro option available for your site.

Your turbine will be designed for the site data you supply above. **If you operate it on a different site, the output power will differ and not necessarily match the prediction of the advanced calculator**. A new generator core may be required to obtain the best results in such cases. If you intend to run your turbine over a wide range of flow rates, you need to state this at the time of ordering. A different generator core can be supplied for an additional charge.

Hydro site data required for PowerSpout product manufacture

Question	Units	
PowerSpout turbine type	PLT, TRG, LH, LH Pro, LH mini	
Have you read the PowerSpout product manuals? You must do so before placing an order	Yes/No	
Head at site (vertical drop/fall of pipe)		m or ft
Pipe or flume length required to get fall		m or ft
Supply pipe inside diameter if installed		mm or inch
Do you want us to advise your pipe size?	Yes / No	-
Flow available at intake		l/sec or gal/min
What is the cable length from turbine to the power shed?		m or ft
If cable is installed, what size is it?		mm^2 or AWG
Do you want us to advise cable size?	Yes / No	-
For MPPT applications state your battery voltage	12/24/48	Volts
For MPPT applications state the controller make and model		
For Grid connect applications state the inverter make and model you intend to use		
How much power do you require at your site on average?		kWh/day

Additional Hydro site data required for PowerSpout LH and LH Pro manufacture

Questions	Units	
Can a vertical draft tube be installed?	Yes / No	
Can you buy 200mm and 250mm OD thin-walled PVC pipes locally to make the draft tube?	Yes / No	
If No above then state the inside and outside dimensions of the PVC pipes you can obtain of a similar size. State these dimensions for both the plain and flared ends on the pipe. (read LH Installation manual for more information)	Flared end ID Flared end OD Plain end ID Plain end OD	___ mm or Inch ___ mm or Inch ___ mm or Inch ___ mm or Inch

Measuring Head

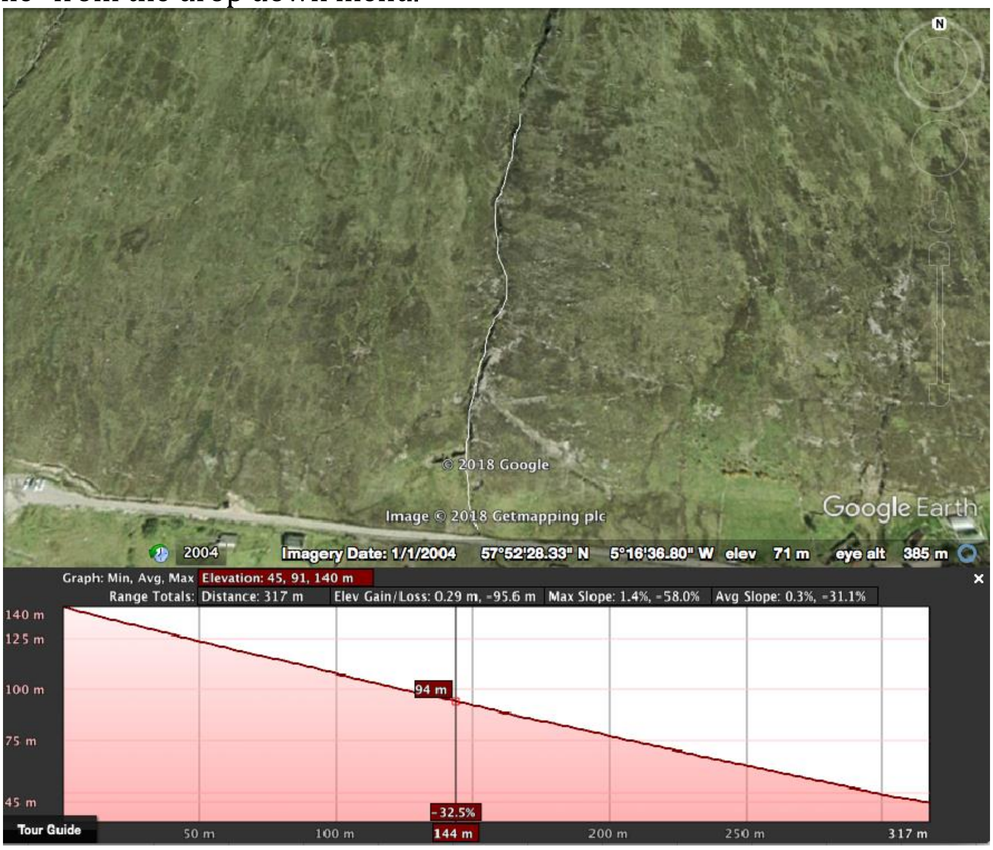
You will need to measure the vertical drop in feet or metres (referred to as head or fall). A map with contours can be useful for initial feasibility study followed by a site survey using the methods below. It's a very good idea to use more than one approach, so you can check accuracy.

Altimeter

Obtain an altimeter accurate to 3m (10ft) or better. This is good for measuring falls greater that 20m (70ft). Take the average of several readings. Some modern hand-held GPS instruments that are fitted with internal altimeters can read altitude to 1m if the air pressure is stable during the survey. Turn off "auto-calibration" during the survey, so that the air pressure calibration does not change.

