Types of Hydropower Facilities

- **Impoundment Hydropower-** uses a dam to store water. Water may be released either to meet changing electricity needs or to maintain a constant water level.

- ***Run-of-River Projects -*** utilize the flow of water within the natural range of the river, requiring little or no impoundment. Run-of-river plants can be designed using large flow rates with low head or small flow rates with high head

- **Microhydropower Projects** - produce 300 kilowatts (kW) or less. Microhydro plants can utilize low heads or high heads

- **Diversion Hydropower** - channels a portion of the river through a canal or penstock, but may require a dam

Pumped storage - pumps water from a lower reservoir to an upper reservoir at times when demand for electricity is low. During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity.

What is Micro Hydro?

- Micro-hydro is generally less than 300 kW.
- Hydro power is cost effective in a limited number of places.
- Hydro is more consistent than wind or solar.
- Hydro is “concentrated solar energy.”

Micro Hydro Costs

- High Capital Cost
  - Labor and Earth Moving Equipment
  - Civil Works and Penstocks
- Low Operating Cost
  - No Fuel
  - Inexpensive maintenance
- Especially economic for Do-It-Yourself.

Micro Hydro is Run-of-River

- No water storage.
- Much simpler to design and build.
- Less environmental impact.
- May be seasonally dependent.
- Some schemes have a small reservoir for supplying peak daily loads.

Water Rights

- Sufficient water must be available.
- Fish or riparian habitat must not be affected.
- Other licensed users take precedence.
- Environmental impact must be addressed.
  - Erosion due to civil works
  - Water temperature increased due to low water.
  - Dams are not recommended.
- Easements required if crossing private land.

AC systems

- River flow must exceed peak demand.
- Standard wiring and electrical equipment.
- Components
  - Generator
    - Induction
    - Synchronous
  - Frequency Control and Governors
  - Voltage Control
  - Diversion loads

Grid Tie Systems

- Utility Concerns
  - Fault Protection
  - Line Worker and Public Safety
  - Power Quality
- Metering Options

Line Worker and Public Safety

- Islanding
  - Generator supplies an isolated portion of grid during a power outage.
  - Poses safety hazard to line workers.
  - Inverters meet UL standards
  - Induction Generators (Motors)

Power

- An instantaneous measure.
- The ability to do work.
- Measured in Watts and Horsepower.

$$746\ W = 1\ hp$$

$$Hp = \frac{\text{Flow (cfs)} \times \text{Head (feet)}}{8.8} \times .8$$

Hydro Power

- Site Assessment – potential power
- Loads – required power
- System capacity – designed power
- Locating the Intake
- Locating the Powerhouse

Site Assessment

- Flow
  - The **design flow** will be a percentage of the measured stream flow.
  - Design flow determines penstock size
  - Design flow determines nozzle size
- Head
  - Elevation difference between the penstock intake and the turbine
- Penstock length.
  - Often the major cost.

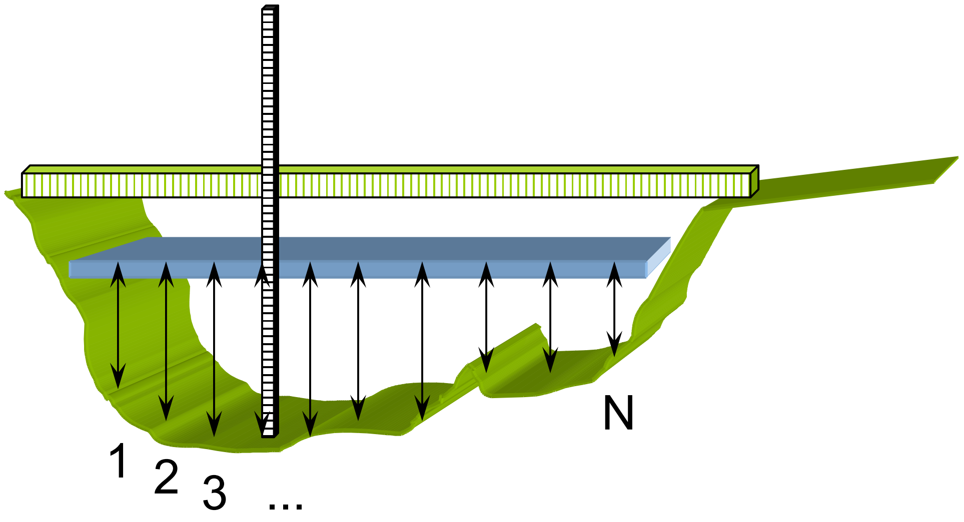
Measuring Flow

- Velocity-Area Method
- Velocity Head
- Flow Meter
- Weir method
- Bucket method

Determining Area

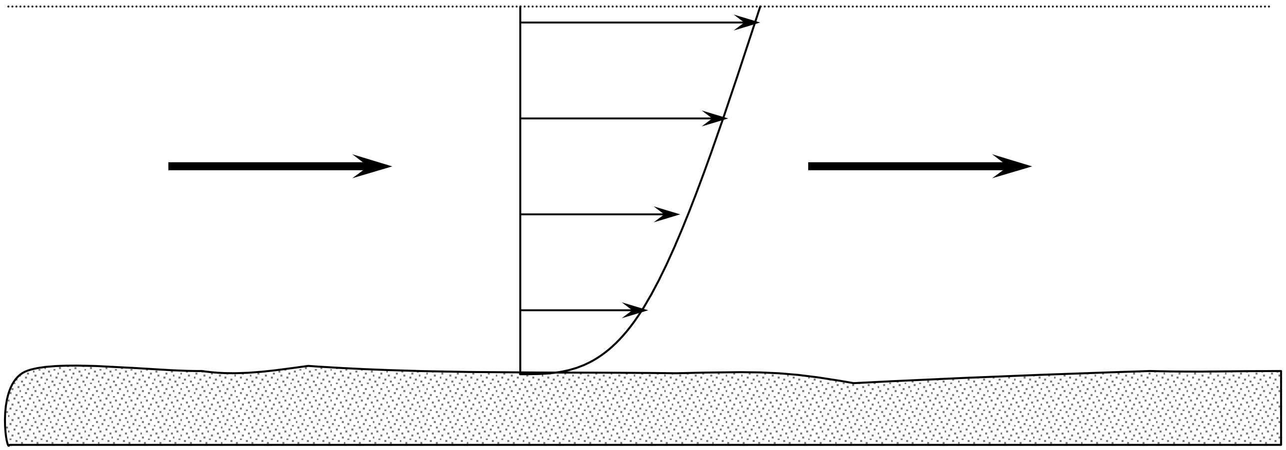
Average Depth = $\frac{\text{Sum of (N)depths}}{\text{N}}$

