

Final Technical Report

Fond du Lac Hydroelectric Project

“Recovery Act: Hydroelectric Facility Modernization”

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Executive Summary

Refurbishment of the Fond du Lac Hydro Station, which began in 2010 and was completed in 2013, faced unique challenges with changing scope and an unprecedented weather event. The refurbishment began as a generator overhaul that included rewinding the generator rotor and stator and minor repairs on the turbine runner. It expanded to include replacing the original cast iron runner with a stainless steel runner through the financial assistance of DOE funding. Associated projects included electrical infrastructure improvements, upgrading the station and dam cranes, replacing the unit headgate and sliplining the penstock. In total, Minnesota Power reinvested over \$12 million in the Fond du Lac facility.

Scope changes were primarily the result of deteriorated infrastructure identified as equipment was disassembled and closer inspections took place. Most significant was corrosion found in the 18-foot diameter steel penstock, which was ultimately replaced with a new 16.5-foot diameter penstock. As plans for the penstock refurbishment were underway, the area was hit with heavy rains and flooding that further affected construction progress.

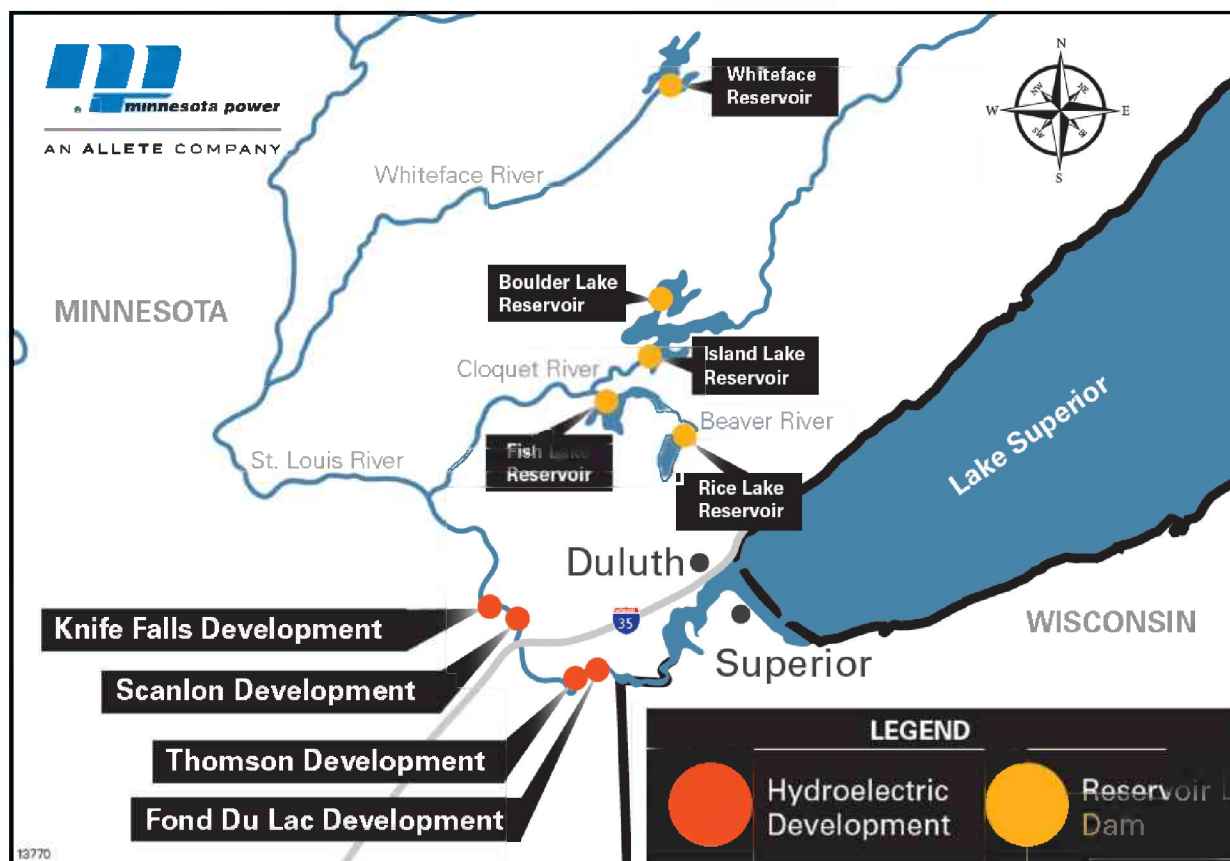
The construction added significant economic benefits to the regional economy. The stimulus project alone employed more than 30 tradespeople working over 20,000 labor hours and used more than 25 tons of American steel.

