Partnerships to Develop Rural Small Hydro Projects

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ABSTRACT

Successful development of a small hydro project entails the alignment of site conditions, regulation, value, risk acceptance, knowledge, and enthusiasm. Partnerships amongst parties with complementary goals can help achieve this alignment. Such a partnership was formed in rural northwestern Colorado between an Irrigation Company and a Rural Electric Coop. The shareholders of the Irrigation Company are also members of the Rural Electric Coop. This overlap creates shared goals and mutual benefits. Profits from the project are used to reduce the operation and maintenance costs of both organizations. Both organizations are incentivized to optimize operation and generation at the plant. The Irrigation Company brought the site control, knowledge of water delivery, operation and maintenance, and enthusiasm to utilize their resource. The Rural Electric Coop brought knowledge of power generation, operation and maintenance, value to the electricity, a willingness to accept risk and invest up front capital, and enthusiasm to self-generate cost-effective electricity for the membership. The project is located at the base of a piped drop on an irrigation canal. The irrigation canal traverses a mesa before dropping into a valley formed by a creek. The demands of irrigators downstream will dictate flows available to the small hydro project. A 160 kW Cross Flow turbine achieves high efficiency over the range of possible flows. The project was designed with redundancy to ensure the delivery of irrigation water regardless of the generation status. When the project is complete, it will generate consistent sustainable revenue, taking advantage of previously unharnessed energy present within existing infrastructure.

Introduction

Much of rural Colorado gets its electricity from electric cooperatives. There are 22 electric cooperatives which cover about 75% of the land area in Colorado, yet they only generate 10% of Colorado’s electricity revenue (CREA, 2017). Because of lower population densities (less consumers served per mile of line), electric cooperatives receive less revenue per mile of line than investor-owned utilities and municipal electric systems (Michalewicz, 2017). Nationwide, investor-owned utilities earn approximately five times as much revenue per mile of line than cooperatives, and municipal systems earn over seven times as much as cooperatives.

In order to make electricity affordable, rural electric cooperatives like the White River Electric Association (WREA) team up with other cooperatives to form organizations like Tri-State Generation and Transmission. WREA is one of 43 rural utilities in Colorado, New Mexico, Wyoming and Nebraska that buy power from Tri-State. Tri-State can generate less expensive electricity than the cooperatives can on their own thanks to economy of scale. However, this arrangement can make it difficult for electric cooperatives to develop local resources because so much of their budget is dedicated to purchased power. In 2016, approximately 86% of WREA’s expenditures were purchased power.

Because of the amount of land area covered by cooperatives, most of the opportunities for developing small hydropower in Colorado lie within the areas served by the electric utilities with the least financial resources to develop them; rural electric cooperatives. Despite the obstacles however, many electric cooperatives across Colorado have been developing small hydroelectric projects and are taking advantage of local renewable resources, as seen in Figure 1.