Google earth

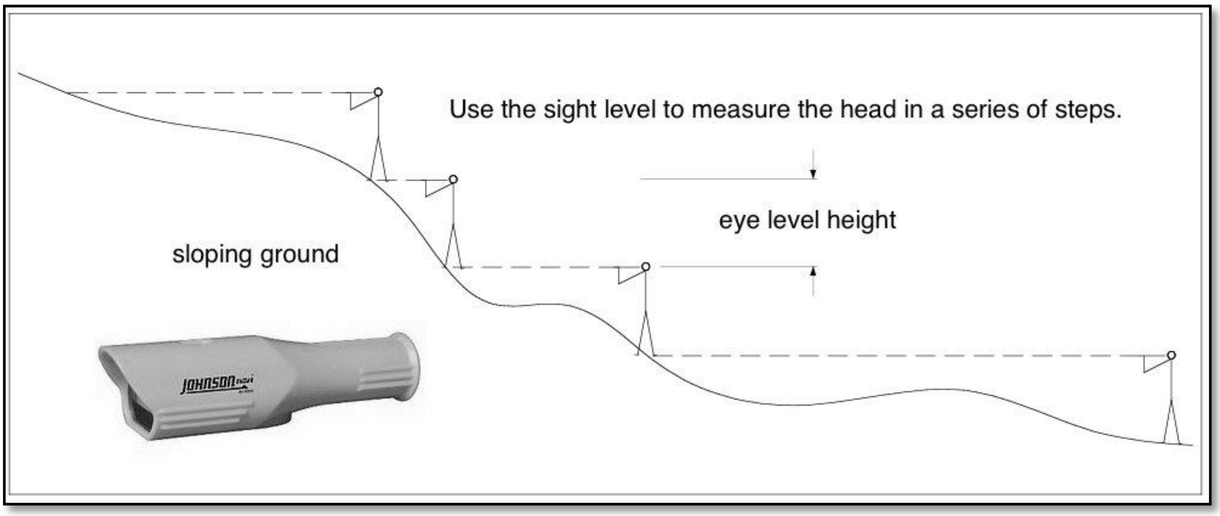
Install the software on your computer and find the site location.
Click the "add path" icon and drag the cursor along the proposed pipe route.
Give a name to the path, choose units and close the dialogue box.
Right-click on this path name in the list of places and choose "show elevation profile" from the drop down menu.



The altitude profile allows you to see the change in height along the route, and you can also estimate pipe length. Remember to allow for fall as well as horizontal distance in the pipe length calculation.

Builder's optical level ("sight level")

Measure the fall between intake and turbine in steps as you progress along the pipe route. This is good for lower falls and it is very accurate. You can use the height of the spotter's eye level as a unit of measure and move up the slope in a series of equal steps. Use a helper to mark the spot, or simply keep your eye on that spot until you are standing on it ready to sight the next one.

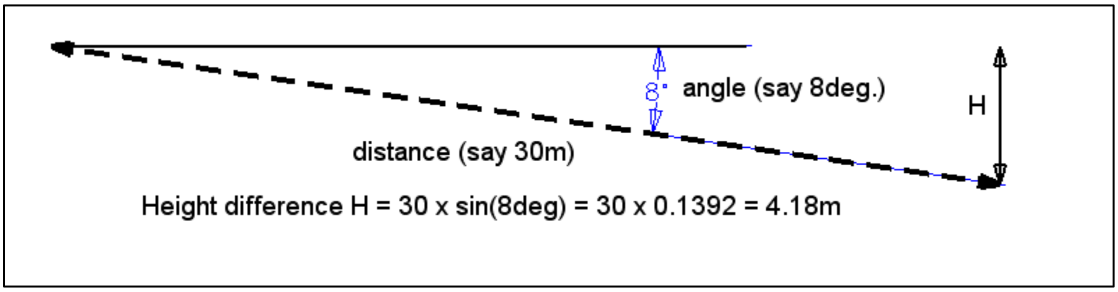


Low cost laser level

At dusk or in low light conditions project a horizontal beam and using a long staff measure the vertical drop, as you progress down alongside the stream. You may have to repeat this at a few locations.

Clinometer

By measuring the gradient of the slope and measuring the distance accurately it is possible to arrive at both the pipe length and the head in one survey sequence. If done carefully with a quality instrument the result can be quite accurate. Two people with a 30metre tape and a clinometer can cover the ground quickly. The person in front should drop a marker before moving on to the next station where the person behind reaches the marker. A smart phone app is one way to obtain a clinometer but you may need an extra person to read the screen or use a mirror.



Pressure gauge

Lay a length of small-bore plastic pipe or hose, fix a pressure gauge to the end and measure the pressure of the water with the pipe full. 14.5 psi is 33 feet of fall (100 kPa is 10m of fall). Make sure you clear the line of all air first. This is a very accurate method and easy to do.

Measuring Flow

Measurements of flow do not need to be so accurate (in percentage terms) as measurements of head but it pays to take several measurements over as long a period of time as possible. Flow will vary, and you need to consider whether it is worth harnessing all the power available in short duration high flow events.

IMPORTANT: "Gallons," and "gpm" here and in the online calculator refer to the US Gallon (3.8 litres), as opposed to the UK Imperial Gallon.

Timing the flow into a bucket

Try and find a place in the stream where it drops quickly over a rock, place your bucket below and measure the time to fill it. On some sites it may help to use polythene sheet, rocks, sandbags and pieces of wood to form a temporary weir and spout.