It is anticipated the refurbishment at Fond du Lac will produce an additional 6,000 megawatt-hours of renewable electricity each year, 3,000 of which are a direct result of the stimulus-funded runner project.

Introduction

Minnesota Power owns and operates the largest hydroelectric system in Minnesota, licensed to produce 120.8 MW of electricity. The St. Louis River Hydro Project is the Company's largest, licensed by the Federal Energy Regulatory Commission (FERC) to produce 87.6 MW of electricity. It is located along the St. Louis, Whiteface and Cloquet Rivers with its headwaters north of Duluth, Minnesota. The St. Louis River Hydro Project consists of nine separate developments, including four generating stations and five headwater reservoirs as shown in Figure 1. The Fond du Lac Development is the most downstream development of the St. Louis River Hydro Project.

Figure 1. St. Louis River Hydro Project Map



The individual developments within the St. Louis River Hydro Project were developed in various years between 1905 and 1924. The Fond du Lac Hydroelectric Development was constructed in 1923 to 1924. The powerhouse contains a single 12-megawatt generating unit,

which was originally equipped with a Francis turbine operating under approximately 78 feet of head. Figure 2 is a photo of the Fond du Lac Development showing the dam and powerhouse.

Figure 2. Fond du Lac Hydroelectric Development



Through normal operation, the performance of this unit had degraded and was scheduled for an overhaul in 2010-2011. The \$3 million overhaul plan focused on electrical improvements (rewinding the generator rotor and stator and replacing the generator excitation system) with mechanical rehabilitation to be completed as needed. Anticipated mechanical refurbishment consisted of replacing worn items (e.g., bushings, bearings and seals), smoothing out rough spots on the turbine runner, and painting the turbine with epoxy paint.

However, with the funds from the American Resource and Reinvestment Act (ARRA), Minnesota Power expanded the mechanical portion of the project from refurbishment of the existing turbine equipment to replacing the original cast iron runner with a state-of-the-art stainless steel runner and refurbishing the original wicket gates. It was estimated that these additional mechanical upgrades would increase annual electrical energy production by approximately 3,000 megawatt-hours (MWh), which is about a 6 percent increase from the

approximately 50,000 MWh normally produced annually. The expanded scope of the overhaul increased the cost of the project by about \$2.5 million, with \$815,995 of the additional cost recovered through a grant from the Department of Energy (DOE) ARRA grant.

In addition to the overhaul work, Minnesota Power completed electrical infrastructure improvements (including significant arc flash safety improvements), replaced the unit headgate, installed a new 16.5-foot diameter steel penstock by sliplining it inside the original 18-foot diameter steel penstock, and upgraded the station and dam cranes. Including these additional investments, the 2010 to 2013 reinvestment in the Fond du Lac facility totaled over \$12 million.

