The Small Hydropower Handbook

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Notice

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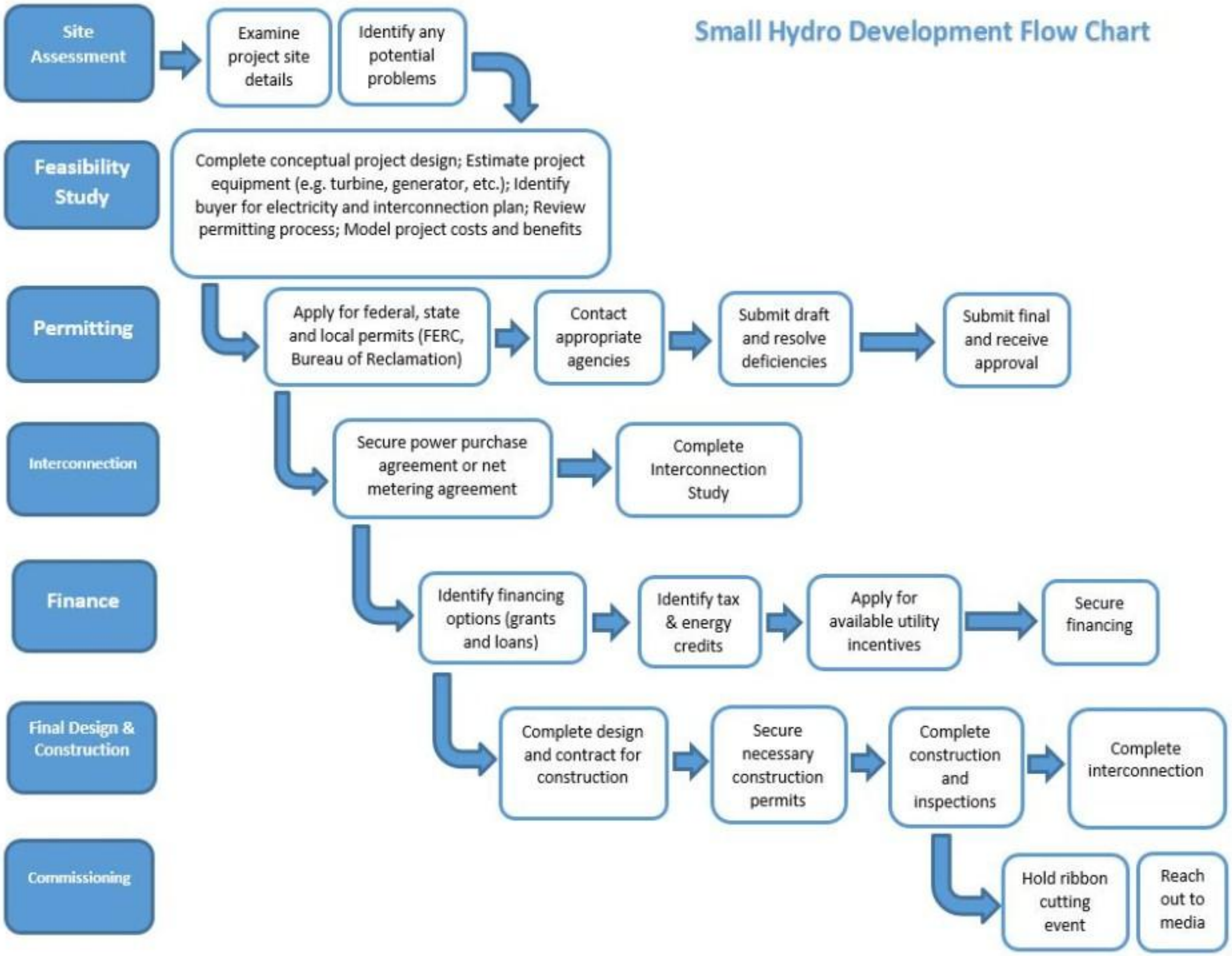
Small Hydro Development Flow Chart
Site Assessment
Examine project site details
Identify any potential problems
Feasibility Study
Complete conceptual project design; Estimate project equipment (e.g. turbine, generator, etc.); Identify buyer for electricity and interconnection plan; Review permitting process; Model project costs and benefits
Permitting
Apply for federal, state and local permits (FERC, Bureau of Reclamation)
Contact appropriate agencies
Submit draft and resolve deficiencies
Submit final and receive approval
Interconnection
Secure power purchase agreement or net metering agreement
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Identify financing options (grants and loans)
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Secure financing
Final Design & Construction
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Secure necessary construction permits
Complete construction and inspections
Complete interconnection
Commissioning
Hold ribbon cutting event
Reach out to media

Introduction

The Colorado Energy Office's (CEO) mission is to improve the effective use of all of Colorado's energy resources and the efficient consumption of energy in all economic sectors, through providing technical guidance, financial support, policy advocacy and public communications. CEO is working to accelerate development of cost-effective hydropower across Colorado. The purpose of this handbook is to provide a resource for developers, utilities, agricultural businesses and others interested in developing a small hydropower project in Colorado.

What is Small Hydro

Hydropower is the nation's most reliable, affordable and sustainable energy source. It is also America's largest source of clean electricity, currently accounting for about two-thirds of all renewable energy generation in the United States.[i] With the right federal and state policies in place, hydropower has the potential to grow substantially.

Unlike large hydropower projects, small hydropower projects typically divert a small portion of a river or are constructed on pre-existing diversions and pre-existing dams.[ii] According to the Low Impact Hydropower Institute (LIHI)[iii], in order for a hydropower project to be deemed low-impact, it must meet criteria in areas including minimum river flows, water quality, fish passage, watershed protection, threatened and endangered species, recreation, and cultural resource protection.

Colorado's Existing Hydro and Untapped Potential

According to EPA data, as of 2012, there were 60 operating hydropower facilities throughout Colorado with a combined installed capacity of 1,150 megawatts, producing about 661,000 megawatt-hours of electricity annually.[iv] In addition, in the past few years, Colorado has seen a flurry of new hydro development, much of which has taken place on Bureau of Reclamation dams and canals, including the following:

- Carter Lake (2.6 MW): completed 2013
- South Canal Drops 1 and 3 (7.5 MW): completed 2013
- Ridgway Reservoir (8 MW): completed 2014
- Pueblo Reservoir (7 MW): being developed
- Shavano Falls (2.8 MW): being developed
- Lake Granby (1.2 MW): being developed
- South Canal Drop 2 (1 MW): being developed

Colorado still has great hydropower resources that have the potential to be developed.

In 2013, the Colorado Department of Agriculture (CDA) completed a report showing that Colorado has substantial untapped capacity for hydro development utilizing existing agriculture-related infrastructure, including the following:

- **Pressurized Irrigation Systems**: Approximately 7% of Colorado's irrigated land has pressurization potential, primarily located in mountainous areas. The statewide untapped capacity of pressurized irrigation systems is approximately 30 MW.
- **Ditch drops:** An analysis looking at ditches with flows of over 100 CFS or drops of at least 150 feet yielded approximately 123 potential project sites statewide.
- **Existing Dams**: Colorado has approximately 102 agriculture-related dams with technical development potential.

In addition, the Bureau of Reclamation and the Department of Energy's Oak Ridge National Laboratory completed studies of untapped U.S. hydropower potential utilizing existing infrastructure.

According to the Bureau of Reclamation, Colorado currently has more than 30 potential hydropower sites at Reclamation facilities with the potential to produce more than 105,000 MWh/year. The DOE report estimates an additional 11 potential sites with the potential to produce over 632,000 MWh/year.

Steps in Small Hydropower Development

Step 1 Site Assessment

The first step in developing a hydropower project is to complete a simple assessment in order to determine whether a project site is promising enough to warrant proceeding to the second step, completion of a feasibility assessment. A site assessment typically includes the following:

Step 1A. Site Location, History and Ownership

Factors to consider when evaluating a project site include who owns the site, who owns the surrounding land, and what will the project mean for the surrounding area. You will also need to identify existing property rights associated with all aspects of the project. It also can be helpful to identify previous owners of the existing infrastructure and understand what alterations have been made since the infrastructure was originally built.

Step 1B. Stream or Body of Water

The purpose of this step is to understand the potential impact of the proposed project on the relevant stream or body of water and to understand the flow available for power generation. You will need to know what water agency (e.g., water district, ditch company, etc.) controls the available water, and whether there are any diversions upstream that influence flow at the project site.

Step 1C. Water Rights

1C1. **Prior Appropriations System**

The Colorado State Engineer's Office administers water rights and allocates water to water right holders. Water rights in Colorado are based on the "Prior Appropriations System," which often is referred to as *first in time, first in right*. The Prior Appropriations System uses the date of a water right's decree to establish when the user is able to divert the water allocated by that right. The most senior water right holders (those that were obtained at the earliest date) are entitled to water available in the river before the junior water right holders, independent of their location along the river. For example, if a junior water right holder is located upstream of a senior water right holder, the water must flow past the diversion point of the junior right to satisfy the holder of the senior right in case there is not enough water to satisfy both needs. Generally, the more senior a water right, the more certainty there is that water will be available in years of low water supply. However, the scenario described above is simple; depending on the basin, water rights can be much more complicated. It is often beneficial to consult with an attorney and/or a water resources engineer to assist in the process of changing a water right to include a decreed use of Power Generation, or to obtain a new water right.

1C2. **Water Rights for Power Generation**

Power generation generally is considered a non-consumptive use. There may be an exemption to this if a reservoir is constructed to hold water or a canal feeds the hydropower plant since evaporation may consume a portion of the water diverted. Some rivers and streams in Colorado have minimum flow requirements, also known as in-stream flow rights. These are water rights held by the Colorado Water Conservation Board for the purpose of maintaining minimum flows in the river. These in-stream rights may be junior to a senior water right holder, but new hydro junior rights need to consider their impact even if the water right is non-consumptive. There may be a portion of the river or stream between the intake and the discharge where in-stream flows cannot be reduced.

Figure 1 provides a simplified flow chart to preliminarily determine if a new water right is needed. In order to divert water from a stream for the purpose of generating hydroelectric power in Colorado, a water right must be obtained with the beneficial use of power generation. However, if water is diverted for another reason, such as for irrigation or municipal use, and hydropower is added to that existing system, a new water right may not be needed if the timing and duration of diversions are not changed from their previous or historic use. For example, if hydropower was added to the water supply system for a municipality, and water deliveries and diversions were made only to meet the municipal needs of the system while hydropower was generated incidentally, a new water right would not need to be obtained. As an alternative example, if hydropower was added to an irrigation pipeline and new diversions were made throughout the year to supply the hydropower facility (in the past, diversions were only made during irrigation season) a new water right would need to be filed for the diversions outside of irrigation season.

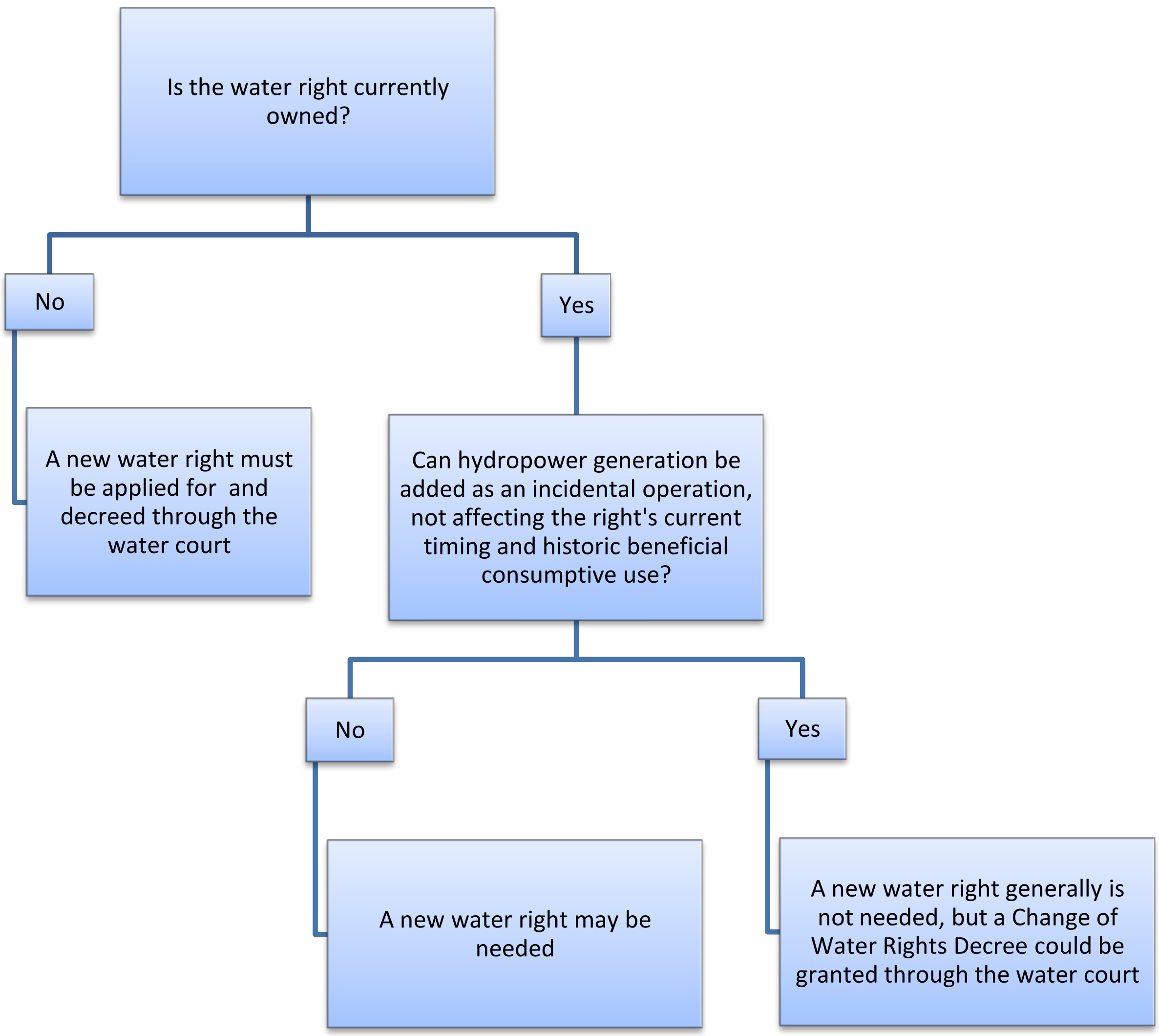


Figure 1: New and Existing Water Rights

Hydropower operations may not change the timing of diversions and return flows, historic beneficial consumptive use, or otherwise cause injury to other water rights holders, or else a new water right will need to be obtained. In general, if the aforementioned conditions are met, there is no need to obtain a new water right or amend a current water right, and the water court process can be avoided. However, a water rights holder can obtain a Change of Water

Rights Decree from the Water Court to explicitly add power generation as an additional decreed use to an existing water right.

1C3. **Changing an Existing Water Right for Power Generation**

To amend an existing water right so that power generation is added as a use, a Change of Water Rights Decree can be obtained from the water court; although as previously mentioned, it may not be necessary. It also is possible to change the point of diversion and/or the place of use of a specific water right by obtaining a Change of Water Rights Decree. The original priority date of the water right can be kept, but it must be shown that the change to the water right will not increase the historic beneficial consumptive use, nor change the timing of that use. The change cannot add injury to the water rights of other users, and usually existing return flow patterns must be maintained. The process of changing a water right often can be complicated, so consulting an attorney or water resources engineer may prove beneficial.

1C4. **Obtaining a New Water Right**

Power generation generally is considered a non-consumptive use since water is diverted and returned to the river in the same amount, and no water is consumed through the use. Applying for a new non-consumptive water right typically will face less objection than a new consumptive water right, although the process for both is complex. The Colorado Division of Water Resources provides guidance, but recommends the assistance of an attorney when applying for the right. There are many attorneys in Colorado that focus specifically on water issues. See the Appendices for a list of resources.

If a water right is not already held and there still is unappropriated water available, a new water right can be attained by applying to the water court and obtaining a decree for a specified amount, location, priority date and use. In Colorado, this process potentially can be extensive and involve engineering design and permitting. The water will be subject to availability, depending on the diversions made by any senior water rights, or those “In Priority.” At this point, the newly obtained water right is considered “Conditional.”

1C5. **Conditional Water Right**

A conditional water right is a placeholder in the Prior Appropriation System that has not yet been recognized by the water court as being put to beneficial use (described below). A conditional right gives a project proponent time to develop their water right and put it to beneficial use without losing their place in the priority system. A conditional water right must show due diligence toward perfecting the water to an absolute right and is reviewed every six years by the Water Court for progress.

1C6. **Absolute Water Right**

An absolute water right is one that has been put to beneficial use and that has been recognized by the water court as valid. Beneficial use is the overt act of taking water from a water source and applying it to a specified purpose, without implementing wasteful practices. Beneficial uses include irrigation, domestic, municipal, industrial and power generation, among others.

1C7. **Estimated Head and Flow**

During the site assessment, obtaining an initial estimate of head and flow will make it possible to estimate the generation capacity at the site. In the feasibility study stage, these estimates will be refined to take into account system losses and variability in flow. Estimating head at a site requires measurement of the elevation difference between the intake and the powerhouse. This can be measured with a GPS or estimated from maps such as U.S. Geological Survey topographical maps or Google Earth. These methods will be approximate but will be satisfactory at this stage of development. Flow can be estimated from historic measurements or stream gauges (this is discussed in more detail in the feasibility phase below). Once a flow rate and head have been estimated, the following equation can be used to estimate the capacity of a hydropower plant.

$$Power\ (kW) = \frac{Head(feet)\ \times Flow(cfs) \times efficiency}{11.8}$$

Efficiency will be evaluated after the plant configuration is finalized and the turbine selected. At this stage, the efficiency can be assumed between 70% and 80% for a preliminary estimate.

Step 1D. Road Access

It is necessary to understand how all aspects of the project will be accessed by road, including the intake, penstock and powerhouse. When considering road access, be sure to consider if the road is public or private. If the road is private, consider whether it will be possible to get permission to use the road. Also, be sure the road is large enough for passage of necessary construction equipment. If there is not suitable road access, estimating road construction costs will need to be part of the feasibility assessment.

Step 1E. Distance to Utility Connection

This step requires understanding about how electricity generated by the project will be transferred to the local electric grid, either directly or through an existing meter with an adjacent on-site electrical load that can be served by the new hydro plant. You will need to know the distance to the nearest utility distribution or transmission line and what type of line it is, either single phase or three phase.

Step 1F. Political, Community or Environmental Issues

It is important to determine early in the development process whether there are likely to be any political, community, or environmental concerns associated with the project that may turn into larger problems later. Seeking to identify and address potential problems or project opponents early can help streamline the project and avoid wasting time and money. Many facets of a project will be affected by the presence of the types of issues outlined below. The impact to the surrounding community and environment will greatly influence the rules and regulations applicable to a small hydropower project. Each project must be closely examined to forecast potential future hindrances to its development.

It is also important to consider whether there are any sites nearby that have cultural, historical, or tribal significance that could potentially be impacted by the construction or operation of a hydropower facility. The Colorado Historical Society maintains a Register of Historical Places for structures and locations deemed to have historical significance. The National Park Service also administers the National Register of Historic Places. These two sources could facilitate an initial screening of historic places near the small hydro project; however, further investigation may be necessary. When trying to determine if tribal areas or Indian Trust Assets are affected by a hydropower project in Colorado, the Bureau of Indian Affairs, Southwest Regional Office can provide guidance.

Other potential community impacts could be commercial and recreational activities that may be negatively affected. If there are businesses, residences, or recreation areas nearby, the people negatively affected by construction and/or hydropower operations may be affected by the development of small hydropower. Issues like noise, light, air pollution, or hindrances to access roads can create project issues. Obtaining community involvement and feedback early in the process can circumvent possible future delays in the project.

Depending on the extent of the site being affected by hydropower operations, environmental constraints can drastically alter the feasibility of hydropower development. Potential "red flags" to consider include the presence of wetlands, threatened or endangered flora and fauna, and sensitive ecological and aquatic conditions. The existence of any of these red flags can relate to how extensive the permitting process will be.

In Colorado the U.S. Army Corp of Engineers (USACE) ultimately will dictate if a wetland is jurisdictional or not, and the appropriate permits and regulations that apply. USACE's Wetlands Research Technology Center can assist in identifying jurisdictional wetlands potentially impacted by a small hydropower project. A preliminary threatened and endangered species screening can be conducted for a Colorado project by visiting the U.S. Fish and Wildlife Service (FWS), Mountain-Prairie Region website. From the Critical Habitat Portal on the FWS website, the Critical Habitat Mapper will allow for an interactive map search of critical habitats, and a custom report for threatened and endangered flora and fauna easily can be developed based on geographical location.

STEP 2 Feasibility Assessment

If a project appears viable after the initial site assessment, the next step is to complete a full feasibility study. Below is an overview of what a feasibility study typically includes.

Step 2A. General Project Types

There are several types or configurations of small hydropower schemes. A number of common types are described below.

2A1. **Small Hydropower on a Dam**

Dams generally are constructed for water supply purposes, flood control, or recreation. Depending on the type of dam and the outlet configuration, several alternatives are available for hydropower development. A general schematic of hydropower on a dam is shown in Figure 2.

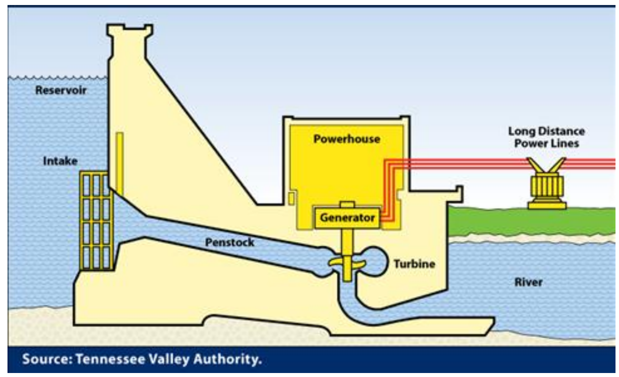


Figure 2: Schematic of a Hydroelectric Dam

Photo courtesy of Tennessee Valley Authority

i.) **Existing Dam: Carter Lake**

The Carter Lake Hydroelectric Project was constructed in 2012 by the Northern Colorado Water Conservancy District. It consists of two 1.3 MW Francis turbines. The turbines utilize 147 feet of head and 125 cfs each. The project was constructed on a secondary outlet from the reservoir. Using a secondary outlet creates redundancy, which in turn allows the dam to function as intended with the primary outlet if for any reason the hydropower plant cannot supply water downstream.

