Executive Summary: PA No. 12 – Micro-hydro at Graham Hill Water Treatment Plant

Description

A micro-hydro project at SCWD's Graham Hill Water Treatment Plant (WTP) would replace an exisiting non-operational hydropower turbine at the Graham Hill WTP to generate renewable energy and reduce indirect GHG emissions from purchased electricity. A portion of the source water to the Graham Hill WTP comes from Loch Lomond through the Newell Creek Pipeline. The hydraulic energy in this water from Loch Lomond could produce energy through a new hydropower turbine. Other water sources to the Graham Hill WTP do not have available hydraulic energy.

Amount of GHG Reduction

Historical and projected flow data for Loch Lomond was provided by SCWD. The micro-hydro project could offset approximately 76 MT CO_2e per year if the turbine runs with current Loch Lomond flows, generating electricity approximately 85% of the time. This project could reduce approximately 10 to 20% of the potential GHG reduction goals for SCWD.

Project Life and Sustainability

A micro-hydro project at the Graham Hill WTP would continue to provide GHG reductions for the estimated 20 year life of the project and beyond. The project would be sustained by normal routine maintenance.

Project Cost

Table ES-1 summarizes the project cost and cost per metric ton of GHG emissions reduced. Modifying the flows to run the project at a higher capacity factor of up to 85% could generate more electricity which would in turn create more revenue. With the additional revenue the benefits exceed the costs of the project, resulting in an overall net benefit which is represented by a negative lifecycle cost.

Table ES-1: Micro-hydro Project Summary

Life (yr)	Average Annual GHG Reductions (MT/Yr)	Capital Cost ($)	Average Annual Net Cost ($/Yr)	Lifecycle Energy Cost ($/KWh)	Lifecycle GHG Reduction Cost ($/MT)
20	76	$180,363	-$21,163	-$0.062	-$212

Draft Project Assessment No. 12 – Micro-hydro at Graham Hill Water Treatment Plant

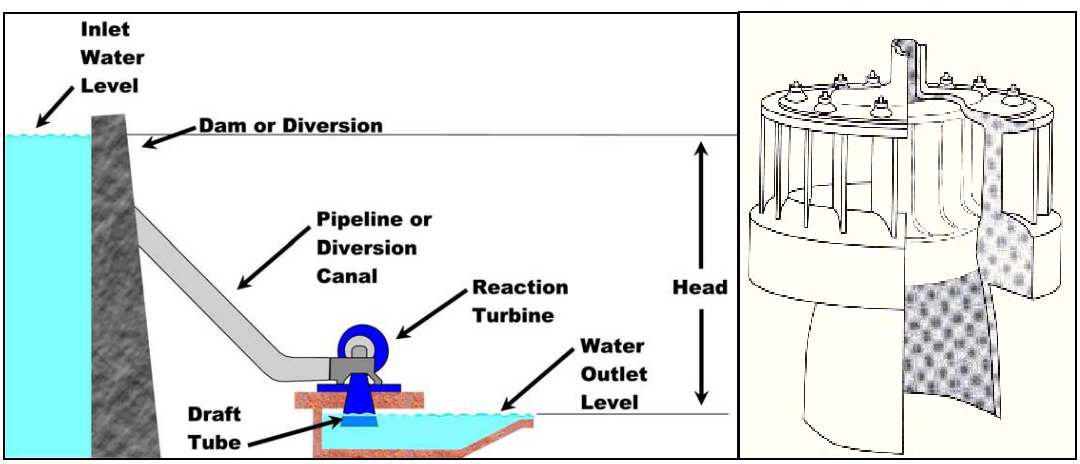
Description

This assessment estimates the energy generation and GHG reduction potential from the development of a micro-hydro project at the SCWD Graham Hill Water Treatment Plant (WTP).

Background: In general, hydroelectric power is created by converting the energy of falling or flowing water to mechanical energy which in turn can perform work such as turning an electric generator. To determine the amount of electricity from a particular site, the flow and elevation change, or head, must be calculated, and the pipeline losses must be subtracted. Given the flow and effective head at a site, one can calculate the potential kilowatts that can be generated at the site. Hydropower sizes commonly are defined as large (> 30 MW), small (< 30 MW), mini (< 1 MW), and micro (< 100 KW).