Use the largest possible bucket you can find as the longer it takes to fill the more accurate your reading will be.

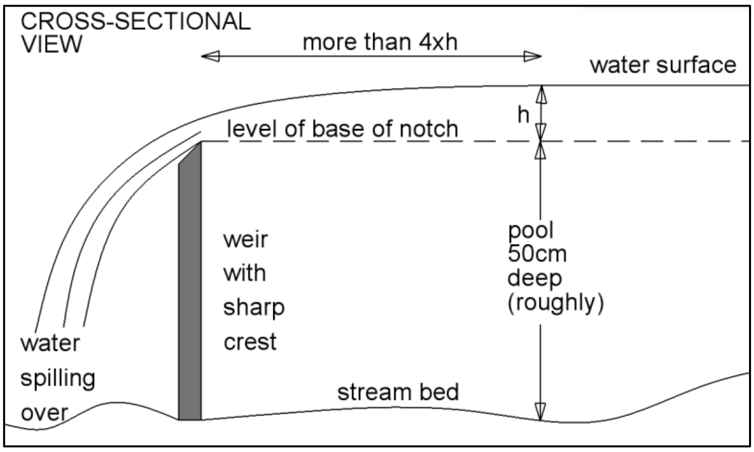
For flows greater than 10l/s (150gpm) try to estimate your flow using a larger bucket in the river and measure at various places across the river. It will not be as accurate but at higher flows it is not that critical.

Notched weir method

A better method is to make a temporary "V notch weir" from plywood (with 90 degree notch in it as shown below) and observe the depth of water in the pool behind the weir.

h (cm)	Flow l/s
12	7
13	9
14	10
15	12
16	14
17	17
18	19
19	22
20	25
21	28
22	32
23	36
24	40
25	44
26	48

This table gives the flow in litres per second for various depths of water in cm. The depth is measured from the bottom of the V. Measure from the level in the pool behind, and not the level over the lip of the notch.



See this web site for more technical guidance

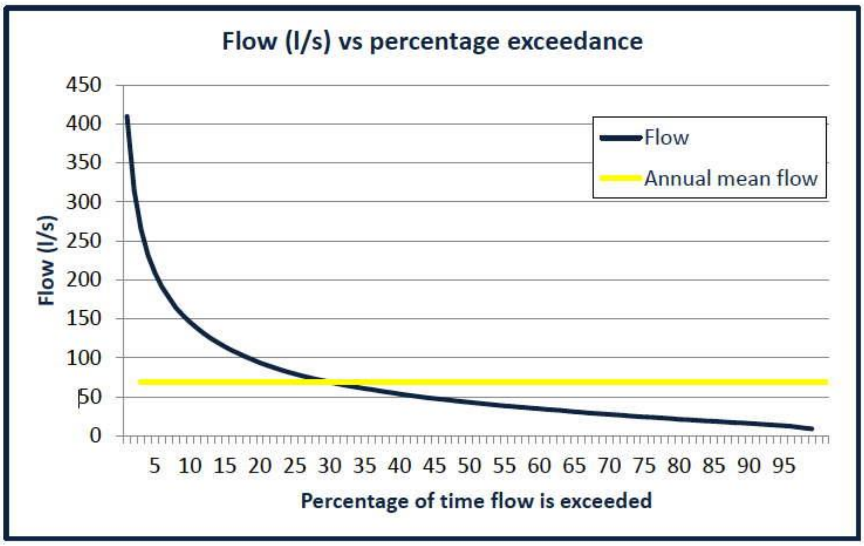
If you can plant a post in the centre of the pool with a scale fixed to it then it is possible to take regular readings of the height h over a period of months and learn how the flow varies.

Hydrological studies

Flow studies can be conducted at a desktop level using proprietary software. You enter details of the catchment into the software and it produces a notional flow duration curve predicting how much flow you will get for how long over a typical year.

Here is a link to an example in the UK.

Your dealer may have access to such software. This approach can be costly and results are often erratic for small catchments. But the environmental protection agency may require them as a part of their permitting procedure.



Example of a flow duration curve.

Choosing the correct turbine for your site

Different sites will need different PowerSpout models depending on the head and flow. Multiple turbines can be used where one turbine is unable to handle the flow.

All PowerSpout products are named with one of the following model abbreviations:

- PLT (PeLTon turbine)
- TRG (TuRGo turbine)

TRG and PLT model turbines are connected to pressurised pipework (penstock and manifold) that feeds water through jets towards the turbine runner, spinning the runner and hence the generator, which generates electricity. These are normally referred to as "impulse turbines".

Where possible the pelton is a better choice than the turgo due to its lower RPM but the turgo can handle higher flows per turbine, reducing cost on sites with more flow.

Version	Head (m)	Flow (l/s)	Photo
PowerSpout PLT (Pelton) & PLT-Cube	3 – 130 m	0.1 – 10 l/s	
PowerSpout TRG (Turgo)	2 – 30 m	8 – 16 l/s	

- LH & LH Pro (Low Head propeller turbine)

LH model turbines are driven by a propeller that is immersed in water. These are normally referred to as "reaction turbines". The turbine sits close to the intake water surface with the alternator on a stalk above flood levels. Water is actually driven by suction created by the weight of water in the draft tube **below** the turbine. The head is measured from the water surface at the turbine to the water surface of the tailrace where the draft tube discharges.