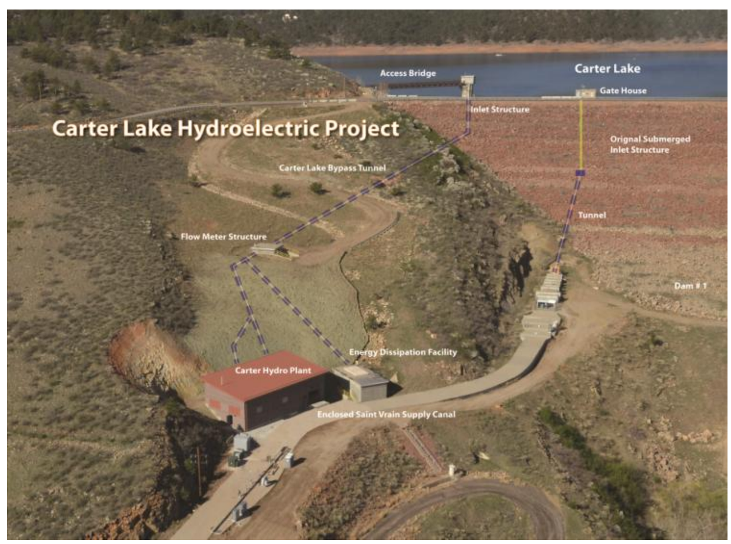


Figure 3: Schematic of Carter Lake

Photo courtesy of Northern Colorado Water Conservancy District ii.) **Siphon Penstock: Humphreys Hydro Project**

Another alternative for building a hydropower plant on a dam is to use a siphon penstock over the dam instead of an outlet through the dam. This alternative may be preferred if the existing outlet to the dam is not adequate for the pressures or flow rates required. There is a limit to the maximum theoretical lift between the reservoir water surface and the top of the siphon that needs to be considered in the design. The Humphreys Hydroelectric project near Creede, CO, is an example of a project with a siphon penstock. This project was constructed by a private landowner. It consists of one 310 kW Cross Flow turbine using 91 feet of head and 60 cfs of flow.

Figure 4: Humphreys Hydro Powerhouse

Figure 5: Humphreys Hydro Siphon Intake (See Upper Right)

iii.) **Spillway/Other Outlet**

Some dams may provide an opportunity to use the existing spillway. The capacity of the spillway needs to be maintained for safety and flood protection, but it may be an alternative worthy of exploration. The Catamount project on Lake Catamount is an example of such a project that is still in the planning stages. This project would use 37 feet of head and 280 cfs of flow to generate 695 kW of power with a Kaplan turbine.

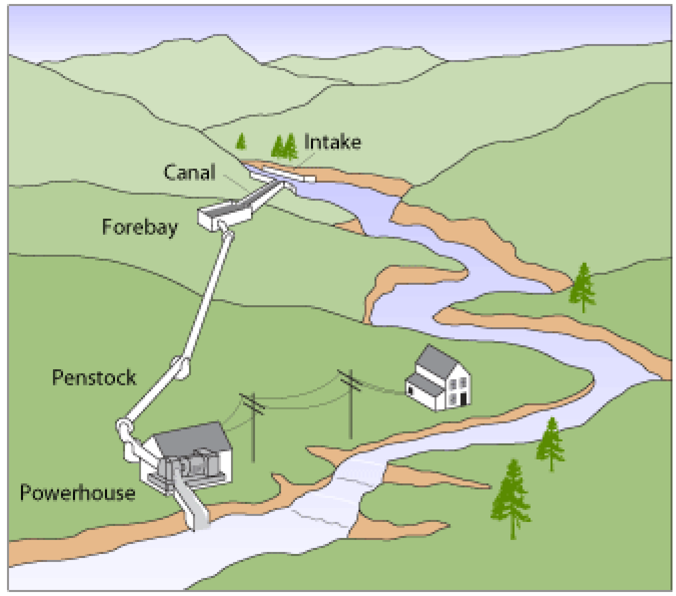


Figure 7: Run-of-the-river Schematic

Figure Courtesy of U.S. DOE

Figure 6: Lake Catamount Spillway

2A2. **Run-of-the-River Hydropower**

Run-of-the-river hydropower is a term to describe a hydropower plant which diverts water from a watercourse through a penstock and powerhouse, and returns the water back to the watercourse downstream, as shown in Figure 7.

i.) **Diversion for Hydropower only**

The Maroon Creek Hydropower plant in Aspen is an example of a run-of-the-river hydropower plant where the diversion is used solely for the purpose of supplying flow to the hydropower plant. The diversion is located on Maroon Creek and diverts up to 60 CFS. The water then passes through a 450 kW Cross Flow turbine.

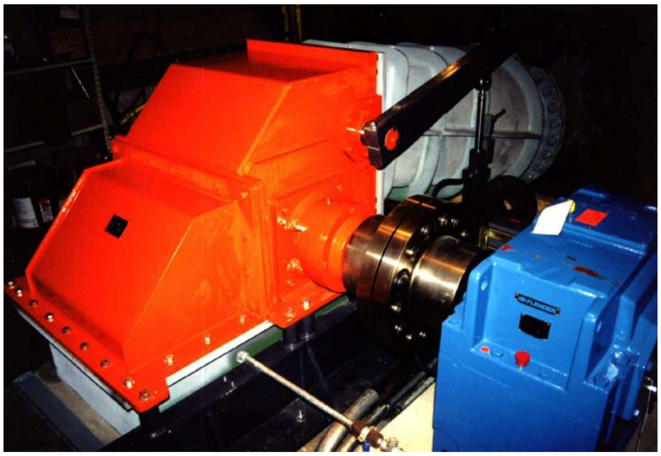


Figure 8: Maroon Creek Turbine

Figure 9: Maroon Creek Intake

ii.) **Using an Existing Diversion**

Run-of-the-river hydropower also may be installed on a diversion and canal that exists for another purpose. One example in Colorado is the Grand Valley Power Plant on the Orchard Mesa Irrigation District irrigation system. Flows for the hydropower plant and the irrigation system are diverted from the Colorado River though a canal. Hydropower flows are discharged back into the river downstream while irrigation flows continue through the canal. Two Kaplan turbines produce 3 MW of power using 79 feet of head and up to about 300 cfs of flow each.

Figure 10: Grand Valley Power Plant turbines

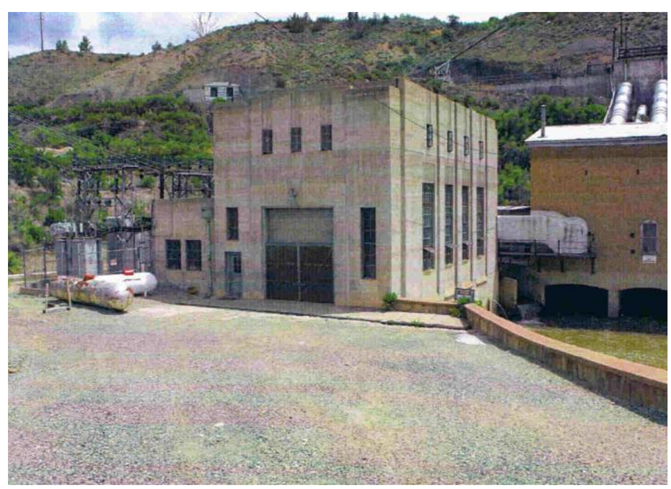


Figure 11: Grand Valley Power Plant powerhouse

2A3. **Conduit Hydropower**

Conduit hydropower uses a conduit (pipe or canal) that exists for another purpose, such as municipal water supply or irrigation. Power can be generated from excess pressure in the pipeline that otherwise would have to be mechanically reduced by pressure reduction valves. Ditch drops also can be converted to generate hydroelectricity by either piping the drop or installing a low head turbine specifically designed for this purpose. This type of hydropower plant is generally cost-effective due to the utilization of existing infrastructure.

i.) **Water Supply System**

Municipal water supply systems that are located in or near mountains may be fed by gravity. The water supply reservoir is commonly located at a higher elevation than the water treatment plant and water flows downhill by gravity. In many cases, this results in excess pressure at the water treatment plant. This pressure either is used in the treatment process or reduced using a pressure-reducing valve. When this excess pressure is not needed, it provides an opportunity for hydroelectric generation. This is the case at the Project 7 water treatment plant near Montrose. The pressurized water from the water supply reservoir is passed through the turbines instead of the pressure-reducing valves, producing power that offsets the water plant's electrical demand. The system consists of two different turbines, one 90 kW and one 60 kW, allowing for a larger variation in flow. The plant utilizes up to 132 feet of head and between 7 and 17 cfs of flow depending on the season.

ii.) **Irrigation System**

Irrigation system pipelines offer an opportunity for hydropower development if excess pressure is available. The Wenschhof project utilizes an existing pipeline to feed a 23 kW Pelton turbine. The turbine uses 160 feet of head and up to 2 cfs to produce power during irrigation season.

Figure 12: Wenschhof Turbine

Figure 13: Wenschhof Intake

The power produced is used to offset the demands of the irrigation system and other electrical demands on the ranch.

iii.) **Wastewater Outfall**

Wastewater outfalls may provide hydroelectric opportunities if a significant elevation drop is available. Currently this type of hydropower plant does not exist in Colorado. Large municipalities with a large wastewater treatment plant may have the elevation drop and flow rate necessary at their wastewater treatment plant to produce a significant amount of power.

iv.) **Low Head Canal**

The Redlands Canal provides irrigation water to a portion of Grand Junction. The hydropower plant is located on a low head drop within the canal, created without a pipeline. The Kaplan turbine was installed in the early 1900s and produces 1.6 MW using 690 cfs and 30 feet of head.

Figure 14: Redlands Powerhouse

Figure 15: Redlands Turbine

2A4. **Hydrokinetic**

Hydrokinetic turbines are a relatively new type of turbine technology. Pilot installations are being tested in river, canal, and tidal flows. Hydrokinetics produce power from the velocity of the water instead of using pressure accumulated in a penstock. This design results in a relatively low output power facility that needs very high flows. The concept is similar to a wind turbine, but underwater. Currently there are no

Figure 16:Hydrovolts – Roza Canal

Photo courtesy of Hydrovolts

hydrokinetic installations in Colorado.

i.) **Canal**

The canal installation shown in Figure 16 is a Hydrovolts turbine installed in the Roza Canal in Oregon. This was a test installation in operation for six weeks. The turbine produces 5 kW with 6.5 ft/sec of flow velocity. The canal is 14 feet wide at the bottom with a maximum water depth of 11 feet. The canal flows between 1,100 cfs and 2,100 cfs. The installation of this turbine requires little civil infrastructure, although the canal must have adequate geometry and freeboard to handle the resulting rise in water surface elevation upstream of the turbine (six to eight inches in this case).

ii.) **River**

Hydrokinetic river installations can be installed by anchoring to a structure, such as a bridge, or to the bottom of the riverbed. The example below is a floating barge attached to a bridge in Manitoba, Canada. The turbine was in place for less than a year and removed prior to the river icing. This is a 5 kW turbine, requiring velocities of more than 6.5 ft/sec. The turbine is 7.5 feet tall and five feet in diameter.

Figure 17:EnCurrent – Manitoba, Canada

Photo courtesy of New Energy Corp

2A5. **Hydro-Mechanical**

A less frequently used, but traditional method of hydropower development is to use water power to turn mechanical machinery. No electricity is produced by these plants. The turbine simply turns the rotating machinery to do mechanical work. Historically hydro-mechanical plants were used to power sawmills, textile mills, or grain mills. Below are two examples of operating hydro-mechanical plants in Colorado: one is used to pump water and the other to power an irrigation sprinkler system.

The Bear River Ranch hydro-mechanical irrigation system is discussed in more detail in the attached case study: a turbine powers a hydraulic pump which moves the center pivot sprinkler system. There, 126 feet of head and 850 gpm provides the equivalent of 21.5 HP to the hydraulic pump.

The Orchard Mesa Pumping Plant uses the power of falling water to pump water to a higher elevation. The turbine and pump shafts are coupled to operate together. This plant was constructed at the turn of the century and has been in continuous operation since. Four pumps supply up to 150 cfs to two canals, one at 130 feet above the inlet canal and one at 41 feet above the inlet canal. The turbines use over 200 cfs of water falling 74 feet to produce the equivalent of 1.1 MW of energy. The pumping plant is located directly adjacent to the Grand Valley Power Plant mentioned earlier.

Figure 18:Bear River Ranch turbine

Figure 19: Orchard Mesa Pump Plant

Step 2B. Head and Flow

During the feasibility phase, a more accurate measurement of head and flow must be made to calculate the annual energy production and to size the system accurately.

2B1. **Hydrology**

Flows available to a hydropower plant can be estimated using the hydrologic conditions of the site or flows can be physically measured. The choice of method will depend on the available data. Methods and resources will be described below to calculate present or historic hydrologic conditions. When using these methods, keep in mind that available flows can change due to meteorological conditions. Forecasting future available flow requires careful consideration of past drought conditions and current climatic trends. Please see the Appendices for more Colorado hydrology resources.

i.) **Historic Hydrology Data**

There are several resources for calculating the flow that will be available to a small hydropower plant.

Existing Diversions:

In instances where water already is diverted from a stream for agricultural, municipal or industrial uses under an existing water right, historic records of diversion may be available. The joint efforts of the Colorado Water Conservation Board (CWCB) and the Colorado Department of Water Resources (DWR) maintain Colorado's Decision Support Systems (CDSS) database, which among other things, provides Historic Diversion Records and Streamflow Stations data.

The CDSS website offers users the ability to search for diversion records using multiple criteria, such as by diversion name, water source, owner's name, and legal location. Streamflow Stations also can be searched using multiple criteria, such as by station name or county. In many cases, the database provides free downloads of daily records and/or yearly averages of flow data. Use of these data can be helpful when estimating water availability annually or at different times of the year.

New Diversions:
In cases when the hydropower facility will be utilizing a new diversion, water availability may be approximated by using flows from nearby stream gauges. Typically, gauges are located along the main stem of rivers, although in some instances they also may be used to monitor ditches. If the proposed hydro site lies in close proximity to an operational stream gauge, that data can be applied to the proposed site. Average flows over multiple time periods typically can be accessed through the U.S. Geological Survey database (USGS) or the Colorado Division of Water Resources (DWR) database. It is important to check for tributary, diversion, or other disruptions to flows between the known stream gauge and the proposed hydro site and adjust flow data to obtain a more accurate flow estimate.

ii.) **Measurement of Flow**
If historic records do not exist, it may be necessary to measure flow for a period during the planning stages of a hydropower plant. There are many structures to measure the flow rate in a channel. The United States Bureau of Reclamation (USBR) has a free on-line publication titled, "*Water Measurement Manual*," which serves as a helpful reference for various methods of flow measurement. By using the structure's dimensions, in conjunction with flow depths, a flow rate can be determined by referencing tabulated flow discharge values. Such tables can be obtained from various sources. The USBR manual has tabulated data in its Appendices for three commonly used flow measurement structures: the Parshall Flume, the weir, and the flow meter.

a) Parshall Flume

The Parshall Flume is one of the most common types of flume used in Colorado, depicted in Figure 20. Generally, canals are metered using this type of flume. Use of a flume is likely the best alternative for flow measurement when water depth is low. For this particular type of measurement structure, a flume of known geometry is installed perpendicular to the flow in a channel. Using the measured water depth and throat width in the flume, an associated flow discharge can be calculated or obtained through reference to flow discharge tables (located in Appendix A8 of the USBR Water Measurement Manual).

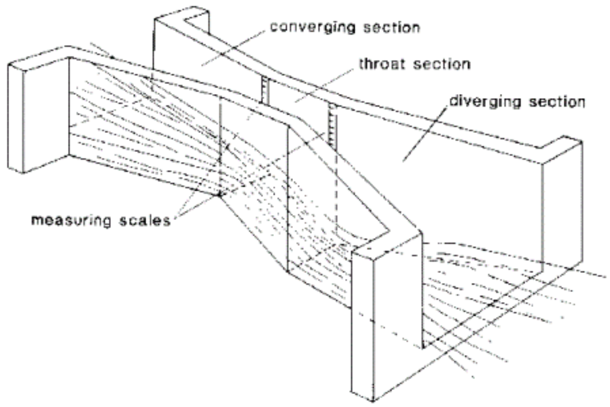


Figure 20: Parshall Flume Schematic

Photo courtesy of the Food and Agriculture Organization of the United Nations

Figure 21:Parshall Flume in Box Elder Ditch, Cache la Poudre

Photo courtesy of the Poudre Heritage Alliance

a) Weir

A weir is an overflow structure of known dimensions, installed perpendicularly in the channel to measure the flow rate, as viewed in Figure 22. Sharp-crested weirs (Figure 23a) have a center notch of varying shapes through which water will be directed, while broad-crested weirs (Figure 23b) have a horizontal crest over which water will flow. Using the upstream pool depth, weir dimensions, and depth of water flowing over the weir, the discharge flow rate can be calculated or obtained from a table. Appendix A7 in the USBR Water Measurement Manual provides discharge tables for the more common types of sharp-crested weirs.

Figure 22: Cipoletti Weir

Photo courtesy of the USBR Water Measurement Manual

b) Flow Meter

There are multiple types of flow meters. The most commonly used type is the submerged orifice flow meter, shown in Figure 24 and Figure 25. It consists of a precisely defined, sharp-edged opening placed perpendicularly to the channel flow, through which all water passes. As small changes in the orifice's construction can have a large impact on the accuracy of its associated flow values, it is imperative that the orifice be well-machined and dimensioned as

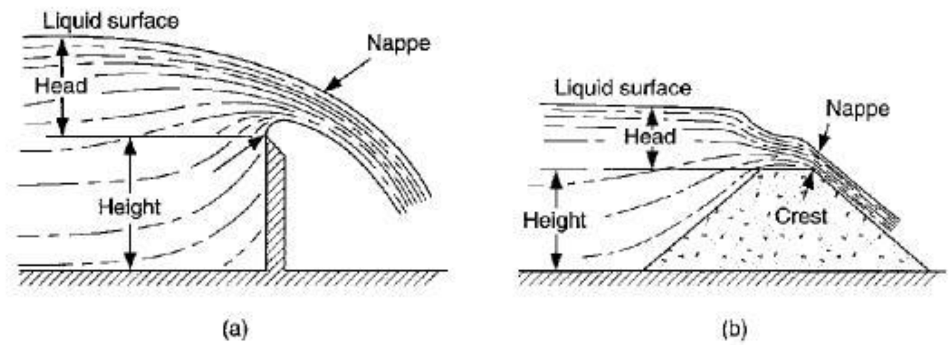


Figure 23: Types of Weirs

Figure courtesy of the USBR Water Measurement Manual

accurately as possible. By measuring the water depth immediately upstream and downstream of the orifice, flow rate can be obtained through use of discharge tables. Appendix A9 of the USBR Water Measurement Manual provides discharge tables for commonly used orifices.

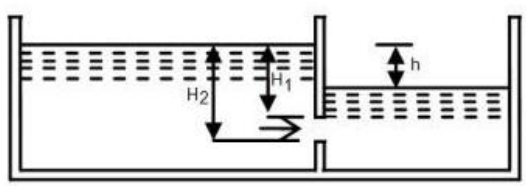


Figure 24: Submerged Orifice Flow Meter

Figure courtesy of USBR Water Measurement Manual

Figure 25: Constant Head Orifice Turnout

Photo courtesy of USBR Water Measurement Manual

c) Current Meter/Velocity Meter

Flow measurement with a velocity meter measures the velocity of the channel flow. It involves the placement of a current meter at specific cross-section intervals along a reach of channel and taking an average flow over those sections. Optimally, current meters should be used in straight, uniform sections of the channel reach in order to minimize flow disturbances. Additionally, the flow velocity should be greater than 0.5 feet per second and the meter should be kept as still as possible. This type of flow measurement is ideal for investigation of larger flows or for flows containing larger amounts of sediment. There are multiple types of current meters to measure the velocity of the channel flow:

1) Anemometer and propeller velocity meter (Figure 26): This type of current meter is commonly used for irrigation and watershed applications. It measures velocity by dragging anemometer cup wheels or propellers through calm waters.

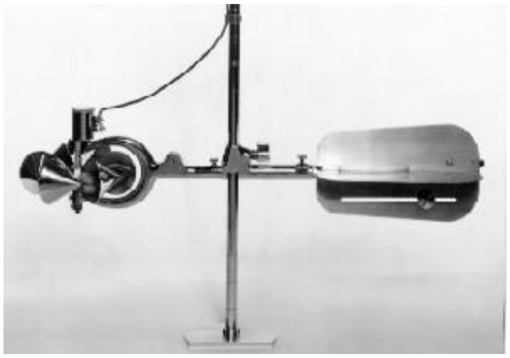


Figure 26: Anemometer and Propeller Current Meter
Photo courtesy of USBR Water Measurement Manual

2) Electromagnetic velocity meter (Figure 27): This type of current meter produces voltage proportionate to the stream velocity and has an easily read analog display. It is able to account for directional velocities and measure cross flows, but is not as accurate as anemometer-propeller current meters.

Figure 27: Electromagnetic Current Meter

Photo courtesy of Valeport, Ltd.

3) Doppler velocity meter (Figure 28): These meters measure the change in source light or sound frequency to measure velocity. Electromagnetic current meters are versatile, providing measurement in a wide range of water body sizes and types. They are able to measure multiple directions of flow velocity simultaneously.

Figure 28: Doppler Current Meter

Photo courtesy of SonTek

iii.) **Flow Duration Curve**

Stream gauges, such as that depicted in Figure 29, are located in many waterways. The gauges generally consist of a water level sensor which logs the elevation of the water on a daily, hourly, or sub-hourly basis. The section of stream will have been studied previously and a relationship between the water surface elevation and the total flow is known. The flow is measured by monitoring the water level. The variance in annual flow can then be depicted graphically, such as in Figure 30. Use of these data can allow for more accurate small hydro planning by enabling consideration of maximum and minimum flows and observing trends in consecutive yearly data.