The type of turbine must also fit the site's characteristics. There are two general categories of hydro turbines – impulse and reaction. Impulse turbines, such as Pelton and Turgo turbines, are used in situations with high head and low flow. Impulse turbines derive power from the change in momentum of the flowing water as it strikes the turbine blades. Reaction turbines, such as the Francis, Kaplan, and cross-flow turbines are used in situations with low head and high flow. Reaction turbines operate by harnessing reactive forces of the flowing water. Reaction turbines can be utilized in situations with heads as low as 2 feet but require much higher flow rates than impulse turbines. Because of the low head at Graham Hill WWTP the turbines in this assessment are reaction turbines, similar to the existing turbine previously installed at this location. Figure 1 below shows a general reaction hydro turbine installation and a cut away picture of a hydro turbine.

Figure 1: Typical Reaction Turbine System and Cut-away View of a Reaction Turbine



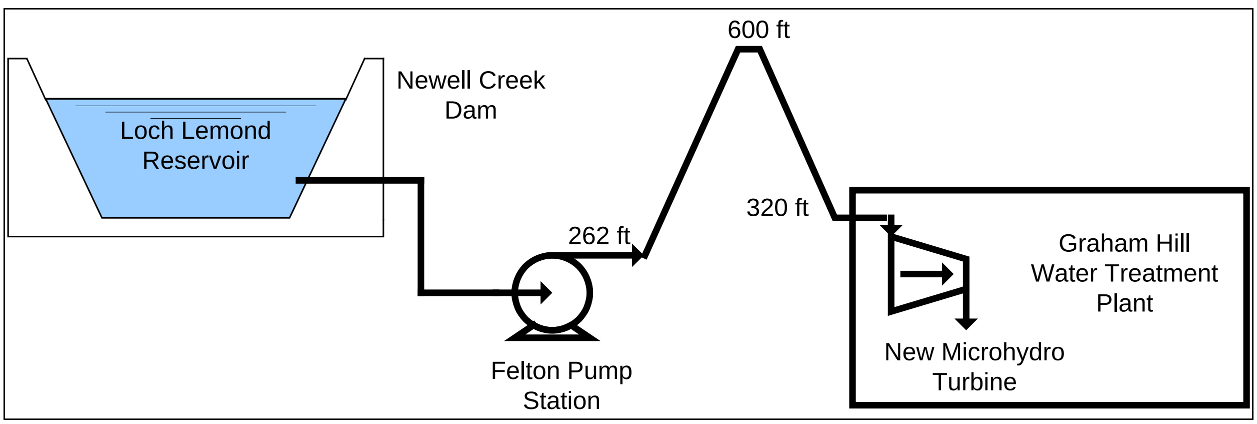
Sources of water to the Graham Hill WTP: The Graham Hill WTP receives surface water from the SCWD North Coast Diversions, from the San Lorenzo River, and from the Loch Lomond Reservoir. Water from the North Coast and San Lorenzo River diversions is pumped up to the Graham Hill WTP and does not have available hydraulic energy. Water from Loch Lomond flows through the Newell Creek Pipeline, with assistance for the Felton Booter Pump Station, and arrives at the Graham Hill WTP with approximately 260 feet of head, or hydraulic energy. See Figure 2 below.

While water from Loch Lomond has available hydraulic energy, the water in Loch Lomond is an important part of the SCWD system for drought supply and meeting habitat conservation requirements, and diversions from Loch Lomond to the Graham Hill WTP are limited to approximately 1,000 million gallons per year.

Previous Micro-Hydro Installation at Graham Hill WTP: A micro-hydro reaction turbine was installed at the Graham Hill WTP in 1987 and operated for over 20 years until 2008. Discussions with SCWD personnel indicate that the turbine operated satisfactorily but was not able to handle variable flows and had become inefficient. When a solar PV array was installed on the roof of the plant in 2008, PG&E requested a change in the connection wiring to meet current interconnection guidelines, and the turbine was disconnected to prevent a delay in the solar system coming on-line.

Figure 2 shows a schematic of the Graham Hill WTP source water system, including the micro-hydro turbine. Water is drawn from the Loch Lomond Reservoir through the Newell Creek Pipeline and the Felton Pump Station, where it is pumped over a hill to the Graham Hill WTP.

Figure 2: Graham Hill WTP Micro-hydro Turbine Supply Arrangement



The non-operational turbine is a Cornell Model 6TR3-F10X and appears to be oversized for the average amount of water passing through the Newell Creek Pipeline. The design point of this turbine was 3.9 mgd and 260 feet of head. Currently the average flow at the Graham Hill WTP from Loch Lomond through the Newell Creek Pipeline is about 1.3 mgd. The average of the annual permitted diversion from Loch Lomond is approximately 2.7 mgd.

Figure 3 shows the projected flow for the Newell Creek Pipeline for 2012. Both historical data and flow projections, with monthly flow from 2006 to 2031, were provided by SCWD for this analysis. In addition to the flow projection data, probability distributions were provided showing the likelihood of a particular flow rate over the course of a year. Probability data was provided for 2015 and 2030 both with and without desal.