Background

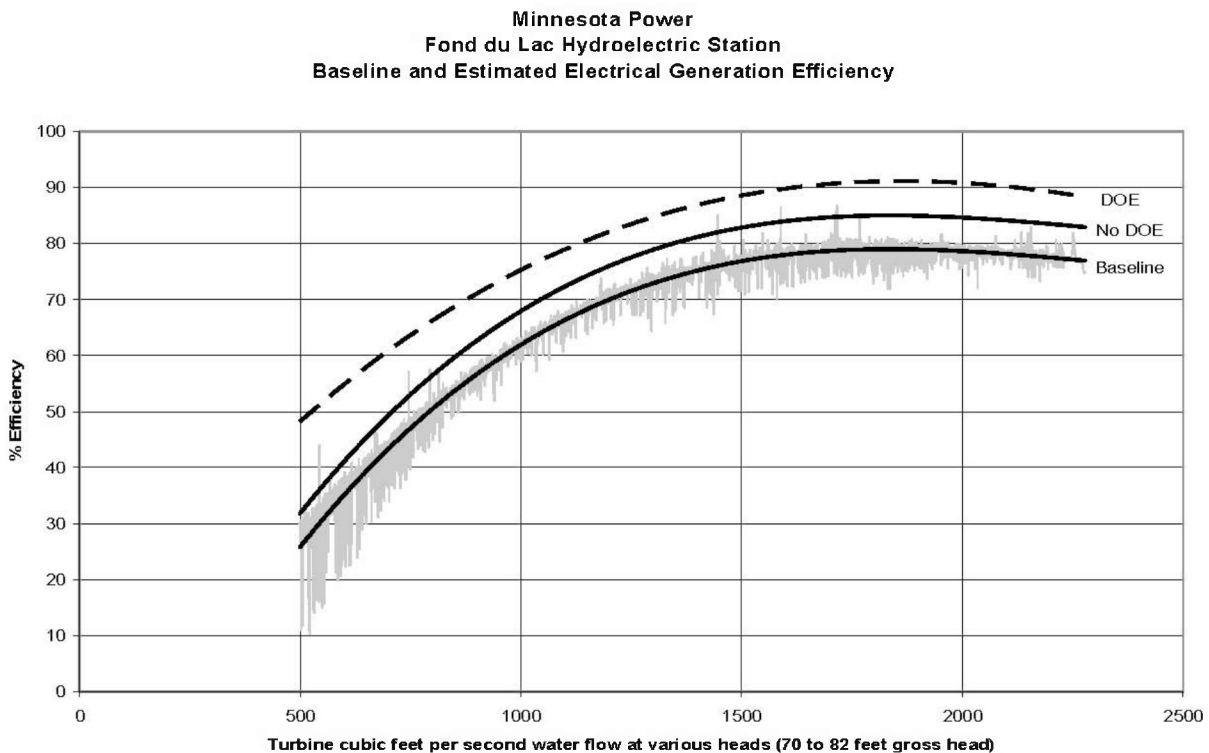
Energy Improvements

As originally planned, the overhaul did not include the runner replacement because the capital cost for the additional megawatt-hours exceeded company financial measures. The original planned refurbishment was anticipated to yield an increase of about 3,000 MWh/year (6%). Upgrading the unit by replacing the runner was anticipated to yield an additional increase of about 3,000 MWh/year for a total of 6,000 MWh/year (12%).

Operating data from 2008 was used to establish the efficiency for the Fond du Lac generating unit, shown in Figure 3 as the performance curve labeled “baseline.” Minnesota Power used the same operating data to estimate increases in generation post refurbishment with the DOE funds and without the DOE funds and develop the performance curves labeled “DOE” and “No DOE,” also shown in Figure 3. Performance curves for both the original runner and new runner are included in the appendix.

The station megawatt-hours production for the last 10 years was averaged to calculate an annual energy increase. Using efficiency improvements from the 2008 performance curves and the average annual megawatt-hours from the past 10 years yielded increases of approximately 3,000 MWh a year (6% increase) without DOE funds and approximately 6,000 MWh a year (12%) with DOE funds.

Figure 3. Fond du Lac Electrical Generation Efficiency



A license amendment for the project was not required because the unit capacity was not being increased. The project increased the amount of energy produced through efficiency gained by installing the new runner.

Grant Funding

The timing of the grant funding fit well into Minnesota Power's plans. The expanded project was "shovel ready" as the broader upgrades already had been considered but ruled out due to financial considerations, and the overhaul project was in its early stages.

