Hatchery Modernization Development and Effluent Treatment Alternatives Evaluation

Powder Mill Fish Hatchery

New Hampshire Fish and Game Department

New Durham, New Hampshire
February 28, 2023

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Abbreviations

NHFGD	New Hampshire Fish and Game Department
NHDES	New Hampshire Department of Environmental Services
NPDES	National Pollution Discharge Elimination System
TP	Total Phosphorus
EPA	Environmental Protection Agency
CAD	Computer Aided Drafting
SFH	State Fish Hatchery
UV	Ultraviolet Light
LOX	Liquid Oxygen
O&M	Operations and Maintenance
H&H	Hydrology and Hydraulics
SRP	Soluble Reactive Phosphorus
HVAC	Heating Ventilation and Air Conditioning
RAS	Recirculating Aquaculture System
PRAS	Partially Recirculating Aquaculture System
NPV	Net Present Value
TBL	Triple Bottom Line
OPCC	Opinion of Probable Construction Cost
AACE	Association for the Advancement of Cost Engineering
R&R	Repair and Replacement
SRF	State Revolving Fund
LHO	Low Head Oxygenators

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Executive Summary

Powder Mill State Fish Hatchery received a new National Pollutant Discharge Elimination System monthly average total phosphorus effluent limit of 12 µg/L which is currently the lowest known TP limit in the country. Under current operations, the hatchery effluent annual average TP concentration is 24 µg/L with peak concentrations in a range of 50 to100 µg/L during the main fish growth season during summer months. A condition assessment of the hatchery was completed (Existing Conditions and Facility Evaluation, HDR 2022) and determined the existing facility would need additional investment to extend the useful life of the hatchery in addition to the new effluent treatment required to meet permit limits. Due to its age, several upgrades to the rearing facilities are likely to run into significant design and construction challenges such as structural integrity and hydraulic grade concerns.

Phosphorus, unlike many other pollutants of organic origin, has a cumulative impact to receiving waters, not acute. It is more critical that the phosphorus load is reduced overall rather than maintaining one numerical limit over a short period of time. A system designed for an annual average limit of 12 µg/L needs to remove on average 55% TP. This is achievable with membrane ultrafiltration without chemical addition. However, to meet the same limit on a monthly average basis, the system needs to be capable of achieving 90%+ TP removal to meet 12 µg/L in peak loading summer months. While systems designed based on annual average or monthly average limits are capable of maintaining the cumulative load-based limit of 227 lb/year, the latter requires addition of adsorption units or chemical sequestration and coagulant and alkalinity addition to reach the stringent limits during peak loadings. This increases resource consumption across the board from capital cost and operating cost to labor and greenhouse gas emissions. Thus, an annual average limit would be a more sustainable solution. Another more sustainable solution than the existing monthly average limit of 12 µg/L TP is to modify the limit to be based on the phosphorous species which are bioavailable in the environment.

Under current hatchery operations, the effluent limit is the same as the EPA instream target of 12 µg/L in Merrymeeting River as the hatchery utilizes almost all flow from the source water (Merrymeeting Lake) to the river. Hatchery modernization alternatives are proposed in this evaluation that would significantly reduce the required flow rate from the source water from 6 MGD to approximately 1 MGD. This allows for a minimum dilution factor of 2 where the hatchery effluent could be diluted with the lake water in a dilution zone before being discharged to the river. Thus, the instream target would be disconnected from the effluent limit and could allow for potential permit modification to increase the hatchery average monthly effluent limit up to 24 µg/L. Consequently, the required TP removal would decrease from 90% to 70% in peak loadings summer months, eliminating the need for chemical sequestration or adsorption units and reducing coagulant addition significantly. With such permit modification, a more sustainable and cost-effective treatment solution would be possible.

The Pilot and Bench Testing Results and Recommendations Report (HDR 2022), determined that membrane filtration with the correct pH and chemical dose can meet the 12 µg/L limit alone. Performance under seasonal and/or diurnal variabilities can be improved through chemical sludge retention.