Figure 4 shows the average monthly flow from Loch Lomond. A new turbine in the Newell Creek Pipeline would be sized to better recover energy from the flow. A Cornell 4TR3 turbine can generate around 35 kW at a flow of 1.3 MGD with the available 280 ft of head. The probability data provided shows that this flow rate will be available over 85% of the time. It may be possible to add a second turbine to capture additional energy from the pipeline, but this smaller turbine would only operate a few months out of the year, during the summer.

Figure 3: Average Daily Flow – Newell Creek Pipeline, Projected for 2012

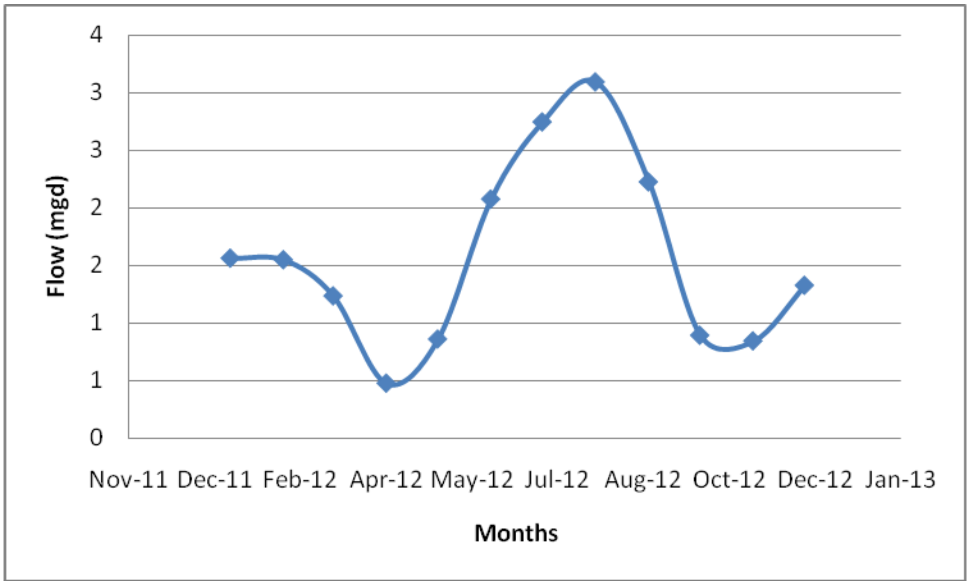
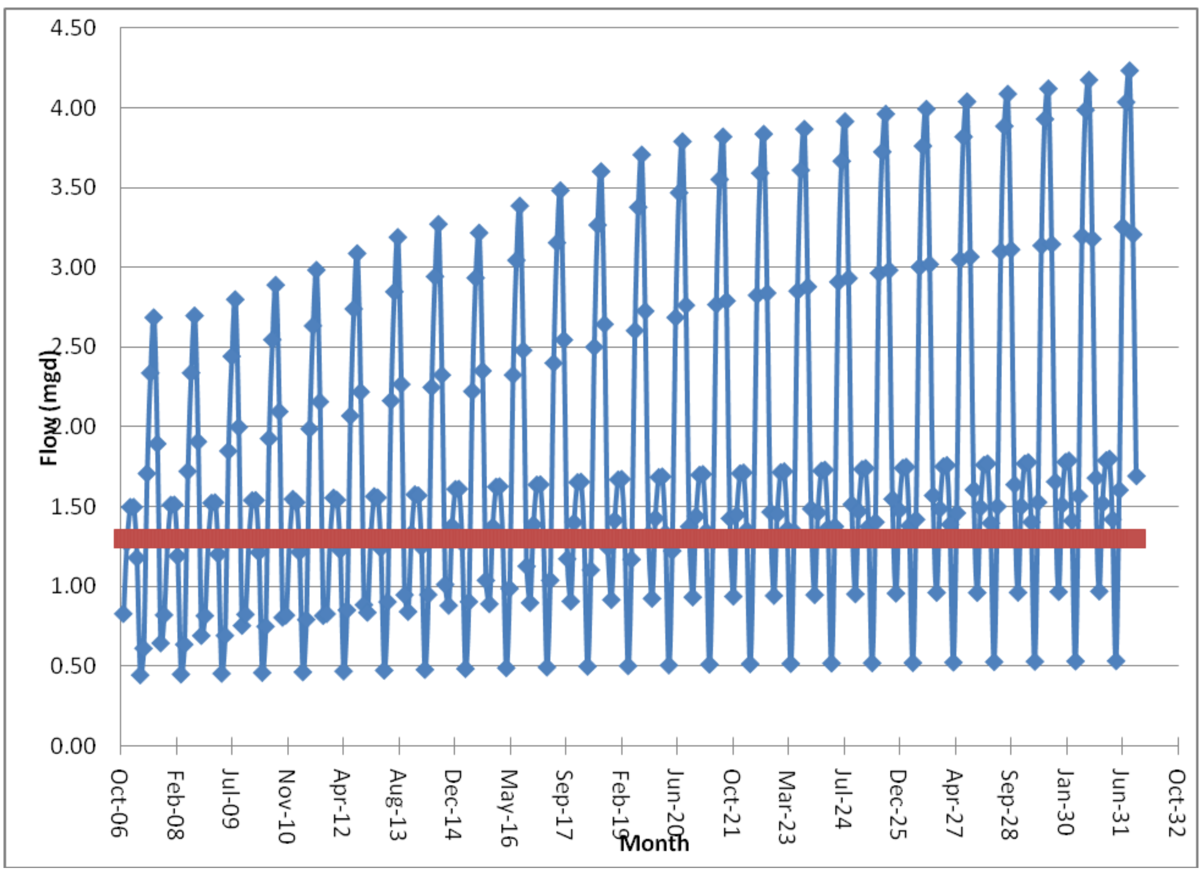