Figure 29: Stream Gauge on Andrews Creek, CO;

Photo courtesy of the USGS Colorado Water Science Center

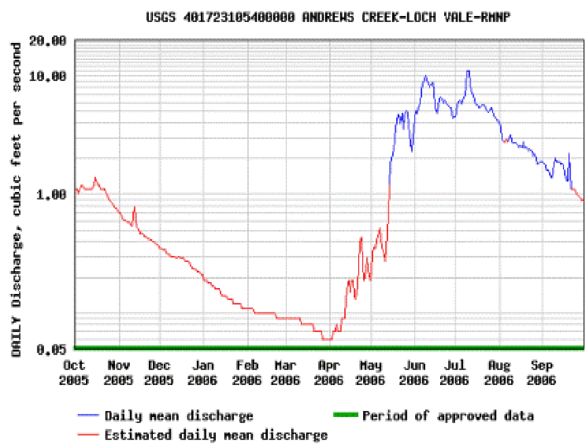


Figure 30: Annual Discharge Graph for Andrews Creek, CO

Figure courtesy of the USGS Colorado Water Science Center

From stream gauge data or historic flow records, a flow duration curve (FDC) like that shown in Figure 31 can be developed. An FDC graphically will represent flow probability based on magnitude. FDCs depict the relationship between channel flow and the percentage of time that specific flow rates are met or surpassed. If the majority of the FDC is a steep slope, the curve is indicative of a channel that is highly variable throughout the year and largely dependent upon surface runoff. For a curve that has a relatively flat slope, it can be concluded that the channel for which it relates has a recharge sourced from surface water or ground water. A flat slope at the end of the curve is characteristic of a large amount of storage associated with the channel; conversely, a steep slope is indicative of a negligible amount.

a) <u>How to Select the Design Flow using this Curve</u>

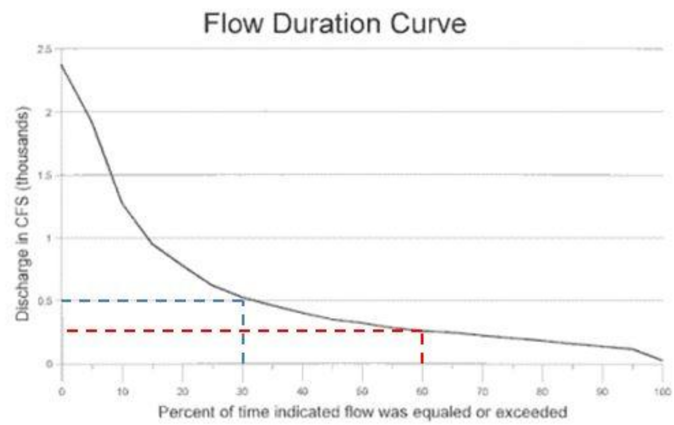


Figure 31: Flow Duration Curve with 30 and 60% Exceedance Indication

Figure courtesy of Missouri Department of Conservation

The FDC enables the assessment of flow variability at the proposed hydro site and the determination of an initial design flow for the hydropower system. The design flow is the flow at which the turbine operates most efficiently and is the maximum flow rate that the hydro system should operate at for an extended period of time. When looking at an FDC, an initial estimate of the design flow for a small hydro system typically will be the flow associated with an exceedance value between 30% and 60%. For the example FDC above, the design flow at 30% exceedance and 60% exceedance would be approximately 500 cfs and 250 cfs, respectively. Developing the system for a design flow with an exceedance of 60% means that the system would run at design capacity for approximately 60% of the year and somewhat less than that value for the remaining 40% of the year. This is a more conservative design than would be reached were a 30% flow exceedance used as the design flow since the flow will only be at this maximum 30% of the time.

Once a general range of potential design flows is obtained, the Turbine Selection Chart shown below will provide an initial selection of turbines most suited to the range of design flow. In order to size the system appropriately, each system will have to be analyzed individually and the costs and benefits compared among potential turbines. Generally, the design flow can be exceeded by approximately 10%; however, running the turbine at this higher flow rate should not be a frequent occurrence as turbine efficiency will decrease and excessive wear or damage on the turbine or components may result.

b) <u>How to use Multiple Turbines</u>

Multiple turbines can be combined in a hydro system to achieve a desired design flow, allowing for more flexibility in production. Two of the same type of turbines having different size capacities can be used in conjunction to cover a larger range of discharge at a hydro site. An example situation constituting an appropriate use of multiple turbines is when there is a significant variation in flow seasonally. If winter flows are very low, it may make sense to use a smaller turbine that operates in the winter, and a larger turbine to capture the spring, summer, and/or autumn flows (Figure 32). Another pertinent application of multiple turbine usage may be if a standard turbine size, such as a pump used as a turbine, cannot accommodate the design flow; several turbines may be used in parallel to compensate, illustrated in Figure 33.

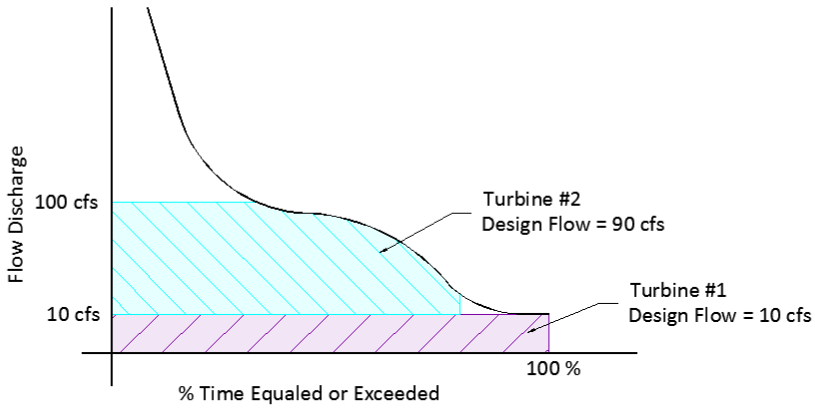


Figure 32: Flow Duration Curve Depicting Two Turbine System

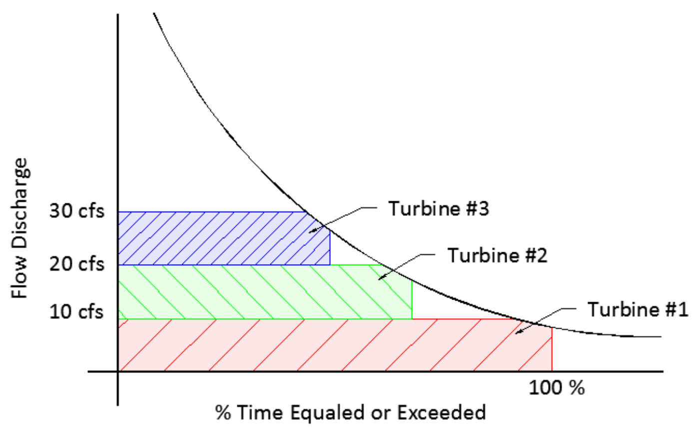


Figure 33: Flow Duration Curve Depicting Three Turbine System

2B2. **Head**

Head is representative of the water pressure at a hydro site. The term "head" can be applicable to two different values. The *gross head* is quantified by the change in water elevation between the top and bottom of the vertical drop, prior to the commencement of any water flow (see Figure 34). However, because energy is lost when converting from one form to another, the available head for integration into the hydro system's design must be adjusted to account for energy loss that occurs as the water navigates the penstock. The resulting adjusted head, called the *net head,* represents the pressure at the bottom of the pipeline during water flow after accounting for any energy loss that occurs in the penstock. The net head in a well-designed system will generally be 85%-90% of the gross head value. The net head is important, as it represents the actual amount of head available for use in the turbine. It should be noted that energy loss in the penstock has the same effect on a hydro system as if the gross head were lowered; therefore the terms "energy loss" and "head loss" are synonymous in penstock applications. The relationship between gross head and net head is as follows:

$$\begin{matrix} Gross \\ Head \end{matrix} - \begin{matrix} Head \\ Loss \end{matrix} = \begin{matrix} Net \\ Head \end{matrix}$$

Total energy loss in the penstock resulting in decreased net head can be divided into two categories: friction losses and minor losses. Friction loss in the penstock is a function of penstock diameter and length, flow rate, water pressure, and pipe composition. An increase in penstock diameter will reduce friction losses. Alternately, as water pressure, flow rate, and/or penstock length increase, losses resulting from friction will increase as well. Some pipe materials will result in a greater head loss due to increased pipe friction. Penstock material options are addressed in more detail below. Minor losses in the penstock are attributable to any bends, fittings and valves and the penstock entrance. The total energy loss can be quantified as follows:

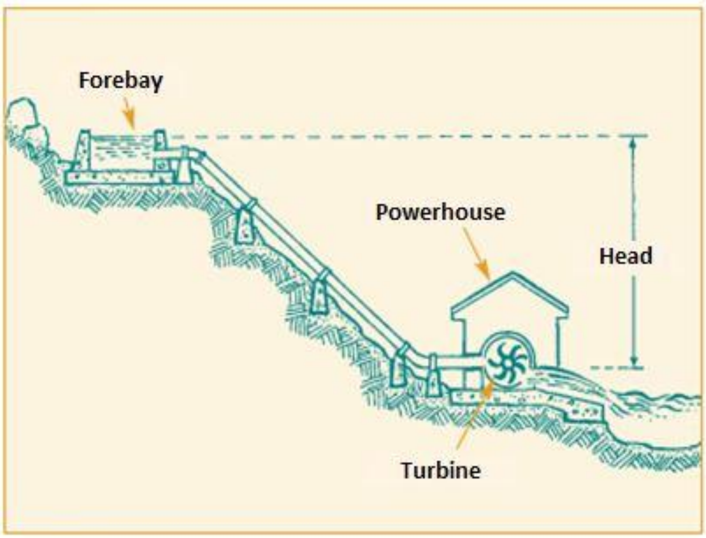


Figure 34: Gross Head of a small hydro system

Figure courtesy of Micro-Hydropower Systems, A Buyer's Guide; Natural Resources Canada

$$\begin{matrix} Total\ Energy \\ Loss \end{matrix} = \begin{matrix} Friction \\ Losses \end{matrix} + \begin{matrix} Minor \\ Losses \end{matrix}$$

i.) **Estimate Gross Head from Survey or Topographical Maps**

Elevations derived from survey data or topographical maps, such as those produced by the USGS, can be useful in estimating the gross head available at a hydro site. Typically, an estimate using topographical maps is most effective for high-head sites, as the distance between contour lines can vary depending upon the mapping available in the area. The contour intervals in the example shown in Figure 35 below are occurring at every 40 feet of elevation change. Using the elevation data, the elevation difference between the upstream point of the drop and the downstream point of the drop is the gross head. For low-head hydro

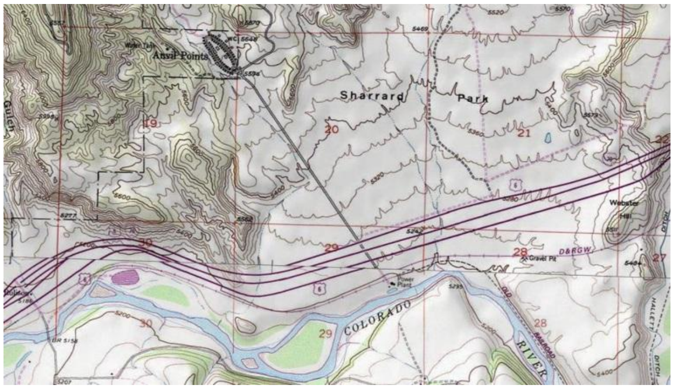


Figure 35: USGS Topography Map

Photo courtesy of USGS

applications, gross head can vary significantly dependent upon the current river conditions. To accurately obtain the available gross head, the headwater and tailwater levels need to be measured with more exact methods over the full range of channel flows.

See Appendices for more resources on Colorado topography.

ii.) **Convert Pressure to Head**

Gross head also can be calculated using some type of pressure meter, such as a piezometer or pressure gauge. By utilizing a pipe or tube completely filled with water that spans the full elevation drop, pressure can be measured at the bottom of the outlet. Each psi of pressure accounts for approximately 2.31 feet of vertical head. When using this method, it is best to use a continuous pipe or tube, although segments can be used if care is taken to eliminate any leakage at the connections. If a single span of tubing is unavailable, multiple readings can be taken along the elevation drop; however, this method will greatly increase chances for error. Since there is no water flowing out of the pipe when this pressure measurement is taken, it is a measure of the gross head.

iii.) **Estimate Head Loss at Varying Flow Rates**

Flow rate is one of multiple variables in the design of a penstock that can significantly affect head loss. Equations can be used to estimate head loss based upon water velocity, pipeline length, diameter, and material. Engineeringtoolbox.com has a Calculator for head loss in pipes, in which flow rate, pipe diameter and length are input to obtain approximate head loss. A

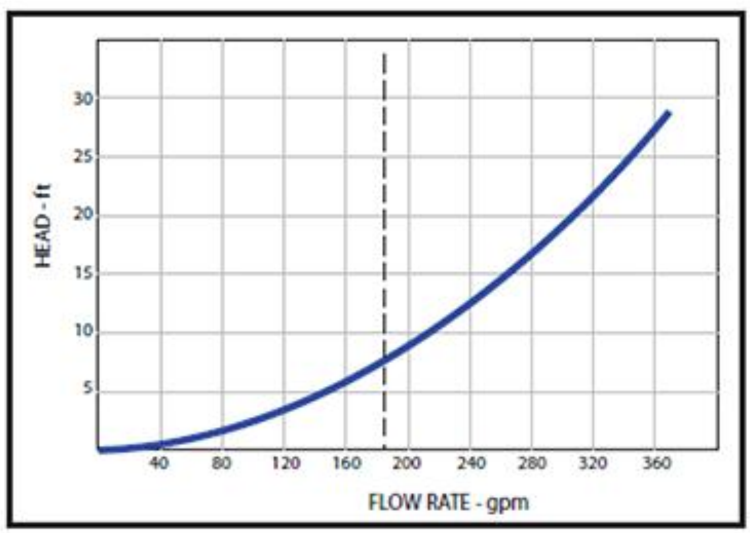


Figure 36: General Pipeline Resistance Curve

Figure courtesy of Engineered Software, Inc.

Pipeline Resistance Curve may be consulted for head loss estimation as well. As is evident from the Pipeline Resistance Curve depicted in Figure 36**Error! Reference source not found.**, head loss increases with increased flow rate. For example, a flow rate of 240 gpm would cause approximately 12 feet of head loss in the hydro system used to create the curve. Pipeline Resistance Curves are created through the completion of multiple head loss calculations, which require the specification of a general range of flow velocity, penstock material, and pipe length and diameter. The most accurate Pipeline Resistance Curve to use will be that which is applicable to specific site conditions. See Appendices for more resources on head loss.

Step 2C. Penstock Selection

2C1. **Using Existing Infrastructure**

The penstock can constitute the most expensive component of a hydro system, so achieving an optimal design between material cost and energy losses in the penstock should be thoroughly analyzed. In cases where a penstock is already present, it may be possible to use the existing infrastructure rather than constructing a new pipe; however, the potential for reuse is dependent upon whether the pressure rating and the condition of the existing pipe is acceptable. Having the pipeline inspected by a qualified engineer can aid in the determination of suitability. The existing pipeline also will have to be evaluated for friction losses. The original design of the pipeline may not have minimized friction losses and it significantly may affect the amount of head available for hydropower generation.

Figure 37: Deteriorated Penstock

Photo courtesy of Canyon Hydro

2C2. **Sizing the Penstock**

The losses occurring in the penstock have the potential to significantly affect the power available to the turbine. When sizing a penstock, pipe length and diameter, design flow, and gross head must be considered because they contribute to the head loss in the system. In general, the pipe length, design flow and gross head are fixed variables, meaning they are unalterable. As such, the primary alternative to reduce head loss in the system is to adjust the penstock diameter to minimize the velocity in the pipe, and thus, the friction created.

However, an increased penstock diameter leads to additional material cost; therefore, an optimum balance should be considered between the two.

When sizing a penstock, a good place to start is calculating a rough diameter of pipe that would adequately pass a flow velocity of 10 feet per second (fps). The flow velocity can be calculated by dividing the flow rate by the area of the pipe opening, taking care to ensure that units are identical. When beginning the design process with an initial 10 fps flow velocity, this relationship can be used to obtain a preliminary inside pipe diameter.

Once an initial pipe diameter is reached, head loss analysis can take place to further refine the penstock sizing. According to Canyon Hydro, a good rule of thumb is to size the pipe such that no more than 10% to 15% of the gross head is lost due to pipe friction. Canyon Hydro released a *Head Loss Chart* (Table 1) that serves as an example for the determination of an appropriate preliminary penstock size, using the example following the table to show how to use the chart. It can be seen that the chart is not all-inclusive; additional calculations can be made outside of the range shown here.

Table 1: Head Loss Chart

Design Flow														
GPM	0.25	0.5	100	150	200	300	400	500	600	700	800	900	1000	1200
CFS	0.05	0.1	0.2	0.33	0.45	0.66	0.89	1.1	1.3	1.5	1.78	2	2.23	2.67
Pipe size and loss per 100 feet														
2"	1.28	4.65	16.8	35.7	60.6	99.2								
3"	0.18	0.65	2.33	4.93	8.36	17.9	30.6	46.1	64.4					
4"	0.04	0.16	0.57	1.23	2.02	4.37	7.52	11.3	15.8	21.1	26.8	33.4		
6"		0.02	0.08	0.17	0.29	0.62	1.03	1.36	2.2	2.92	3.74	4.75	5.66	8.04
8"				0.04	0.07	0.15	0.25	0.39	0.5	0.72	0.89	1.16	1.4	1.96

Table courtesy of Canyon Hydro

Example site characteristics:

- Gross Head = 100 feet
- Pipeline length = 400 feet
- Acceptable Head Loss = 10% to 15% = 10 feet to 15 feet
- Design Flow = 200 gallons per minute = 0.45 cfs

For the above example, the maximum acceptable head loss would be 15 feet (15% of the 100-foot gross head), which equates to 3.75 feet of head loss for every 100 feet of the 400-foot pipeline. Beginning with the design flow of 200 gpm and following the column down, it is discovered that a 4-inch-diameter pipe is the smallest diameter that provides a head loss not exceeding the maximum of 3.75 feet.

Using a four-inch pipe, the associated head loss would be:

- Head Loss = 2.02 feet (per 100 feet) x 4 = 8.08 feet

Therefore, net head would be:

- Net Head = 100 feet – 8.08 feet = 91.92 feet

In looking at the Head Loss Chart, it is also evident that a six-inch-diameter pipe would decrease friction losses further, thereby providing more power to the turbine; however, the tradeoff must be weighed between increased power and increased pipe cost.

2C3. **Alignment**

In the event that a new penstock must be constructed, ideally it will be as short and straight as possible. In doing so, material and installation costs are reduced and the loss of power resulting from internal friction will be reduced, thereby conserving as much energy as possible. Figure 38 illustrates the preference of slope alignment. Ideally, the penstock will have a consistent rate of decline. A penstock can be either above ground, or below ground. Burying the penstock may facilitate the achievement of an appropriate slope and protect it from damage. Proper anchoring of both buried and above ground penstocks is required to ensure movement does not occur under any conditions, particularly at points of direction change. Each penstock will need to be evaluated individually to determine the need for anchoring and thrust blocks.

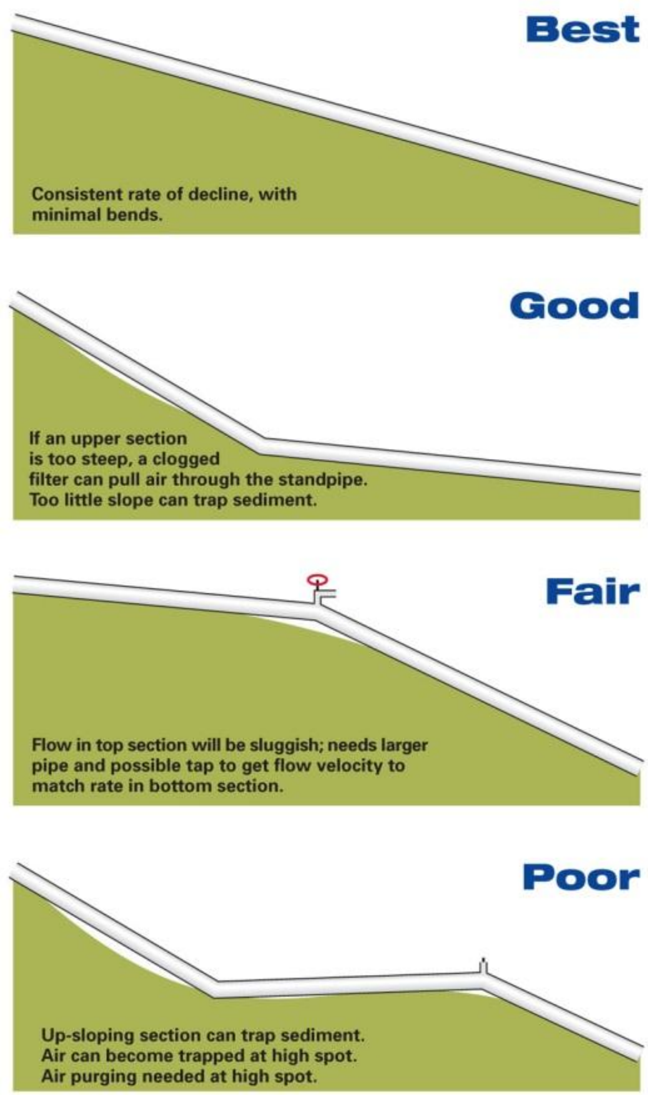


Figure 38: Penstock Slope

Figure courtesy of Home Power

2C4. **Material Selection**

For small hydro applications, there are multiple options for penstock material composition, with pros and cons associated with each. The table below lists potential materials for penstock composition, with mild steel, polyvinyl chloride (PVC), high-density polyethylene (HDPE) and medium-density polyethylene (MDPE) being the most commonly used materials. Each material has been assigned a number ranging from one to five, with one being poorly rated and five being excellently rated. More specific material characteristics are provided below.

Table 2: Penstock Material Composition

Penstock Material Options						
Material	**Friction Loss**	**Weight**	**Corrosion**	**Cost**	**Jointing**	**Pressure**
Ductile Iron	4	1	4	2	5	4
Concrete	1	1	5	3	3	1
GRP	5	5	3	1	4	5
Mild Steel	3	3	3	4	4	5
PVC	5	5	4	4	4	4
HDPE	5	5	5	3	2	4
MDPE	5	5	5	3	2	5

1 = Poor 5 = Excellent

Table adapted from Table 3.8.1 from Microhydro Design Manual, a Guide to Small-scale Water Power Schemes, A. Harvey 1993

Ductile iron: These pipes can have an internal coating of cement, affording better corrosion protection and low friction loss. Ductile iron is a heavy material, however, which leads to a difficult and more costly installation. Ductile iron allows for multiple jointing options, including mechanical joints (bolted gland), push-in spigot and socket with a flexible seal, or occasionally flanged.

Figure 39: Ductile Iron Pipe

Photo courtesy of Alibaba.com

Concrete: Several factors come into play with concrete penstocks which make them typically unsuitable for use, even at moderate pressure. Concrete's friction loss characteristics can be highly variable. Further, the material's excessive weight makes transportation and installation difficult. However, steel reinforced concrete pipes, particularly when they are pre-stressed, can serve as a cost-effective alternative for low- and medium- head sites. Concrete penstocks typically have rubber ring joints.

Glass-reinforced plastic (GRP): GRP can be a material option, depending on the cost and availability. The pipes are comprised of resin reinforced with spirally wound glass fiber and inert filler such as sand. GRP pipes are suited for high pressure applications and have a low weight and minimal corrosion and friction loss. Typically, joints are spigot and socket with a flexible seal. The pipe is fragile and requires careful installation. To provide the best protection, it is recommended that GRP pipes are buried and backfilled with fine material.

Evidence suggests that GRP may be weakened over a long period of time, due to water absorption via osmosis.

