Micro-hydropower — a working example

By Greg & Bonnie Chaney

The advantages of micro-hydropower installations are often mentioned in the literature about independent energy systems, but actual examples of working installations are rarely cited. This is probably because solar power is the current high-tech trend. Meanwhile micro-hydropower installations are restricted by their unique site-specific requirements.

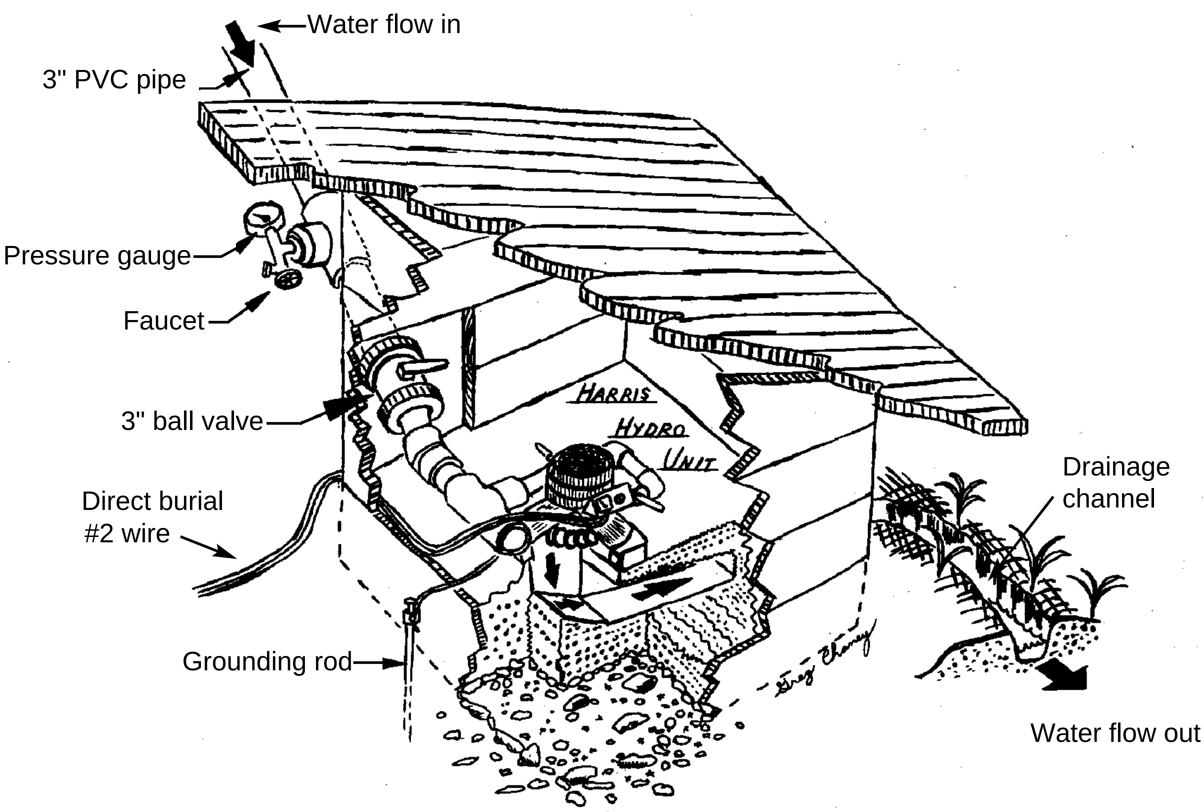
There are numerous books on the topic of how to turn running water into usable energy, so the scope of this article is restricted to the story of our own installation. Anyone attempting to install their own hydro system will end up doing things differently, because every setup must be adapted to the local terrain; but the same series of decisions will need to be made.

The vital prerequisite for hydro power is an available water supply. The climate where we live near Juneau, Alaska, is extremely wet. We average two or three sunny days per month; the rest of the time it is usually overcast with a better than 50% chance of rain or showers. In our case, one of the requirements we had when we looked for remote property was that a ready water supply be available.

Measuring potential — volume, head, & friction

We purchased a four-acre beachfront lot. There is a small beaver pond bordering the upper edge of the property. I discovered that there are several small streams which flow into and out of the pond, which means that some water can be taken from the pond without draining it. I measured the volume of water flowing in one of the streams which fed the pond during the dry season to get a feel for the potential minimum water volume.

To measure flow volume, I used a stopwatch to time how long it took to fill a five-gallon bucket. The stream had a low flow volume of about 20 gallons per minute. This turned out to be lower than the total volume of water flowing in and out of the pond because I only measured the flow of one the streams which feed the pond, but it provided a good minimum figure. During the rainy season, you would be hard pressed to hold a five-gallon bucket in the stream without it



Cut-away view of our micro-hydro power shed.

getting washed away. It is normal for water volume in streams to fluctuate wildly, so it's advisable to look at your water source during both wet and dry periods to get a feel for its seasonal dynamics.