Three hatchery modernization alternatives and two effluent treatment alternatives were evaluated for the Powder Mill Hatchery, for a total of six Alternatives:

- Alternative 1 – Reuse of Existing Rearing Units with Aquaculture Upgrades
- Alternative 2 – Addition of a New Circular Rearing Tank Building with 75% Water Recirculation and Aquaculture Upgrades
- Alternative 3 – Addition of a New Circular Rearing Tank Building with 95% Water Recirculation and Aquaculture Upgrades
- Effluent Treatment Alternative A – Membrane Filtration with Chemical Sequestration
- Effluent Treatment Alternative B – Membrane Filtration with Adsorption

The six alternatives evaluated in the analysis resulted in Alternative 3B – Addition of a New Circular Rearing Tank Building with 95% Water Recirculation with Membrane Filtration and Adsorption effluent treatment receiving the highest recommendation rating. While each alternative meets current production goals and permit compliance, it is unlikely that any alternative represents the most effective investment for the New Hampshire Fish and Game Department (NHFGD) at this time. To maximize the benefits from investment, upgrades at each hatchery must be considered together. It is recommended that NHFGD discuss the additional alternative approach outlined in Section 5.1.3 of the report recommendations within the agency to determine the impact.

1 Introduction

Powder Mill State Fish Hatchery was originally constructed in 1947. The hatchery was updated in the early 1970s and again in the early 1990s with new rearing units. The hatchery consists of 101 exterior ponds and raceways, a fish spawning/incubation building, three storage sheds, a main garage and one residence. Currently, the station produces Brown Trout, Rainbow Trout, and Brook Trout with an annual average of 344,007 fish that are stocked in public waters throughout the state. Fish at 200-300 fish per pound arrive by the end of March through April and stock out by the end of June through early July the following year from the Sea Coast to the Maine border.

Up to 4,500 gpm of water is supplied to the hatchery by gravity from Merrymeeting Lake. Merrymeeting Lake is a spring fed lake surrounded by a forested community, covers a surface area of roughly 1,111 acres, and is approximately 120 ft deep. The lake was formed by Merrymeeting Dam, which is owned by New Hampshire Fish and Game Department (NHFGD) and operated and maintained by New Hampshire Department of Environmental Services (NHDES) Dam Bureau. Most water released from the lake year-round is directed to the hatchery and utilized for fish rearing. The hatchery utilizes two intakes within the lake to supply the facility with water. Flow from each intake is separately routed to both the east and west side of the facility. Raceways B, C, and D are located on the east side of the facility. Overflow water from these raceways proceeds down to the southern ponds and circular tanks where it is reused before being discharged into Merrymeeting River just upstream of Marsh Pond at Outfall 002. Raceways E, F, G are located on the west side of the facility. Overflow from these raceways is discharged through Outfall 001 at the termination of the concrete lake overflow channel.

EPA has authorized the Powder Mill facility to discharge the hatchery effluent through Outfall Number 001 and 002 (shown in Figure 1-1) to Merrymeeting River with specified discharge limits effective from January 1, 2021 to December 31, 2025 (Permit No. NH0000710). The Powder Mill Fish Hatchery received a new NPDES (National Pollution Discharge Elimination System) Permit in January 2021 with concentration and load-based total phosphorus (TP) limits for the hatchery effluent discharged to Merrymeeting River. An average monthly TP discharge concentration limit of 12 µg/L is established for each of the hatchery outfalls along with cumulative load-based limits of 227 lb/year and 19 lb/month.

These new TP limits were brought about through years of discussions and studies on the impacts of cyanobacteria on the three impoundments downstream of the hatchery: Marsh Pond, Jones Pond, and Downing Pond. A lake loading model and watershed-based plan funded by a local community group was conducted in 2019 by FB Consulting. This study concluded that the hatchery was the largest single source of TP into the watershed. Based on this data, other information provided by New Hampshire Department of Environmental Services (NHDES), and public comments on the draft permit, EPA chose to make the instream target for TP 12 µg/L for the Merrymeeting River. It is believed that these TP effluent limits are currently the most stringent in the country.

Dual drain circular rearing tanks and dedicated effluent filters provide rapid solids removal and are industry standards for hatchery modernization and treatment. Those upgrades alone can meet production goals but would be insufficient for permit compliance. To meet the TP limit, membrane ultra-filtration (MF) along with either chemical addition or adsorption is required. Details on the treatment plant pilot study can be found in the "Pilot and Bench Testing Results and Recommendations". Effluent treatment costs are heavily dependent on the flows they receive. In an effort to reduce flows, recirculating (RAS) and partially recirculating (PRAS) aquaculture systems were considered for hatchery modernization alternatives. Along with reducing flows discharged to the receiving water body, the RAS and PRAS alternatives are not constrained to the existing site and could be built on new land or in addition to an existing hatchery. Should the regulatory environment make fish rearing on the Merrymeeting River unfavorable, those facilities could be constructed in a location where the environmental effects of a state fish hatchery are less impactful on the receiving waters and standard effluent treatment facilities are sufficient.