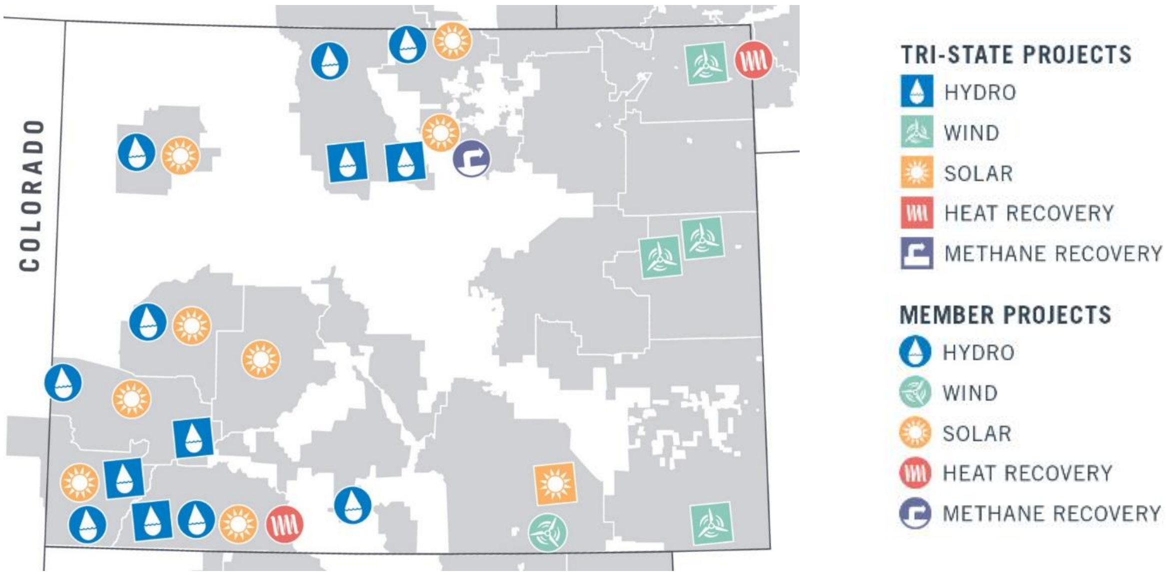

Figure 1. Renewable energy resources developed in Colorado by Tri-State and its members (Tri-State, 2016).

One such project is the Miller Creek Ditch Hydroelectric Project located about four miles south of the Town of Meeker, developed by WREA in partnership with the Miller Creek Ditch Company. The project will be operational during irrigation seasons, and will return a production fee to the Ditch Company based upon total generation. The plant will utilize water from the Miller Creek Ditch to generate about 460,000 kWh annually, which will serve electricity to the equivalent of 55 homes based on WREA's per home average of 700 kWh per month (WREA, 2017).

WREA retained Lindsay George with Small Hydro Consulting, LLC to complete the feasibility analysis and final engineering design for the project. Jeremy Wells with Wells Engineering and Craig Ullmann with Applegate Group assisted with the design as subconsultants. WREA went through a competitive bid process with several local and national contractors and selected local contractor Rock Hawg Construction. After two years of planning and preparation, WREA began construction on Miller Creek Ditch Hydro in March 2017. The project will be constructed in phases with the goal to be operational by early fall 2017.

Partnership Approach

The Miller Creek Ditch Company investigated the opportunity for hydropower at the Flag Creek Drop (the location of Miller Creek Ditch Hydro) back in 2011. Although a preliminary feasibility study showed that the project was technically and financially feasible, the Ditch Company was not in a financial position to fund or finance the cost of the project. Meanwhile, WREA was actively pursuing opportunities to self-generate cost-effective, local renewable energy.

The WREA Board established a goal of identifying local renewable generation projects that make both electrical and financial sense for WREA and its membership and is engaged in an ongoing process of studying the feasibility of potential hydroelectric facilities within its service territory. The Flag Creek Drop was one of the first sites that WREA considered for small hydropower generation; it met the Board's criteria and it assists WREA in its compliance with Colorado's renewable generation mandates.

Before approaching the Ditch Company regarding the project, the WREA Board of Directors developed a policy outlining how any renewable generation site is evaluated and considered for development by WREA. The policy outlines a phased approach:

1. WREA commissions a preliminary site assessment through an independent consultant. If that site assessment shows the site has promise, it moves on to the second phase.
2. An in-depth feasibility assessment is completed. Since WREA will be investing funds into the site, it asks that the site owner enter into an option agreement with WREA. The agreement protects WREA's initial investment by reserving the right to develop the project pending the results of the feasibility assessment. The terms of the option agreement are site- and project-dependent and are undefined until the results of the economic assessment are known.
3. If WREA decides to move forward with the project based on the results of the feasibility assessment, the terms of the agreement with the site owner are finalized and negotiations are made with impacted landowners.
4. Once the necessary contracts are in place, the project goes to final engineering design and construction.