Figure 40: Concrete Penstock with Spun Rubber Ring Joints

Photo courtesy of Hynds Water

Mild steel: Mild steel is likely the most widely utilized penstock material for small hydro systems. Its low cost and ease of acquisition add to its appeal. Mild steel provides a greater versatility for pipe diameter and thickness. It has moderate friction loss. Mild steel penstocks are resistant to mechanical damage but can be more susceptible to corrosion when the pipelines are buried. While these pipes are heavy, they easily can be manufactured in smaller segments, thus making transportation and installation easier. The jointing on mild steel pipes can be achieved by on-site welding, flanges, or mechanical joints.

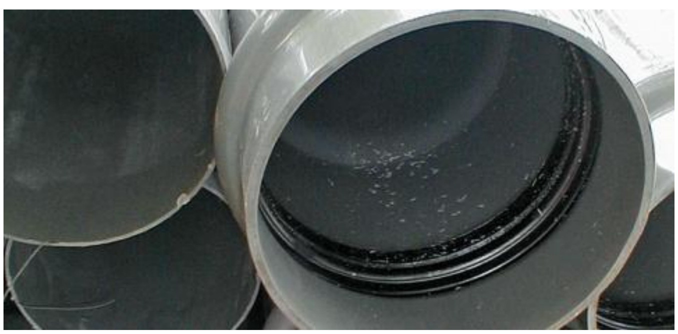


Figure 41: PVC Piping

Photo courtesy of Home Power

Polyvinyl chloride (PVC): PVC is a commonly used penstock material. It has low friction loss and a high resistance to corrosion. PVC is available in a large range of sizes and pressure ratings and the cost is relatively low. Additionally, the material is lightweight, increasing the ease of transportation and installation. However, PVC is relatively fragile and susceptible to mechanical damage from impacts, particularly at low temperatures. Further, PVC will deteriorate when exposed to ultraviolet light; the sun exposure will cause surface cracking, which in turn, will have a significant consequence on the pressure rating of the pipe. As such, the pipe must always have protection from direct sunlight by burying, covering with foliage, wrapping, or painting. PVC also requires continuous support along the length of the penstock due to its high vulnerability to stress fatigue. If the PVC is allowed to bend, there will be an introduction of internal forces against the wall of the pipe; further, vibrations induced by water flow can be enough to cause a stress fatigue failure after only about 5 to 10 years of operation. Because of this, it is recommended that PVC pipe be run along the ground or preferably buried. PVC pipe segments can be joined using spigot and socket with PVC pipe cement or using spigot and socket with a flexible sealing ring.

Figure 42: HDPE Penstock

Photo courtesy of KWH Pipe

High and medium density polyethylene (HDPE and MDPE): HDPE and MDPE pipes have minimal friction losses and are highly resistant to corrosion. The materials provide a good alternative to

PVC although material cost is somewhat greater. HDPE and MDPE pipes are available in sizes from less than an inch to more than three feet in diameter. Installation is relatively easy, particularly in smaller-scale applications.

Jointing generally is achieved by heating the ends of the segments and fusing them together using special equipment. Because this method is more labor-intensive, installation cost will be higher. For smaller diameter pipes, mechanical compression fitting joints can prove to be a cost-effective alternative to fused joints.

Step 2D. Turbine Selection

Hydro turbines can be categorized into two groups: impulse turbines and reaction turbines. The difference relates to the way that energy is produced from the inflows. In a reaction turbine, the water flows over the runner blades (Figure 43) and energy production results from the combined forces of the pressure and moving water. The turbine must be encased in a pressurized housing and fully submerged in water.

Reaction turbines are generally better suited for lower head, higher flow applications. An impulse turbine uses the force of a jet of water impacting a runner's curved buckets (Figure 44) to change the direction of flow, and thus creating momentum to produce mechanical energy. An impulse turbine can be open to the air, and only needs a casing to control splash. Impulse turbines are generally well suited for high head, low flow applications.

Figure 43: Reaction Turbine (Kaplan) Runner

Photo courtesy of www.ucmr.com

Figure 44: Impulse Turbine (Pelton) Runner

Photo courtesy of Canyon Hydro

There may be several turbines capable of operating at a given design flow, although they will likely differ in efficiency or range. The design flow for smaller systems also may be dictated by standard turbine sizes. The chart below shows seven major types of turbines and their recommended range of head and flow.

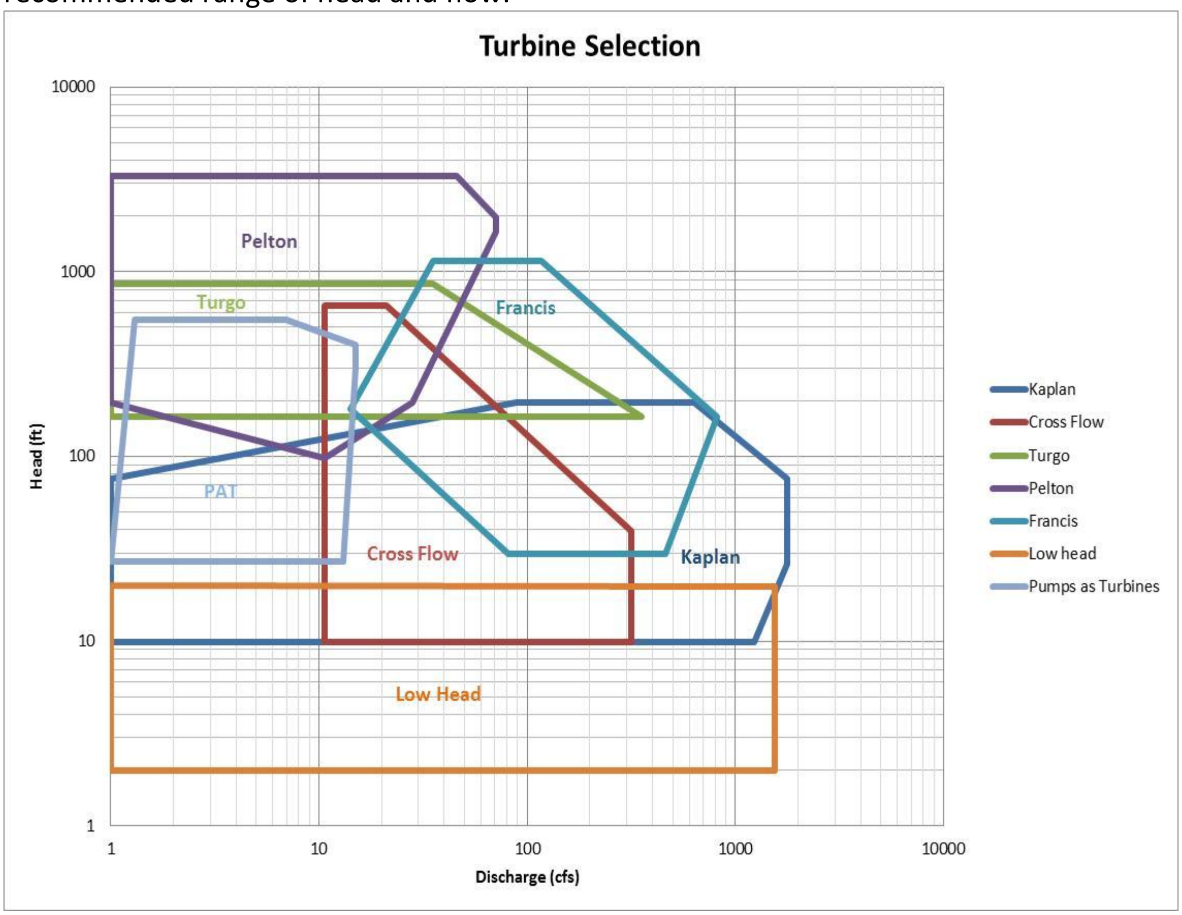


Figure 45: Turbine Selection Chart

Preliminary use of this chart will enable the identification of potential turbine types that are suitable for a given design head and flow. For example, if the design head is 100 feet and the design flow is 100 cfs, three turbines may be appropriate for the site: a Francis, a Kaplan or a Cross Flow. Each turbine has certain advantages and disadvantages which may dictate selection. All turbines in the chart are discussed in more detail in the next section.

Each turbine has an associated efficiency curve that may be obtained from the turbine manufacturer; the curve depicts the relationship between the flow and efficiency at the design head. Use of these diagrams will allow for the analysis of how each turbine will perform under specific conditions. Generally, a flatter efficiency curve represents a turbine that can operate under broad ranges of head and flow. Curves that are steeper and narrower are indicative of a turbine designed for more focused ranges of operation.

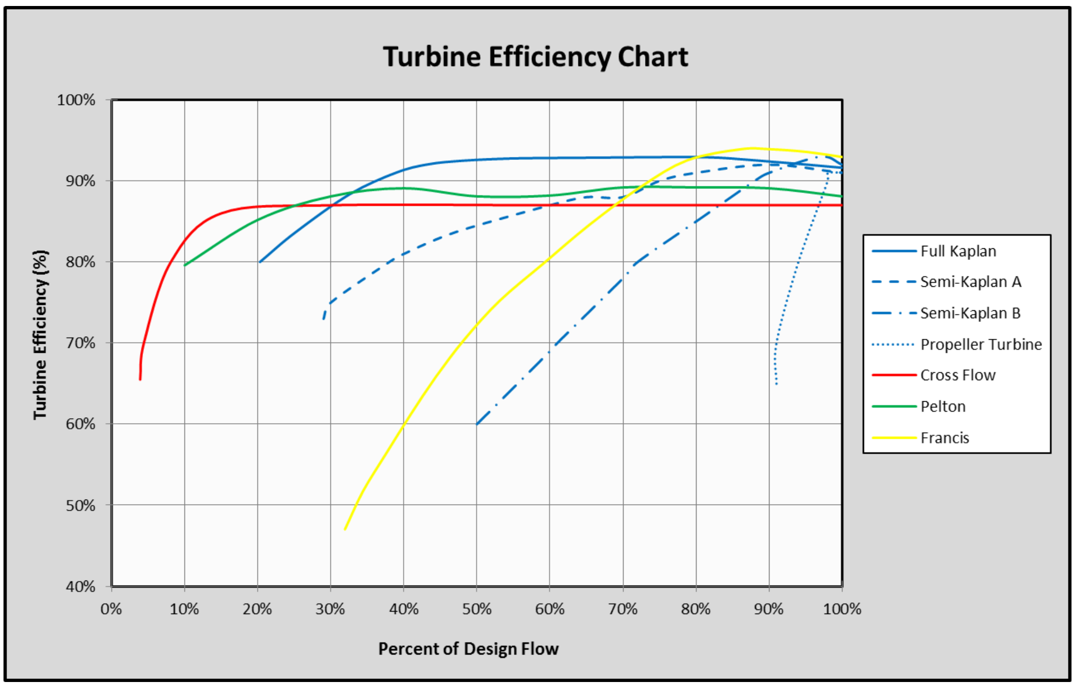


Figure 46: Typical Turbine Efficiency by Type

Generalizing the cost for turbines can be very difficult as they can be designed specifically to accommodate individual site conditions. The Appendices contain a list of turbine manufacturers. When contacted directly with the specific conditions of the proposed hydro site, an appropriate quote can be obtained. Generally speaking, turbines that are able to effectively cover a large operating range will be greater in cost. A reduction in the target operating range could equal cost savings, though the hydro system will be less able to accommodate variable flow.

Kaplan Turbine: (Figure 47): The Kaplan Turbine is highly adjustable, in both the pitch of the runner blades as well as the inlet guide vanes. This adjustability increases efficiency and allows for a larger flow operating range. Figure 48 shows the varied positions of the rotor blades to accommodate changing flows. A Kaplan is ideal for low head sites, ranging in net head from about 10 feet to 65 feet. Optimally, the turbine will have large flows through the turbine; the peak discharge for which the Kaplan operates ranges from approximately 100 cfs to 1050 cfs.

The turbine works by utilizing flow through the inlet guide vanes that act upon the propeller-like blades to create shaft power. While the Kaplan is relatively expensive compared to other types of turbines, its adjustability, and thus, higher efficiency, adds to its appeal. Different versions of the Kaplan are available for varying conditions, which can reduce the price of the turbine. The full version of a Kaplan Turbine has both adjustable inlet guide vanes as well as adjustable pitch on runner blades (“Full Kaplan” on the efficiency chart depicted in Figure 46). There are also two versions of “Semi-Kaplan” turbines: one version has only adjustable runner blades (“Semi-Kaplan A” in Figure 46) and the other version has only adjustable inlet guide vanes (“Semi-Kaplan B” in Figure 46). A propeller turbine is basically a Kaplan with both fixed runner blades and inlet guide vanes. As evident from the Efficiency Curve, a propeller turbine is optimized for a very specific operating range. The Semi-Kaplan and propeller turbines will have a lower cost than a Full Kaplan; however, their operating efficiencies are reduced by varying degrees.

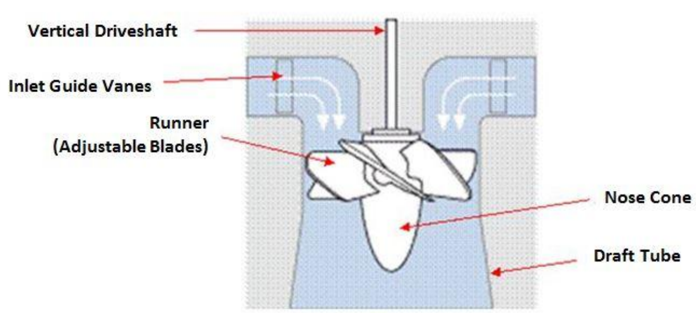


Figure 47: Kaplan Turbine Schematic

Photo courtesy of Renewables First

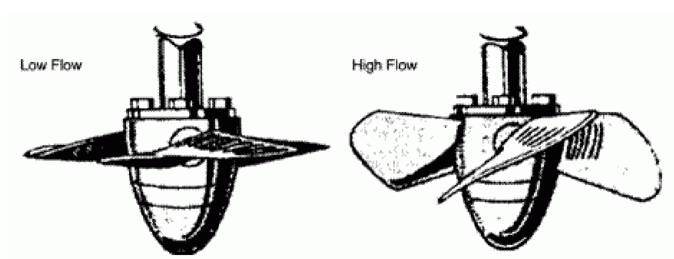


Figure 48: Kaplan Runner Blade, Varied Pitch

Photo courtesy of Renewables First

Cross Flow Turbine (Figure 49 and Figure 50): The Cross Flow Turbine is named for the way the water flows across the runner. Because most Cross Flows have two or more inlet guide vanes, this type of turbine can maintain a high efficiency over a wide range of flow rates. By altering the operation of the inlet guide vanes to better suit flow conditions, flow can be directed at just a portion of the runner during low inflow, or the entire runner when higher flows dictate. As evident from the efficiency curve, the Cross Flow is able to maintain a consistent efficiency.

The Cross Flow has a large operating range of net head, spanning from approximately 5.5 feet to 650 feet, although it will become less cost effective for heads greater than 130 feet. The Cross Flow can maintain a higher percentage of efficiency over a broad range of flow, on as little as 1.5 cfs, up to 175 cfs, making it well-suited for seasonally fluctuating flow sources. The Cross Flow's major advantage is that one turbine can operate over a large range of flow. Further, due to its self-cleaning design and standardized componentry, the turbine requires very little maintenance and should operate efficiently for at least 40 years.

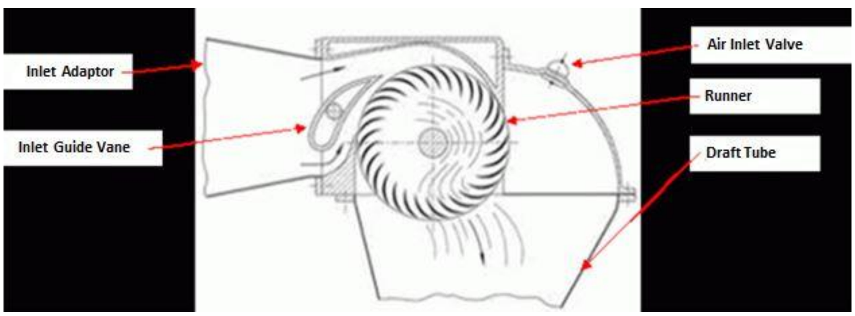


Figure 49: Cross-section of Cross Flow Turbine

Photo courtesy of Renewables First

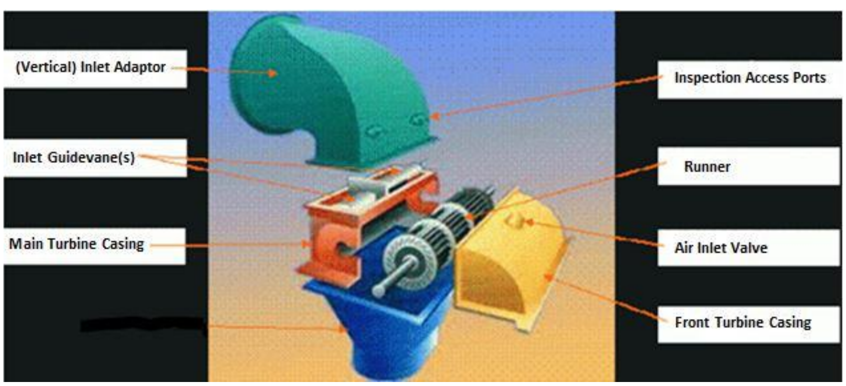


Figure 50: Cross Flow Exploded Schematic

Photo courtesy of Renewables First

Pelton Turbine (Figure 51): The Pelton Turbine has a high operating head. Because the operating head is so high, the flow rate tends to be low, amounting to as little as 0.2 cfs. The turbine requires the flow through the inlet to be highly pressurized, making proper penstock design crucial. The Pelton utilizes a nozzle located in the spear jet, which is used to focus the flow into the buckets on the runner. The spear jet and buckets are designed to create minimal loss; this leads to a potential efficiency of 90%, even in small hydro applications. A Pelton Turbine can have up to six spear jets (shown in Figure 52), which effectively increase the flow rate to the turbine resulting in a greater power production and efficiency. The efficiency curve depicted in Figure 46 depicts an efficiency curve for Peltons having a twin-spear jet.

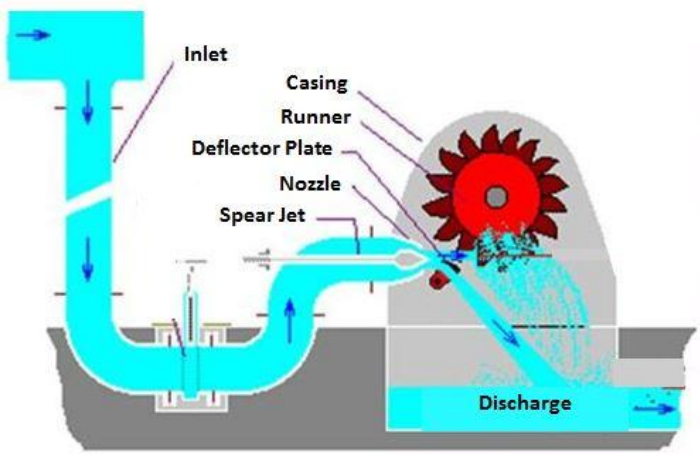


Figure 51: Pelton Turbine Schematic

Figure courtesy of PumpFundamentals.com

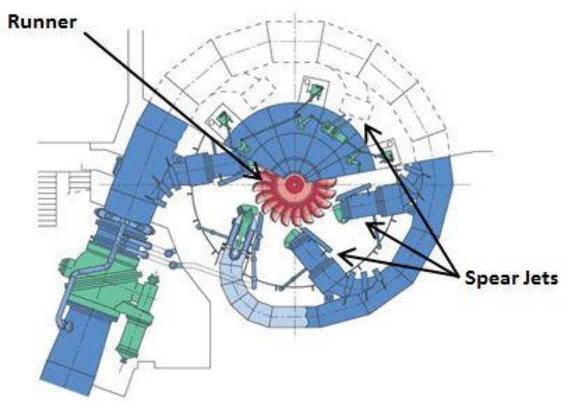


Figure 52: Cross-section of Pelton Turbine

Figure courtesy of Voith Hydro Power

Turgo Turbine (Figure 53): The Turgo Turbine was developed from the Pelton Turbine and utilizes much of the same technology. Turgo turbines are typically utilized for lower heads and higher flow rates than Pelton turbines. Turgo efficiency is less than that of the Pelton, but the Turgo retains the ability to support a broad flow range. The main physical differences between the two relate to the flow path of water through the turbines and the cup shape on the runners.

Figure 53: Turgo Runner

Photo courtesy of PowerPal

Francis Turbine (Figure 54 and Figure 55): The Francis Turbine is the traditional turbine for standard, medium head. It has a reliable, simple construction, with adjustable guide vanes and fixed runner blades. From the efficiency curve, it can be seen that the Francis has a narrow operating range for peak efficiency.

Figure 54: Francis Runner

Photo Courtesy of Oak Ridge National Laboratory; Best Practice Catalog, Francis Turbine

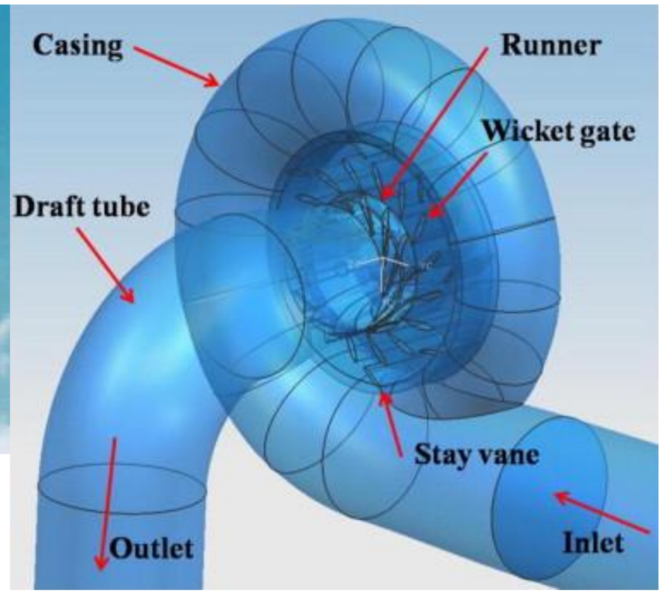


Figure 55: Francis Turbine

Photo Courtesy of ScienceDirect

Low Head Turbine: The use of Low Head Turbines is an emerging market. While the previously described turbines are generally bought as custom units, low head Tturbines have been standardized in an attempt to keep associated costs low. Companies that manufacture Llow head turbines continually are attempting to design low cost, standard turbines for particular situations and markets. There are multiple types of low head turbines. For very low head sites, a low head turbine system may be a suitable and economical alternative to a traditional turbine system. Figure 56 shows an

Figure 56: Multiple Low Head Turbines System

Photo courtesy of Mavel

installation comprised of multiple low head turbines. Applegate Group and Colorado State University published a Low Head Hydropower Study in which a more detailed list and description of available low head turbines can be found.