Area = Stream Width x Average Depth

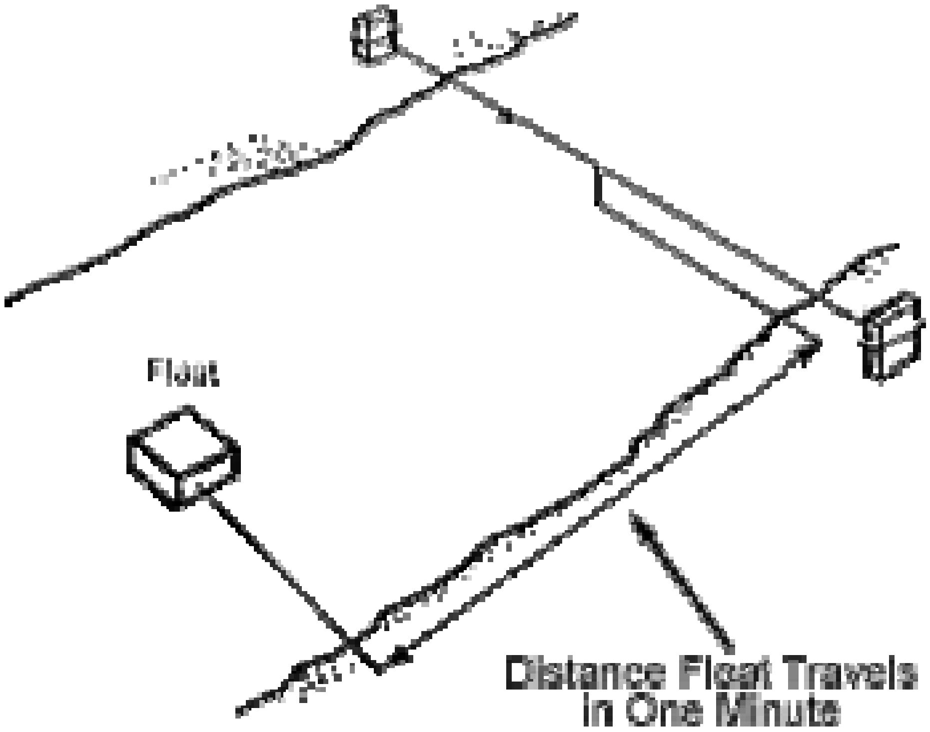


Measuring Velocity

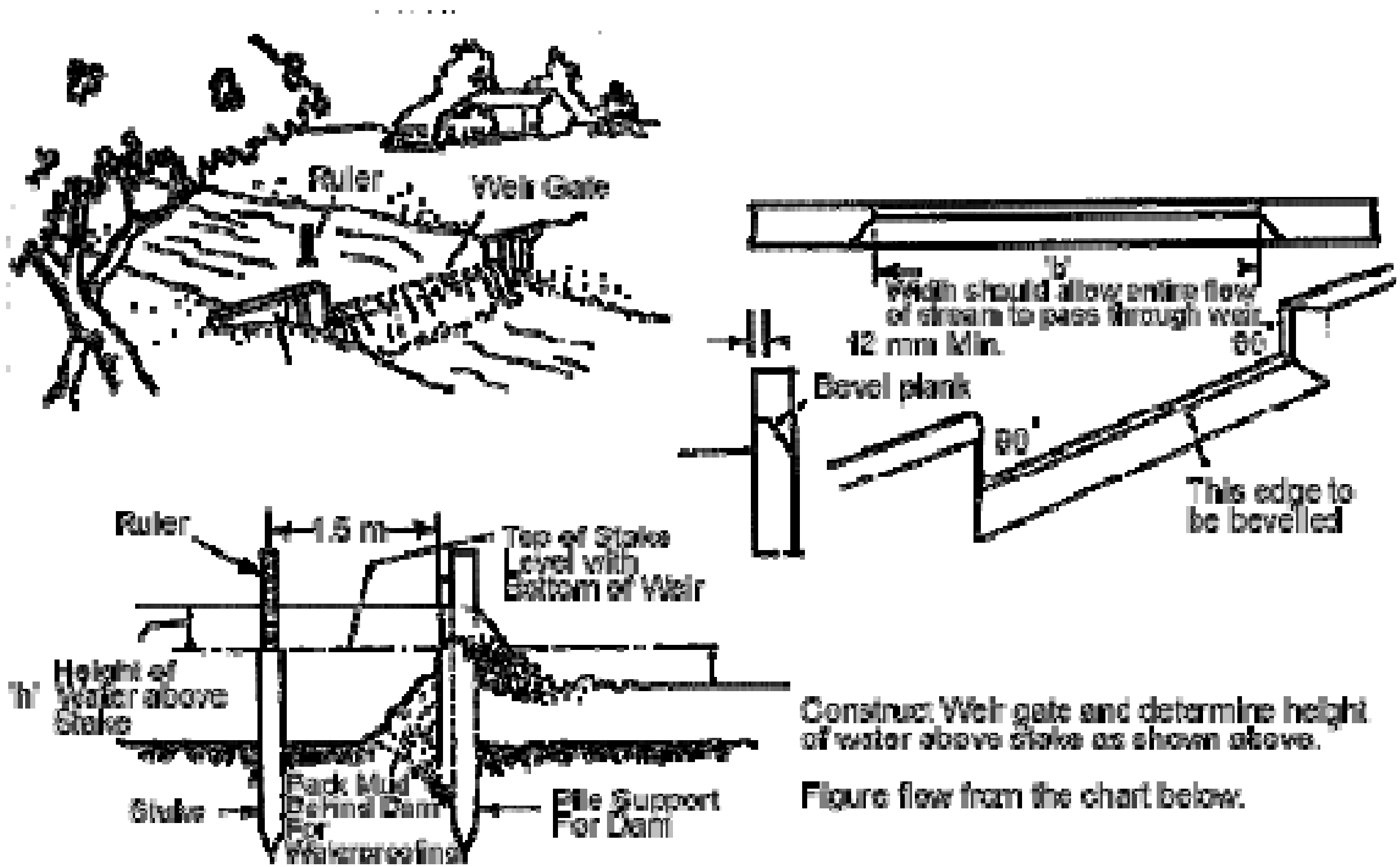
- Stream velocity varies with depth.