The agreement with the Miller Creek Ditch Company for the Flag Creek Drop site resulted in a water rental fee paid to the ditch company based on the kilowatt-hours produced by the generator. A percentage of this fee must be dedicated to ditch maintenance activities, as WREA now has a vested interest in the future operation and maintenance of the ditch. Additionally, separate easement agreements were made with two property owners impacted by the construction of the project.

One of WREA's goals in developing local renewable energy is to generate cost-effective electricity from local resources while keeping as much of their expenses and revenue within the membership community as possible. This project will allow WREA to generate electricity below their wholesale costs in the long term, while supporting local contractors for the construction of the civil works and returning a portion of the revenue to the local Ditch Company.

Technical Overview

Site Conditions

The right to divert water through the Miller Creek Ditch was granted in 1896.The Ditch was originally constructed by the Miller Creek Ditch Company from 1898 to 1903. It starts at a diversion point on the White River just upstream of the confluence with Miller Creek and extends approximately 15 miles westward where it crosses Flag Creek about four miles south of the Town of Meeker, Colorado. Near the end of the ditch, there is a piped section where the ditch drops approximately 93 vertical feet before it crosses over Flag Creek. The Miller Creek Hydro powerhouse is located along the bottom portion of this piped section as shown in Figure 2.

By partnering with the Miller Creek Ditch Company, WREA gained access to a water right that dates back to 1896 and a pre-existing ditch to convey water from its natural source to the penstock intake. WREA did file a junior water right with the Colorado Water Court to become a party with standing in any future water right related actions that may impact diversions from the White River. Although the project will only utilize existing irrigation diversions for power generation and will not increase diversions from the White River solely for the purpose of power generation.

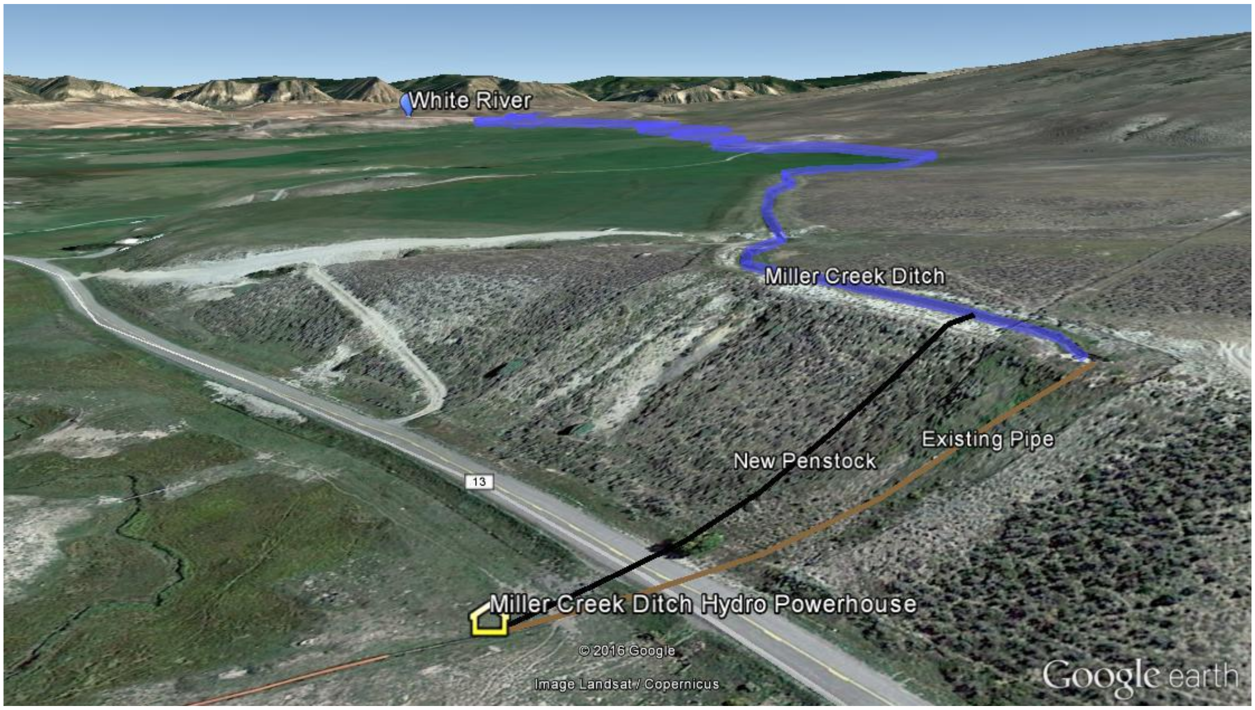

Figure 2. Schematic of the Miller Creek Ditch Hydro Project.