Pump as Turbine (PAT): Centrifugal pumps can function as turbines by running flow through them in reverse (see figure57) Their use is optimal in conditions in which a fixed flow rate is consistently available throughout the year. Because pumps are mass-produced, this alternative can be an appealing option. PATs are available in a multitude of standard sizes and in a large operational range of head and flow. Replacement parts are more readily accessible and affordable and will typically have a faster turn-around time for delivery. The PAT system offers a simple design as well. In most cases, it is more reasonable to have a direct drive, in which the pump shaft is connected directly to the generator, rather than fitting the system with a belt drive. This absence of a belt drive adds further benefit to the PAT system: reduction in friction loss, longer bearing life, less maintenance, and a lower cost. The ease of installation increases without the presence of a belt drive as the PAT and generator are designed as a single unit. The main disadvantage to having a direct drive system is that the PAT and generator must run at equivalent speeds, thereby reducing the operational range of flow. When engineered correctly, a pump used as a turbine can prove very cost effective and efficient, particularly when multiple pumps are used in a system to maximize efficiencies. See Appendices for a complete list of turbine manufacturers in all sizes.

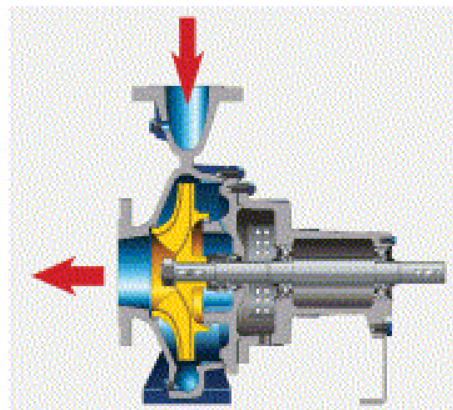


Figure 57: Pump as Turbine

Photo courtesy of World Pumps

Step 2E. Powerhouse

The size of the powerhouse is dictated by the equipment configuration, type and quantity of turbines and the landscape of the site. The necessary equipment needs to be configured in an efficient manner with adequate clearance for installation and maintenance. Turbine manufacturers can give recommendations about powerhouse size requirements as well as clearances and offsets between equipment.

Since hydro turbine and generator equipment have substantial weight, it is imperative that the powerhouse foundation be designed to adequately handle the loads to which it will be subjected. The turbine's discharge channel (tailrace) is commonly integrated into the foundation and requires placement consideration when designing the powerhouse foundation. Any access to the structure must be large enough to accommodate the placement of the equipment it will house. A permanent crane also may be necessary to lift and position the equipment within the powerhouse. Structural components will need to be designed to withstand the large forces that heavy equipment will transfer to the powerhouse structure.

There are multiple variations for powerhouse configurations based on the demands of the specific hydro system. For example, Figure 58 depicts a reaction turbine powerhouse. Water is discharged through a tailrace that is incorporated directly into the powerhouse foundation. However, for an impulse turbine powerhouse shown in Figure 59, the tailwater is discharged directly into an open-air excavation rather than via a tailrace. Particular turbine requirements and specifications will need consideration when designing the powerhouse.

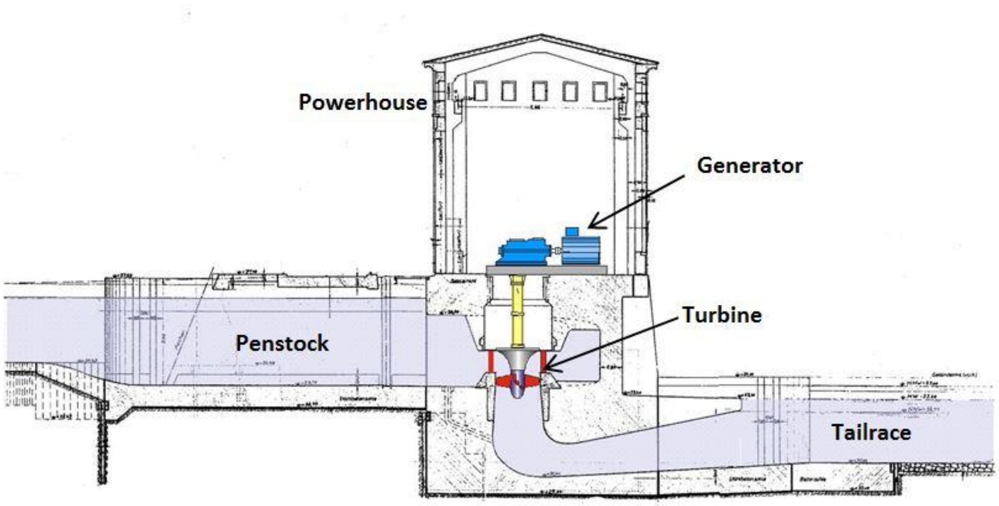


Figure 58: Low Head Powerhouse Schematic

Figure courtesy of "Guide on How to Develop a Small Hydropower Plant" ESHA 2004

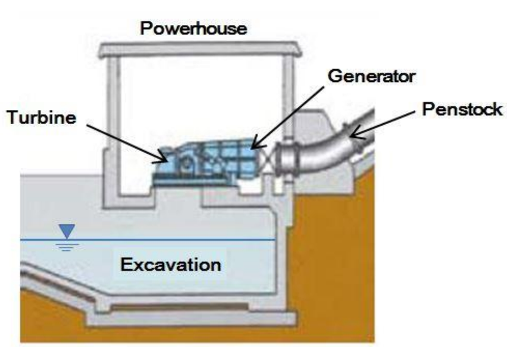


Figure 59: Impulse Turbine Powerhouse Schematic

2E1. **Intake Structures**

Intake Structures are needed for Run-of-the-River projects and Conduit projects to direct the appropriate flow into the penstock and provide for adequate screening. There are several general configurations that can be used in a natural stream or a canal; a lateral, side or bottom intake. These three basic configurations are shown in Figure 60 - Figure 62.

The higher the head on the turbine, the more important is to have water free from sediment. Of the three intake configurations shown below, the side intake is desirable because most of the debris and bed loads can completely bypass the screens. The first two configurations, the lateral and side intake, require the watercourse to be checked up or dammed to an elevation that will result in an overflow onto the screens. This can be accomplished with a permanent or movable structure, with permanent structures ranging from rock dams and dikes to concrete structures. All diversion dams or other structures should include a gate to sluice the sediments that will accumulate behind the dam. Adding a movable gate to the diversion structure allows for more control of both the intake and bypass flow. Several types of movable gates and checks are listed by manufacturer in the Appendices.

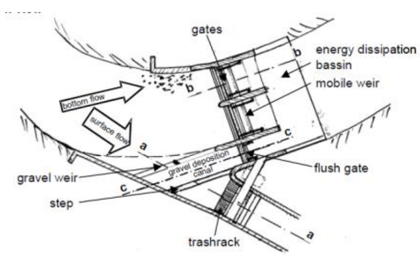


Figure 60: Lateral Intake

Photo courtesy of "Guide on How to Develop a Small Hydropower Plant" ESHA 2004

Figure 61: Side Intake

Photo courtesy of HydroScreen, LLC

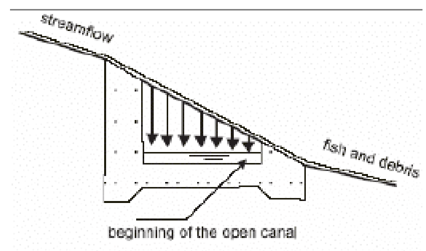


Figure 62: Bottom Intake

Photo courtesy of "Guide on How to Develop a Small Hydropower Plant" ESHA 2004

2E2. **Screening**

Common to all intake structures is sediment and trash control. Screening the water before it enters the turbine will prevent accelerated wear of runners and other components of the turbine. Floating debris may also cause significant damage if allowed to enter the turbine. Screen selection will depend on the type of debris and sediment expected. Several screen types are shown below with general characteristics of each type.

Table 3: Comparison of Several Screening Options

Screen type	Screen Size	Electricity Required	Turbine Type	Flow	Head Loss
Wedge Wire	Very fine	No	All	Medium	High
Bar Trash rack and Rake	Coarse	Yes	Low head	High	Low
Drum Screens	Very fine	Some	All	Low	High
Motorized Screens	Medium	Yes	Low Head	Medium	Medium

When choosing a screening method, considerations should include accessibility for maintenance, access to service power, size of the debris and sediments and the selection of the turbine. The head loss that occurs through the screen also should be considered. A list of manufactures of screens, trash racks, cleaners and other intake devices can be found in the Appendices.

2E3. **Submergence**

Submergence of the penstock inlet is a design consideration for the intake structure. The inlet of the penstock must be sufficiently submerged under water such that air is not drawn into the penstock or vortexes created on the water surface. To prevent this from occurring, a general rule of thumb is to submerge the penstock inlet a full penstock diameter below the water surface. This depth may be reduced through a hydraulic analysis of the structure.

2E4. **Discharge Structure**

The Tailrace, or discharge structure, is located downstream of the turbine and takes the water discharged from the turbine back to the watercourse. The discharge structure design will depend on the type of turbine and the turbine configuration. The typical powerhouse layouts shown above show that the discharge structure may be integral to the building foundation. This will save on civil construction costs and space.

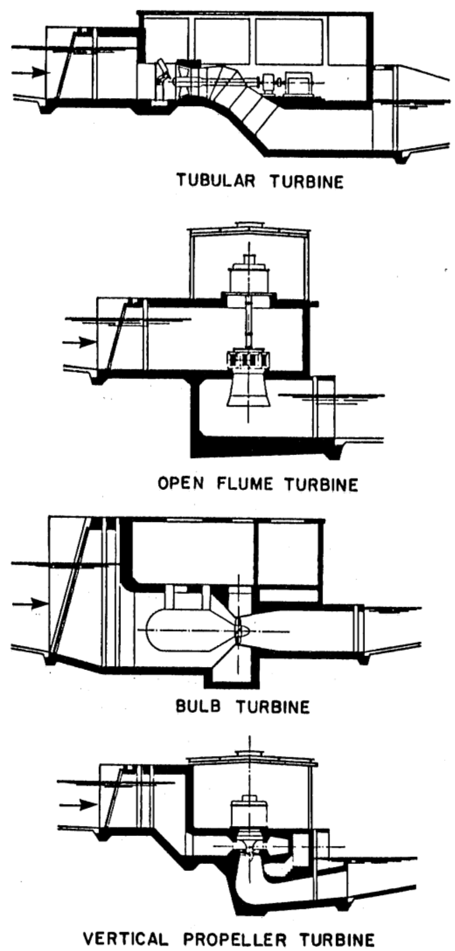


Figure 63: Discharge Examples

Photo courtesy of Gulliver and Arndt, 1991

Reaction turbines (Kaplan, Propeller, or Francis) will require a draft tube and tailwater to function properly. These turbines take advantage of the suction provided by the draft tube downstream of the turbine. A draft tube is simply the outlet pipe downstream of the turbine. The draft tube must be submerged in water, which is achieved by maintaining tailwater with the concrete structure, or setting the bottom of the draft tube below the downstream water surface. Several examples of draft tubes and discharge structures are shown in Figure 63.

Alternatively, impulse turbines (Pelton, Turgo and Crossflow) do not take advantage of head downstream of the turbine. These turbines will discharge into the open air and do not require a set tailwater elevation or a draft tube.

Step 2F. Controls

2F1. **Grid Tied**

Small hydro turbine/generators are commonly sold as “water-to-wire” packages. The manufacturer/distributor will supply all of the equipment, turbine, generator, controls, and switchgear according to specifications and interconnection requirements.

i.) **Grid Interconnection Controls**

Grid interconnection controls, including automatic controls and switchgear, will synchronize generation with the frequency and voltage of the grid. It also will safeguard both equipment and the grid in the case of failure. The system will monitor the grid frequency and voltage and automatically adjust generation to match. This is a fundamental interconnection requirement for all utilities. Additional capabilities may be included in customized controls including water level monitoring and operation of flow control valves. Please see Appendices for a list of controls manufacturers that can provide additional information.

ii.) **Emergency Shutdown System**

The ability of the system to disconnect automatically is also a fundamental interconnection requirement. The turbine and generator need to stop operating if the grid fails. The generator cannot be feeding power into the grid in this case for the safety of electric utility line workers and the general public. The controls will detect the loss of power and automatically disconnect the generator. This creates a problem where the generator is no longer experiencing a load and it will tend to increase in speed if the turbine is still passing water and turning the generator. Ultimately, if the turbine is allowed to spin at “runaway speed,” there is the potential that it will spin so fast that water will not be able to pass through the turbine. This could cause a catastrophic pressure surge in the pipeline. It also will cause damage to the generator if it is allowed to spin freely.

There are several safeguards that can be included in the system, depending on the turbine type. In general, the safeguard is a method to remove water from entering the turbine and spinning the runner. For impulse turbines, a deflector may be used that simply deflects water from the runner in the case of an emergency shutdown. Water still will be traveling through the penstock, but will be discharging directly without turning the runner. Reaction turbines need to be shut down slowly and water flow stopped through the penstock or directed away from the penstock. This type of control generally is achieved through automatic valves or gates that close slowly to prevent a pressure surge.

2F2. **Off the Grid Applications**

Without the grid to regulate the frequency and voltage of the generator, a load governor is needed. A governor or load management system can distribute generation to loads according to preset priorities and includes one load to shed excess generation. Loads to shed excess generation may include battery charging, space, water or ground heaters. A governor is necessary to balance varying loads and generation that do not have the benefit of the grid.

Step 2G. Electrical Interconnection

It is advisable to contact the local electric utility regarding a proposed project early in the process to gather information regarding interconnection and net metering requirements. Utilities typically will be able to provide a template net metering and interconnection application, which will specify information required.

For a smaller project, a simple net metering agreement and interconnection agreement usually can be arranged with the local utility without difficulty. Under current Colorado law, most utilities are obliged to provide net metering for residential systems up to 10 kW and commercial systems up to 25 kW (larger limits apply to Colorado’s two investor-owned utilities). If a project site has multiple electric meters, it may be advantageous to combine meters into a single interconnection point in order to maximize the ability of the hydropower generation to offset onsite electrical road at a payment rate equal to the utility’s full retail rate.

Larger projects which are not eligible for net metering will need to secure a Power Purchase Agreement, typically with the local utility (see additional information in the following section).

For larger hydro systems, the local utility may require an interconnection study to determine whether or not the project would cause any adverse impacts on utility infrastructure or operations. The interconnection study might be completed by the utility itself or by an engineering firm approved by the utility, although in both cases costs of the interconnection study typically will be paid by the project developer.

Step 2H. Identifying a Buyer for Energy and Renewable Energy Credits

2H1. **Net Metering**

Small hydro systems typically will sell their energy via net metering. Under a net metering agreement, generated electricity is used directly by an adjacent facility. Meters record electricity usage in both directions, meaning electricity can be consumed from the grid or the excess generated electricity can be exported back onto the grid. In many cases, a generating facility might not use all the locally-generated electricity, resulting in a credit from the utility.

For projects located in the service territory of Colorado's two investor-owned utilities, net metering projects must not exceed 120% of the customer's average annual consumption. For projects located within rural cooperatives, customer-sited generation typically cannot exceed 10 kW for residential projects and 25 kW for non-residential projects without special utility approval.

2H2. **Energy**

The most logical energy purchaser for a project is usually the local utility. Colorado's electric utilities are comprised of investor owned utilities, rural electric cooperatives and municipal utilities.[v]

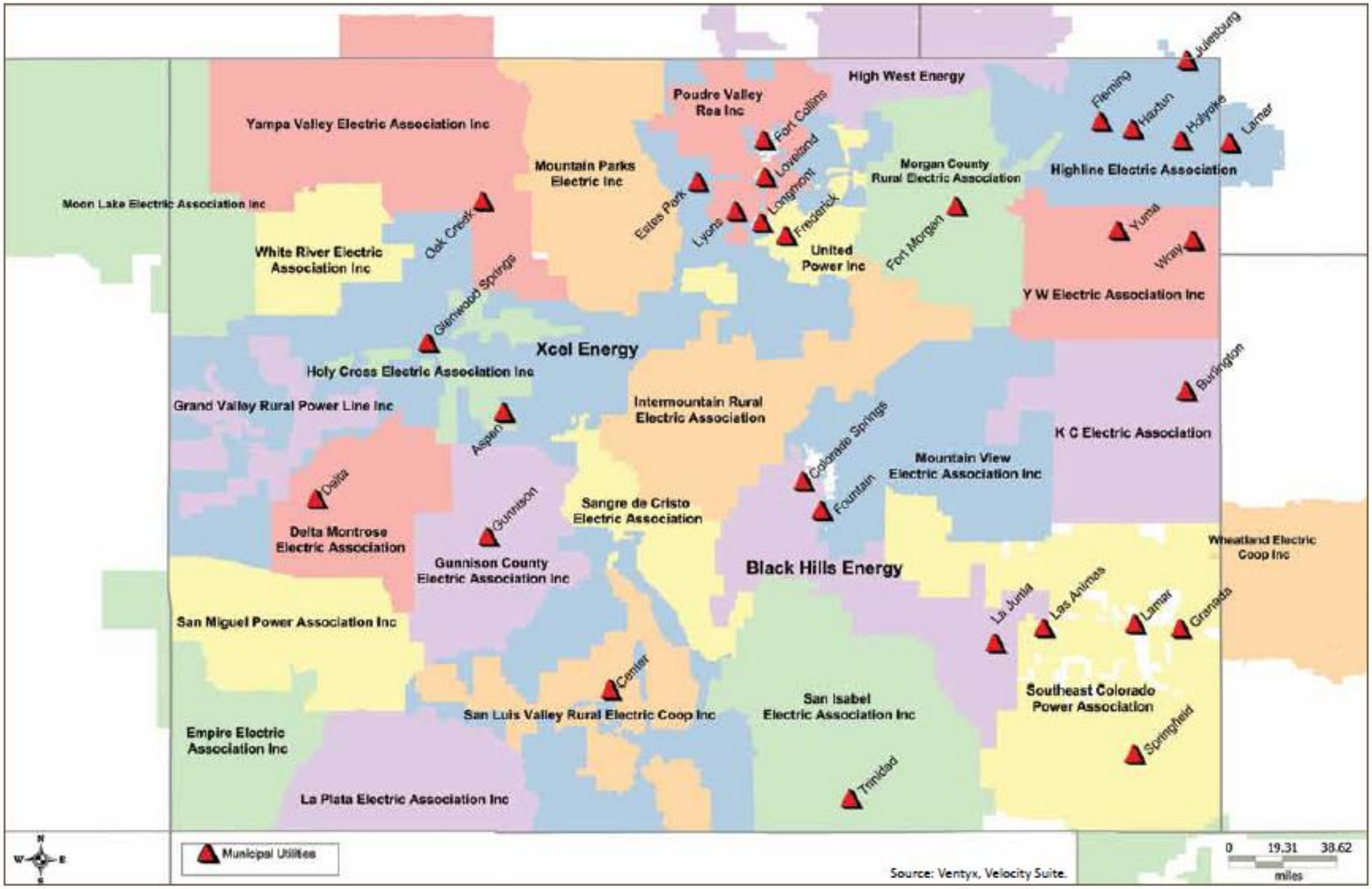


Figure 64: Colorado's Electric Utility Service Territories

Source: Colorado Governor's Energy Office. Prepared by Navigant Consulting. *2010 Colorado Utilities Report.* August 2010, p iv.

Energy typically is sold in kilowatt-hour or megawatt-hour increments through a power purchase agreement (PPA). A PPA is a contract between two parties, one who generates electricity and one who purchases the electricity. The PPA typically defines all of the commercial terms for the sale of electricity between the two parties, including delivery of electricity, penalties for under-delivery, payment terms and termination.

Many Colorado rural cooperatives purchase their energy wholesale from Tri-State Generation and Transmission (Tri-State). Tri-State's Local Renewable Program (aka Policy 115) enables Tri-State member cooperatives to purchase the output from local renewable resources, including hydropower, in an amount up to 5% of annual energy sales. The local electric cooperative determines whether a particular local renewable project qualifies under Tri-State Policy 115. The energy payment amount under Tri-State Policy 115 is determined through a payment schedule established by Tri-State.

i.) **Renewable Energy Credits**

A Renewable Energy Credit (REC) represents a claim to the environmental attributes associated with renewable energy generation. RECs are tradable instruments that can be used to meet voluntary renewable energy targets as well as to meet compliance requirements for renewable portfolio standards. An REC is a certificate that represents the generation of one megawatt-hour (MWh) of electricity from an eligible source of renewable energy. Each REC denotes the underlying generation energy source, location of the generation, and year of generation (a.k.a. "vintage"), environmental emissions, and other characteristics associated with the generator. Unlike electricity, RECs do not need to be scheduled on a transmission system and they can be used at a different time than the moment of generation. Certificate tracking systems have been established to issue and record the exchange of RECs. REC prices vary according to market trends in both the voluntary and compliance market.

For larger projects, RECs can be sold separately from energy. For smaller systems which are net-metered, utilities typically require that ownership of RECs transfers along with the sale of energy.

Colorado's Renewable Portfolio Standard (RPS)

Colorado has a Renewable Portfolio Standard which helps drive Colorado REC pricing. Small hydro is an eligible renewable resource compliant with Colorado's RPS requirements. Eligible hydro includes new hydro with a nameplate rating of 10 MW or less, or hydro in existence on January 1, 2005, with a nameplate capacity of 30 MW or less. Colorado RPS requirements are as follows:

- Investor-owned utilities: 30% by 2020

- Electric cooperatives serving 100,000 or more meters: 20% by 2020
- Electric cooperatives serving fewer than 100,000 meters: 10% by 2020
- Municipal utilities serving more than 40,000 customers: 10% by 2020

Step 2I. Permitting: Types and Timelines

Hydropower projects typically require a license or exemption from the Federal Energy Regulatory Commission (FERC) or the Bureau of Reclamation (see Step 3 below for additional detailed discussion regarding federal permitting requirements).

In addition to these requirements, construction activities in a river or stream can trigger additional local, state and Army Corps of Engineers permitting.

2I1. **Army Corps of Engineers, Clean Water Act, Section 404**

The Army Corps of Engineers regulates all construction activities occurring in "Waters of the U.S." by authority of the Clean Water Act, Section 404. Construction activities include the removal or deposition of material from below the ordinary high water mark. This can include any natural waterway or wetland. There are basically three levels of Army Corps involvement in a hydropower project: 1) if the project is located on a canal or pipeline, the Army Corps may have no involvement; 2) if the construction activity is minor and/or the project qualifies for a FERC exemption, the project may qualify for a Nationwide permit, discussed more below; or 3) if the amount of disturbance or quantity of dredge or fill is more than what qualifies for a Nationwide permit, an Individual permit is required.

2I2. **No Army Corps involvement**

If the project is located entirely on a manmade waterway or a conduit, the Army Corps may not have jurisdiction over the project. This is explained in more detail in a guidance document provided by the Army Corps: Regulatory Guidance Letter No 07-02: SUBJECT: Exemptions for Construction or Maintenance of Irrigation Ditches and Maintenance of Drainage Ditches Under Section 404 of Clean Water Act.

