Relicensing Bypass Flow Report

VERMONT HYDROELECTRIC RELICENSING:

INITIAL IMPACT ASSESSMENT

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September 28, 2017

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Executive Summary

At the request of the Vermont Independent Power Producers Association ("VIPPA"), this report presents the results of VHB's assessment of the impact on renewable energy generation, and corresponding increases in emissions of Carbon Dioxide to the atmosphere, that would occur due to new flow requirements that may be imposed during a relicensing process, at run-of-river hydroelectric stations in Vermont.

Numerous hydroelectric stations in Vermont, and elsewhere, are due to be re-licensed by the Federal Energy Regulatory Commission ("FERC") in the coming years. At existing hydroelectric stations, bypass flow requirements may increase during the relicensing process, based on the Vermont Agency of Natural Resources' interpretation of the Vermont Water Quality Standards.

This assessment analyzed run-of-river hydroelectric projects of different sizes that are representative of the range of most hydroelectric stations in Vermont, and thus the results can be generalized. A site-specific flow and aquatic-habitat study would be needed to determine a bypass flow requirement; for this evaluation VHB assumed these flow rates to represent a typical range of values that might result from such a study, based on experience at other sites in Vermont.

Energy generation may decrease by 5 percent to 25 percent at existing run-of-river hydroelectric stations in Vermont, due to increased conservation flow requirements that would be imposed during relicensing. According to VIPPA, there are 82 hydroelectric stations in Vermont, averaging 2.4 MW with a total capacity of approximately 200 MW, equivalent to 12 percent of Vermont electrical energy consumption. The State's Comprehensive Energy Plan (2016) requires the state to obtain 25 percent of its energy from renewables by 2025, including "*shifting toward cost-effective wind, solar, and hydroelectric power.*" If all in-state existing hydrostations were to experience a reduction in energy generation in this predicted range, the impact to VT's energy supply and renewable energy goals would be significant.

1.0 Introduction

Numerous hydroelectric stations in Vermont, and elsewhere, are due to be re-licensed by the Federal Energy Regulatory Commission ("FERC") in the coming years because many were initially approved in the late 1970's and 1980's due to the energy crisis and interest in renewable energy sources at the time; licenses which expire after 30 to 50 years will be due for renewal. As part of the FERC relicensing process, the federal Clean Water Act requires a Section 401 Water Quality Certification ("WQC") to be issued by the State where a hydroelectric project is located. In Vermont, the Vermont Agency of Natural Resources ("ANR") issues WQC's for hydroelectric projects that meet the Vermont Water Quality Standards ("VWQS"). At existing hydroelectric stations, bypass flow requirements may increase during the relicensing process, based on the ANR's interpretation of the VWQS. Bypass flows are explained below in section 2.0 of this report.

At the request of the Vermont Independent Power Producers Association ("VIPPA"), VHB assessed potential decreases in renewable energy generation, and corresponding increases in emissions of Carbon Dioxide (CO_2) to the atmosphere, that could result from an increase in the required bypass flows at run-of-river hydroelectric stations in Vermont. The CO_2 assessment was completed assuming a typical "grid mix" of power sources as a replacement for the estimated loss in hydropower.

2.0 Background Information

Vermont's goal is to achieve 90 percent renewable energy by 2050, and the State's Comprehensive Energy Plan[1] requires the state to obtain 25 percent of its energy from renewable resources by 2025, including the goal of "*shifting toward cost-effective wind, solar, and hydroelectric power*." The Plan also includes a goal to "*Maintain production levels from existing Vermont based hydro projects to the extent they comply with Water Quality Standards.*"

[1] Vermont Department of Public Service, 2016. "Vermont Comprehensive Energy Plan."

A. Run-of-River Hydropower

The term 'Run-of-River' refers to hydropower operations that allow the flow rate of a river to be the same downstream of the hydroelectric station as it is upstream, on an instantaneous basis. Run-of-river operations do not store water for later use, do not release peak flows downstream when generating, and do not draw-down impoundments to be replenished in the future. The ANR's Streamflow Procedure[2] states that "hydropower facilities shall be encouraged to operate in a true run-of-the-river mode." The Vermont Comprehensive Energy Plan, in Section 3.2, states *"Investment in dams to install or increase hydroelectric production should also maintain or enhance the hydrodynamic properties of the river."* (i.e., run-of-river operation, or store-and-release operations that maintain appropriate river hydrology).