Minnesota Power had applied for funding in 2009 and did not receive an award on the first review. On July 21, 2010, Minnesota Power received notification that additional DOE ARRA stimulus grant monies had become available and that Minnesota Power would receive an award of \$815,995 for the "Recovery Act: Hydroelectric Facility Modernization" of the Fond du Lac Hydroelectric Project.

Economic Impact

In total, Minnesota Power reinvested over \$12 million into the Fond du Lac facility, which included about \$2.5 million additional investment due to receipt of the stimulus funding. The stimulus project employed about 32 tradespeople, safely working over 20,000 labor hours. There were no lost-time injuries on the overhaul or any of the reinvestment projects. Most personnel were residents of the local community and all materials and support were obtained from local suppliers.

Turbine manufacture and head gate fabrication required over 25 tons of domestic steel. In accordance with the ARRA goals, the runner was made with domestic steel and manufactured by American Hydro in York, Pennsylvania (American Hydro was purchased by in November 2010 by the Scotland-based Weir Group, and is now known as Weir American Hydro).

Project Description

The project was originally planned for completion in the last half of 2011. After the grant was awarded in July 2010, Minnesota Power ordered the new runner from American Hydro for delivery in September 2011. On July 1, 2011, the Fond du Lac Hydroelectric station generating unit was removed from service and the penstock (the pipe that delivers water to the unit) was drained to facilitate the disassembly of the unit. The original runner and wicket gates are shown in Figures 4 and 5 soon after removal from the unit.

Figure 4. Original Fond du Lac Runner



Figure 5. Original Fond du Lac Wicket Gates



In conjunction with the overhaul, a thorough inspection of the Fond du Lac water conveyance system was completed. The inspection revealed significant corrosion in the penstock, necessitating major repairs before the mechanical upgrade work could be completed. Delivery of the runner was rescheduled to June 2012, and the runner was delivered on June 15, 2012, just days ahead of a damaging storm that would ultimately set back construction for months.

On June 19-20, 2012, the Duluth region experienced an extreme rainfall event of up to 10 inches, with the heaviest rains occurring in the lower St. Louis River basin. The event set a flood of record at the Fond du Lac facility, surpassing the previous record by over 30 percent, and causing significant damage to the region and Minnesota Power's hydroelectric facilities on the lower St. Louis River. Upstream from Fond du Lac, the Thomson Hydroelectric station, Minnesota Power's largest hydroelectric facility, experienced the most damage. At Fond du Lac, the powerhouse basement flooded, but overall suffered minimal damage. Near Fond du Lac, erosion and flooding severely damaged the state highway leading to the facility. Light vehicle access to the Fond du Lac facility was restored within a few weeks, but it was months before the road was passable for heavier construction equipment and material deliveries.

The penstock project was completed in February 2013, the new runner installation and unit reassembly was completed in April 2013, and after commissioning, the unit was returned to service in June 2013. Figure 6 shows the new runner as it was being installed, Figure 7 shows the refurbished wicket gate assembly, and Figure 8 is of the reassembled unit.