2I3. **Nationwide Permits**

Nationwide permits are designed for specific activities that have little impact on water or environmental quality. These permits are subject to fewer requirements than an individual permit and are meant to expedite the permitting process. There are several nationwide permits that could apply to hydropower construction activities:

i.) **Nationwide Permit #17 for Hydropower**

For discharges of dredged or fill material associated with hydropower projects having: (a) less than 5000 kW of total generating capacity at existing reservoirs where the project, including the fill, is licensed by the Federal Energy Regulatory Commission (FERC) under the Federal Power Act of 1920, as amended; or (b) a licensing exemption granted by the FERC pursuant to Section 408 of the Energy Security Act of 1980 (16 U.S.C. 2705 and 2708) and Section 30 of the Federal Power Act, as amended. (Section 404)

ii.) **Nationwide Permit #18 for minor discharges**
For minor discharges of dredged or fill material into all waters of the United States, provided the activity meets all of the following criteria: (a) the quantity of discharged material and the volume of area excavated do not exceed 25 cubic yards below the plane of the ordinary high water mark or the high tide line; (b) the discharge will not cause the loss of more than 1⁄10-acre of waters of the United States; and (c) the discharge is not placed for the purpose of a stream diversion. (Sections 10 and 404)

iii.) **Nationwide permit #19 for minor dredging**
For dredging of no more than 25 cubic yards below the plane of the ordinary high water mark or the mean high water mark from navigable waters of the United States (i.e., section 10 waters). This does not authorize the dredging or degradation through siltation of coral reefs, sites that support submerged aquatic vegetation (including sites where submerged aquatic vegetation is documented to exist but may not be present in a given year), anadromous fish spawning areas, or wetlands, or the connection of canals or other artificial waterways to navigable waters of the United States (see 33 CFR 322.5(g)). (Sections 10 and 404)

2I4. **Individual Permit**
If a project does not fit into the requirements of one of the nationwide permits, an individual permit must be obtained. These permits will take more time to obtain and have more requirements than a nationwide permit. To ensure adequate compliance with the Clean Water Act, the local USACE office should be contacted and consulted regarding specific projects. A map and list of contact information is included in the Appendices under permitting resources, entitled "USACE Colorado Offices."

2I5. **State Department of Environmental Quality, Section 401**
The Colorado Department of Public Health and the Environment, Water Quality Control Division issues water quality certifications for facilities that may result in any fill or discharge into the navigable waters of the United States. These certifications are required if a federal permit is issued for the facility, such as a FERC exemption or license. Additional guidance for these certifications is included in the Appendices, entitled "State of Colorado Water Quality Certification fulfilling the requirements of Clean Water Act Section 401".

2I6. **1041 Regulations**

In 1974, the Colorado General Assembly enacted measures to further define the authority of state and local governments in making planning decisions for matters of statewide interest. These powers are commonly referred to as "1041 powers," based on the number of the bill of the proposed legislation (HB 74-1041). These 1041 powers allow local governments to identify, designate, and regulate areas and activities of state interest through a local permitting process. The general intention of these powers is to allow for local governments to maintain their control over particular development projects even where the development project has statewide impacts. The statute concerning areas and activities of state interest can be found in Section 24-65.1-101.

1041 regulations may apply to a hydropower project if it is considered an activity of state interest which include the following: site selection and construction of major facilities of a public utility; efficient utilization of municipal and industrial water projects; or site selection and construction of major new domestic water and sewage treatment systems and major extension of existing domestic water and sewage treatment systems, among others. In general, a hydropower project on its own would not be considered an activity of state interest, but if the hydropower project is the part of a larger utility scale project, 1041 regulations may apply. Not all local governments have adopted 1041 regulations; each county would need to be contacted to see if these regulations would apply to a specific site.

For a full list of permitting resources, please see Appendices.

2I7. **Other Federal Permits**

For projects located on federal land there, may be specific permitting requirements of the federal agency such as the Bureau of Land Management (BLM), U.S. Forest Service, Bureau of Reclamation, or U.S. Fish and Wildlife.

2I8. **Additional Permitting Issues**

i.) **Local Governments**

As explained above, most small hydropower projects will need to submit some sort of federal permit application, either through FERC or through the Bureau of Reclamation. In addition, however, there may be local permits required including through county and town governments. Be sure to check the local zoning laws early on to ensure hydropower is an acceptable land use for the project site.

ii.) **Neighbors**

A project's neighbors can potentially play a large role in the project's development. It is important to engage potentially-affected neighbors early on in the development process. If sound is a concern for a neighbor, local government can create a local noise ordinance which specifies a certain decibel level that cannot be exceeded. If powerhouse aesthetics are an issue of concern, a powerhouse can be designed to match nearby buildings or potentially even placed underground if necessary to minimize aesthetics concerns.

Step 2J. Construction Costs and Cost Categories

The Electric Power Research Institute (EPRI) has issued a report used in the development of a general estimate for costs incurred when creating a small hydro site. See EPRI's report, *Quantifying the Value of Hydropower in the Electric Grid: Plant Cost Elements*. While the items outlined below may not be all-inclusive, they encompass the majority of expected project tasks. There can be significant variations in cost, depending upon materials used, scale of the system, type of turbine, geological conditions, etc.

Table 4: Typical Small Hydro Costs

Typical Micro Hydro Site	
Typical Equipment Alternative: TBD	
Typical installed capacity: TBD kW	
Preparation of Final E/M Design	$
Permitting/Mitigation	$
FERC Small Conduit License Exemption	$
FERC Qualifying Facility Self Certification	$
Interconnection Application	$
Other Permits and Miscellaneous Fees	$
Legal Fees	$
Acquisition of Access and Rights of Way	$
Cost of Project Components	
Power Transmission	
Interconnection Costs	$
Service Transformer	$
Secondary Service, Disconnect and Metering	$
Hydropower Plant	
Turbine Generator & Controls Supply	$ See Comment 1
T/G Installation and Other E/M Modifications	$ See Comment 2
SCADA Input	$ See Comment 3
Structural and Site Work Allocation	$ See Comment 4
Mobilization and Demobilization	$
Temporary Facilities and Equipment Rental	$
Miscellaneous	$
Subtotal Project Components	$
Field & Technical Support @ 10% of Above Subtotal	$
Profit, Insurance, Bonds, etc. @ 15% of Above Subtotal	$
Subtotal	$
Contingency @ 20% of Above Subtotal	
Total Construction Costs	$
Total Project Costs	$
Total Cost Per kW	$ See Comment 5

Table created with guidance from EPRI (Electric Power Research Institute, 2011)

For a list of construction cost resources and Colorado construction companies, see Appendices.

Step 2K. Federal Incentives

In recent years, hydro projects greater than 150kW have been eligible for the following federal tax incentives (projects can choose one or the other): 1) the Investment Tax Credit (ITC), which can be claimed in year one of a project for 30% of depreciable capital costs; the ITC also reduces the project's depreciable basis by 15%; 2) The Production Tax Credit (PTC), which is worth $11/MWh for the first 10 years of the project's operations (with the PTC value escalating slightly with inflation). Only private sector entities are able to take advantage of these tax credit incentives. These tax incentives are now expired, although they could potentially be extended by Congress.

In 2014, hydropower projects became eligible for so-called Section 242 incentives, a name which derives from Section 242 of the Energy Policy Act of 2005 which authorized the incentives. Funds were appropriated for the program for the first time in 2014, providing payments currently in the amount of 2.3 cents/kWh for new hydropower being developed on existing facilities, with maximum payments of $750,000 per year for up to 10 years, subject to availability through ongoing congressional appropriation for the program.

Step 2L. Financial Analysis

A feasibility study typically will include economic modeling for an estimated construction cost and energy sales scenario.

For smaller systems, this usually will start with simple payback analysis represented in years. The simple payback is the project incentives total subtracted from the total project cost, and then divided by the annual revenue/savings. This is a simple economic measure that does not take into account the rising cost of electricity or any annual operation or maintenance costs associated with the facility. But it is an easy measure to understand.

More complicated projects typically entail development of a more complicated financial model that will provide greater accuracy in accounting for variables, including energy value escalation, debt service, operations and maintenance costs, as well as creation of a capital reserve account.

STEP 3 Permitting, Finance and Interconnection

Recent federal permitting requirements for small hydropower have been substantially simplified through reform legislation.

Thanks to Colorado legislators, in August 2013, Pres. Barack Obama signed into law two pieces of legislation aimed at making the regulatory process more efficient for small hydro: H.R. 267, the Hydropower Regulatory Efficiency Act (HREA), sponsored by Rep. Diana DeGette (Denver), and H.R. 678, the Bureau of Reclamation Small Conduit Hydropower Development and Rural Jobs Act, sponsored by Rep. Scott Tipton (Cortez).

The Hydropower Regulatory Efficiency Act created a “regulatory off-ramp” from FERC permitting requirements for non-controversial hydro projects on existing conduits that are less than 5 MW in capacity, provided that there are no public objections to the project during a 45-day public notice period administered by FERC. The bill also increased the FERC conduit “exemption” to 40 MW. It directed FERC to explore a two-year licensing process for hydropower development at existing non-powered dams and closed-loop pumped storage projects and increased the FERC small hydro “exemption” from 5 MW to 10 MW. The bill also authorized FERC to grant developers two-year preliminary permit extensions, and directed DOE to prepare reports regarding pumped storage and conduit project opportunities.

The Bureau of Reclamation Small Conduit Hydropower Development and Rural Jobs Act authorized small conduit (under 5 MW) power projects on Reclamation-owned infrastructure, while providing irrigation districts and water-user associations the first right to develop hydropower projects. The bill also directed the Bureau of Reclamation to use its National Environmental Policy Act categorical exclusion process for small conduit applications.

In addition, the June 2014 Water Resources Development Act included language stating that it is the policy of the United States that the development of non-federal hydroelectric power at Corps of Engineers civil works projects, including existing dams, must be given priority and that permitting must be completed by the Corps of Engineers in a timely manner.

i.) **Identifying the Proper Federal Permitting Processes**

The Federal Energy Regulatory Commission (FERC) is the default federal permitting agency for hydropower development, although projects being constructed on Bureau of Reclamation facilities are subject to Reclamation’s permitting process, referred to as a Lease of Power Privilege (additional details below). If there is any ambiguity regarding the appropriate permitting agency for an individual project, determination as to whether FERC or Reclamation is the relevant federal permitting authority is governed by a Memorandum of Understanding between FERC and Reclamation.

3A2. **Filing a Notice of Intent Seeking “Off-ramp” from FERC Requirements**

Many small hydro projects likely to be developed in Colorado will qualify for the “off-ramp” created by the Hydropower Regulatory Efficiency Act of 2013.

A “qualifying conduit hydropower facility” must meet the following provisions;

1) A conduit is any tunnel, canal, pipeline, aqueduct, flume, ditch, or similar manmade water conveyance that is operated for the distribution of water for agricultural, municipal, or industrial consumption, and is not primarily for the generation of electricity.

2) The facility generates electric power using only the hydroelectric potential of a non-federally owned conduit.

3) The facility has an installed capacity that does not exceed 5 megawatts (MW).

4) The facility was not licensed or exempted from the licensing requirements of Part I of the FPA on or before August 9, 2013.

The FERC application is a "Notice of Intent" document that requests general information about the conduit and the hydropower project. Several drawings must be included, such as a location map and a plan view of the proposed facility.

The Notice of Intent application form and necessary drawings can be filed electronically with FERC. Additional information is available on the FERC website. The applicant must sign up on the FERC eRegistration website after which all of the application files can be uploaded electronically.

The Notice of Intent application is reviewed by FERC over a 15-day period. If the application is found to meet the qualifying criteria, FERC will issue a letter and request public comments during a 45-day period. If no comments are received, a letter notifying the applicant of acceptance for exemption is issued.

See Appendices for the FERC template Notice of Intent application, as well as an example exemption acceptance letter from FERC.

3A3. **Filing for a Conduit "Exemption" or Small Hydro "Exemption"**

Projects that are ineligible for the "off-ramp" created by Hydropower Regulatory Efficiency Act of 2013 can apply to FERC, requesting either a small hydro "exemption" (for projects on existing dams under 10 MW) or a conduit "exemption" (which typically means an existing manmade conduit built primarily for purposes other than power production i.e., agricultural, municipal, or industrial consumption).

Note that the "exemptions" described here are not exemptions from FERC requirements. They are simply exemptions from FERC's licensing requirements. Projects eligible for an exemption must go through an application process related to that of a FERC license application. Exemptions are issued in perpetuity, unlike FERC licenses, which typically are issued with a 30- to 50-year term and are subject to renewal.

Detailed information is available on the FERC website regarding exemption requirements, including templates for developing an exemption or application. At the beginning of the application process, project developers should contact FERC to clarify what requirements will apply to a given project site.

As part of the FERC "exemption" application process, applicants must develop a stakeholder process which likely will include consultation with Colorado organizations, including the following:

Colorado Division of Wildlife	303-291-7267
Colorado Historical Society	303-866-2776
U.S. Fish and Wildlife Service	970-243-2778 ex 26
CO Department of Public Health and Environment Water Quality	303-692-3586
U.S. EPA Denver Office	303-312-6776
American Rivers	303-454-3395
Trout Unlimited	720-581-8589
CO Division of Water Resources	303-866-3581 ext. 8239
National Heritage Areas Coordinator	303-969-2781

Pursuant to HB14-130, signed into law by Colorado Gov. John Hickenlooper in May of 2014, the Colorado Energy Office (CEO) was directed to coordinate and compile state agency comments when small hydropower projects apply for FERC permits.

Project developers should notify CEO when they file an application with the FERC for a small hydropower permit. Upon notice, CEO will:

- Notify State agencies as noted above with potential interest in the project;
- Provide agencies a general description of the FERC review process;
- Forward project information to the interested agencies for their review;
- Set a deadline for interested agencies to submit comments to CEO, which then will submit any comments received to FERC in a timely manner commensurate with federal timelines.

3A4. **Filing for a FERC License**

Projects that are ineligible for either the recently-developed "off-ramp" pursuant to the Hydropower Regulatory Efficiency Act of 2013 or one of the two types of FERC "exemptions" (conduit exemption or under 10 MW exemption), must apply to FERC for a license.

If applying for a FERC license, there are three processes available: Traditional Licensing Process (TLP), Alternative Licensing Process (ALP), and Integrated Licensing Process (ILP). The ILP is FERC's default licensing process.

FERC licensing is a comprehensive process designed to document environmental, engineering, economic, and other characteristics of an applicant's project. The process involves gathering information, which could result in studies, and consultation with interested resource agencies and members of the public. The documentation resulting from this process is provided in a license application and forms the basis for FERC's decision-making. The documentation also helps FERC to determine if the project complies with other federal laws, including the National Environmental Policy Act (NEPA).

Applying for a FERC license is beyond the scope of many small hydropower projects that may be developed in Colorado. Substantial additional information is available on the FERC Website.

3A5. **Federal Permitting through the Bureau of Reclamation: Lease of Power Privilege**

Projects being developed on infrastructure built by the Bureau of Reclamation are subject to permitting through a process known as a Lease of Power Privilege. Most of the small hydro development that has taken place in Colorado in recent years has been through the Lease of Power Privilege process.

A Lease of Power Privilege (LPP) is a contractual right given to a non-federal entity to use a Reclamation facility for electric power generation consistent with Reclamation project purposes. Reclamation's main concern in awarding an LPP is ensuring that the integrity of Reclamation facilities not be impaired. A new hydro plant must not interfere with existing operations, jeopardize existing water rights, or create safety problems.

Under an LPP, the lessee is responsible for compliance with NEPA and the Endangered Species Act (ESA). Reclamation is responsible for lease development, as well as review and approval of designs, plans and specifications and NEPA documentation.

Under an LPP, title of the federal facility remains with Reclamation. Title of the hydro plant is with the lessee unless contracted otherwise. Reclamation also has the first right to take over the hydro plant in the event of a sale or default.

Once selected for development of an LPP, the potential lessee must develop a cost recovery agreement with Reclamation for Reclamation costs related to development of the lease. That is including, but not limited to NEPA, review of designs, administrative costs, construction, operation, maintenance and security.

Initiation of a Lease of Power Privilege application typically starts with a simple application letter to Reclamation requesting a Lease of Power Privilege. In response, Reclamation posts a formal solicitation in the *Federal Register* asking for LPP applications.

After selection of the lessee, the LPP process cannot be finalized until after completion of the NEPA process. Assuming that the environmental process does not uncover any problematic issues and yields a "Finding of No Significant Impact," the process moves to final negotiation of the LPP. Once signed, the typical LPP length is 40 years. Additional information regarding the LPP process is available on Reclamation's Lease of Privilege website.

Step 3B. Finance

3B1. Grants and Loans

i.) Federal Grants and Loans

a) WaterSMART.

The Bureau of Reclamation's WaterSMART grant program can help fund hydro project development. Eligible WaterSMART grant applicants include States, American Indian tribes, irrigation districts, water districts, or other organizations with water or power delivery authority located in the western United States. Successful WaterSMART hydro grant recipients typically include a hydro project with some type of additional public benefit, such as salinity reduction or water conservation.

b) USDA Rural Energy for America Program

The USDA's REAP program (Rural Energy for America Program) can provide loan guarantees up to $25 million, project feasibility grants up to $50,000 covering 25% of study costs, and renewable energy project grants up to 25% of project costs with a maximum of $500,000. Hydropower is an eligible project type for REAP grants. Eligible REAP grant applicants are typically rural small businesses.

c) EQIP Grants for Small Hydro

If a project is being developed by a Colorado agriculture producer, it may be eligible for the Environmental Quality Incentives Program (EQIP) grants, which became available for the first time in 2015. The EQIP incentive is divided into three different payment rates: regular EQIP, EQIP special initiatives, and EQIP historically underserved. The current payment rates for 2015 are shown in the table below, and are subject to change:

Component	Unit	Regular EQIP	EQIP Special Initiatives	EQIP Historically Underserved (HU)
Micro Hydroelectric Power Plant	Kilowatt	$1,965.18	$2,679.79	$3,215.74
Micro Hydro-mechanical Power Plant	Horsepower	$897.15	$1,223.38	$1,468.06

3B2. **State Grants and Loans**

The Colorado Water Resources and Power Development Authority (CWRPDA) has a feasibility grant program which can provide as much as $15,000 in 50% cost-shared funds to support feasibility studies, permitting, final design and other costs associated with FERC or Bureau of Reclamation permitting processes.

CWRPDA also has a small hydropower loan program which can lend up to $2 million at a rate of 2% for project construction. CWRPDA-eligible borrowers include cities, towns, counties, water districts, water and sanitation districts, metropolitan districts, water conservancy districts, water conservation districts, and irrigation districts. Loans are limited to a maximum of $2 million per governmental agency. The interest rate is 2%, and the maximum term is 20 years.

The Colorado Water Conservation Board (CWCB) also has a hydro loan program that can finance the engineering and construction of hydro projects with loan terms of 30 years at an interest rate of 2%. There is no maximum loan amount; however, borrowers are required to apply to the CWRPDA for the initial $2 million of funding. The CWCB loan will finance the remainder of the project costs. In addition to governmental agencies, the CWCB also can lend to agricultural borrowers.

3B3. **Utility Incentives**

Some Colorado utilities have incentives that can support hydro project development. For example, Holy Cross Energy has a hydro tariff with an offer to purchase hydropower from projects less than 100 kilowatts. In addition, some Colorado utilities provide a capacity-based cash rebate for eligible renewable energy projects, including small hydropower.

Step 3C. Interconnection

3C1. **Interconnection Study**

The cost, complexity and process for grid interconnection are dependent upon the scale of the project and type of interconnection. For a smaller project, a simple net metering agreement and interconnection agreement typically can be arranged with the local utility without difficulty. For larger systems, a utility may require an interconnection study to determine whether the project would cause any adverse impacts on utility infrastructure of operations. The interconnection study might be completed by the utility itself or by an engineering firm approved by the utility. Costs of the interconnection study need to be paid for by the project developer.

STEP 4 Final Design and Construction

Step 4A. Construction Contract Options, List of Engineering Firms and Related Resources

Once a small hydropower project has been found to be feasible, a permitting approach determined and financing arranged, the project enters into final design and construction. Depending on the size of the project and the owner's acceptable level of risk, several contracting options are available. A few general contracting options are discussed below. There is a significant amount of flexibility within these options, and negotiations with the design team and the construction team can tailor these options to the owner's needs.

An additional resource available to agriculture producers developing micro-hydro on a pressurized irrigation system is the Natural Resources Conservation Service (NRCS). The Environmental Quality Incentives Program (EQIP) offers technical and financial assistance to qualifying agriculture producers for water and energy conservation measures that include some types of hydropower. If you are an agriculture producer interesting in adding small hydropower to a pressurized irrigation system, contact your local NRCS office first.

4A1. **Design-Bid-Build**

The traditional contracting method for construction projects is Design-Bid-Build. The owner will hire an engineer to complete the final design, develop construction drawings, and specify materials and methods of construction. The engineer also will prepare bid documents and solicit fixed bids from contractors. A selection process based on qualifications, experience and cost will be used to select a contractor to construct the plant. Generally the engineer, or another construction management firm, will manage construction providing quality control and management services.

An estimate for the final construction cost is known after engineering is completed. However, the construction cost is finalized only after the selection of a contractor. The owner is involved in the design process and works with the engineering firm to ensure that the project is designed to the owner's specifications.

4A2. **Engineer-Procure-Construct**

Under an EPC contract, the contractor designs the installation, procures the necessary materials and builds the project, either directly or by subcontracting part of the work. In some cases, the contractor carries the project risk for schedule as well as budget in return for a fixed price. This approach will reduce the risk associated with cost for the owner, although the owner will be less involved in the design process.

4A3. **Design-Build**

Design-Build is similar to EPC. There is one point of contact for both design and construction. A design-build firm handles both the engineering design and the construction. Generally the owner is more involved in the design and assumes some risk. The design-build firm and the owner share risk associated with changes to the design, and this division will be stipulated in the contract documents. This method does not ensure a fixed price at the time of contractor selection, but it does allow for increased owner involvement.

Step 4B. Construction Management

Depending on the contracting method chosen for the project, construction management is assigned to the appropriate party. Management of construction generally includes the following responsibilities:

1) Contract management including selection, award, document management and invoicing;
2) Quality assurance including inspection and testing;
3) Coordination of contractors, scheduling and change order management.

Engineering companies generally provide construction management services. There are also firms that specifically provide construction management services. A list of Colorado hydropower consultants is included in the Appendices.

Step 4C. Construction Permitting

Several permits generally are obtained by the contractor prior to construction, rather than by the owner. The construction contract documents should outline the responsible party for obtaining these permits and the associated timelines.