The second critical requirement is that there must be a path for the water to run downhill to a lower elevation. The difference in elevation between where the water is taken into the systemand the hydro generator site is called "head." Hydro power systems are generally divided into high head and low head categories. Roughly speaking, anything over 25 feet can be considered high head. Low head installations can often use traditional water wheels to good advantage, but high head situations usually employ pelton wheels to gain highest efficiency.

I tried to use a topographical map to determine elevation change, but due to its scale it proved to be too crude to be useful. In order to accurately determine the elevation difference between the pond and the generator site, we used a han-held level and a 20 foot section of pipe. Although the tools were simple, we were able to measure a vertical drop of 93 feet from the pond to the generator site.

Another consideration is the distance the pipeline will run between the intake site and the point of use. In our case, the distance turned out to be around 500 feet. The pipeline distance is important because the farther water has to travel through a pipeline, the greater friction losses will be.

The amount of potential hydro power is related to how much water volume is available and how much elevation change you have. The more water you have, the more potential power you have. The same principle applies to elevation change: the greater the drop, the greater the power potential. And of course, the shorter a pipeline is, the lower friction losses will be. Perhaps the most often-overlooked additional requirement is the legal right to use water from a particular source for a hydro project.

If you have a site which meets these requirements, then comes the question: Do you have enough water and head to make it worthwhile?

Our system

In our case, we're drawing water from a pond, so we have a natural reservoir which buffers changes in stream flow. As I mentioned earlier, we have a minimum input to the pond of 20 gallons per minute, but this flow grows so high it can't be measured during the rainy season. Harris Hydro Company has put out a chart which lists the potential power available from various combinations of water volume and head. In our case, we have over 200 gallons per minute available water flow during the wet season and 93 feet of head. From the chart I figured out that we could generate about 1100 watts of continuous power.

Unfortunately, friction losses in the pipeline need to be factored in to bring things into focus. Power lost due to friction in a pipeline is something which can be compensated for by using larger diameter pipe. The larger the pipe, the lower friction losses will be. Unfortunately, bigger pipe costs more money. In our case, we bought the largest pipe we could afford, but friction losses reduced our maximum potential output to around 720 watts.

At first I was depressed by this lower output, but when I actually began to use the system I found that we got by very well with 400 watts continuous (300 kw hr/month) of power without any significant conservation effort. We have lots of lights, a VCR, computer, washer, propane dryer, stereo, and a 16 cubic foot freezer. We do have a propane range, propane hot water heater, propane dryer, and a wood stove. If we were running heating elements with electricity, we would need more power.

Our hydro system consists of several components. It starts with a six-square-foot intake screen on the edge of the beaver pond which borders the eastern edge of our property. This connects to 100 feet of four-inch schedule-22 PVC pipe which reduces to three-inch schedule-40 PVC for another 400 feet. The vertical drop from the pond to the beach is 93 feet, so the static water pressure is about 40 pounds per square inch at the bottom of the line. The end of the pipeline is near the beach by our house.

Where the pipeline ends, we have built a little shed which houses a Harris Hydro pelton wheel connected directly to a 24 volt high-output automotive alternator. This produces DC electricity, which is fed to a battery bank at the house. The battery bank consists of eight deep-cycle "Group 27" 12-volt batteries wired to produce 24 volts. The batteries are in a separate compartment vented outdoors. All positive battery cables which run out of the battery compartment are fuse protected.

We selected a 24 volt system for several reasons. Harris Hydro high output units are wired for 24 volts. 12 volt systems require thick wire to keep line losses down to a minimum. 24 volt systems transmit electricity more efficiently and therefore smaller diameter wire can be used. Trace 24 volt inverters have better performance characteristics. The only negative side to a 24 volt system is that there are very few appliances which can be run directly on 24 volts, while there are many 12-volt appliances available. In selecting a 24 volt system, we had to use an inverter to make it worthwhile. Our Trace 2460 inverter changes the DC power into standard 110 volt AC household electricity. The house is wired using standard residential components. This saved us a great deal of money over a 12-volt system, because the wire size is smaller and residential electrical components benefit from the economy of mass production.

Although the whole system sounds complicated, we received a great deal of design help from the staff at Real

Goods. The amount of electricity present in the system could be lethal or start a fire if the installation were improperly designed. I strongly recommend getting assistance from a competent source when designing an independent electrical system. You could be putting yourself and your family in grave danger if you approach the project like a big version of a car's electrical system.

Laying the pipeline

The most difficult thing by far turned out to be installing the pipeline. Everything we read concerning pipelines mentioned that burying a pipeline solves several problems including UV damage from sunlight, freeze protection, less potential damage from vandals or accidents, and stability. We decided to bury as much of the pipeline as we could, but when we asked the backhoe operator who was installing our septic tank if he could dig the trench for our hydro pipeline, he took one look at the steep, boulder-strewn, wooded slope and said, "Nope."

So we buried the lower half of the pipe by hand; the upper half lies mostly on the surface. Digging a ditch up a steep slope through rocks, roots and boulders proved to be a massive undertaking. We also installed a branch line to the house for a water supply. All in all, we spent lots of time standing in muddy ditches in the rain hacking at gnarled tree roots which were twisted between boulders.