Figure 6. New Runner Installation



Figure 7. Refurbished Wicket Gate Assembly



Figure 8. Reassembled Fond du Lac Unit



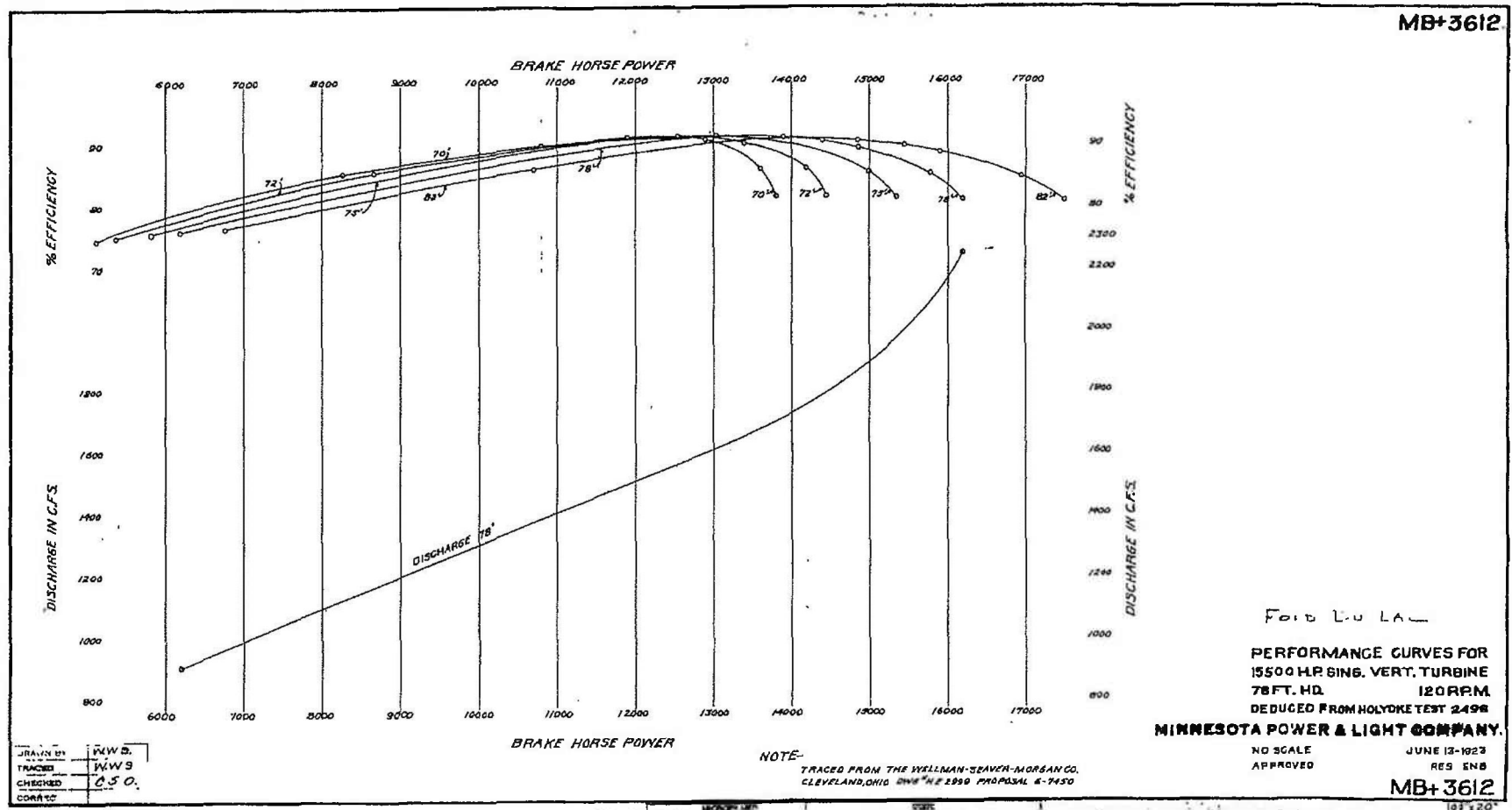
Conclusion

Although the Fond du Lac unit has been in service and performing well for over a year, we have not been able to fully confirm efficiency gains as the pond has been held lower due to impacts from the flood and reconstruction at the Thomson station upstream. In short periods of time when normal flow and pond level were available, the unit met or exceeded performance goals.

Overall, the runner upgrade and additional refurbishment position Fond du Lac to provide reliable, cost-effective renewable generation well into the future, and we anticipate our actual generation will meet or exceed estimates.

Appendices

Original (1923) Fond du Lac Runner Performance Curve



Upgraded (2013) Fond du Lac Runner Performance Curve

Fond du Lac Expected Performance
Turbine Efficiency & Turbine Discharge Vs. Turbine Output
at 75ft (22.86m) and 78ft (23.77m)