Intake, Penstock, and Emergency Bypass

The existing piped drop was left in place to be used as an emergency bypass. A new penstock was installed, and a new spillway structure and penstock intake were constructed in the Ditch upstream of the intake to the existing piped drop.

The design flow of 30 cfs was based on input from the ditch operator and from ratios of the recorded flow rates at the diversion from the White River 15 miles upstream, since flow records were not available near the drop. The spillway structure was designed to overflow at 30 cfs so that flows exceeding 30 cfs continue down the ditch and enter the emergency bypass, which is the pre-existing 30-inch-diameter steel pipe.

30-inch pipe diameter was selected for the penstock based on a long-term revenue analysis. Since the penstock length is relatively short at only 360 feet, the system was able to be designed with very low headloss (approximately 3% of the total available head at design flow) without excessively increased construction costs. HDPE was selected for the penstock material based on economic and other factors. HDPE pipe is very durable and corrosion resistant, exhibits very low friction resistance, provides flexibility for easy installation and field alignment, and has very high fatigue resistance, making it an excellent choice for penstocks where significant surge pressures can occur (PPI, 2009).

Powerhouse and Tailrace

Geotechnical studies in the area of the powerhouse indicated very weak soils with an estimated bearing capacity of 800 pounds per square foot (psf). Another challenge was that, due to easement restrictions, the turbine tailrace had to discharge into the pre-existing pipe. The pre-existing pipe was installed on the ground surface and could not be lowered because it crosses over Flag Creek just downstream of the powerhouse location. So this meant that the powerhouse finished floor elevation would be around five feet above natural grade.

In order to address the potential for differential settlement, a foundation slab was designed to distribute the building and equipment loads across the footprint of the powerhouse. Anchor blocks were constructed on top of the slab for the turbine and generator. It was preferred to keep the powerhouse floor at one level for ease of access and maintenance, so structural foam was placed on the remaining portion of the foundation slab, and floating slabs were placed on top of the foam at the finished floor elevation. The foam used was Foam-Control EPS39 Geofoam with a density of only 2.4 pounds per cubic foot (pcf) and a compressive resistance of 2,160 psf at 1% deflection. The structural foam allowed the powerhouse floor to be at a single level five feet above natural grade while reducing the amount of structural fill material that had to be imported and addressing the risk of differential settlement.