Progress was excruciatingly slow, and there never seemed to be much to show for all the effort at the end of a day. Most of the time we measured progress in inches per hour or feet per day.

One day I was outside cutting the trench through bedrock with a pick. Our son Connor wanted me to wear a silly hat from my childhood trip to Disneyland. Well, there I was, swinging the pick for all I was worth, wearing this silly hat, and my wife Bonnie walks out. I finally had to take the hat off so she could stop laughing hysterically and get up off the ground.

Once the trench was roughed out, we put in the pipe. Even that turned out to be slow, because the PVC pipe must be dry when it's glued. So a makeshift tent had to be erected over every section before it could be glued. It is a real challenge to keep two pieces of pipe dry in a mud-filled trench in the rain! I hope we never have to do anything like that again.

Eventually came the time to pressure test the pipeline before burying it. I didn't have the proper pieces to cap the ends of the pipe to the house and the hydro shed, so I put a cap which was held on with a hose clamp on the end under the house and a plastic cap on the end by the shed site. Well, since I am going to the trouble of telling you this, you can guess what happened. The cap under the house blew off and for a little while we had a three-inch pipe blasting water into the underside of the house. It got my heart going, but there wasn't any damage and it's sort of a funny thing to look back on (although I don't ever want it to happen again). The pipeline held, and it hasn't given us any trouble so far.

Burying the pipe turned out to be almost as hard as digging the trench, because the rocks, roots and muck we had dug out of the trench all rolled to the bottom of the slope. So when it was time to fill the trench in, we had the choice of carrying the rocks back up the hill or digging more out of the ground.

System testing — ours and nature's

November 15 was the first day we were able to test the system to see if it worked. Once the "big test" showed we had a success, we were busy cleaning up the yard when Bonnie spotted a pod of killer whales right in front of our place. There were several milling around in front of our place. As we watched, they drifted north. When they were about 100 yards north of our mooring buoy, they all started swimming right for the beach. At first we couldn't figure out what they were up to, then we saw the sea lions in very close to shore. The whales definitely wanted to eat the sea lions, but the whales couldn't follow the sea lions into the shallow water. The killer whales stayed by the sea lions for at least an hour. The whales were slapping their tails, spy hopping, and nearly jumping out of the water. It was quite a show. It eventually got dark and we didn't see any sea lions eaten.

A couple of days before Thanksgiving, the weather got pretty cold (mid teens) and a north wind came up which blew 50 knots. It was blowing very hard in the early morning, so I went outside to check on things. I saw and heard a large tree fall near the pipeline. It fell because we had cut its roots on one side. By the end of the day, four trees had been blown over and I was a nervous wreck. I couldn't help but wonder if a tree was going to fall on the house. We were very fortunate that the pipeline wasn't damaged by all the roots that were torn up by all the falling trees. It is hard to describe how relieved I felt once the winds subsided.

The winds died, but it remained cold. Things started freezing hard. The shut-off valve for the hydro plant froze in the open position, but water still ran through the pipe. Eventually the bathtub drain froze too. (I've put more insulation on it since then.) Large icicles formed on all the waterfalls in the area, and an ice sheet even formed on the hydro shed floor. Although things were very cold, the bottom line was that the pipeline didn't freeze, the hydro plant still produced power, and the household water system worked fine.

We just experienced the coldest February in 15 years. Our system held up well until the last week. At that point the power output began to drop substantially. After two days of decreasing electrical output we had no power, but some water was still flowing through the pipeline.

I chopped a hole in the ice on the pond over our intake and found the screen covered with slush. Very little water was able to get through. Temperatures were near zero with sustained winds of over 30 mph. There was nothing to do but wait.

At the beginning of March, things warmed up to the 20's and low 30's. After the weather warmed up, our system turned itself back on. So a micro-hydro system can even work through a Southeastern Alaska winter, but the more insulation you have and the deeper you bury your pipeline, the better.

Cost comparisons

A word about cost. The components for our system cost us about $5000. We did all of the installation ourselves. If we'd had a contractor do the work for us, the cost would have been much higher. The biggest unexpected expense in terms of labor and money turned out to be the pipeline. This is probably the most site-specific aspect of any hydro power installation.

On the positive side, we do not have to buy fuel or listen to a generator droning away. Our friends with gas and diesel generators are constantly buying and hauling fuel and doing the required maintenance.

Our annual maintenance consists of changing the bearings and brushes, which costs about $20. If we compare our costs to electricity purchased in town, it will be 10 to 15 years before our system pays for itself. (Juneau's electricity is generated by hydro power and is relatively inexpensive.)

This comparison isn't very realistic because we don't have access to our municipal power supply. When we compare our cost to a gas or diesel generator based system, our system will pay for itself much sooner.

There are many good suppliers of independent energy products. The best supplier we found for our system was Harris Hydroelectric Systems, 632 Swanton Road, Davenport, CA 95017, 1-408-425-7652. This is a small shop that produces a good quality line of micro hydro generators and provides detailed installation information for everything they sell. Δ