Float Method

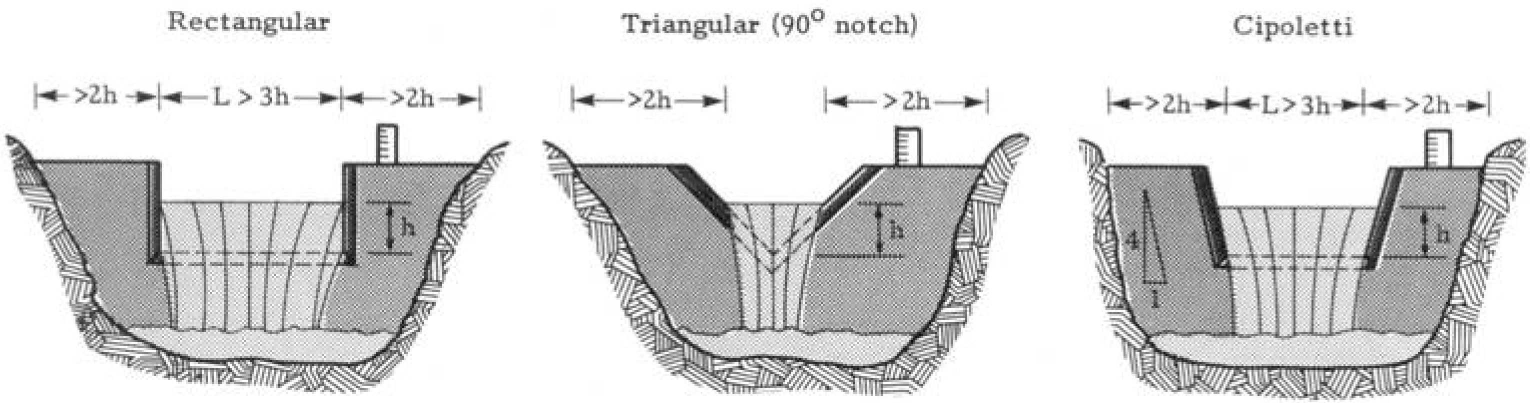


Weir method



Reference: Canyon Industries Inc., Micro-hydro Design

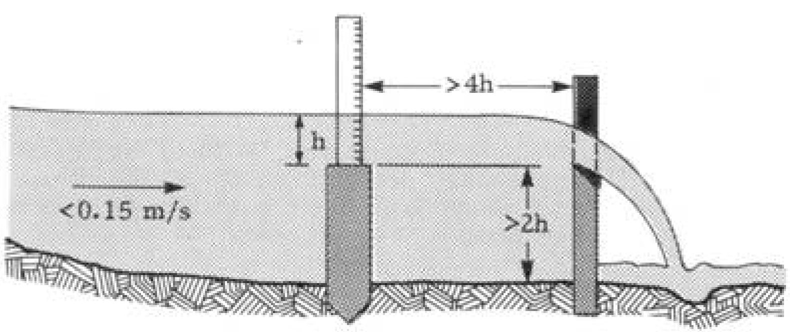
Weir Method



$$Q = 1.8\ (L - 0.2\ h)\ h^{3/2}$$

$$Q = 1.4\ h^{5/2}$$

$$Q = 1.9\ L\ h^{3/2}$$

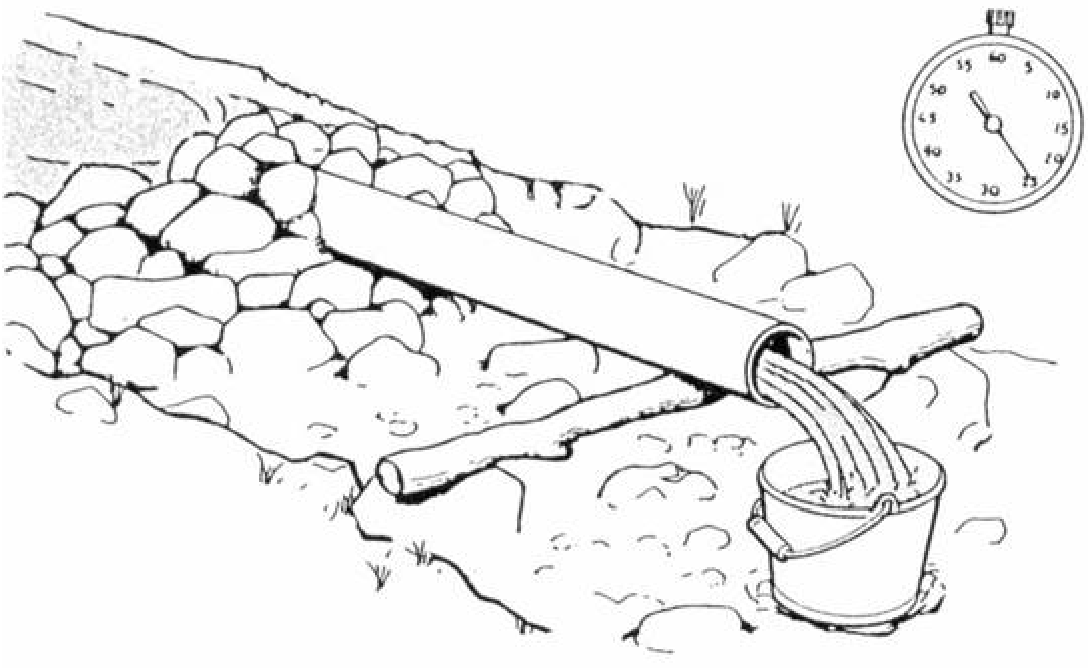


where:

- Q = discharge over weir (m^3/s)
- L = length of notch (as defined in sketch, in m)
- h = head (m)

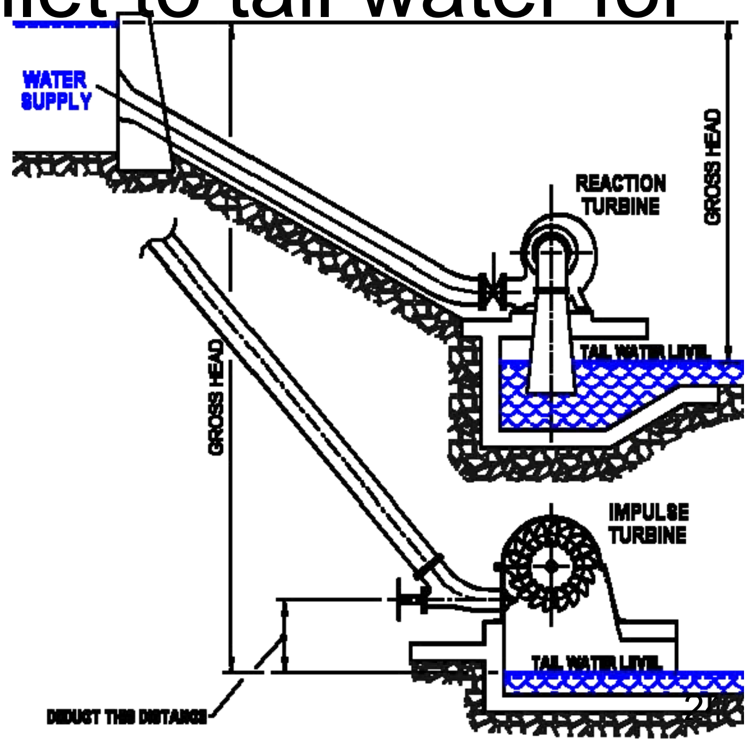
Reference: Inversin, Micro-hydropower Sourcebook

Bucket Method



Head

- Vertical distance from inlet to turbine for impulse turbine.
- Vertical distance from inlet to tail water for reaction turbine.



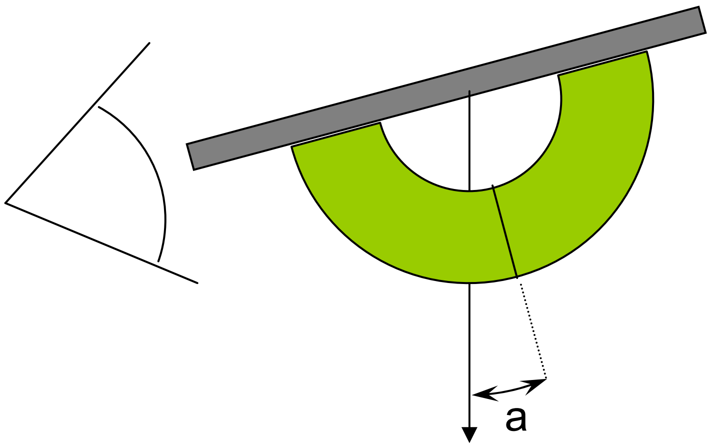
Measuring Head

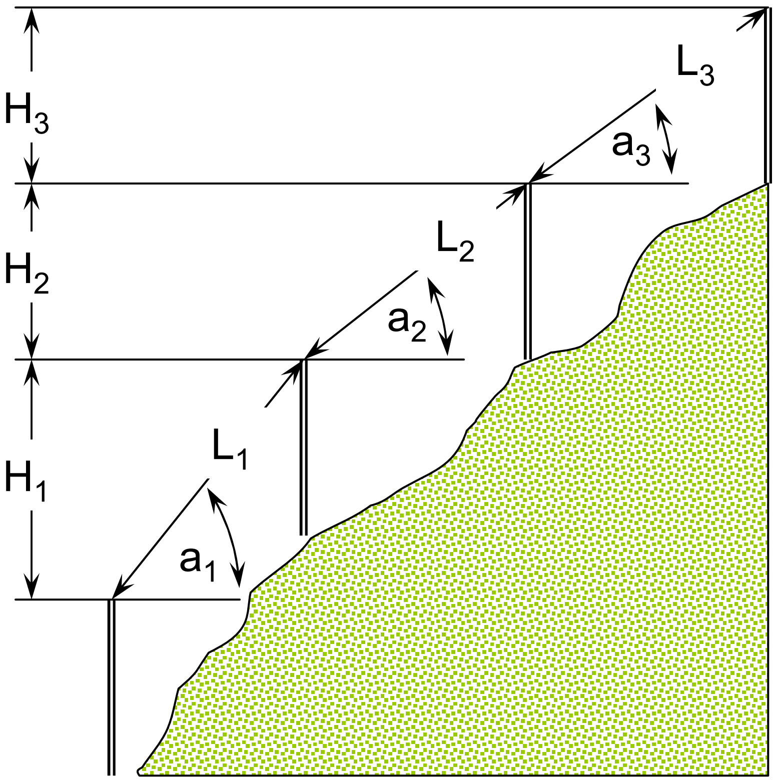
- Inclinometer
- Altimeter
- Hose and Pressure gauge
- Level

An Inclinometer

- Also called an Abney Level.
- L is measured with a tape or hip chain.