HDR performed a pilot study to investigate the efficiency of the treatment technologies and assess the hatchery effluent TP speciation in the peak loading months. As a result of pilot study, HDR submitted a separate technical memorandum "Powder Mill Pilot Testing" to determine how to consistently meet the limit with a single or combination of treatment method(s). In total, three hatchery alternatives (reuse of existing raceways, PRAS, and RAS) and two effluent treatment alternatives (membrane filtration with chemical addition and membrane filtration with adsorption) were combined resulting in six overall alternatives which could meet the current production goals and discharge permit. An opinion of probable construction cost was developed to the ASEE Class 4 standard based on escalated costs of recent hatchery projects and vendor quotes. Operation and maintenance costs were developed based on equipment replacement, electrical usage, consumables, and wages for new employees. Based on those values, the 20-year net present value was determined, and a benefit ratio was applied based on rankings of several non-financial criteria.

The purpose of this report is to evaluate the Powder Mill hatchery modernization including upgrades of wastewater treatment facilities to achieve compliance with permit effluent limits. Hatchery modernization evaluations were conducted based on the results of the Existing Conditions and Facility Evaluation, HDR 2022, NHF&G Production and Stocking Review Report, HDR 2022, and the Pilot and Bench Testing Results and Recommendations Report, HDR 2022.

1.1 Facility Summary

The existing site plan, process flow diagram, and hydraulic profile shown in Figure 1-1 through Figure 1-3, illustrate the hatchery boundary, approximate topography, and general hatchery infrastructure. The study drawings were developed using digitized (i.e., traced) Computer Aided Drafting (CAD) techniques and map overlay technology. The drawing is a to-scale representation of hatchery resources for planning purposes only.

Water is supplied to the hatchery by gravity flow from Merrymeeting Lake (1,111 surface acres) located just north of the facility. The NHFGD owned, earthen-type dam was rebuilt in 1983 and has a concrete spillway. NHFGD operates the dam and the NHDES maintains the dam. The NHFGD owns the water rights to Merrymeeting Lake and is authorized to divert 4,500 gallons per minute (gpm) or 7,258 acre-feet per year. The lake level changes throughout the year due to environmental conditions and hatchery use. Average summer lake drawdown is about one foot.

Flow enters the facility at the north end and drains to two series of raceways. Flow is also directed to the Hatch House. Raceways E through G drain to a lake overflow channel and remain separate from the rest of the facility. Raceways A through D drain to a series of ponds from the Show Ponds, Woods Ponds, Bass Ponds, and finally to the Circular Tanks. There is also a fresh water supply line that drains straight to the Bass Ponds and Circular Tanks. Outflow from the Woods Ponds flows to the discharge point where it combines with the outflow from the circular ponds currently in use for fish rearing prior to discharging to Merrymeeting Creek at Outfall 002 (Figure 1-2).