PowerSpout LH & LH-Pro (Low Head) LH-mini	1 – 5 metres (below turbine in draft tube)	25 – 56 l/s 14 -31 l/s (mini)	

When you have found out the head and flow rate at your site, this chart will quickly tell you the maximum power you can generate (refer to black angled lines indicate 100W to 12kW).

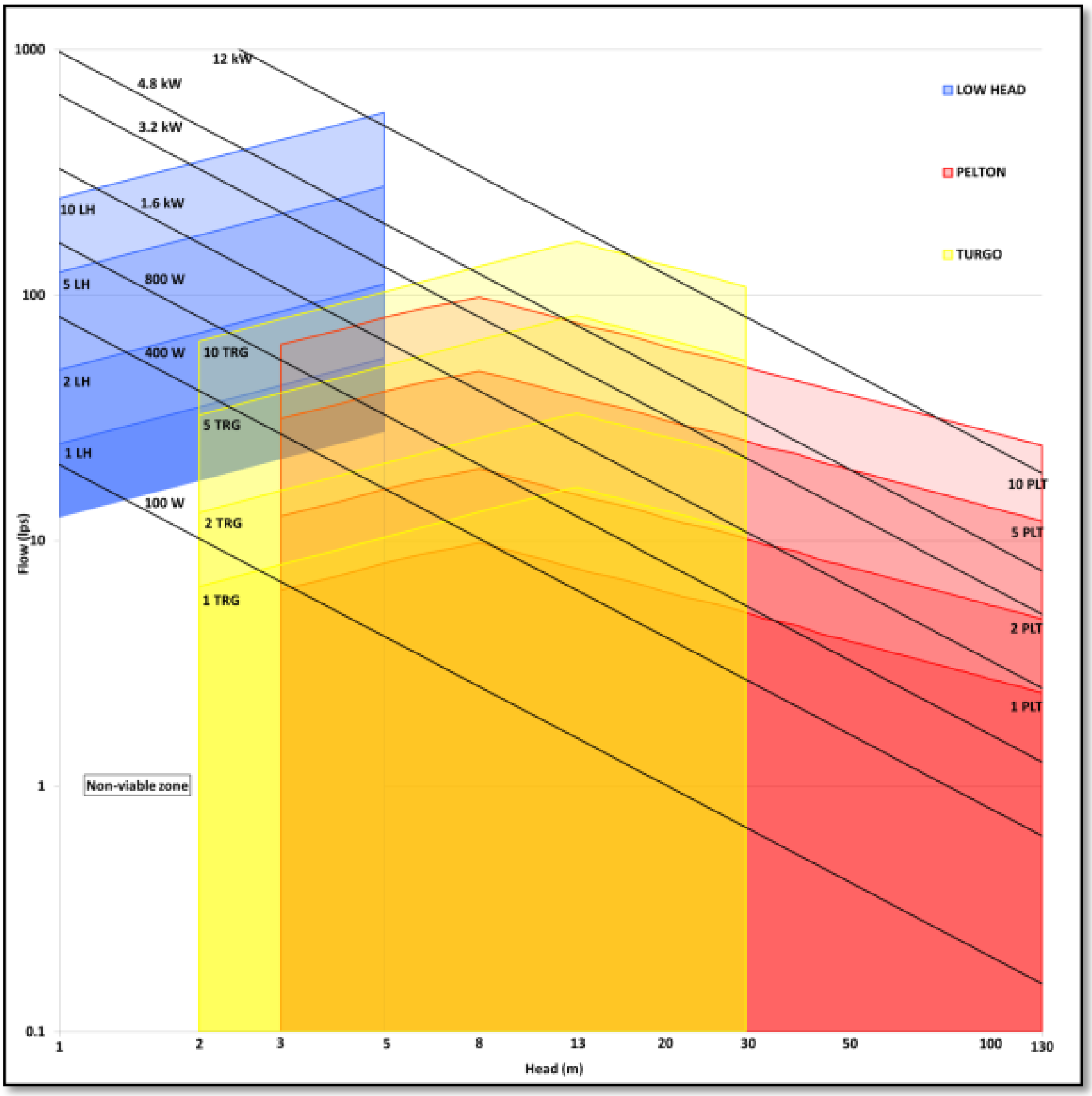
The coloured zones refer to the range for each product type:

The red lines are 1, 2, 5, 10 PowerSpout Pelton (PLT) turbines respectively

The yellow lines are 1, 2, 5, 10 PowerSpout Turgo (TRG) turbines respectively

The blue lines are 1, 2, 5, 10 PowerSpout Low Head (LH) turbines respectively

For example a site with a head of 20m, and flow of 10l/s can generate about 1000 W with 1 TRG or 2 PLT turbines.



Siting your PowerSpout turbine

For help with the intake structure please see our document **PS all intake guide** in the document index.

Some tips for locating a good site for your turbine include:

Choose a place that is accessible.

If necessary make steps and put in rope handrails to ensure that your turbine can be accessed safely.

Choose a site that has the most fall

You should position the PowerSpout to obtain the greatest fall (head of pressure) possible with the shortest length of pipe. If it makes the cable unacceptably long then consider using a higher voltage MPPT (or GTI) controller to raise the cable voltage.