  $H = L \times \sin(a)$



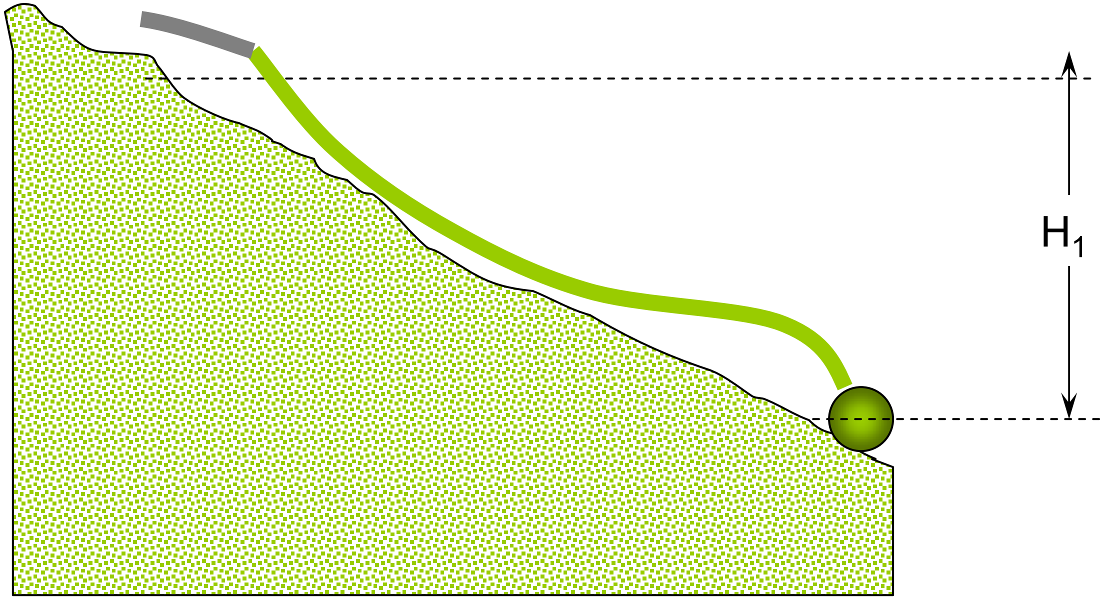


Altimeters

- Measuring relative height, therefore absolute calibration is not necessary.
- The interval between measurements must be short to avoid error from weather changes.
- Best to take multiple readings.

Hose and Pressure Gauge

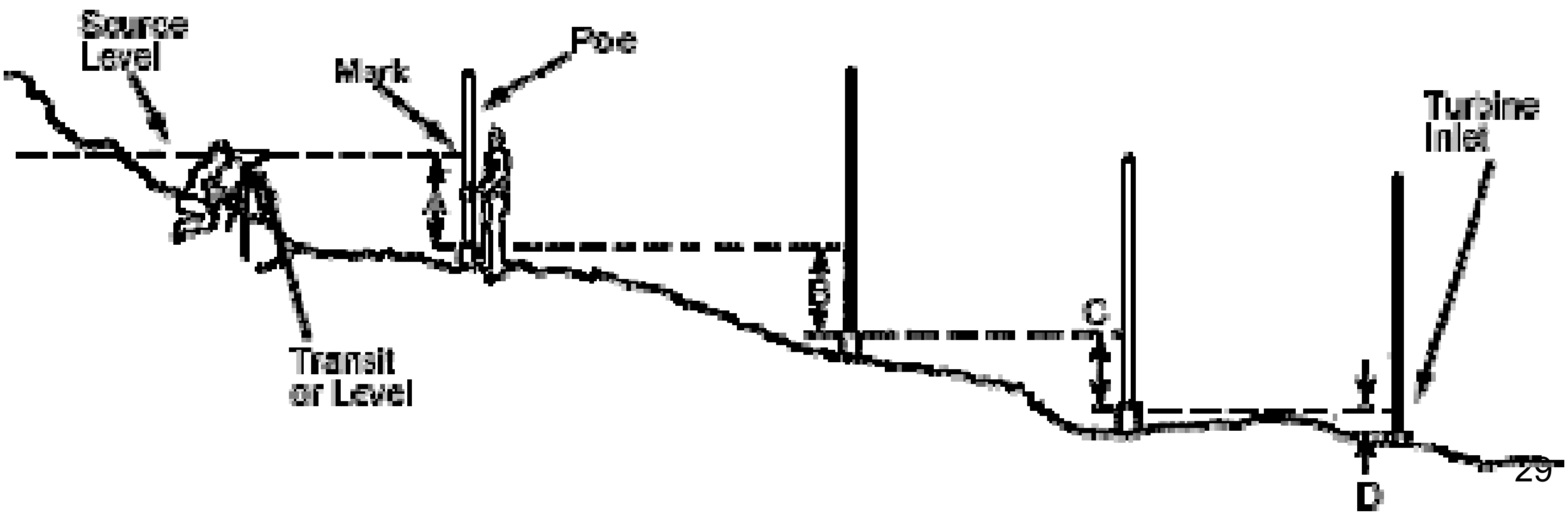
- Accurate and simple method.
- Bubbles in hose cause errors.
- Gauge must have suitable scale and be calibrated.
- Use hose a measuring tape for penstock length.



Using a Level

- Use a person or a measured pole.

$H_{total} = A + B + C + D$



Static Head vs. Net Head

- Static head is the vertical distance from the intake to the power house
- Net head takes into account friction loss
- Pipe sizing – rule of thumb

A pipe diameter should be chosen so that only 10 – 15% of the static head is lost in pipe friction. Tables are available for every pipe material, diameter and flow rate.

Locating the Intake

- Choose a site with a stable stream bed.
  - Constant flow stream
  - Bedrock
  - Small gradient
- The inside of bends accumulate sediment.
- The outside of bends are subject to erosion and flood damage.
- Place the intake along a straight section.