Figure 4: Average Monthly Flow – Newell Creek Pipeline, 2006 through 2032



Vendors: Many hydro turbines are custom built to precisely match the flow and head conditions expected at a particular site. Canyon Industries, a micro-hydro system manufacturer based in Deming, Washington, provides custom designed systems, as well as systems utilizing off-the-shelf turbines. Other examples of manufacturers include Dependable Turbines (Surrey, British Columbia) and St. Onge Environmental Engineering (Amsterdam, New York).

Figure 5: Example Canyon Industries Micro-Hydro Turbine

Installation: Some manufacturers provide off-the-shelf turbines that can be matched to common flow and head scenarios. These turbines are often less expensive than the custom built turbines. For example, Cornell Pump Company produces Francis turbines for heads between 30 to 700 feet and flows up to 15 cubic feet per second (cfs). Energy Systems and Design produces a small, ultra low head turbine (LH-1000) that produces power in flow conditions between 2 to 10 feet and 450 to 1000 gallons per minute (gpm). The LH-1000 can be placed in situations with only 18 inches of water above the turbine, as long as the total drop (surface of the water above the turbine to the surface of the outlet water) is 2 to 10 feet.

History and Technical Maturity

Water power has been used throughout history as a renewable resource. Hydroelectric turbines are used to provide approximately 8% of the electricity generated in the United States. California is the second largest producer of hydroelectric power in the United States, generating 33,876 megawatt hours of electricity in 2010, according to the Energy Information Administration. Independent power producers generated 1,478 megawatt hours of electricity during 2010 and many of those systems were in-pipe potable water micro-hydro systems.

Hydroelectric turbines have been used in place of pressure reducing valves in potable water systems for more than 20 years. Turbines have been placed in new installations as well as replacing pressure reducing valves in existing systems. Turbines are reliable and have maintenance requirements similar to pumps. The technology is well known and is similar to conventional hydro turbine installations.

The turbine shown in Figure 6 was installed in place of a pressure reducing valve in a potable water system near Las Vegas.

Figure 6: Example Micro-hydro Installation

Reliability and Operational Complexity

The micro-hydro system would reliably produce energy and reduce indirect GHG emissions.

Operationally, adding a new micro-hydro turbine to replace the existing non-operating system would have minimal effect on the system operations

Major design issues that would still need to be investigated include:

- Analysis to determine if additional equipment is necessary to prevent damage to the pipeline from a potential surge created by the turbine. Surges can result from a loss of utility power or malfunction in the electrical connection that causes the turbine to speed up instantaneously – a condition known as turbine runaway.
- Electrical interconnection to the grid.
- Bypass capacity available for system operation when the turbine is down for maintenance.
- Local and Federal Energy Regulatory Commission (FERC) permitting issues.

Sustainability

A micro-hydro project at the Graham Hill WTP would continue to provide GHG reductions for the estimated 20 year life of the project and beyond. The project would be sustained by normal routine maintenance.

Local Considerations

Adding a new efficient micro-hydro turbine on the flow from the Newell Creek Pipeline at the Graham Hill WTP will benefit the local community by reducing the amount of energy SCWD uses to treat potable water and will take advantage of a Non-Utilized resource.

Air: Hydroelectric turbines do not have any air emissions.