In many situations it is possible to divert the pipeline closer to the home to provide a pressurised water supply as well as electrical generation. In combined power and water schemes electric power is often employed to UV treat the water. In some cases the PowerSpout is only used for UV treatment at remote water storage tanks for small communities. This is often more cost effective that installing grid power to the site.

Keep your PLT/TRG turbine as low as possible

Maximise the head, but do ensure that it is above maximum river flood level. Your PLT/TRG turbine should also be positioned at least 50-100 mm above ground height to allow exhaust water to escape. Choose a site where the exhaust water can be returned back to the river cleanly. Mounting the turbine on a raft is one solution to maximising head whilst avoiding flood damage.

Consider the cost of the cable from the turbine to point of use

The cost of the cable is important, although cost depends very much on the chosen voltage. A low cable voltage means that a short, heavy cable is desirable. The distance between your turbine and batteries also has a significant bearing upon the cable size required.

It will generally be more effective to use a longer cable than to use a longer pipe in the penstock when choosing where to place the turbine.

Contrary to popular myth DC is actually more efficient than AC for power transmission (at the same voltage). In most cases now we recommend using relatively high DC cable voltages compared with battery voltages 12/24/48V.

Hydro turbines do make some noise, so keep them at least 30 m from your home.

Some clients have installed turbines too close to their homes.

Noise test at PowerSpout on PLT turbine

Test parameters:

Watts:	1000
Flow:	3,05 l/s
Pressure:	95,5 psi
Head:	600 kPa

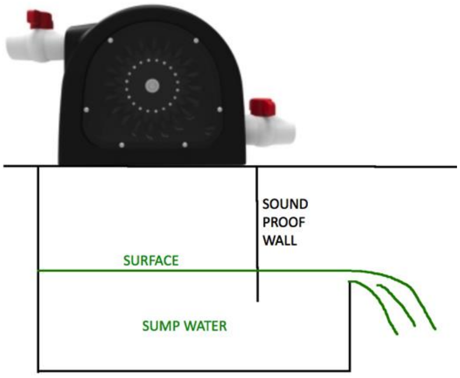
 In front of running turbine: 93.8 dBA	 On top of running turbine: 81.7 dBA
 1m away from running turbine: 83.3 dBA	 2m away from running turbine: 81.9 dBA
 6m away from running turbine: 73.9 dBA	 12m away from running turbine: 56.7 dBA

For a YouTube video of typical noise levels [click here]

Generally the higher the head the more noise from the unit. At our test site at 160m head and 1.6 kW you can talk normally standing by the turbine, but you are very aware it is there. You can just hear it at 30-40m away. It sounds like a washing machine in spin.

On low head sites less than 10m (30ft) the river is likely to make more noise than the turbine. A turbine can be closer to a dwelling in such cases. Vegetation around the turbine will dramatically reduce the distance that noise carries.

Often the space under the turbine is open to the surrounding air. If the noise level of the turbine is a critical concern then we suggest enclosing the sump to reduce noise emissions from the pelton rotor. Arrange for the water to drain out below the surface, creating a "trap" to prevent any air pathway for the sound.



Do not seal this sump chamber completely. Air must enter to replace bubbles swept away by the tailrace, or the level will rise and flood the turbine runner. The drainage hole in the dry side floor is suitable to vent this chamber.

See also **PLT Case Study 3 - High head installation** for details of a soundproof box that was used on a site where the turbine is close to the house.

Connecting two small streams into one PowerSpout

We are often asked if two small streams can be piped into a common turbine. This is not recommended, unless the head and pipe friction losses for each stream/pipe are very similar.

Generally we would advise two turbines, one for each site. The electrical output of both could then be joined together into a common supply cable, but only for PLT/TRG 12/24/48 VDC turbines. To use MPPT you will need a separate cable and MPPT for each turbine.

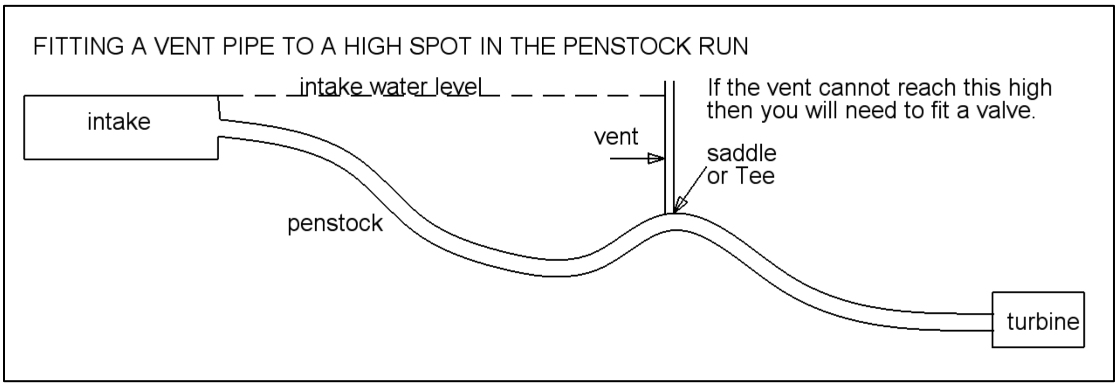
The picture on the right shows a Dual install. One unit runs on 30m (98 ft) head the other 10m (33 ft) head.