Intake and Powerhouse

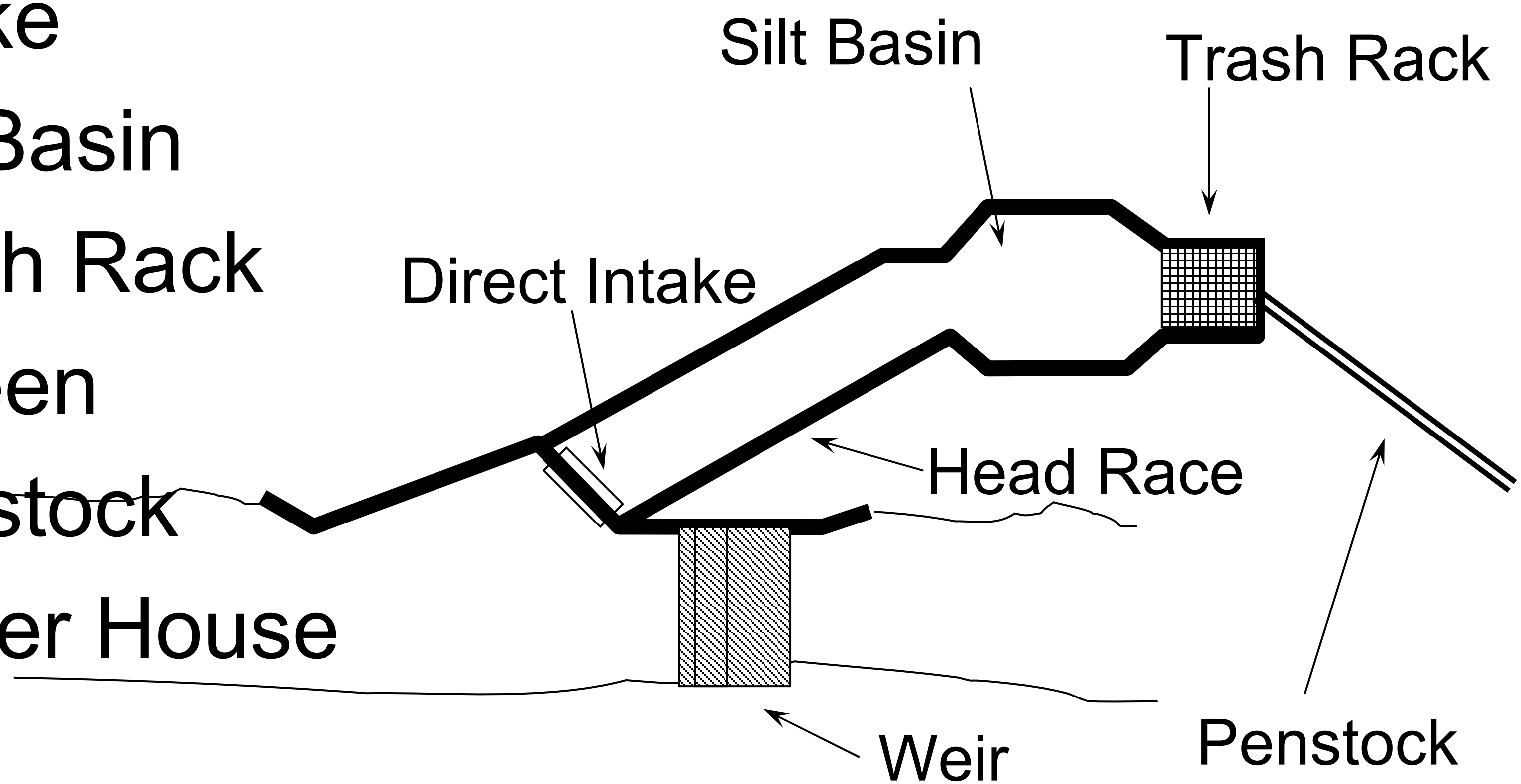
- Flood conditions must be planned for.
- Composition and nature of stream bed determines erosion and future path changes.
- Natural features can protect civil works.
- Locate upstream to avoid competing with other water users.
- Access for construction and maintenance.

Locating the Powerhouse

- Power house must be above flood height.
- To maximize head:
  - Place the turbine below the powerhouse floor.
  - Use draft tubes.
- Locate powerhouse on inside of bends.
- Use natural features for protection.
- Tail race oriented downstream.
- May be some distance from stream.

Civil Works

- Diversion
- Intake
- Silt Basin
- Trash Rack
- Screen
- Penstock
- Power House



Civil Works

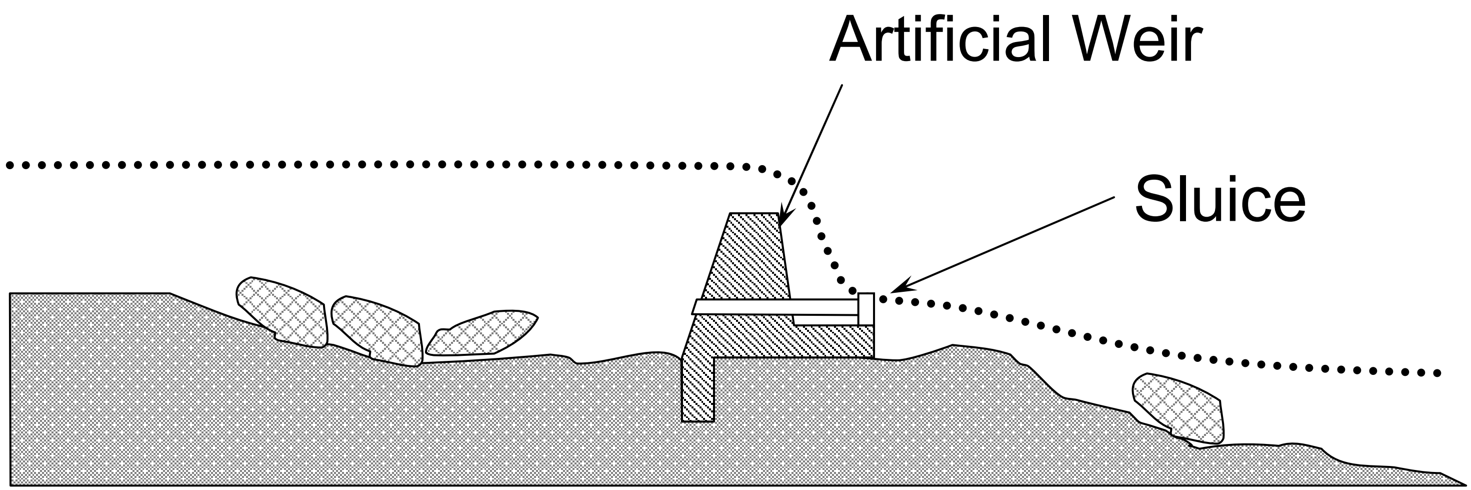
- The river flow will be seasonally variable.
- Sediment must be removed.
- Must be accessible for construction.
- Erosion occurs if water flows <u>around</u> weirs.

Diversion

- Weirs maintain the water level at the intake.
- A Weir does not store water.
- Natural riverbed features may be used.
- Weirs may also be :
  - Concrete
  - Gabions
  - Wood

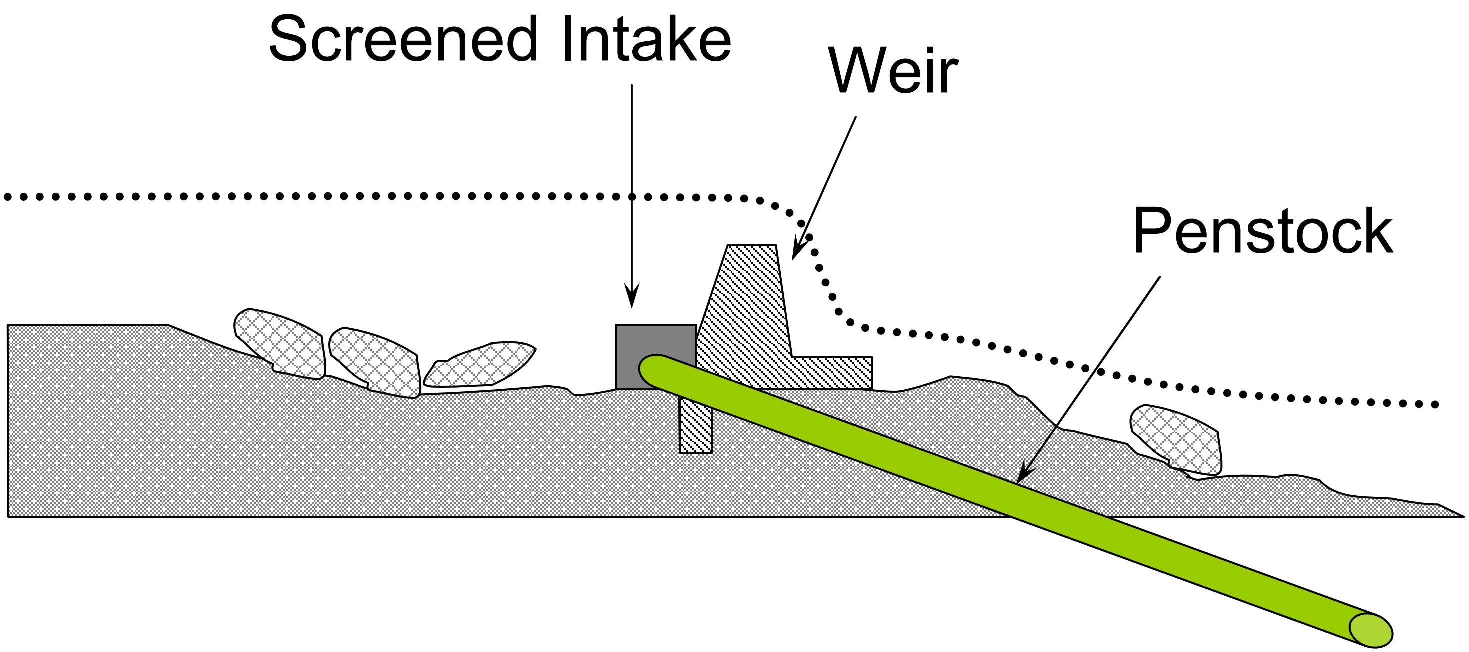
Weir

- The sluice is a short length of pipe for clearing away sediment.