Land: Since this project involves replacing a non-operational unit with a new unit of the same function and similar size, no change or impact is anticipated.

Water: Hydroelectric turbines do not consume water or create any water pollution.

Noise: Hydroelectric turbines do produce some noise, similar to any rotating equipment. Based on other installations, placing equipment in a vault minimizes the noise to below local noise ordinance levels. Further sound proofing maybe required in areas sensitive to noise.

Aesthetic/Visual: The turbine would be placed inside the existing building and therefore no change or impact is anticipated.

Waste by-product: Some hydroelectric turbines utilize grease to lubricate bearings in the generator which will need to be disposed of properly.

Energy Production and GHG Reductions

From discussions with PG&E we infer that a new micro-hydro turbine in normal operations would not feed the grid and the generated electricity would be used on-site. However, in the instance where part of the WWTP load were to fall off electricity could flow back onto the grid. The turbine connection to the grid would be required to meet PG&E's interconnection requirements for self generation in the Net Metering Program, similar to the addition of a stand-by generator.

The turbine is assumed to operate 85% of the time based on the flow data shown in Figures 3 and 4, and the energy production values assume that the flow and head are constant through the turbine. This project could reduce approximately 10 to 20% of the potential GHG reduction goals for SCWD.

Table 1: Estimated Energy Production and GHG Reductions for a Micro-Hydro Project

Flow (MGD)	Head (ft)	Max kW	Annual Energy Produced (kWh/yr)	Annual GHG Reduction (MT CO_2e)
1.30	289	65.0	260,610	76

Cost

The capital cost of a micro-hydro project, including: engineering, mechanical, electrical, site development, markups, and installation is estimated at approximately $180,000. The turbine itself is expected to cost approximately $45,000, based on a typical cost of $1,300/kW for this size turbine. Operation and Maintenance cost should be similar to a pump, and average $0.005/kWh, plus about 0.1 FTE. With proper maintenance, a turbine should have a lifetime of 20 plus years.

Since there is a possibility of electricity flowing back onto the grid this assessment assumes that this micro-hydro project will use the Net Energy Metering (NEM) program. NEM applies to micro-hydro projects as long as the project is behind the meter and a maximum of 1 MW in size. Net metering is a method of metering the energy consumed and produced by a utility customer that has a renewable resource generator, and credits the customer with the *retail* value of the generated electricity. Effectively, the meter runs backwards, causing a credit with the utility. Net metering's benefit is the deferred cost of the electricity that SCWD does not have to purchase, providing the full retail value of the electricity produced (on average 15 cents/KWh). Net excess generation (NEG) beyond that month's actual usage is carried over as a credit for a 12-month cycle, but at the end of the 12-month period, any NEG is zeroed out and SCWD will not be paid for that generation. It therefore becomes important to correctly size the project so that over the course of a year the project does not create any NEG.

However, in the unlikely event that this project were to create NEG virtual net metering would allow SCWD to realize the value of the NEG. California Assembly Bill (AB) 2466 (codified as Section 2830 of the Public Utilities Code), was signed into law in September 2008 and allows a local governments & special districts to install renewable generation of up to 1 MW at one location within its geographic boundary (water service area) and to generate credits that can be used to offset the generation charges at one or more other locations within the same geographic boundary. This billing arrangement is called virtual net metering (VNM). But unlike NEM, VNM only credits the generation portion of the utility bill and the benefiting account will still pay the transmission and other utility fees. At this time, it is assumed that the energy generating facility needs to be in the same county as the benefiting account. However, in this analysis, we assumed that all of the project's generation would be used on-site.

The cost of the project and the GHG reductions are shown in Table 2 below. This table shows that running the project a capacity factor of 85% would result in a negative cost, or benefit, because the project would generate substantially more electricity thereby creating more revenue than the cost of the project.

Table 2: Estimated Micro-hydro Project Costs

Life (yr)	Capital Cost ($)	Average Annual Net Cost ($/Yr)	Lifecycle Energy Cost ($/KWh)	Lifecycle GHG Reduction Cost ($/MT CO_2e)
20	$180,363	-$21,163	-$0.0617	-$212

Summary of Advantages and Disadvantages

Advantages:

- Take advantage of a renewable resource not currently utilized.
- Lower lifecycle costs than utility power.
- Indirect GHG reductions.
- Mature, low risk, well understood technology.
- Modest FTE requirements and low impact on operations.
- Local benefit from the GHG reductions coming from within the local community.

Disadvantages:

- Modest capital expenditures.
- Uncertainty about cost and generation. Need to confirm flow and time-of-use rates, and if additional equipment is necessary due to potential surges.