The Penstock

The online advanced calculator at http://www.powerspout.com/ will have advised the appropriate internal diameter (ID) of pipe for the "penstock" or pipeline, based on the site data you entered. This is a guide, based on a target of 90% efficiency. You will need to choose an available size with similar internal diameter that is cost-effective for your site. Enter this size in the calculator to check the efficiency and to compute the expected power output.

When you have chosen the locations for the intake and the turbine, measure the pipe length using a long tape or wheel, be accurate, as this information will be required to buy the pipe, and it's important to get it right.

Try to lay the pipe on a downhill gradient at all times, to avoid high spots in the line that might trap air bubbles. Use a level to check that it is always graded downward. If a high spot is unavoidable you will need to place a bleed valve at the highest point in the pipeline to purge air. Air locks in the line will significantly affect the power output of the turbine. The longer the penstock the more of a problem this tends to be. Penstocks over 1 km long can be problematic if there are many high spots trapping air. Automatic bleed valves may be useful in such cases.



You can use an open pipe as a vent provided that:

- it can reach above intake water level
- the point on the pipe where it Tees off is not so high that air is drawn in during operation due to pressure losses in the penstock above that point.

Pipe sizes

Pipe sizes commonly used with our hydro products include:

- PVC for larger sizes based on OD (110-300 mm normally)
- MDPE or HDPE based on OD (50-110 mm normally)
- LDPE based on ID in NZ/AUS (40-50 mm normally)

Many different standards exist for pipe sizes, which vary depending on industry and geographical area. The pipe size designation normally includes two numbers - one that indicates the outside diameter (OD) and the other that indicates the wall thickness. American pipes were categorized by inside diameter (ID) in the past but this was abandoned to improve compatibility with pipefittings and joiners that usually fit the OD of the pipe.

Inside diameter is critical for calculation of pipe friction loss since a variation of as little as 1 mm can have a very significant effect on the output power of the turbine. Take care with which diameter you are referring to since if calculations are done based on pipe ID and the pipe is then purchased based on OD your turbine will generate less power than predicted due to increased pipe friction. Pipes below 40 mm ID cannot normally be used, as friction losses are too high.

Pipes have different pressure ratings so a given pipe size is often available in a number of pressure ratings. These different ratings are achieved by either altering the material grade (Low, Medium or High Density PE) or increasing the pipe wall thickness. The OD is kept constant so standard pipe joiners still fit.

In NZ for example, polyethylene (PE) pipes can be purchased from 35 m (50 psi) head rating to 160 m (230 psi) head rating. Some sizes are based on ID but most are based on OD sizing, so be careful and double check with your supplier the OD and ID of the pipe.

		Greenline (370 Series)		Redline™ (360 Series)		Blueline (2500 Series)		Blackline (3500 Series)	
		Bar	PSI	Bar	PSI	Bar	PSI	Bar	PSI
Pressure Rating *	20	9	131	12.5	182	12.5	182	✗	✗
	25	8	116	12.5	182	12.5	182	✗	✗
	32	8	116	9	131	12.5	182	16	233
	40	6.3	91	9	131	12.5	182	16	233
	50	6.3	91	9	131	12.5	182	16	233
	63	6.3	91	9	131	12.5	182	16	233
Mean Internal Diameter	20	16.0		16.6		16.1		✗	
	25	21.0		20.7		20.1		✗	
	32	26.9		27.8		25.9		25.9	
	40	35.0		34.8		32.3		32.3	
	50	43.8		43.5		40.5		40.5	
	63	55.2		54.8		51.0		51.0	

(Iplex web site)

Pipe material

A pipe should be:

- Equal to or larger than recommended from the calculations that specified the output power (Watts) of your turbine. If possible please enter the final pipe size in the calculation before you order.
- Cost effective, tough and durable for 20-50 years.
- Able to handle the static pressure of the head of water.
- Able to handle the running head x a factor 1.5 to allow for water hammer
- Easy to lay and bend around obstacles.
- Able to be purchased in long lengths.

The PowerSpout PLT has a maximum running head rating of 130 m and allowing for up to 25% pipe friction loss, sites up to 160 m static head can be used. A higher water head can be used successfully but with reduced lifespan and warranty. We do approve PLT and TRG applications up to 2kW/turbine in some cases, contact us if you have a suitable site.

MDPE and HDPE pipes

The range and the fact that they are durable, low cost and commonly available in a wide range of sizes, pressure ratings and lengths makes PE pipes the obvious choice for the PowerSpout PLT turbines.

Remember that you can vary the pipe pressure rating to minimise costs. For example, if you have a 100 m head you start with low grade (50 psi, 3.5 bar) pipe, a length of 6 bar, then 9 bar and finally 12 bar. Laying 12 bar pipe all the way would almost double the cost of the pipeline. If you do this the pipe ID will change, so the calculated output may not be correct. To avoid disappointment use the smallest pipe ID in the online calculator and your turbine should generate a little more than predicted.