Weir

- If spring run-off is not severe, the penstock may lead directly from the weir.



Sluice

A Sluice allows sediment removal.

Wing Walls

- Wing walls prevent erosion and flood damage to the civil works.
- Natural rock walls along a stream can serve the same purpose.
- Walls may be built from:
  - Gabions
  - Concrete
  - Rock and mortar
  - Wood

Intake Depth

- Pipe intakes should be submerged deep enough not to draw air.

$$\mathbf{H = (0.0622)\ Q^2 / D^4}$$

H = intake depth[in]

Q = flow rate [gpm]

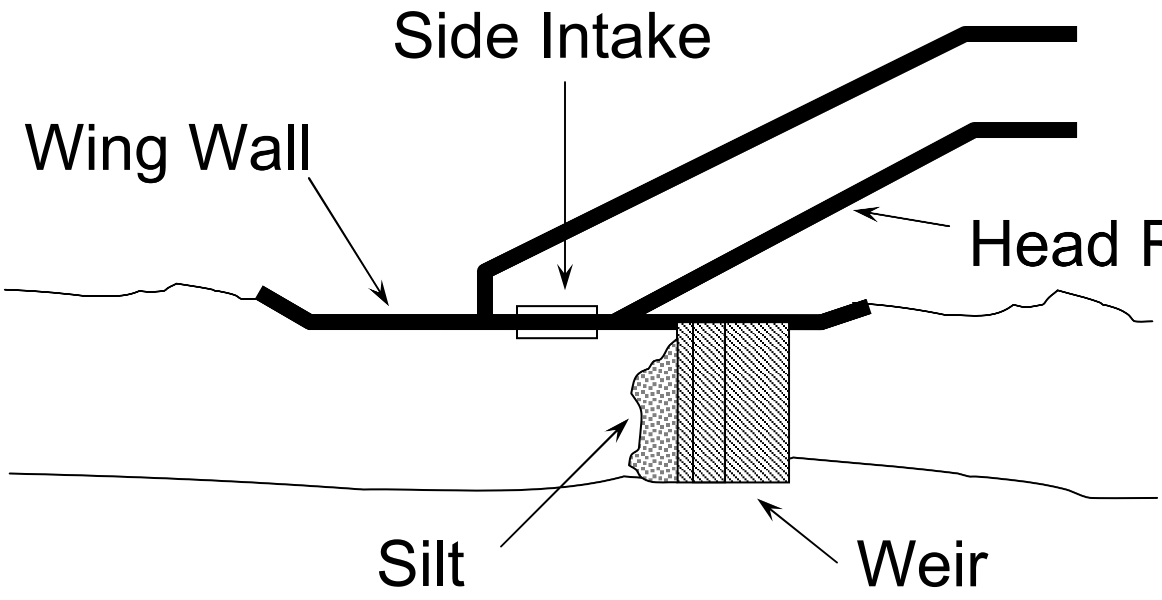
D = pipe diameter [in]

Intake Depth

- Rule of thumb – pipe should be submerged 3x the pipe diameter
- Screening is the weak point
- Intake structures are the most maintenance intensive part of hydro

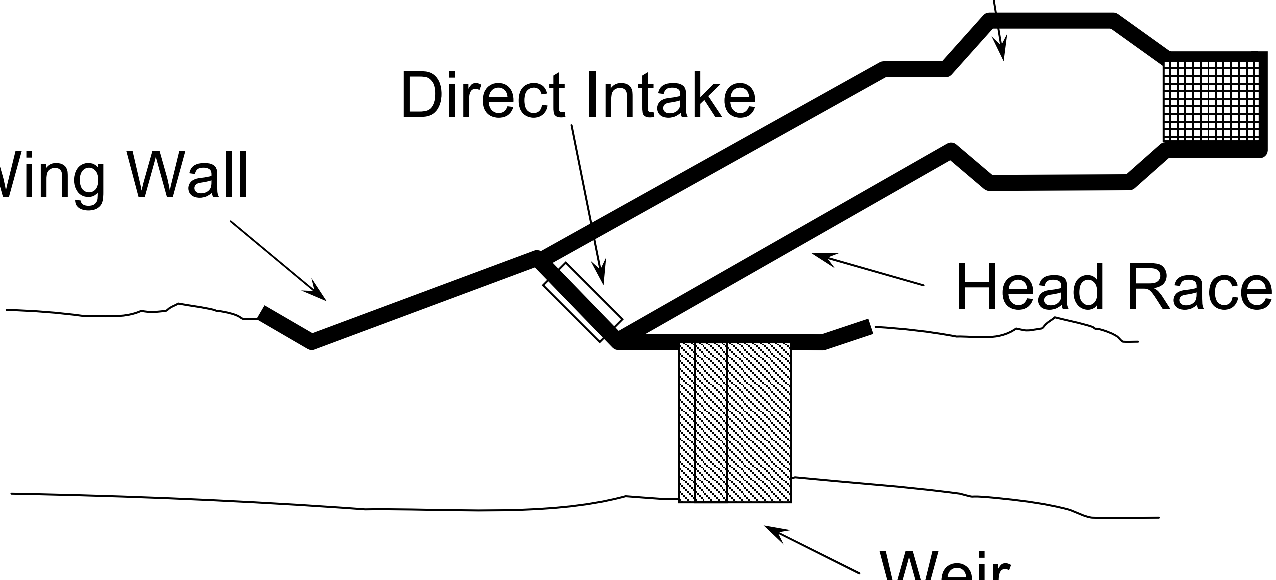
Side Intake

- Place a side intake far enough upstream to avoid silt deposited behind the weir.



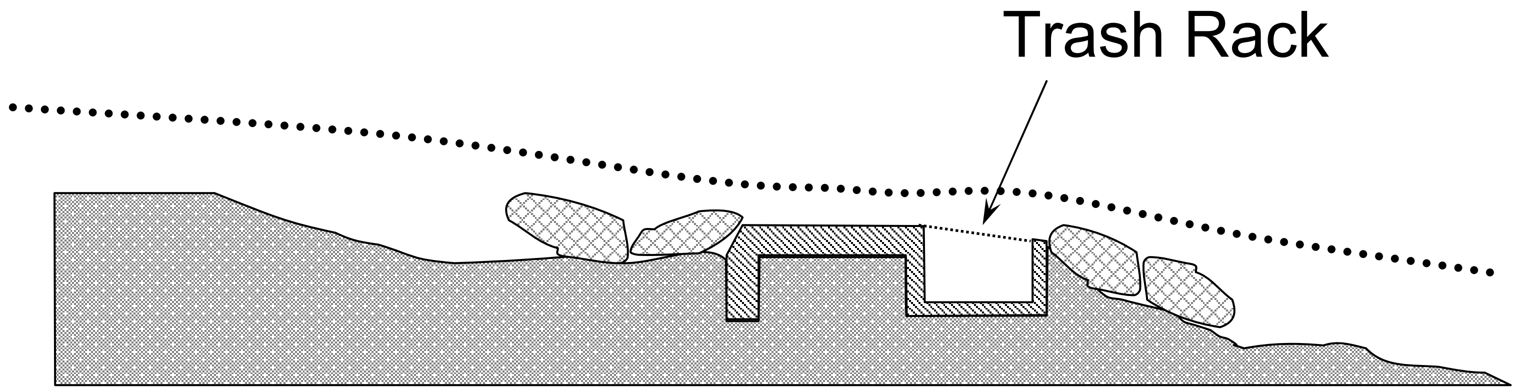
Direct Intake

- A direct intake allows silt to be drawn into the head race to settle in the silt basin.