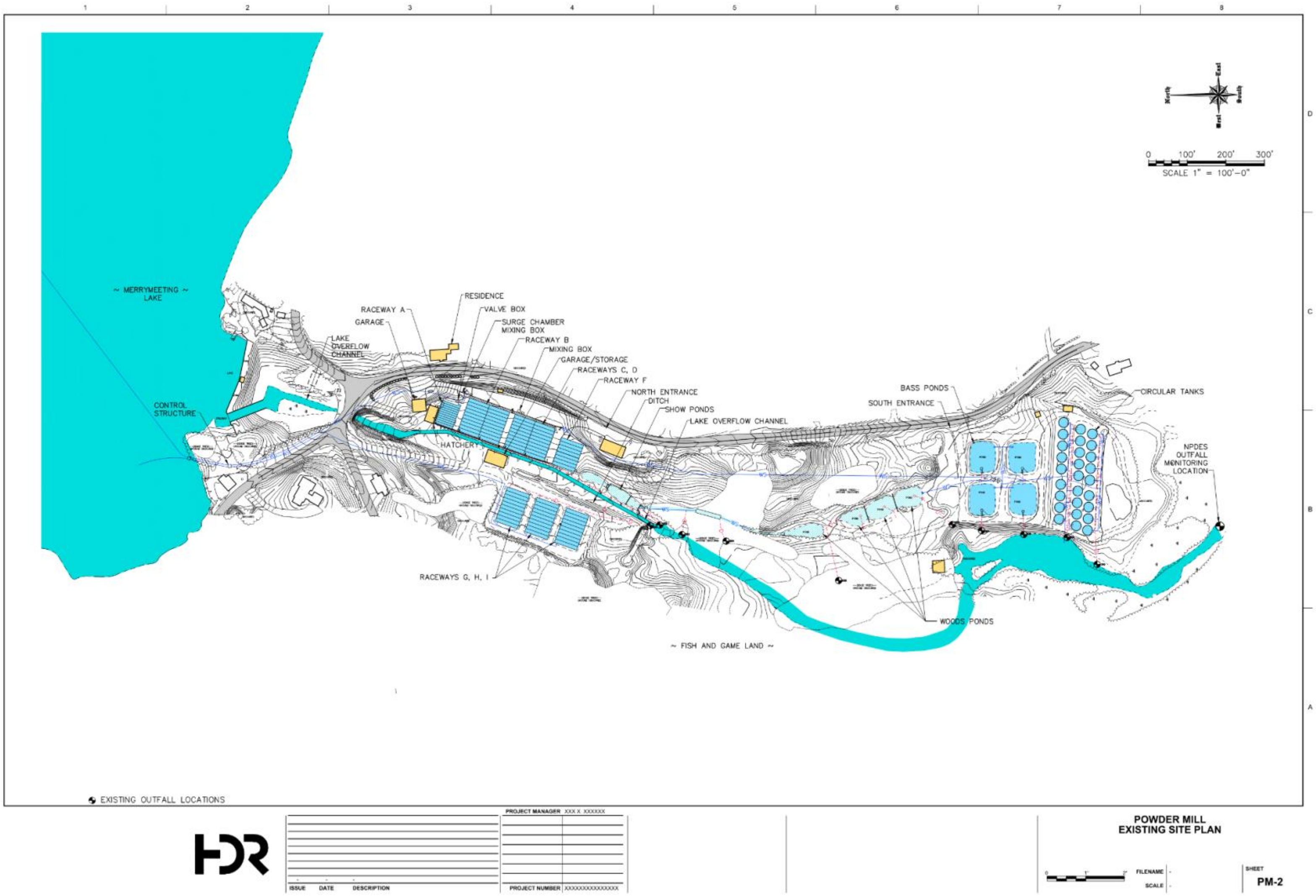

Figure 1-1 Existing Powder Mill Site Plan

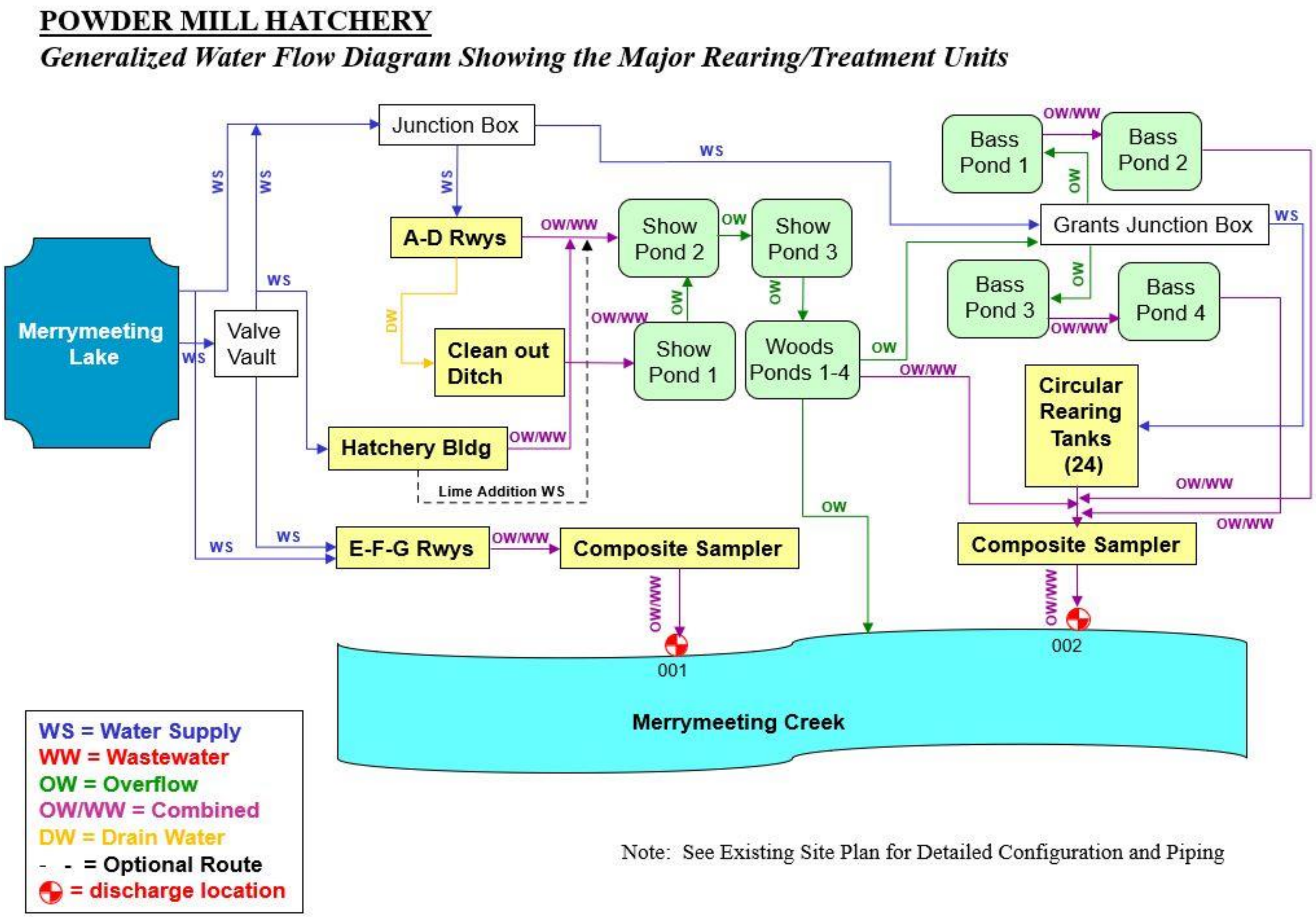

Figure 1-2 Existing Powder Mill Process Flow Diagram

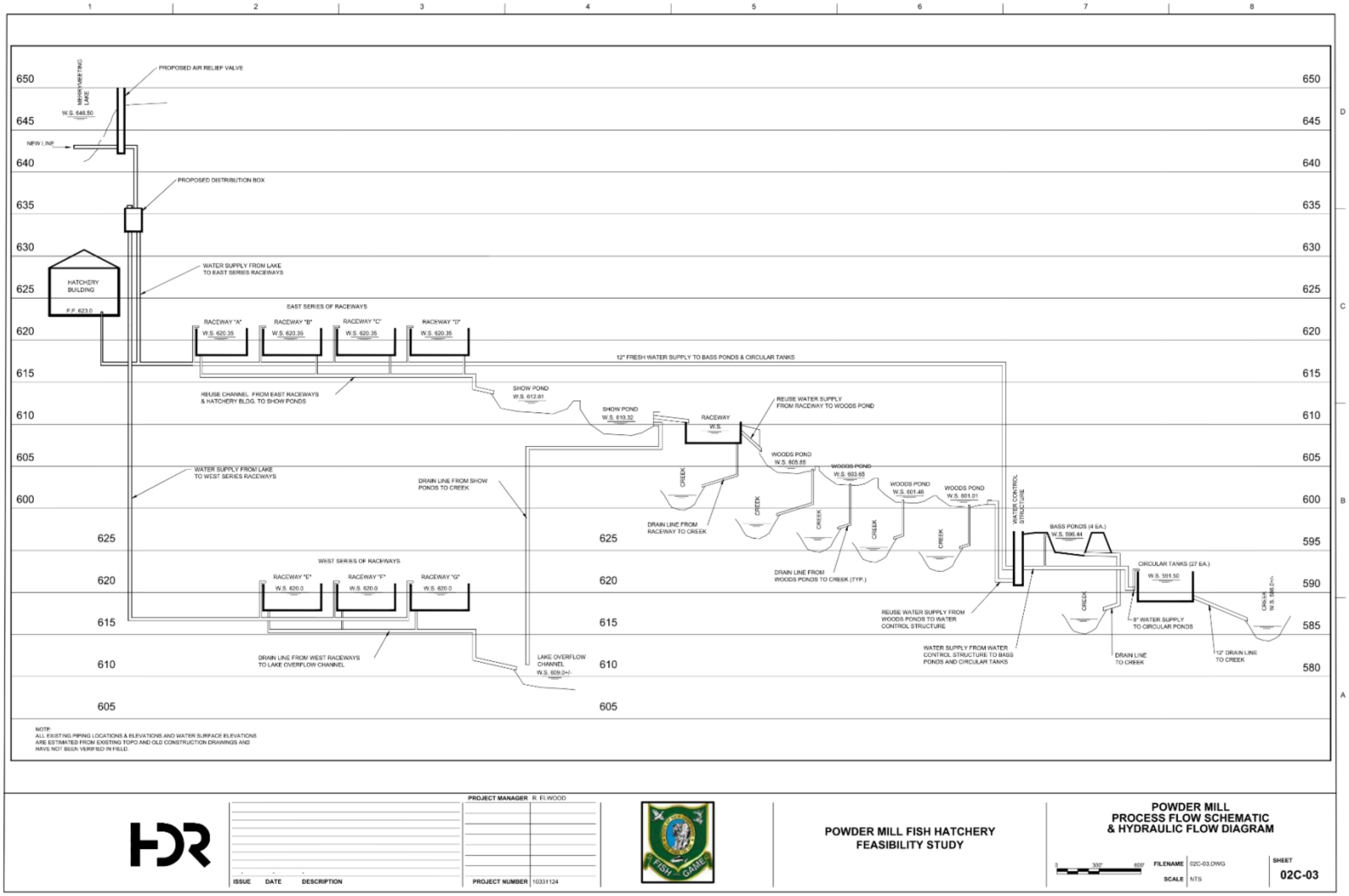

Figure 1-3 Existing Powder Mill Hydraulic Profile

2 Fish Production Summary

Powder Mill is one of six NHFGD operated facilities supplying Brook Trout, Brown Trout and Rainbow Trout for the State's production program. The goal for the program is to stock fish between nine and 10 inches. Powder Mill operates an annual production cycle to produce fish for this goal taking fish transferred from other NHFGD facilities as fingerlings and raising them to a stockable size. Annual production at the facility begins with receiving fingerling fish (approximately 200-300 fpp) in either late winter or early spring from other state hatchery facilities. The fish are placed in outdoor units upon arrival for growout. Historically, Powder Mill also