Pipes common in NZ (Rural Direct)– indicative prices 2017

Pipe OD mm	Pipe ID mm	Material	Pressure rating PSI	Pressure rating M	Pressure rating kPa	Pressure rating Bar	Approx cost/m NZ$	Approx cost/ft US$
57	**50**	MDPE	102	70	700	7	4.00	0.89
63	53	HDPE	131	90	900	9	4.95	1.11
63	50	HDPE	174	120	1200	12	7.00	1.56
75	65	HDPE	116	80	800	8	6.87	1.53
90	79	HDPE	116	80	800	8	8.90	1.98
110	94	HDPE	116	80	800	8	11.68	2.60

Bold indicates the change from ID to OD sizing

There are also larger sized HDPE culvert pipes up to 450 mm but these often require expensive joiners as they cannot be glued together, though plastic welding is possible.

PVC pipes

PVC pipes are widely used in applications ranging from low cost road culverts to mains pressure water distribution networks in cities. PVC pipe sizes vary around the world and frequently the available pipe sizes differ between countries. Most countries seem to either use the American or British pipe size dimensions, or develop their own standards for pipe sizes.

PVC pipes are often more cost effective than PE pipes in sizes above 110 mm. As PVC pipes glue together the cost to join them is low, so short lengths can be used (normally 4-6 m). They can be bent in-situ by applying heat to the tension side of the bend. We therefore see them mainly used at lower head sites where more water flow is available and often on sites running multiple turbines from a common pipe line.

PVC is not as durable as PE and can be shattered by falling rocks and trees. Where these risks can be managed and the price is right for the application they are commonly used. PVC left in direct sunlight will weaken and become brittle with age. Pipes can be protected from UV by paint.

We see larger PVC pipes (150 mm and larger) used for lower head applications below 30 m and often with less than 200 m of pipe needed. Our PowerSpout TRG turbine has been specifically designed for this application. Below 20m head it is feasible to use PVC soil and waste drainage pipe pipes that push together, provided they are buried and supported to prevent the joins popping apart.

PVC culvert grade farm pipes glued together are the lowest cost PVC pipe you can obtain.

The tables below are to assist in the understanding of the PVC pipe sizes available in your country. Countries that have sizes very similar to other countries are shown coloured the same, so they are easy to spot.

USA PVC pipe sizes - Provided in metric and imperial

OD of Pipe	Schedule 40 Pipe ID mm	Schedule 80 Pipe ID mm	OD of Pipe	Schedule 40 Pipe ID inch	Schedule 80 Pipe ID inch
48.3	40.4	37.5	1.9	1.6	1.5
60.3	52.0	48.6	2.4	2.0	1.9
73.0	62.1	58.2	2.9	2.4	2.3
88.9	77.3	72.7	3.5	3.0	2.9
101.6	89.4	84.5	4.0	3.5	3.3
114.3	101.5	96.2	4.5	4.0	3.8
141.3	127.4	121.1	5.6	5.0	4.8
168.3	153.2	145.0	6.6	6.0	5.7
219.1	201.7	192.2	8.6	7.9	7.6
273.1	253.4	241.1	10.8	10.0	9.5
323.9	302.0	286.9	12.8	11.9	11.3
355.6	332.1	315.2	14.0	13.1	12.4
406.4	379.5	361.0	16.0	14.9	14.2
457.2	426.9	406.8	18.0	16.8	16.0
508.0	476.1	452.5	20.0	18.7	17.8
609.6	572.6	544.0	24.0	22.5	21.4

New Zealand and Chinese pipe sizes are on the next page.

Table 1. NZ PVC Pipe sizes

OD of pipe	PN6 Wall mm	PN6 pipe mm	PN9 Wall mm	PN9 pipe mm	PN12 Wall mm	PN12 pipe mm	PN15 Wall mm	PN15 pipe mm	PN18 Wall mm	PN18 pipe mm	NB
48.3	1.7	44.9	2.1	44.1	2.8	42.7	3.4	41.5	3.9	40.5	40
60.4	1.8	56.8	2.6	55.2	3.4	53.6	4.1	52.2	5.0	50.4	50
75.4	**2.2**	71.0	**3.3**	68.8	**4.2**	67.0	**5.2**	65.0	**6.1**	63.2	65
88.9	2.6	83.7	3.8	81.3	5.0	78.9	6.1	76.7	7.2	74.5	80
114.3	3.3	107.7	4.9	104.5	6.3	101.7	7.8	98.7	9.2	95.9	100
140.2	4.0	132.2	5.9	128.4	7.7	124.8	9.5	121.2	11.3	117.6	125
160.3	**4.5**	151.3	**6.7**	146.9	**8.8**	142.7	**10.8**	138.7	**12.8**	134.7	150
225.3	5.8	213.7	8.4	208.5	11.1	203.1	13.7	197.9	16.2	192.9	200
250.4	**6.4**	**237.6**	**9.4**	231.6	**12.3**	225.8	**15.2**	220.0	**18.0**	214.4	225
280.4	7.1	266.2	10.5	259.4	13.8	252.8	17.0	246.4	20.2	240.0	250
315.5	8.0	299.5	11.8	291.9	**15.5**	284.5	**19.1**	277.3	**22.7**	270.1	300
400.5	10.1	380.3	14.9	370.7	19.7	361.1	24.3	351.9	28.9	342.7	375

NB refers to nominal bore which is the approximate inside diameter of the pipe series