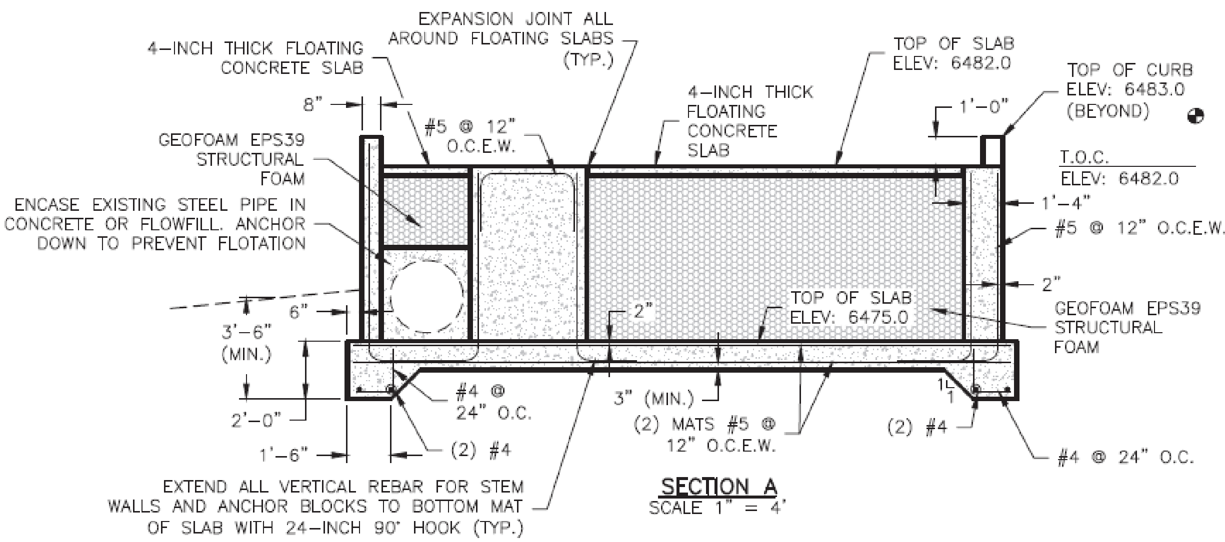

Figure 3. Powerhouse foundation section showing bypass pipe, turbine block, and structural foam.

Turbine Selection

A Crossflow turbine was selected for this project so that a single turbine could operate with relatively high efficiency over the expected range of flow. The Crossflow turbine is named for the way the water flows across the runner. Crossflow turbines can maintain good efficiency over a range of flow from as little as 1.5 cfs up to 175 cfs, making them well-suited for seasonally fluctuating flow sources such as irrigation canals. Further, due to their self-cleaning design and standardized componentry, they require very little maintenance and are expected to operate efficiently for at least 40 years (CEO, 2015).

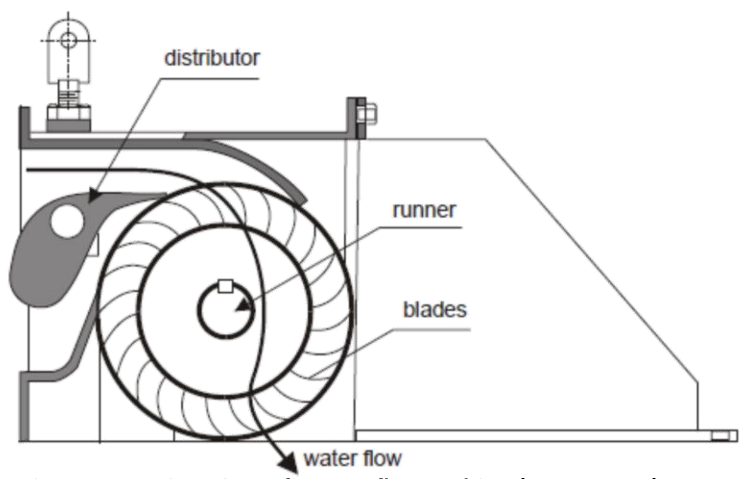

Figure 4. Section view of a Crossflow turbine (ESHA, 2004).

Although technically classified as an impulse turbine because it is not entirely immersed in water, the Crossflow turbine is typically used in relatively low-head, high-flow systems (Canyon, 2014). The water passes through a large, rectangular opening to drive the turbine blades, in contrast to the small, highpressure jets used for Pelton and Turgo turbines. The good efficiency over a large range of flows is obtained by altering the operation of the inlet guide vanes; flow can be directed at just a portion of the runner during low flows, or the entire runner during higher flows. The wide range of heads and flows applicable to Crossflow turbines overlaps that of Kaplan, Francis, and Pelton turbines.