4C1. **Building and Use Permits**

Requirements for building permits vary depending on the municipality and the zoning within the municipality. Check local codes to verify requirements for construction of a powerhouse on non-federal land. Some municipalities have begun including hydropower plants in their land use codes, although this is infrequent. For example, Pitkin County provides the land use code for hydropower plants on their website.

4C2. **Construction Dewatering**

The Colorado Department of Public Health and the Environment, Water Quality Control Division also regulates construction dewatering activities. During excavation, if groundwater is encountered, it may need to be discharged into groundwater or surface water. This will require a certification under the Construction Dewatering (CDW) general permit. Generally, Excavation Contractors are aware of this permit and will include the cost of obtaining this permit in the cost of facility construction. The State of Colorado has a guidance document addressing frequently asked questions pertaining to Construction Dewatering permits.

Step 4D. Final Electrical Inspection and Approval

Project final approval will require approval by a state electrical inspector, with the applicable inspection guidelines varying depending upon whether the project is net metered. The State of Colorado Electrical Board has jurisdiction over the majority of the state except in local jurisdictions that have their own electrical inspection program. Larger utility scale systems will be inspected, pursuant to the National Electrical Safety Code. Smaller, net-metered systems typically will be required to ensure compliance with the most recently adopted National Electrical Code. Because of the specialized nature of a hydroelectric system, Colorado has developed alternative inspection measures.

In the case of an inverter-based hydroelectric system generating 100kw or less, Colorado HB15-1364 outlined that projects meet the the minimum standards set forth in the 2011 NEC for small wind electrical production except that subsection 694.3 and article 705 of that code do not apply.

In the case of an induction-based system generating 100kw or less, the installation of a hydroelectric turbine, induction generator, and control panel can be certified through the two methods.

1. The components and installation can be certified by a field evaluation body approved by the state electrical board or a Nationally Recognized Testing Laboratory. A list of qualified firms is included in the Appendices.
2. The components and installation can be certified by a Colorado professional engineer (PE) by means of signing and stamping documents of the project that indicate the project meets Institute of Electrical and Electronics Engineers (IEEE) standards.
    a. The State Electrical Board has created a certification form for PE's to use when approving induction-based hydroelectric facilities. This form is located on the State Electrical Board's website.

If you have any questions or concerns regarding the different methods of state electrical approval please do not hesitate to contact Chief Inspector Kye Lehr at kye.lehr@state.co.us, or Electrical Inspector Supervisor Robert Brant at Robert.brant@state.co.us.

STEP 5 Commissioning and Communication

Once a project is completed, depending on the size and type of project, it may make sense to hold some type of "flip the switch" event to thank project stakeholders, celebrate success and secure press coverage. This would help to make the project a model for others to follow. A project commissioning event and press release can help to maximize the positive publicity and extend the impact of the project.

Figure 65: "Flip the Switch" Event for Humphreys Hydro Project, near Creede, CO

Appendices

1. Legal Resources for Water Rights in Colorado

1) Citizen's Guide to Colorado Water Law prepared by the Colorado Foundation for Water Education
2) Non-Attorney's Guidebook to Colorado Water Court, Colorado Department of Natural Resources, Division of Water Resources
3) Guide to Colorado Well Permits, Water Rights and Water Administration, September 2012, Colorado Department of Natural Resources, Division of Water Resources

2. Hydrology Resources

1) USBR Water Measurement Manual
2) Colorado Decision Support System – Historic Diversion Records
3) Colorado Decision Support System – Streamflow Stations
4) Colorado Division of Water Resources – Surface Water Conditions, stream gages
5) USGS – Colorado Water Science Center – Stream Gauges

3. Topography Resources

1) USGS Topographical Maps – The National Map
2) USDA Geospatial Data Gateway – Digital Elevation Models and Aerial Photography – GIS capabilities required
3) County elevation data (Mesa County example) – GIS capabilities required

4. Head Loss Resources

1) Calculator for head loss in pipes using Hazen-Williams Equation
2) Hazen-Williams Coefficient for penstock materials

5. Turbine Manufacturers

1) Very small hydropower turbine & generators appropriate for net metering or off the grid applications.

Manufacturer	Website	Name	Turbine Type
Energy Systems and Design	www.microhydropower.com	LH1000 Stream Engine	Propeller Turgo
Asian Phoenix Resources	www.powerpal.com	PowerPal Low Head PowerPal High Head	Propeller Turgo
Harris Hydroelectric	http://www.thesolar.biz/harris_hydro.htm	Harris Turbine	Pelton
Scott	http://www.absak.com/catalog/product_info.php/cPath/33_89_91/products_id/1370	Scott Cross Flow Turbine	Cross Flow
PowerSpout	www.powerspout.com	PowerSpout PowerSpout Low Head	Pelton Propeller

2) Small Turbine Distributors:

ABS Alaskan
http://www.absak.com/

Energy Alternatives
www.energyalternatives.ca

3) Traditional turbines and generators, offering "water to wire" packages

Manufacturer	**Website**	**Turbine Type**
Small		
Cornell Pump Company	http://www.cornellpump.com/products/hydroturbine.html	Pumps as turbines
Canyon Hydro	www.canyonhydro.com	Pelton Francis Cross Flow Kaplan
Rentricity	www.rentricity.com	Pumps as turbines
Medium		
Canadian Hydro Components	www.canadianhydro.com	Kaplan Propeller Francis
Dependable Turbines LTD	www.dtlhydro.com	Kaplan Propeller Francis Turgo Pelton

		Pumps as turbines
Toshiba International	http://www.tic.toshiba.com.au/hydro-ekids__8482_/	Propeller
Pentair Tamar	http://www.southerncross.pentair.com/	Kaplan Francis Pelton
Ossberger	http://www.hts-inc.com/ossberger.html	Kaplan Movable Powerhouse (Kaplan) Cross Flow
Gilkes	http://www.gilkes.com/	Kaplan Francis Turgo Pelton
Mavel	http://www.mavel.cz/products-mainframe.html	Microturbines (propeller) Kaplan Francis Pelton
Large		
Voith Hydro	http://us.voith.com/en/products-services/hydro-power/small-hydro-power-plants-552.html	Kaplan Francis Pelton Ecoflow
Andritz	http://www.andritz.com/no-index/pf-detail?productid=9218	Propeller Francis Pelton
Alstom Power	http://www.alstom.com/power/renewables/hydro/turnkey-power-plants/small/	Kaplan Francis Pelton

4) Emerging Technologies that are new to the market or not yet commercially available or implemented in the US.

Manufacturer	**Website**	**Turbine**
Hydrokinetics		
Alternative Hydro Solutions	www.althydrosolutions.com	Darrieus Water Turbine
Hydrovolts	www.hydrovolts.com	Canal turbine
New Energy Corp	www.newenergycorp.ca	EnCurrent
Hydro Green Energy	www.hgenergy.com	Lock+ and Dam+

Hydrodynamic Screws		
Andritz	http://www.andritz.com/products-and-services/pf-detail.htm?productid=8775	Archimedean Screw
ReHart	http://rehart.de/en.html	Archimedean Screw
HydroCoil Power	www.hydrocoilpower.com	Small screw type turbine
Low Head Turbines		
Natel America	www.natelenergy.com	Hydroengine
MJ2 Technologies SAS (VLH Turbine)	http://www.vlh-turbine.com	Low Head (Kaplan)
Propeller Turbines		
Amjet	http://www.amjethydro.com/	Propeller
Clean Power	http://www.cleanpower.no/Home.aspx	Propeller
In-Pipe Turbines		
Lucid Energy	http://www.lucidenergy.com/lucid-pipe/	Vertical Axis

6. Civil Works Resources

1) Gates and Checks:

   Golden Harvest, Inc.

   Obermeyer Hydro

   Safety Gates LLC

   Waterman Industries

2) Screens and Trash racks:

   Atlas Polar Hydro Rake Systems

   Farmers Screen

   Hydro Component Systems

   Hydrolox

   Hydroscreen, LLC.

   International Water Screen

   Intake Screens Inc.

   Lakeside Equipment Corp

   Norris Screens

7. Controls Resources

Powerbase Automation Systems Inc.

Thomson and Howe Energy Systems Inc.

8. Permitting Resources

1) USACE Colorado Offices
2) State of Colorado Water Quality Certification fulfilling the requirements of the Clean Water Act Section 401
3) Pitkin County Land Use Code (Section 4-30-50 (k))
4) Construction Dewatering permits FAQ

9. Construction Costs Resources

EPRI, 2011, "Quantifying the value of Hydropower in the Electrical Grid: Plant Cost Elements", Final Report 1023140, Palo Alta, CA

10. Small Hydropower Consultants in Colorado

AECOM
http://www.aecom.com/

Applegate Group, Inc.
www.applegategroup.com

Black & Veatch
www.bv.com

Community Hydropower Consulting
970-221-4474

HDR
http://www.hdrinc.com/markets/power/renewable-energy/project-types/hydropower

Hutton Consulting, Inc.
303-908-2178
Hydrowest, Inc.
http://www.hydrowest.net/

Knight-Piesold Consulting

http://www.knightpiesold.com/en/

SGM, Inc.
www.sgm-inc.com

Telluride Energy
www.tellurideenergy.com

URS Corporation
www.urscorp.com

11. Construction Companies with Hydropower Experience

Moltz Constructors
http://moltzconstructors.com/

Mountain States Construction
http://64.146.239.120/mtstates/index.php?option=com_frontpage&Itemid=1

Gracon Corporation
http://www.graconcorp.com/

Garney Construction
http://www.garney.com/

12. Field Inspectors for Electrical Inspection

NSS Laboratories, Inc.; Fort Collins, CO – http://www.nss-labs.com/

ASC Engineering Service (ASC); Richmond, CA – www.asceng.net

Canadian Standards Association (CSA); Toronto, Canada – www.csagroup.org

Communication Certification Laboratory; Salt Lake City, UT – www.cclab.com

Curtis-Straus, LLC (CSL); Littleton, MA – 978-486-8880

FM Approvals, LLC; Norwood, MA – www.fmglobal.com

National Technical Systems, Inc. (NTS); Acton, Massachusetts – www.nts.com

NSF International; Ann Arbor, Michigan – www.nsf.org

Intertek Testing Services (ITSNA); Cortland, NY – www.intertek.com

MET Laboratories, Inc. (MET); Baltimore, MD – www.metlabs.com

Underwriters Laboratories Inc. (UL); Northbrook, IL – www.ul.com

Power Science Engineering (PSE); Auburn, WA – www.power-sci.com

ETI Conformity Services; Pleasanton, CA – www.eticonformity.com

13. Case Studies

I. Bear River Ranch Hydro-Mechanical Center Pivot Irrigation Project

Summary

When confronted with rising water costs and low crop yields, Bear River Ranch, located near Steamboat Springs, installed a hydro-mechanical system to power its center-pivot irrigation system. This system uses the power of falling water to directly drive and pressurize the center pivot. This eliminates the need for electricity and significantly reduces operating expenses. The turbine uses 126 feet of head and 560 gpm to produce the equivalent of 5.2 kW of power, which drives the center pivot. The $13,000 project was funded through $6,000 in support from NRCS, yielding out-of-pocket cost to the ranch of $7,000, and an expected payback of slightly more than three years.

Background

The Natural Resource Conservation Service (NRCS) encourages water conservation by supporting the conversion of flood irrigation to sprinklers and also supports renewable energy for on-farm applications. By working with the NRCS for project design and financial assistance, Bear River Ranch was able to achieve both NRCS goals. A center pivot sprinkler was chosen as the water conservation measure, which uses significantly less water than the previous method of flood irrigation. A hydro-mechanical system was installed to eliminate the energy required to power the center pivot.

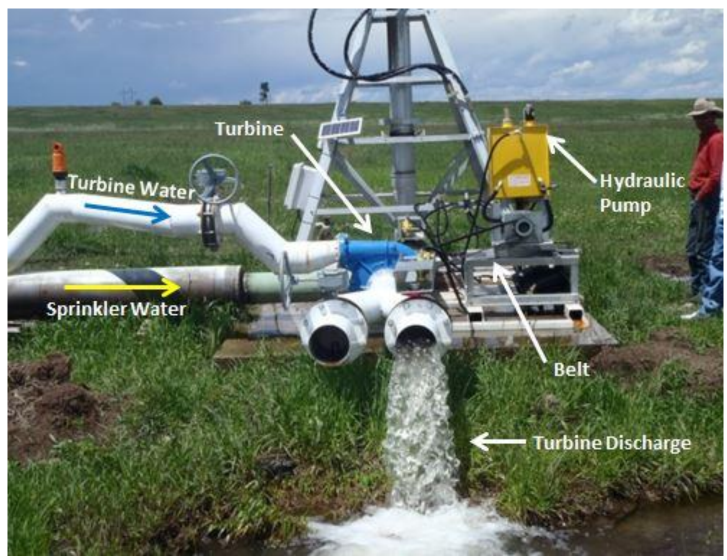


Figure 66. Key components of the Hydro-Mechanical Irrigation System

Design and Technical Details

The photograph in Figure 66 shows the key components of the system: a turbine that powers the hydraulic pump through use of a connecting belt, and water supply lines to power the turbine and provide water to the sprinklers. A single supply pipeline originates from a settling pond at a point 150 feet higher in elevation. This elevation difference pressurizes the water in the pipeline. Just before reaching the center pivot, the pipeline splits into two smaller supply pipes, as shown in Figure 66. The pressurized water powers the turbine (via the pipe denoted with a blue arrow) and supplies the sprinklers (via the pipe denoted with a yellow arrow). The turbine is attached to a shaft which drives a belt connected to the hydraulic pump. The hydraulic pump powers the drive system that moves the center pivot wheels and turns the sprinkler system.

Hydro-mechanical systems are relatively simple, so complex safety and operational procedures are typically not necessary. Because the use of hydro-mechanical systems is relatively rare, a lack of institutional knowledge has prevented their widespread use to date.

The Bear River Ranch turbine produces an equivalent of 5.2 kW or 7 HP to power the hydraulic pump on the center pivot sprinkler system. The hydraulic pump powers the drive system that turns the sprinkler, and the sprinkler is pressurized through gravity. No pumps, motors or electrical connections are required, resulting in very low annual operational expenses and minimal maintenance. Because it does not produce electricity, the project is not regulated by the Federal Energy Regulatory Commission.

The center pivot is operated only during irrigation season, with operation dictated by the crop's water demand. A T-L Irrigation hydrostatic center pivot with manual speed control was selected for the sprinkler system and a Cornell Pump (5TR5) was selected as the turbine. Cornell pumps are easily obtainable due to their dual purpose. Most pumps can be used for both pumping and as a turbine without any modification.

Construction of the hydro-mechanical system was a fast and simple process, spanning only one non-irrigation season. The center pivot distributor, B&B Irrigation, consulted with Jordan Whittaker of Two Dot Irrigation to select the turbine and design the connection. Because the turbine and hydraulic pump are belted together, their power outputs are essentially equivalent. As such, the turbine was sized to provide 7 HP or 5.2 kW, which corresponds to the power needed for proper operation of the hydraulic pump. The turbine uses a flow of 560 gpm at the available 126 feet of working head to provide the 7 HP to the hydraulic pump.

Maintenance of the system is simple. The turbine will need to be maintained the same as a pump would be, with occasional bearing greasing. The center pivot machinery and turbine generally are given a useful lifetime of 20 years, although with proper operation and maintenance, they can last much longer. Premature wear due to debris and sediment in the water is possible and could reduce the expected lifespan of the turbine, so care must be taken to adequately filter the water prior to its entry into the system.

Economics

NRCS supports the project in the design of the irrigation system and partial funding of the entire project through the Environmental Quality Incentives Program (EQIP) program. EQIP provides financial and technical assistance to farmers and ranchers for the planning and implementation of natural resource conservation efforts. During 2011, EQIP allocated more than $26 million for nearly 800 projects in Colorado. For Bear River Ranch, the NRCS grant lowered installation costs enough to make NRCS the only outside source of funding needed.

The only cost incurred that varied from that of a traditional, electricity-driven center pivot was that of the turbine. The center pivot sprinkler and pipeline costs were equivalent to traditional center pivot installations. The purchase of the turbine amounted to $13,000. NRCS contributed $6,000, making the out-of-pocket expense for the system $7,000. The system saves estimated annual energy costs of approximately $2,100. Power to spin to the center pivot alternatively could have been obtained through a diesel generator or grid interconnection, if Bear River Ranch had opted for a traditional center pivot irrigation system. However, this would result in annual fuel/electricity expenses. If electricity had been extended to the center pivot location, it would have cost $22,000. Center pivot systems using diesel or electricity would have higher installation costs and would have resulted in higher annual expenses. With the hydro-mechanical system, the initial investment by the ranch of $7,000 will be recaptured in 3.3 years of energy savings.

Lessons Learned

The project ran successfully through the 2012 irrigation season with no problems reported. It increased crop yields using less water than historically had been used with flood irrigation. Many of the ranchers in the area are expressing an interest in installing the same type of system. Some have submitted applications to the local NRCS office, which is hoping to offer design services for this type of system. Such a system potentially can be replicated throughout Colorado in areas where sufficient pressure can be generated using at least 100 feet to 150 feet of fall.

II. Town of Basalt Small Hydro Project

Summary

The Town of Basalt built a 40 kW hydro system utilizing water delivered to the town's water treatment plant that will generate an estimated 300,000 kWh annually. The project was funded through a grant from the Colorado Energy Office, as well as an innovative energy pre-purchase agreement with the local electric utility, Holy Cross Energy. Holy Cross Energy provided $300,000 to the town to pay for project construction, in return for a future repayment of 6,000,000 kWh from the project.

Background

The Town of Basalt is a small mountain community located between Carbondale and Aspen. Basalt began looking into its hydro potential due to its environmentally conscious citizenry with a long standing desire to develop the area's rich hydro potential. Basalt's Green Team, a committee of residents and elected officials, started exploring the idea of small hydro -- eventually leading to the decision to install a small hydropower project utilizing flow from two nearby springs being piped down to the town's water treatment plant.

Project Design and Technical Details

The project has a generating capacity of 40kW, generating an estimated 300,000 kWh annually at full capacity. The project utilizes water from two springs -- Basalt Springs and Luchsinger Springs -- and does not affect any stream flow. Through pipeline improvements. including slip-lining, valving and installations of ductile iron piping, the springs provide the needed flow for a small hydro project totaling approximately 2.0 cfs. The piping provides approximately 345 feet of head, yielding net pressure at the turbine of 140 to 160 psi. Based on the head and flow, a constant flow variable speed turbine was selected. The project construction timeline was approximately one year.

Two different factors drove decisions regarding the siting of the project: a desire to minimize the visual impact of the structure, and powerhouse placement to ensure maximum generating capacity. The expected lifetime of the powerhouse building is 100 years and 20 years for the mechanical equipment and controls equipment.

The Town enlisted the assistance of an outside consulting firm with experience in the design and development of similar projects. The turbine, generator and controls for the project were provided by Canyon Hydro. The equipment has been working without difficulty since project commissioning.

The town installed equipment at the powerhouse to provide warning notification of problems, providing added safety to both equipment and people. Project monitoring is tied into some of the same monitoring equipment as is used for the water filtration plant in order to lower monitoring costs.

Challenges

The biggest challenge to the project has been related to water rights, which has inhibited the project from operating at full capacity, yielding reduced annual estimated generation of 175,000 kWh. The town is pursuing additional water rights.

Project Economics

The hydro project cost was approximately $207,000 which included ancillary work. However, this cost does not include pipeline work to accommodate the pressures necessary to support the hydro, although the pipeline work would probably need to have been done anyway related to the town's water supply needs. The total cost for the project, including both the pipeline work (much of which was necessary regardless of hydro generation) as well as the hydro equipment, was approximately $394,000. Financing for the project was provided by Holy Cross Energy and the Colorado Energy Office.

The Colorado Energy Office supplied the project with $119,000 in ARRA (federal stimulus) grant funds. Holy Cross agreed to finance up to $300,000 which was scheduled to be repaid through the electrical generation of the plant, estimated at 6,000,000 kWh (for a Holy Cross Energy loan of $300,000). Electricity generated by the project is being used to pay down what is effectively a no interest loan provided by Holy Cross Energy. By having Holy Cross supply the needed money for the project's upfront construction costs, the town avoided taking out a loan, ultimately saving approximately $60,000 in interest payments (assuming a 20 year loan at 2%). The project's generated electricity will be provided to Holy Cross until the initial $300,000 is paid off, after which point the Town will retain the revenue from electricity generated by the project.

The expected payback period involved several varying factors, including annual operations and maintenance costs of approximately $1,500 annually. At maximum production, the plant is expected to generate 300,000 kilowatt hours annually. At a power purchase rate of eight cents per kilowatt hour, revenue is approximately $24,000 per year, yielding a payback of about 11.4 years -- a best case scenario based upon maximum annual generation. The town anticipates that the actual payback period may be closer to 20 years, based on annual generation of 175,000 kWh.

Lessons Learned

Perhaps the most important part of the success of the project was the town's partnership with Holy Cross Energy, without whose assistance the town probably could not have completed the project. This underscores the importance of effective partnerships to project success. In addition to Holy Cross Energy and the Colorado Energy Office, additional project partners included Boundaries Unlimited, Western Pipeway, Teagle Excavating and Martinez Western Construction.

One of the principal project barriers was federal permitting. Basalt's project moved through the FERC permitting process with extensive assistance from the Colorado Energy Office FERC streamlining program. However, based on the town's experience with the costs and time required to comply with FERC requirements, it was decided that it would be best to wait until pending federal small hydro permitting reform legislation becomes law before seeking to proceed with any additional small hydro projects.

III. Wenschhof Hydro Project

Summary

The Wenschhof project in Rio Blanco County is a 23 kW small hydropower project that utilizes water historically used for irrigation to produce power that offsets the electricity consumption of a water-saving irrigation sprinkler. This low impact project provides a rural Colorado rancher with new revenue in the form of electricity savings.

Background

Prior to the Hydropower Regulatory Efficiency Act of August, 2013, the FERC permitting process for hydropower projects was complex, expensive and prohibitive for developing a small hydro operation. In response, the Colorado Energy Office developed a Memorandum of Understanding with FERC to expedite project review. CEO essentially "stacked" multiple regulatory agency reviews to occur simultaneously, trimming the time it took to complete the pre-FERC application review from several years down to months. A single point of contact helped FERC and the other regulatory agencies know that the application

Project Technical Details:

The 23 kW project is located near Meeker, Colorado. It cost approximately $140,000 to build and yields annual generation of approximately 100,000 kWh.

Lessons Learned

The rural rancher had a great idea to use existing water power on his own property to power his entire ranch, but he needed help to determine whether his project was economically viable. Colorado Energy Office (CEO) used financial modeling tools to help the rancher understand that his project was economically viable.

Once the project was viable, the rancher needed assistance to counter a small, rural bank's resistance to a renewable energy project loan. The bank lacked experience with renewable energy projects and was reluctant to move forward without credible information. CEO talked to the rancher's bank to answer project questions, which helped to secure the needed construction financing.