B. Bypass Flows

A bypass reach is a segment of a river or stream that is "bypassed" by a portion of the flow. At a run-of-river hydroelectric facility, a bypass reach is normally between the base of the dam and the powerhouse; a portion of the river flow is diverted at the dam to generate electricity, and is returned to the river at the powerhouse's tailrace. At some sites a penstock (pipe) may be used to gain additional elevation change, extending the bypass reach length; at others sites the powerhouse may be located at the base of the dam and there is essentially no reach of the river that is bypassed if water from the tailrace inundates the area.

Although a minimum bypass flow requirement is normally established by a WQC, flows in the bypass reach vary above the required minimum, such as when river flows exceed the maximum capacity of the hydroelectric generating units, or when river flows are less than the minimum capacity so that no diversion for energy generation occurs and all river flow spills over the dam and through the bypass reach.

[2] Vermont Agency of Natural Resources, Department of Environmental Conservation. "Agency Procedure for Determining Acceptable Minimum Streamflows." July 14, 1993

In general, bypass flow requirements are established to meet VWQS criteria as applicable to conditions at a particular site, including aesthetics, water chemistry (e.g., dissolved oxygen), temperature, aquatic habitat, and support of aquatic life (e.g., fish and invertebrates). Minimum bypass flow requirements are most commonly a flat rate, but at some sites may vary, or may not apply, seasonally, diurnally, or based on total river flow at any moment. At sites with fish passage systems, additional flows above the bypass requirement may be needed to operate the fish passages, which typically operate seasonally during spring and fall.

As noted above, at existing hydroelectric stations that were originally approved under former regulations, bypass flow requirements may increase during the relicensing process, based on the ANR's interpretation of the VWQS.

3.0 Assessment Methods

VHB analyzed three different Vermont run-of-river hydroelectric stations to represent a range of sites that could be affected by increased bypass flows during relicensing. The following facilities were analyzed:

- Bethel Mills: mini-hydropower station (525 kW capacity), located on the Third Branch of the White River, in Bethel, Vermont.
- Gilman: relatively larger small-hydropower facility (4,850 kW capacity), located on the Connecticut River, in Lunenburg, Vermont and Dalton, New Hampshire.
- Morrisville: mid-sized small-hydropower station (1,800 kW capacity), located on the Lamoille River in Morrisville, Vermont. The Morrisville station, owned by the Morrisville Water & Light Department ("MWL"), was selected because it has already been issued a WQC by the Vermont ANR, thus the changes in water management conditions are known. This WQC is under appeal due in part to the impacts of the new bypass flow conditions.

VHB's analysis followed standard methods and involved use of a computer model to determine changes in gross energy generation compared to current conditions, for various regulatory scenarios. The models were calibrated for each site that was evaluated, to verify accuracy.

A baseline scenario, representing existing conditions, was used as a basis for comparison. Three additional scenarios consisted of incrementally increasing bypass flows that could potentially be required, pending results of site-specific studies that may be needed during the relicensing. The potential bypass flows were selected based on VHB's experience at other sites in Vermont.

At the Morrisville station, the scenarios included

1) baseline,
2) MWL's prior proposal for increased flows (2013),
3) MWL's higher proposal for increased flows (2014), and
4) the conditions of the WQC (2016) that is under appeal.

For the other two locations, which have not gone through the relicensing process, the scenarios included

1) baseline,
2) estimated typical requirement for an increased bypass flow that would be set based on a site-specific study,
3) estimated high end of the range of likely bypass flow requirements that would be set based on a site-specific study, and
4) likely upper limit of bypass flow requirements, equal to the Aquatic Base Flow ("ABF", equal to August median flow).

As a standard basis of comparison, for all scenarios at any one facility, the same facility configurations and the same set of river flow data were used. In order to isolate the effects of increased bypass flow requirements, climate change, which is likely to decrease hydroelectric generation further, was not included in the assessment. All analyses were based on a streamflow record consisting of the most recent 30-year "Normal Climate" period, for a consistent basis of comparison among the different regulatory scenarios.