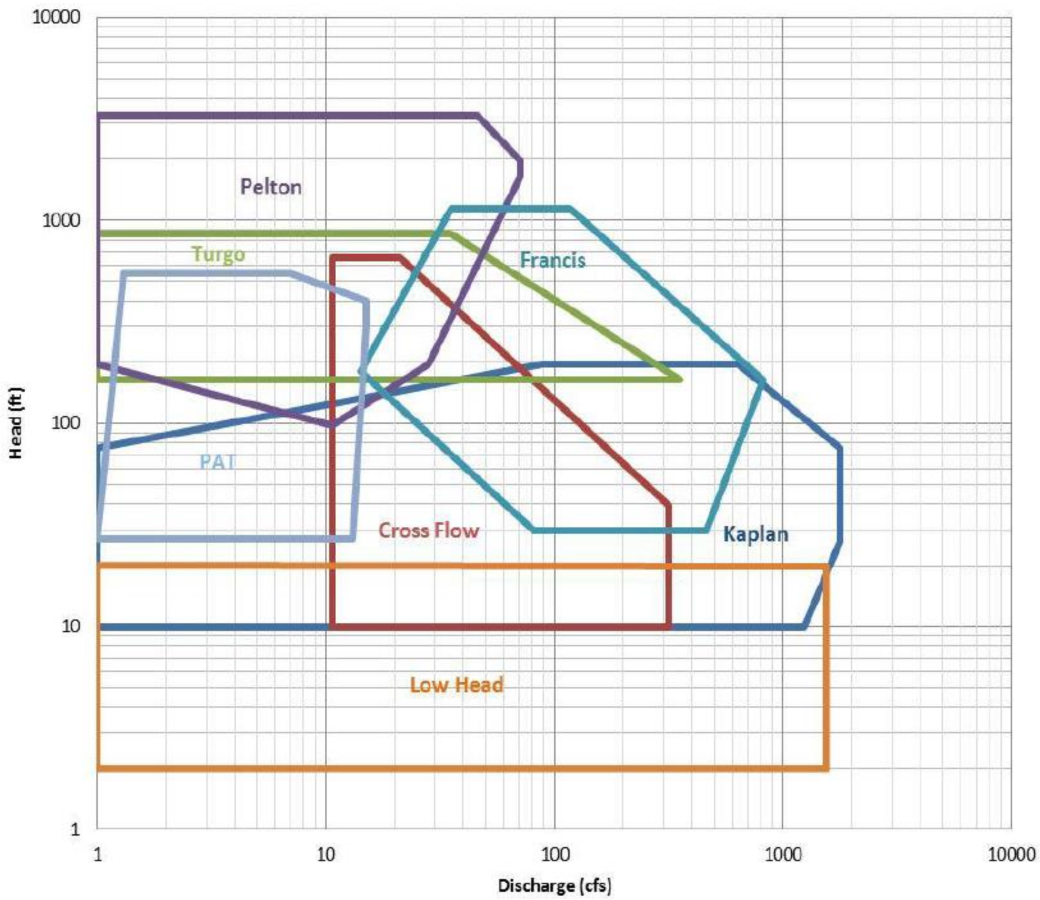

Figure 5. Typical operating ranges of various types of turbines (CEO, 2015).