completed egg incubation, early rearing of fry and production of Landlocked Atlantic Salmon but does not currently complete those phases or species.

The total number and total pounds of each species produced at Powder Mill SFH between 2016 and 2021 are listed in Table 2-1. An annual average of 344,000 fish (117,590 pounds) was produced and stocked. This production level accounted for 31 percent of total state fish pounds produced and stocked in New Hampshire waters making the Powder Mill the largest producer in the state program by pounds of fish produced.

Table 2-1 Average Fish Production by Species (2016-2021)

Species	Number of Fish	Pounds of Fish
Rainbow Trout	91,500	42,600
Brown Trout	47,900	18,300
Eastern Brook Trout	164,000	52,100
Landlocked Atlantic Salmon*	40,600	46,600
Total	344,000	117,600

*The Nashua National Hatchery currently completes the Landlocked Atlantic Salmon rearing

Powder Mill's stocking efforts cover approximately 5,972 square miles and includes 326 bodies of water within the state. This level represented 33 percent of the bodies of water stocked by the NHFGD program in 2021. Table 2-2 summarizes the bodies of water stocked by species for the Powder Mill facility.

Table 2-2 2021 Bodies of Water Stocked by Species

Species	Bodies of Water Stocked
Eastern Brook Trout	185
Rainbow Trout	89
Brown Trout	52
Landlocked Atlantic Salmon*	17
Total	326

*The Nashua National Hatchery currently completes the Landlocked Atlantic Salmon rearing

3 Hatchery Improvement Alternatives

This Section provides an overview of effluent treatment modernization and hatchery modernization alternatives followed by a description of necessary improvements to each existing process at the facility, a discussion of possible alternative solutions, and alternatives evaluation. This list of modernization and improvement needs was developed after the design team's site inspection and condition assessment.