Climate change scenarios were not evaluated due to the considerable uncertainty in predicting when, and to what extent, climate change may affect river flows. Nonetheless, the prevailing theories of Climate Change[3] predict a shift of flows toward the extremes, with greater and more intense flood events interspersed with longer and more severe periods of drought. Warmer temperatures are predicted to cause

[3] e.g., Climate Change in the US Northeast: A Report of the Northeast Climate Impacts Assessment (NECIA, 2006); Climate Change and Vermont's Waters: Climate Change Adaptation White Paper Series (ANR, 2011); Water Resources (Ch. 3) in Climate Change Impacts in the United States: The Third National Climate Assessment (U.S. Global Change Research Program, 2014).

increased evapotranspiration over a longer growing season, resulting in lower streamflows. Such changes would generally decrease hydroelectric energy generation at run-of-river facilities because flood events would fail to increase energy generation since flows would exceed capacities of the generating equipment; whereas increased drought episodes would directly decrease hydroelectric energy generation, resulting in a net decrease in energy generation. To the extent that storage reservoirs can be operated to offset the effects of climate change, some impact can be mitigated at store-and-release facilities, however this analysis focused on run-of-river facilities.

The modeling predicted the long-term average amounts of energy that each facility would generate on an annual and monthly basis under each of the four bypass flow scenarios. The assessment also predicted the corresponding amounts of atmospheric Carbon Dioxide emissions that are avoided under each flow scenario, assuming that the renewable energy generated at the facility replaces a typical "grid mix" of energy sources. Refer to the attached memoranda for each of the assessed facilities for detailed information on methods and input data. Exhibit A presents the Bethel Mills analysis; Exhibit B presents the Gilman analysis, and Exhibit C presents the Morrisville analysis.

4.0 Results

In summary, the theoretical new bypass flows that VHB considered to be representative of the range in potential new license requirements would result in decreases in renewable energy generation ranging from 5 percent to 25 percent annually at Vermont run-of-river hydroelectric stations, as shown in Table 1 below. A site-specific flow and aquatic-habitat study would be needed to determine a bypass flow requirement; for this evaluation VHB assumed these bypass flow rates to represent a typical range of values that might result from such a study, based on experience at other sites in Vermont.

Corresponding increases in emissions of atmospheric Carbon Dioxide would occur if the renewable energy were replaced with a typical "grid mix" of energy sources, as shown in Table 2 below.

Table 1: Summary of Changes to Gross Energy Generation (Annual Long-Term Averages)				
Site	**Existing Conditions (MWh)**	**Potential Increased Bypass Flow (Change in MWh and %)**	**Higher Potential Increased Bypass Flow (Change in MWh and %)**	**Likely Upper Limit for a Bypass Flow (Change in MWh and %)**
Bethel Mills	1,475	-82 -6%	-165 -11%	-355 -24%
Gilman	24,128	-1,387 -6%	-3,413 -14%	-6,132 -25%
Morrisville	5,080	-247 [a] -5%	-302 [b] -6%	-925 [c] -18%
[a] MWL prior proposal (12/10/2013) [b] MWL higher proposal (6/4/2014) [c] WQC (2016 – under appeal)				

Table 2: Summary of Changes to CO_2 Emissions (Annual Long-Term Averages)				
Site	**Existing Conditions (tons avoided)**	**Potential Increased Bypass Flow (Change in tons emitted)**	**Higher Potential Increased Bypass Flow (Change in tons emitted)**	**Likely Upper Limit for a Bypass Flow (Change in tons emitted)**
Bethel Mills	1,018	57	114	245
Gilman	16,648	957	2,355	4,231
Morrisville	3,505	171 [a]	208 [b]	638 [c]
[a] MWL prior proposal (12/10/2013) [b] MWL higher proposal (6/4/2014) [c] WQC (2016 – under appeal)				

Compared to existing conditions, an increase in the required bypass flow would result in reduced energy generation during all months of the year, with the largest percent decrease occurring during the low-flow months of August and September, while smaller percentage decreases would occur during high-flow months such as March, April, and May. Detailed results are presented in the attached memoranda (Exhibits A, B, and C, respectively) for each of the assessed sites.

A decrease in energy generation by 5 percent to 25 percent may occur at existing run-of-river hydroelectric stations in Vermont, due to increased conservation flow requirements that would be imposed during relicensing. This assessment analyzed hydroelectric projects of different sizes that are representative of the range of most hydroelectric stations in Vermont, and thus the results can be generalized. According to VIPPA, there are 82 hydroelectric stations in Vermont, averaging 2.4 MW with a total capacity of approximately 200 MW, equivalent to 12 percent of Vermont electrical energy consumption. The State's Comprehensive Energy Plan (2016) requires the state to obtain 25 percent of its energy from renewable resources by 2025, including the goal of "shifting toward cost-effective wind, solar, and hydroelectric power." If all in-state existing hydrostations were to experience a reduction in energy generation in the predicted 5 to 25 percent range, the impact to VT's energy supply and renewable energy goals would be significant.

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