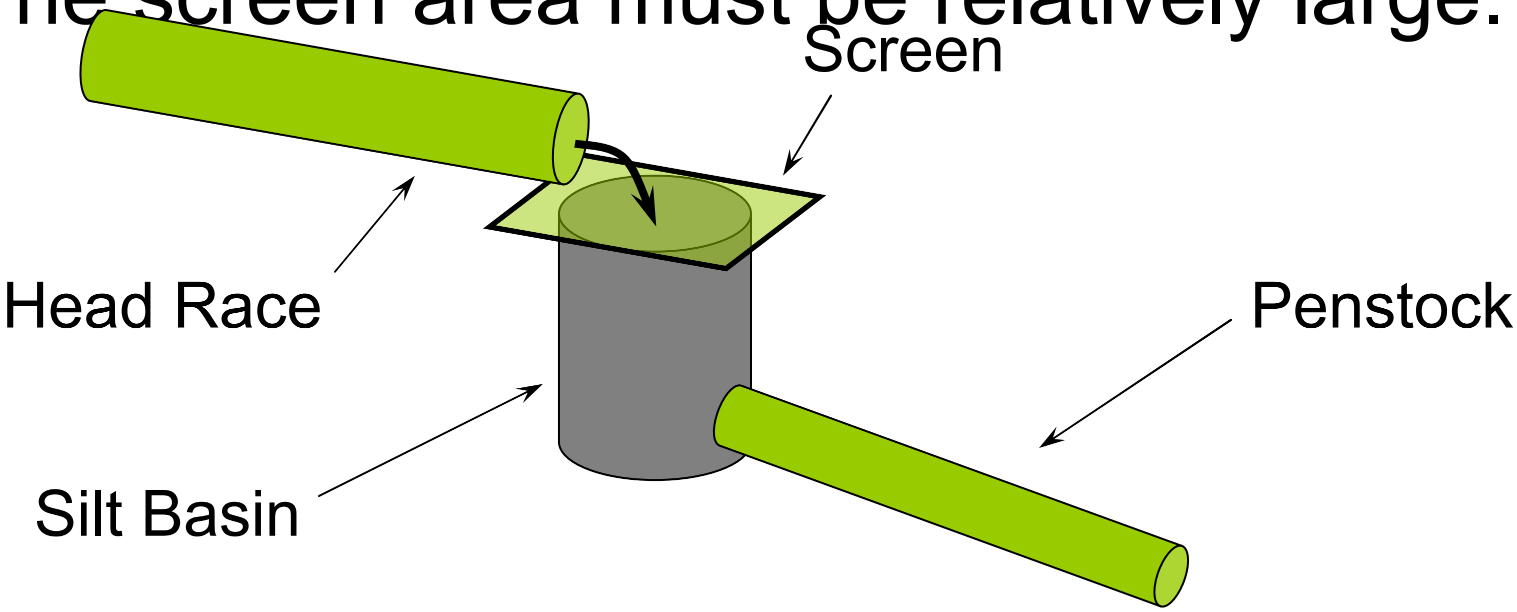
Trench Intake

- A trench intake in a rapidly flowing stream allows large debris to pass over.
- The rapid flow keeps the rack clear.



Screens

- Screens should be half the nozzle diameter.
- A self-cleaning screen design is best.
- The screen area must be relatively large.



Trash Rack

- The trash rack should be at least two pipe diameters from the pipe inlet.
- If the trash rack is not situated in the main stream it is easier to clean.
- If the head race is a pipe, a rack is necessary.
- Drilled PVC Pipe will serve as a trash rack.

Ice and Snow

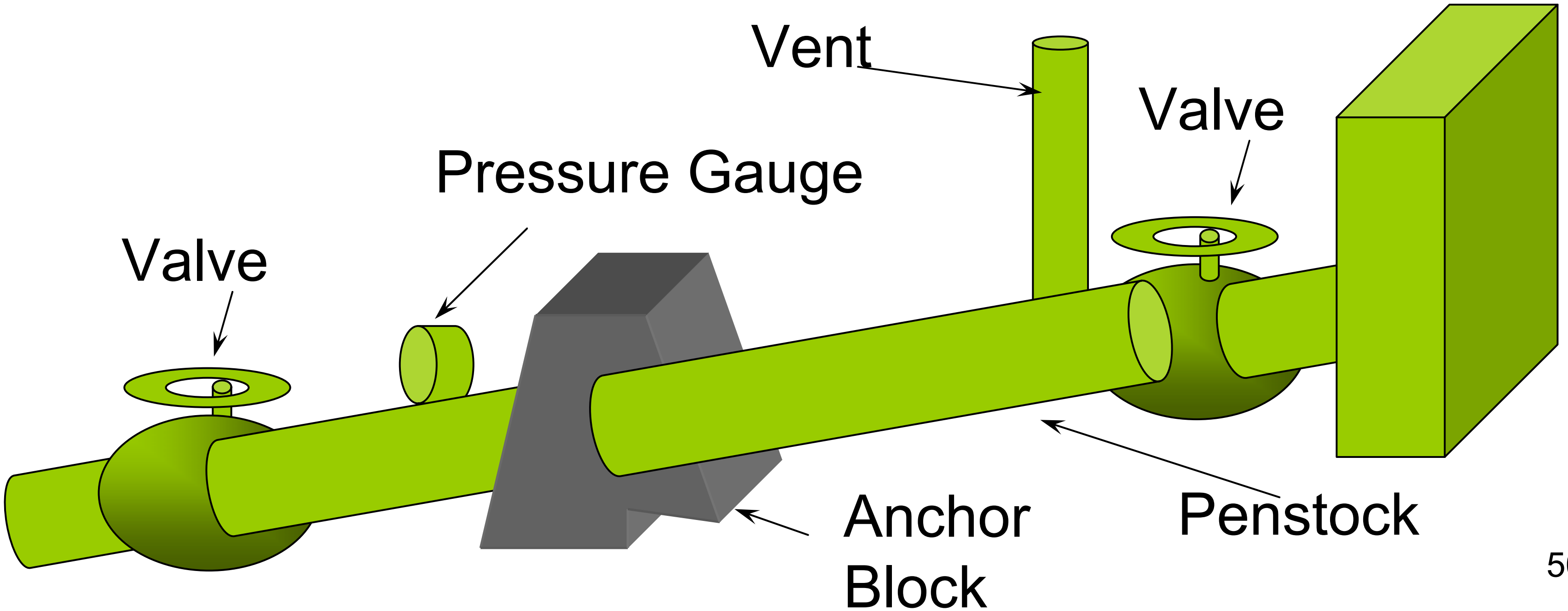
- Frazil ice – super cooled water sticks to everything
- Submerging the intake allows the ice to float.
- Snow may prevent penstocks from freezing.

Penstock

- Materials
- Diameter
- Friction
- Pressure Rating
- Valves
- Gauges
- Thrust Block

Penstocks

- A vent prevents vacuum collapse of the penstock.
- A pressure gauge should always be installed.
- Valves that close slowly prevent water hammer.



Penstocks

- A short straight penstock is least expensive.
- A channel or culvert may be used to reduce penstock length.
- Pipe laid in the creek will abrade.
- Penstocks deliver water under pressure.
- Usually the major expense.