Table 2. China PVC pipe sizes

OD of pipe	0.63 Mpa Wall mm	0.63 Mpa ID pipe mm	0.8 Mpa Wall mm	0.8 Mpa ID pipe mm	1.0 Mpa Wall mm	1.0 Mpa ID pipe mm	1.25 Mpa Wall mm	1.25 Mpa ID pipe mm	1.6 Mpa Wall mm	1.6 Mpa ID pipe mm	2.0 MPA Wall mm	2.0 Mpa ID pipe mm	2.5 MPA Wall mm	2.5 Mpa ID pipe mm
50	2.0	46.0	2.2	45.6	2.4	45.2	3.0	44.0	3.7	42.6	4.6	40.8	5.6	38.8
63	2.0	59.0	2.5	58.0	3.0	57.0	3.8	55.4	4.7	53.6	5.8	51.4	7.1	48.8
75	**2.3**	**70.4**	**2.9**	**69.2**	**3.6**	**67.8**	**4.5**	**66.0**	**5.6**	**63.8**	**6.9**	**61.2**	**8.4**	
90	2.8	84.4	3.5	83.0	4.3	81.4	5.4	79.2	6.7	76.6	8.2	73.6	10.1	69.8
110	2.7	104.6	3.4	103.2	4.2	101.6	5.3	99.4	6.6	96.8	8.1	93.8	14.6	80.8
160	**4.0**	**152.0**	**4.9**	**150.2**	**6.2**	**147.6**	**7.7**	**144.6**	**9.5**	**141.0**	**11.8**	**136.4**	**18.2**	**123.6**
200	4.9	190.2	6.2	187.6	7.7	184.6	9.6	180.8	11.9	176.2	14.8	170.4		
250	6.2	237.6	7.7	234.6	9.6	230.8	11.9	226.2	14.9	220.2				
315	7.7	299.6	9.7	295.6	12.1	290.8	15.0	285.0	18.7	277.6				
355	8.7	337.6	10.9	333.2	13.6	327.8	16.9	321.2	21.1	312.8				
400	9.8	380.4	12.3	375.4	15.3	369.4	19.1	361.8	23.7	352.6				

Pipe myths

We often get told that the pipe has to reduce in size in order to keep up the pressure. This is a huge misconception and arises from confusion with irrigation schemes. If you decrease the pipe size you increase the friction, which will actually decrease the final pressure.

The pipe for an irrigation scheme supplying many farms will reduce in size as the last farm has to convey a smaller amount of water. The start of the pipe has to be larger because it has to convey the water needed for all the farms on the line. The pipe myth arises because pictures of irrigation schemes have often been incorrectly used to depict hydro schemes.

People also confuse pressure with velocity; if you increase the pipe velocity by reducing pipe size the pressure at the turbine will decrease. Reducing pipe size increases water velocity, which increases pipe friction and reduces even further the pressure in the pipe, resulting in less power generation.

If the penstock simply discharges "full bore" (for example, to flush out sediment) then the flow will be large, and there will be no pressure left. Pressure is all used up in pipe friction. Normally the turbine uses jets to restrict the flow and convert the pressure into velocity to drive the runner. The flow in the penstock will be controlled by the size(s) of jet(s) that you use in your turbine(s). Larger jets will demand more flow, which will in turn create more friction loss, and may reduce the pressure at the turbine. Smaller jets will minimise the flow and the pressure will be slightly higher. Using a small bore **jet** may result in higher pressure (due to lower flow rate) but using a smaller bore **pipe** will not, as it simply increases the friction.

Another common myth is that pipe bends are the cause of a lot of penstock losses. In reality, relative to the long hydro penstock, a few correctly sized bends will make no noticeable difference as most friction loss is caused by the length of the penstock.

Laying and securing pipes

When laying the pipe try to do the following:

- Install a good strong intake structure. PowerSpout will have a Coanda intake screen available in 2018.
- Secure the pipe against flash floods during the installation process.
- Obtain a good fall in the first 5-10 m of pipe.
- Lay the pipe on a gradual, always descending line where possible.
- Keep the number of high points to a minimum and vent these to avoid air locks, pressure rises and pressure drops.
- Avoid siphon systems if possible.
- Once the pipe is in position, securely fasten the pipe line to rocks, trees, or ground anchors to prevent it moving down the incline or being washed away in flood events.

Penstock valves

You may wish to install a valve below the intake, but this is rarely useful. If you do install a valve at the top end of the penstock then the weight of water below will cause a vacuum that may collapse your pipe or draw debris into it. It is good practice to fit a vent pipe just below any such valve so the penstock can drain. This vent often helps air to escape while the penstock is filling.

The turbine comes with valves that control the individual jets, but you may also wish to put a larger valve on the penstock just prior to the manifold. Closing this valve allows you to work on the manifold without draining the penstock. It also means that the penstock can be filled and bled of air in advance of installing and commissioning the turbine itself. The air can take time to find its way out via the intake and vents fitted.

You may need bleed valves at high points if the penstock slope is not continuous. These are only used to remove air and can be closed during operation.

Finally you may wish to install a flush valve at the bottom end of the penstock so that you can flush out sediment.

None of these valves are always essential - each has possible merits.

Pipe thrust blocks

On larger hydro schemes using rigid pipes, thrust pads and anchor blocks may be required to prevent movement of the pipe work. On these larger hydro schemes professional engineering advice must be engaged to calculate the supports needed.