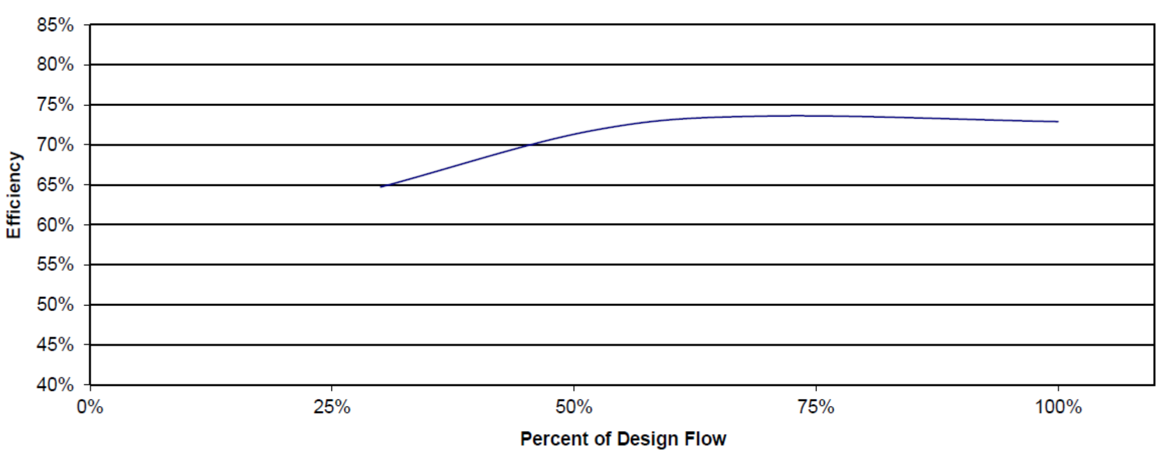

Figure 6. Combined efficiency for Miller Creek Ditch Hydro turbine-generator, supplied by Canyon Hydro.

Cost and Schedule

The total cost of the project is approximately $800,000 including design, permitting, easements and construction. WREA was awarded a grant from the United States Department of Agriculture through the Renewable Energy Assistance Program (REAP) for $177,725. The Colorado Energy Office and Colorado Department of Agriculture also contributed $40,000 towards the development of the project. The resulting net cost to WREA is approximately $3,600/kW.

A rough timeline is provided in Figure 7 showing a total development time of approximately two and a half years. While this project may not impress many by its speed of completion, it is a testament to the benefit of farmers and electric cooperatives partnering together with a common vision. As was said even before this project added the benefit of hydropower to the ditch, "The strong determined people who dreamed the dream and fought the battle to build the ditch can be proud that it remains an impact industry for Meeker and Rio Blanco County" (Herald, 2010).

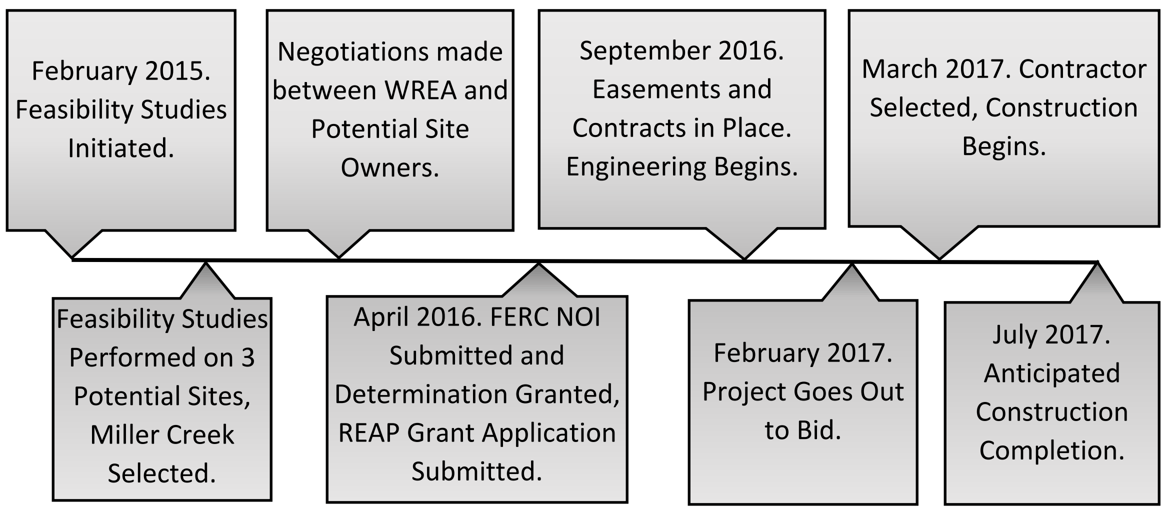

Figure 7. Timeline of Project Development.

Colorado Small Hydro Potential

A study performed by the U.S. Department of Energy identified over 4,000 potential small hydropower sites in Colorado (DOE, 2004). The study used digital elevation models and GIS to analytically assess the power potential of individual stream segments. The study stated that "no aspect of the feasibility of developing these potential resources was evaluated." Most likely, economic and regulatory restraints prevent most of these sites from being possible to develop.