3.1 Effluent Treatment Modernization Alternatives

Achieving an effluent TP limit of 12 µg/L, currently the lowest known TP limit in the country, is technologically challenging. The preliminary analysis showed the presence of particulate phosphorus (PP), soluble reactive phosphorus (sRP) and soluble nonreactive phosphorus (sNRP) species in the hatchery effluent. Several treatment methods and technologies were identified and evaluated.

Process solutions capable of achieving the phosphorus limit of 12 µg/L in the hatchery effluent were evaluated and selected based on information presented in the Source Water and Effluent Characterization and Effluent Treatment Technology Review identified as part of a preliminary study performed in March and April 2022. Three technologies were subsequently chosen for piloting:

- Membrane ultrafiltration unit for sRP sequestration via upstream metal salt addition and removal of suspended solids and PP species via filtration.
- Ion exchange unit to reduce filtration effluent sRP concentration below 5 µg/L.
- Adsorption unit to remove sRP and sNRP fractions to less than 10 µg/L.

From the Pilot and Bench Testing Results and Recommendations Report, HDR 2022, it was determined that membrane filtration with the correct pH and chemical dose can meet the 12 µg/L limit alone. Performance under seasonal and/or diurnal variabilities can be improved through chemical sludge retention. The chemical sludge inventory from solids generated through aluminum or iron based coagulant addition itself can remove phosphorus through adsorption and complexation. In practice, that inventory acts as an additional barrier and adds very little cost.

Although ion exchange achieved sRP concentrations less than 5 µg/L, adsorption with hybrid resin is one of the few technologies available to remove both sRP and sNRP to less than 12 µg/L. However, adsorption alone could not meet the permit as it requires upstream solids removal to reduce PP concentrations. Thus, combined with membrane filtration it could be part of a chemical free treatment strategy whereas membranes alone will meet the limit most months of the year and adsorption is used to polish sNRP and sRP during peak phosphorus season in July and August.

3.1.1 Effluent Treatment Alternatives

The following hatchery effluent treatment alternatives are recommended based on the pilot study conclusions to achieve the average monthly limit of 12 µg/L. Necessity dictates that for planning purposes we must recommend and plan for the treatment option(s) that meet the limits as they are currently written. Due to the limit, membrane ultra-filtration will serve as the primary treatment process for each alternative and additional measures will be incorporated to ensure permit compliance. The additional measures are especially important during periods of increased phosphorus loading. It is possible to omit additional unit process (such as chemical addition or adsorption) at any time before actual construction begins based on permit modifications.

Alternative A – Membrane Filtration with Chemical Dosing
Alternative A adds a coagulant to the membrane filtration system as shown in (Figure 3-1). Alum was considered in this effort due the low cost and availability. Chemicals other than alum may be considered for coagulation during final design; Particularly those that do not reduce alkalinity or ones that can reduce sRP to lower values. Some rare earth metals are showing promise, but additional evaluation is required. This alternative can also be operated with a chemical sludge inventory to reduce the chemical demand. The chemical sludge inventory acts as an additional barrier which reduces the pressure on chemical feed control. With a chemical sludge inventory established, the chemical feed removes some sRP at the injection point while also replenishing the chemical sludge inventory. The chemical sludge then provides additional removal. Best case scenario one can achieve a near stoichiometric chemical dose which can significantly reduce chemical costs, total dissolved solids (TDS) contribution, and alkalinity consumption.

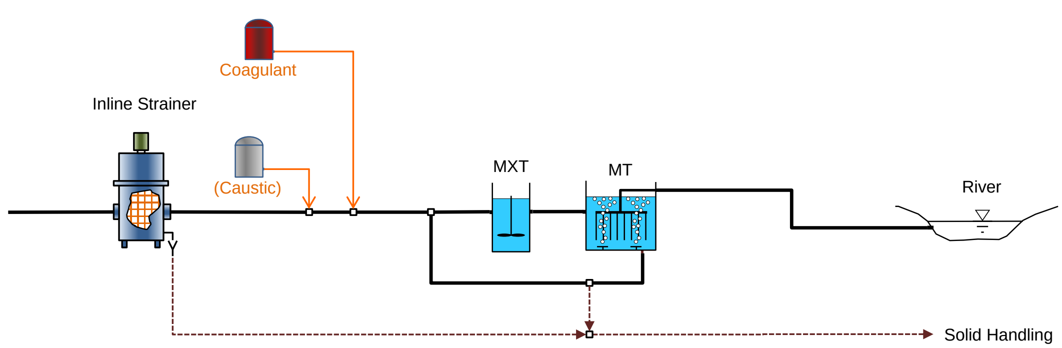

Figure 3-1 Membrane Filtration with Coagulant Addition

Pros

- Can meet a monthly average limit
- Can be operated with chemical sludge inventory to reduce chemical demand
- Use conventional, well-established technologies