As a result of CEO support, the project received a conduit exemption from FERC in about two months, and the rancher will be able to offset 100% of his electrical load – a success which can be replicated.

14. Sample FERC Exemption Application and Project Diagram

BEFORE THE FEDERAL ENERGY REGULATORY COMMISSION

NOTICE OF INTENT TO CONSTRUCT QUALIFYING CONDUIT HYDROPOWER FACILITY

INTRODUCTORY STATEMENT

[*Applicant Name*] applies to the Federal Energy Regulatory Commission for a determination that the [*Facility Name*] is a Qualifying Conduit Hydropower Facility, meeting the requirements of section 30(a) of the Federal Power Act (FPA), as amended by section 4 of the Hydropower Regulatory Efficiency Act of 2013 (HREA).

The location of the facility is:

State or Territory: ______________________
County: ______________________
Township or nearby town: ______________________

Water source: ______________________

The exact name and business address of the applicant(s) is:

Applicant's Name: ______________________

Address: ______________________

____

Telephone Number: ______________________

Email Address: ______________________

The exact name and business address of each person authorized to act as agent for the applicant(s) in this notice of intent is:

Name of Agent: ______________________
Address: ______________________
____

Telephone Number: ____________________

Email Address: ____________________

[*Name of Applicant*] is [*a citizen of the United States, an association of citizens of the United States, a municipality, State, or a corporation incorporated under the laws of (specify the United States or the state of incorporation), as appropriate*].

NON-FEDERAL CONDUIT

The [*Facility Name*] will use the hydroelectric potential of a non-federally owned conduit.

ORIGINAL PROJECT

The [*Facility Name*] has not been licensed or exempted from the licensing requirements of Part I of the FPA, on or before August 9, 2013, the date of enactment of the Hydropower Regulatory Efficiency Act.

Project Information

[You must provide a detailed description of the proposed hydropower project and a detailed description of the conduit it will use, including the purpose of the existing conduit. The following information must be included:]

(1) A detailed description of any conduits and associated consumptive water supply facilities, intake facilities, powerhouses, and any other structures associated with the facility.

[Including, but not limited to: (1) the name of the conduit(s)or consumptive water supply facilities; (2)where the conduit(s)or consumptive water supply facilities begin (including the town, river, or reservoir); (3) the length and width or diameter (if enclosed) of the conduit; (4) the dimensions of the proposed hydropower structure and any other facilities needed for hydropower operation (i.e. intake pipes, powerhouse, turbine generating units, discharge pipes); and (5) how, where, and into what the water will discharge from the proposed power structure. If your project discharges into a natural water body, please explain how the hydroelectric project does not alter the primary purpose of the conduit.]

(2) The purposes for which the conduit is used:

[Section 30(a)(3)(C)(i) of the FPA, as amended by HREA, requires a qualifying conduit hydropower facility to use the hydroelectric potential of a non-federally owned conduit. Such a conduit means any tunnel, canal, pipeline, aqueduct, flume, ditch, or similar

manmade water conveyance that is operated for the distribution of water for agricultural, municipal, or industrial consumption and is not primarily for the generation of electricity. Specify the use of your conduit, such as irrigation, municipal water supply, or industrial uses. The primary purpose of the conduit cannot be for power production.]

(3) The number, type, generating capacity (kW or MW), and estimated average annual generation (kWh or MWh) of the generating units you are proposing, including plans, if any, for future units:

[*The installed generating capacity cannot exceed 5 MW.*]

(4) Your project must use the hydroelectric potential conduit to generate power. However, if your project is associated with any dam or impoundment, please provide a description of the nature and extent of the dam or impoundment, including a statement of the normal maximum surface area and normal maximum surface elevation of any existing impoundment before and after the hydroelectric facilities are installed. If your project involves a dam or impoundment, you must provide a profile drawing showing that the conduit, **not the dam**, creates the hydroelectric potential for the project. You must also provide **evidence that the dam or impoundment would be constructed or continue to exist for agricultural, municipal, or industrial consumptive purposes, even if the hydroelectric generating facilities were not installed**:

Existing Preliminary Permit or Permit Application Pending

If you have a preliminary permit for the facility or have applied for a preliminary permit, please provide the permit number below.

P-________________

Drawings, Maps, Diagrams

Include a set of drawings/maps/diagrams clearly showing the structures and equipment of the hydropower facility in relation to the existing conduit. Project drawings of the project must include:

- *A Plan View (overhead view) drawing of the proposed hydropower facilities. The drawing must include the following:*

- *The hydropower facilities, including all intake and discharge pipes, and how those pipes connect to the conduit*
- *The portion of the conduit in proximity to the facilities on which the hydroelectric facilities will be located*
- *The dimensions (e.g. length, width, diameter) of all facilities, intakes, discharges, and conduits*
- *Identification of all facilities as either existing or proposed*
- *The flow direction labelled on intakes, discharges, and conduits*

- *A Location Map showing the facilities and their relationship to the nearest town. The map must include the following:*

    - *The powerhouse location labeled, and its latitude and longitude identified*
    - *The nearest town, if possible, or other permanent monuments or objects, such as roads or other structures, that can be easily noted on the map and identified in the field*

- *If a dam or impoundment is associated with the facility, a profile drawing showing the conduit, and not the dam or impoundment, creates the hydroelectric potential.*

VERIFICATION

You must provide verification in one of the following forms:

Either a sworn, notarized statement, which states:

1. As to any facts alleged in the application or other materials filed, be subscribed and verified under oath in the form set forth below by the person filing, an officer thereof, or other person having knowledge of the matters set forth. If the subscription and verification are by anyone other than the person filing or an officer thereof, it shall include a statement of the reasons therefore.

    This (notice of intent to construct, etc.) is executed in the:

    State of: ______________________

    County of: ______________________

    By: (Name) ____

(Address)____

being duly sworn, depose(s) and say(s) that the contents of this (notice of intent to construct, etc.) are true to the best of (his or her) knowledge or belief. The undersigned applicant(s) has (have) signed the (notice of intent to construct, etc.) this ________ day of ______________, 20____.

By:____

Subscribed and sworn to before me, a _____________________________ [*Notary Public, or title of other official authorized by the state to notarize documents, as appropriate]* of the State of _________ this day of _________, 20____.

/SEAL/ [if any]

____

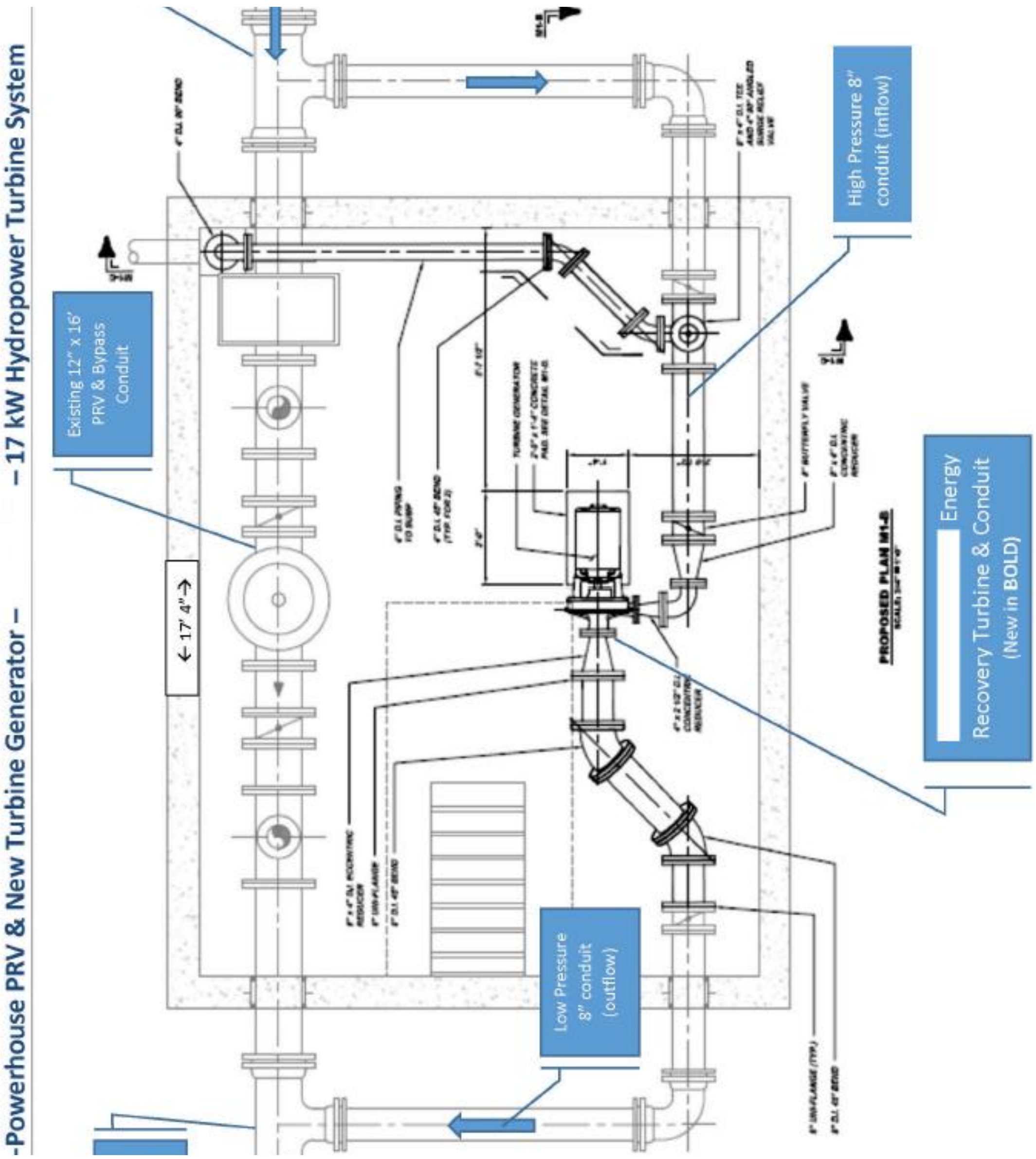
(Notary Public, or other authorized official)

Or an unsworn declaration in the following form:

2. “I declare (or certify, verify, or state) under penalty of perjury that the foregoing is true and correct. Executed on ___________________ [date].”

____

(Signature)


-Powerhouse PRV & New Turbine Generator –
– 17 kW Hydropower Turbine System
Existing 12" x 16' PRV & Bypass Conduit
High Pressure 8" conduit (inflow)
Energy Recovery Turbine & Conduit (New in BOLD)
Low Pressure 8" conduit (outflow)
← 17' 4" →
PROPOSED PLAN M1-B

15. Sample FERC Acceptance for Exemption Letter

FEDERAL ENERGY REGULATORY COMMISSION
WASHINGTON, D.C. 20426

OFFICE OF ENERGY PROJECTS

Docket No. CD13-4-000
Silverton Mayflower Mill Hydro Project
San Juan County Historical Society

November 21, 2013

Ms. Beverly Rich
San Juan County Historical Society
P.O. Box 154
Silverton, CO 81433

Subject: Determination that Project Meets Qualifying Conduit Hydropower Facility Criteria

Dear Ms. Rich:

On September 20, 2013, you filed a notice of intent, pursuant to section 30(a) of the Federal Power Act (FPA), 16 U.S.C. § 823a (2012), as amended by Section 4 of the Hydropower Regulatory Efficiency Act of 2013, Pub. L. 113-23, § 4a, 127 Stat. 493 (2013), to construct a qualifying conduit hydropower facility, the Silverton Mayflower Mill Hydro Project.

On September 30, 2013, Commission staff issued a public notice that preliminarily determined that the project met the statutory criteria for a qualifying conduit hydropower facility and thus was not required to be licensed under Part I of the FPA. The notice established a 45-day period for entities to contest whether the project met the criteria. No comments were filed in response to the notice. Accordingly, this letter constitutes a written determination that the Silverton Mayflower Mill Hydro Project meets the qualifying criteria under FPA section 30(a) and is not required to be licensed under Part I of the FPA.

If you have any questions, please contact Mr. Robert Bell at (202) 502-6062 or robert.bell@ferc.gov.

Sincerely,

Kelly Houff
Chief, Engineering Resources Branch
Division of Hydropower Administration
and Compliance

16. Contact List for Relevant Federal, State and Non-Profit Groups

American Rivers

American Rivers protects wild rivers, restores damaged rivers, and conserves clean water for people and nature. Since 1973, American Rivers has protected and restored more than 150,000 miles of rivers through advocacy efforts, on-the-ground projects, and an annual America's Most Endangered Rivers® campaign. American Rivers has historically supported effortts aimed at educating Colorado landowners interested in small hydro.

Contact
Matt Rice, Director, Colorado River Basin Program
American Rivers
1536 Wynkoop Street, Office 100
Denver, CO 80202
803-422-5244
mrice@americanrivers.org

Colorado Department of Agriculture

The Colorado Department of Agriculture (CDA) has teamed up with a variety of federal and state partners to facilite the development of low-impact small hydropower on new and existing pressurized irrigation systems.

Contact
Sam Anderson, Energy Specialist
Colorado Department of Agriculture
305 Interlocken Parkway
Broomfield, CO 80021
303-869-9044
sam.anderson@state.co.us

Colorado Energy Office

Colorado Energy Office (CEO) seeks to improve the effective use of all of Colorado's energy resources and the efficient consumption of energy in all economic sectors, through providing technical guidance, financial support, policy advocacy and public communications. Additionally, CEO aims to help Coloradoans live more prosperous and healthy lives by promoting innovative energy production and efficient energy consumption practices that are beneficial to the economic and environmental health of the state.

Contact
Michael McReynolds, Policy Advisor
Colorado Energy Office
1580 Logan St., Suite 100
Denver, CO 80203
michael.mcreynolds@state.co.us
303-866-3873

Colorado Department of Regulatory Agencies

Contact
Kye Lehr, Chief Inspector
Colorado Department of Regualtory Agencies
1560 Broadway, Suite 1350
Denver, CO 80202
kye.lehr@state.co.us,
303-894-2977

Colorado Farm Bureau

The mission of the Colorado Farm Bureau is "to correlate and strengthen the member county Farm Bureaus; support the free enterprise system and protect individual freedom and opportunity; promote, protect and represent the business, economic, social and educational interests of farmer/rancher members and their communities; and to enhance the agricultural industry in Colorado."

Contact
Chad Vorthmann, Executive Vice President
Colorado Farm Bureau
9177 East Mineral Circle
Centennial, CO 80112
303-749-7501
chad@coloradoFB.org

Colorado Rural Electric Association

The mission of the Colorado Rural Electric Association (CREA) is to enhance and advance the interests of its member electric cooperatives through a united effort. CREA provides members with education, training and information.

Contact
Liz Fiddes , Director, Member Services and Education
Colorado Rural Electric Association
5400 N. Washington Street
Denver, CO 80216
303-455-2700
liz@coloradorea.org

Colorado Small Hydro Association

The Colorado Small Hydro Association (COSHA) promotes the development of small hydropower in Colorado. It works with statewide partners to assist in developing small hydropower. Additionally, it hosts annual meetings to assist and educate interested parties, as well as provide a networking opportunity for those interested in Colorado hydropower.

Contact
Andrea Hart, Executive Director
Colorado Small Hydro Association
PO Box 1646
Telluride, CO 81435
843- 384-4782
coloradosmallhydro@gmail.com

Colorado State University Extension

Colorado State University Extension is the front door to Colorado State University providing the extensive knowledge, research capabilities and resources of the university to all Coloradans. CSU Extension aims to provide education and support to those interested in developing hydropower.

Contact:
Cary Weiner, Clean Energy Specialist

Colorado State University Extension
Campus Delivery 4040
Fort Collins, Colorado 80523-4040
970- 491-3784 office
970-980-9201 cell
cary.weiner@colostate.edu

Colorado Water Conservation Board

The Colorado Water Conservation Board (CWCB) provides policy direction on water related issues. The CWCB is Colorado's most comprehensive water information resource. The agency maintains expertise in a broad range of programs and provides technical assistance to further the utilization of Colorado's waters. In a joint effort with the Colorado Department of Water Resources (DWR), CWCB maintains the Colorado's Decision Support Systems (CDSS) database, which among other things, provides Historic Diversion Records and Streamflow Stations data. The CDSS website offers users the ability to search for diversion records using multiple criteria, such as by diversion name, water source, owner's name, and legal location. Streamflow stations can also be searched using multiple criteria, such as by station name or county.

Use of CDSS data can be helpful when estimating water availability annually or at different times of the year for potential hydropower sites. Once a potential hydropower sites has been identified and a feasibility study commissioned, the CDSS data can be extremely helpful to both developers and engineers in better understanding the site's potential with long-term and accurate flow data.

The CWCB also has a hydro loan program that can finance the engineering and construction of hydro projects with loan terms of 30 years at an interest rate of 2%. There is no maximum loan amount; however, borrowers are required to first apply to the CWRPDA for the initial $2 million of funding and the CWCB loan will the finance the remainder of the project costs.

Contact

Anna Mauss, Water Project Loan Program, Finance Section
Colorado Water Conservation Board
1580 Logan St.
Denver, CO 80203
303- 866-3441 x3224
Anna.mauss@state.co.us

Colorado Water Resources & Power Development Authority

The Colorado Water Resources and Power Development Authority (CWRPDA) is a quasi-governmental organization created by state statute to provide low cost financing for water and wastewater related infrastructure projects to municipalities and special districts. The Authority utilizes several programs to provide funding for local governments' water, wastewater, and hydropower projects including the State Revolving Fund Programs (Water Pollution Control Revolving Fund and Drinking Water Revolving Fund), Water Revenue Bonds Program, and the Small Hydropower Loan Program.

The CWRPDA offers a small hydropower loan program that can lend up to $2 million at a rate of 2% for project construction. Eligible borrowers for the CWRPDA programs include water, water conservancy and irrigation districts. Eligible projects consist of new hydropower facilities (turbines, mechanical and electrical), pipelines, necessary remodel/reconfiguration of the building housing the facilities and transmission lines. Projects must be for facilities of 5 MW or less. The CWRPDA also has a feasibility grant program that can provide up to $15,000 in 50% cost-shared funds to support small hydro feasibility studies and permitting.

Contact
Keith McLaughlin, Finance Director
Colorado Water Resources and Power Development Authority
1580 Logan St.
Denver, CO 80203
303- 830-1550, Ext. 22
kmclaughlin@cwrpda.com

Ditch and Reservoir Company Alliance

The Ditch and Reservoir Company Alliance (DARCA) is a membership organization for the benefit of all types of irrigation enterprises - ditch companies, reservoir companies, laterals, private ditches, and irrigation districts. Membership is also open to interested individuals, professionals and government/corporate organizations. DARCA's mission is "to become the definitive resource for networking, education and advocacy" for its members.

Contact
John McKenzie, Executive Director
Ditch and Reservoir Company Alliance
1630A 30th St., #431
Boulder, CO 80301

970-412-1960
John.mckenzie@darca.org

United States Bureau of Reclamation

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. Through leadership, use of technical expertise, efficient operations, responsive customer service and the creativity of people, Reclamation seeks to protect local economies and preserve natural resources and ecosystems through the effective use of water.

Contact
Ryan Christianson, Water Management Group
U.S. Bureau of Reclamation
445 West Gunnison Ave. Suite 221
Grand Junction, CO 81501
970-248-0652
rchristianson@usbr.gov

United States Department of Agriculture

USDA aims to expand economic opportunity through innovation, helping rural America to thrive; to promote agriculture production sustainability that better nourishes Americans while also helping feed others throughout the world; and to preserve and conserve our nation's natural resources through restored forests, improved watersheds, and healthy private working lands.

USDA offers several grant and loan programs that may be applied towards eligible small hydropower.

1. USDA offers the Rural Energy for America Program (REAP). Under REAP, guaranteed loans and combination grant/guaranteed loans are available to help agricultural producers purchase and install renewable energy systems. Grant funding under REAP is limited to 25% of total project costs. Loans and grant/loan combinations can cover up to 75% of total project costs. Additionally, REAP offers low cost energy audits and cost share for renewable energy feasibility studies.

2. USDA's Farm Service Agency Loans and *F*arm Ownership loans assist in purchasing or enlarging a farm/ranch, constructing or improving existing buildings, and paying for water conservation or protection measures. A small hydropower project may qualify as "improving existing buildings" as a net metered project would most certainly enhance the buildings current standing. The loan would be under the Conservation Guarantee Loan since hydropower would call under a "practice of conservation." The loan amounts fluctuate on a monthly basis anywhere from 2%-4%.

3. USDA's Operating Loans assist in purchasing equipment and pay for annual operating expenses. A small hydropower project would assist in offsetting a farm's annual electric costs, and therefore could be eligible as it would ultimately assist in paying for the operating expenses.

4. USDA's Rural Development*,* Assistance to Rural Communities with Extremely High Energy Costs provides grants and loans to be used to acquire, construct, extend, upgrade, and otherwise improve energy generation, transmission, or distribution facilities serving communities in which the average residential energy expenditure for home energy is at least 275% of the national average. Eligible entities are persons, state and local governments, and federally recognized American Indian tribes and tribal entities.

5. USDA's Renewable Energy Projects Guaranteed Loans can finance renewable energy systems, such as solar, wind, hydropower, biomass, or geothermal.

Contact
Donald Nunn
Business and Cooperative Programs Specialist
Rural Development
United States Department of Agriculture
Denver Federal Center | Building 56, Room 2300
PO Box 25426 | Denver, CO 80225-0426
720-544-2907
donald.nunn@co.usda.gov

USDA Natural Resources Conservation Service

NRCS provides technical assistance and cooperative conservation programs to landowners and land managers throughout the United States as part of the U.S. Department of Agriculture (USDA). The NRCS works with landowners through conservation planning and assistance designed to benefit the soil, water, air, plants, and animals that result in productive lands and healthy ecosystems.

NRCS created the Environmental Quality Incentives Program (EQIP) which is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of 10 years in length. These contracts provide financial assistance to help plan and implement conservation practices, including small hydropower, that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and non-industrial private forestland. Any owners of land in agricultural or forest production or persons who are engaged in livestock, agricultural or forest production on eligible land and that have a natural resource concern may participate in EQIP.

Contact
Scot Knutson, Civil Engineer
USDA Natural Resources Conservation Service
Glenwood Springs Field Office
258 Center Dr. Glenwood Springs, CO 81601
970.945.5494 x103
scot.knutson@co.usda.gov

17. Additional Reference Websites

National Hydropower Association

Low Impact Hydro Institute

End notes

[i] National Hydropower Association. *Why Small Hydro?* (http://www.hydro.org/why-hydro/)
[ii] Colorado Energy Office. *Small Hydroelectric Projects.* (http://www.colorado.gov/cs/Satellite/GovEnergyOffice/CBON/1251599988450)
[iii] For additional information see www.lowimpacthydro.org
[iv] Based upon EPA's 2012 eGRID database of Colorado existing hydropower.
[v] Colorado Governor's Energy Office. Prepared by Navigant Consulting. *2010 Colorado Utilities Report.* August 2010, p 1.