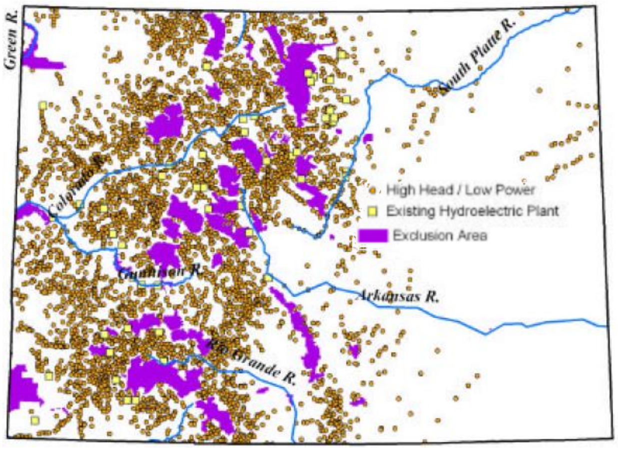

Figure 8. Potential "water energy" sites (DOE, 2004).

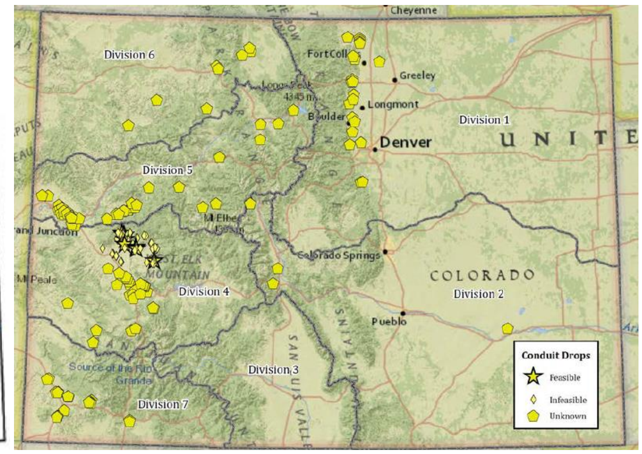

Figure 9. Potential ditch drop sites (AG&TE, 2013).

However, there is great potential for developing cost-effective small hydro in Colorado by utilizing existing agriculture-related infrastructure. A report completed for the Colorado Department of Agriculture assessed three such types of infrastructure; pressurized irrigation systems, existing dams, and ditch drops. The assessment analyzed ditches with flows of over 100 cfs or drops of at least 150 feet and identified approximately 123 potential project sites at ditch drops statewide, as shown in Figure 9 (AG&TE, 2013). An earlier study indicated that typically 14% of drops are piped drops like the one at Miller Creek Ditch Hydro.

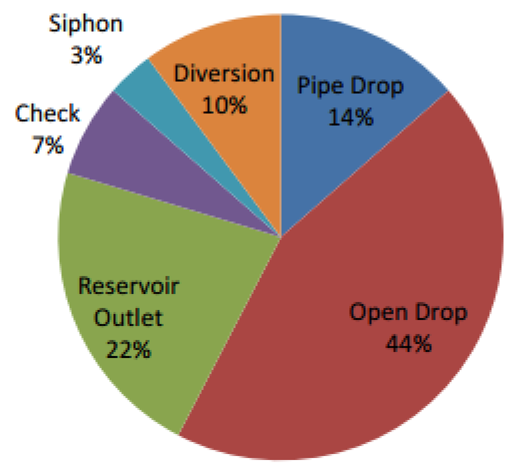

Figure 10. Typical distribution of Colorado canal drop structure types (AG, 2011).

As a final note, it is estimated that cooperatives own less than 2% of small hydropower plants in the United States in terms of number of plants, and less than 0.5% in terms of total power capacity (Hall, 2006). As more of the potential large hydro sites become developed, and as technologies for small hydropower advance, we expect to see more projects like Miller Creek Ditch Hydro become developed and increase the share of rural small hydro projects owned by cooperatives and partnerships.

About the Authors

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