Slide, Anchor and Thrust Blocks

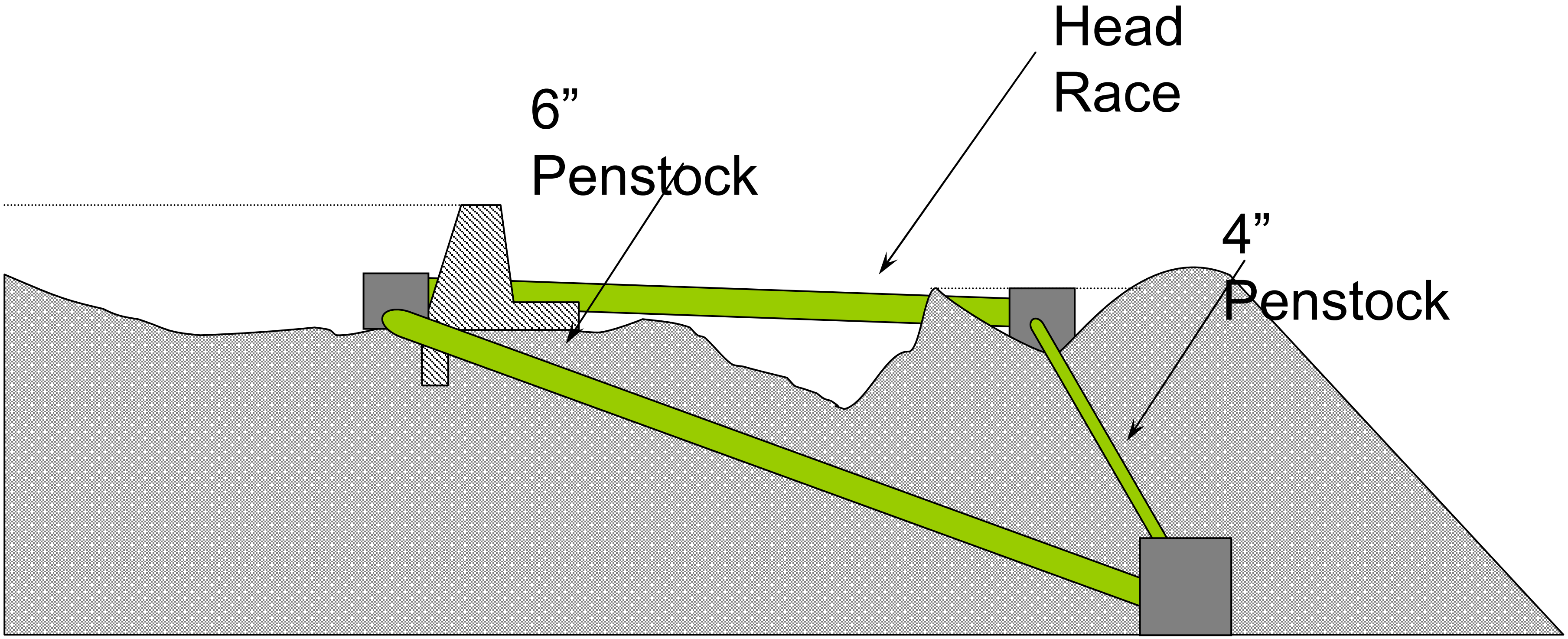
- Prevent unwanted movement of penstock.
- Required at bends and reductions.
- Anchor blocks use mass to prevent movement.
- Thrust blocks are used with buried penstocks.

After bay and Tailrace

- Removes water from power house and turbine.
- Designed to prevent erosion.
- Must be large with enough slope to prevent water backing up in turbine.

Head Race

- It may be less expensive to run low pressure pipe or a channel to a short penstock.



Turbines

- Water under pressure contains energy.
- Turbines convert the energy in water into rotating mechanical energy.
- Impulse turbines convert the kinetic energy of a jet of water to mechanical energy.
- Reaction turbines convert potential energy in pressurized water to mechanical energy.

Selected References

- Microhydro by Scott Davis
- Microhydro Design Manual by Adam Harvey
- Waterturbine.com for picohydro units
- BC Hydro Handbook
- Idaho National Labs

Impulse Turbines

- Tolerate sand.
- Easy to fabricate.
- Efficient at wide a range of head and flow.
- A nozzle converts pressurised water into a high-speed jet of water.

Pelton Turbine – Canyon Industries

Pelton Turbines

- At least one jet of water strike the buckets at atmospheric pressure.
- Maximum jet diameter about 1/3 bucket width.
- More jets increase flow and are used at low head.

0.61m Pelton – Dependable Turbines Ltd.

Turbine application

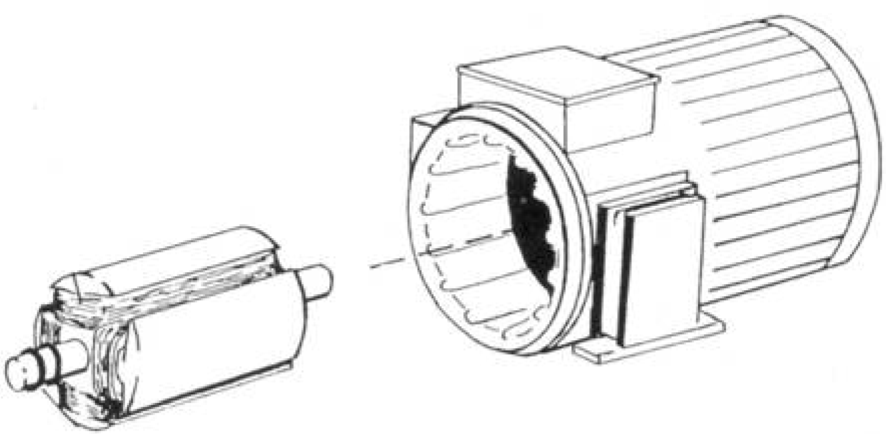
Turbine	Head (pressure)		
	High (30m +)	Medium	Low (<10 m)
Impulse	Pelton Turgo	Crossflow Pelton Turgo	Crossflow
Reaction	-	Francis Pump	Propeller Darius

Generators

- Types of Generators
  - Synchronous
  - Induction
  - DC generators
- Characteristics of Generators
- Selecting a Generator
- Voltage Regulation
- Governing (speed and frequency)
  - Mechanical
  - Electronic

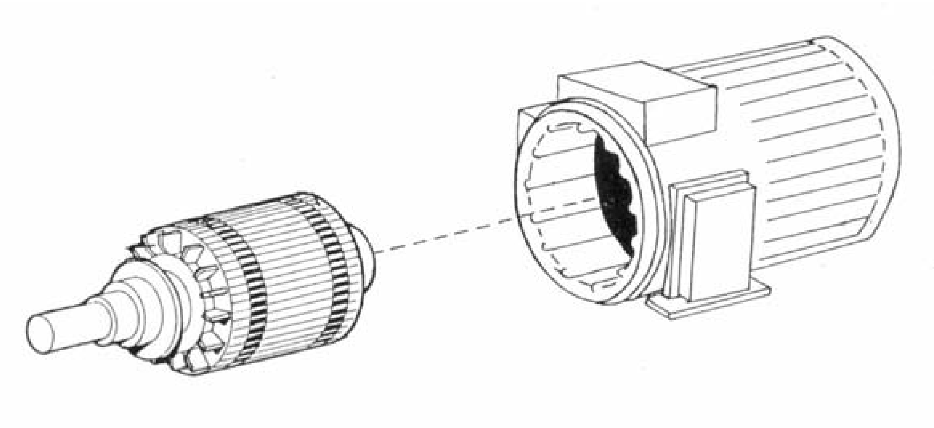
Synchronous Generator

- Used in almost all stand-alone applications.
- Single phase used up to 10 kW.
- Most three phase are smaller than equivalent single



Induction Generator

- Just an induction motor with negative slip.
- Used most often with grid-tie systems.
- Used by some for battery based systems.



DC Alternator

- Produces rectified alternating current.
- Readily available.
- Easy to service.

Electronic Governing

- Frequency governing is used for synchronous generators.
- Voltage governing is used for induction generators
- Diversion Loads
  - A load must always be present.
  - Water heating or air heating.
- Diversion loads may be useful loads.