Cons

- Chemical cost
- Additional solids residual
- Increased TDS
- Increased control requirements (chemical feed)

Pros	Cons
	• Low feed water alkalinity increases chemical costs

Alternative B – Membrane Filtration with Adsorption

Alternative B adds adsorption downstream of the membrane filtration system as shown in (Figure 3-2). Coagulant feeds are not required with adsorption in place. This treatment process requires minimal control (i.e., no chemical dosing), reduces TDS, and it can meet the monthly average limit. Membrane filtration alone may be sufficient most of the year except the summer months where further polishing is needed to meet the monthly average limit. The adsorption media will require replacement periodically, which should be infrequent especially if it's in operation only during the summer.

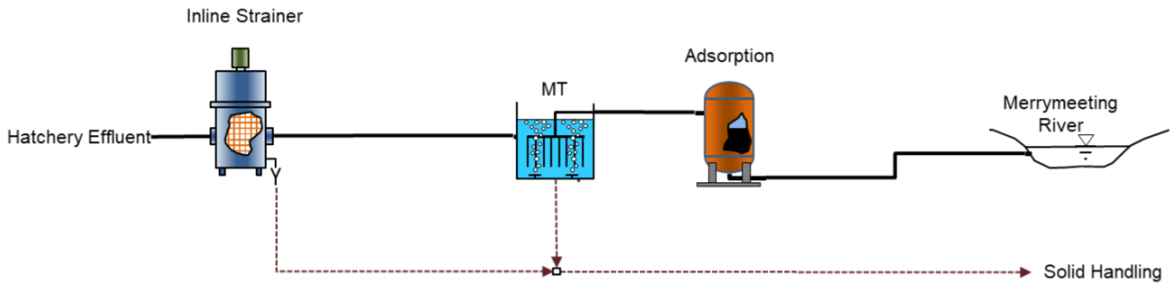

Figure 3-2: Membrane Filtration Followed by Adsorption

Pros	Cons
• Can meet a monthly average limit • No chemicals • Decreases TDS • Simple process control • Low O&M requirement on adsorption	• Adsorption media requires replacement or regeneration • Likely only need adsorption during the summer, unutilized for remainder of year. • Additional headloss through media bed • Need to manage (regenerate/dispose/replace) media as needed

3.2 Hatchery Modernization Alternatives

The management of metabolic fish waste, solids, and nutrients are critical issues for Powder Mill. The majority of the infrastructure utilized to produce fish was constructed prior to the need for enhanced solids and nutrient management. By number, most of the rearing units are linear raceways which currently operate with insufficient flows and velocities to move fish generated solids and associated nutrients towards the drains for efficient removal prior to discharge. For this reason, implementation of measures to reduce waste in the effluent water has been on ongoing challenge for NHFGD staff.

Based on the hatchery's overall age and existing condition, the need to modernize fish culture infrastructure, and the requirement to meet the effluent phosphorus concentration, three hatchery alternatives were developed. These hatchery alternatives will be matched with effluent treatment alternatives outlined in the following Sections. These hatchery alternatives include:

- Alternative 1 – Reuse of existing rearing units with aquaculture upgrades
- Alternative 2 – Addition of a new circular rearing tank building with 75% water recirculation and aquaculture upgrades
- Alternative 3 – Addition of a new circular rearing tank building with 95% water recirculation and aquaculture upgrades

3.2.1 Alternative 1 – Existing Rearing Units with Aquaculture Upgrades

Overview
Alternative 1 maintains the current annual production average of approximately 117,000 pounds of fish. In this alternative, the existing fish rearing units are left in place and the majority of the facility remains unchanged. Repairs to the existing concrete rearing units would be made to the extent possible to extend the life. A liquid oxygen system will be added to the facility to provide for dissolved oxygen management within the existing fish rearing units with delivery by low head oxygenators (LHOs). To improve the movement of fish generated solids towards the drain, flow baffles are recommended to be retrofitted to the existing linear raceways. The current outfalls, discharging directly to Merrymeeting River, would be intercepted and directed to an effluent treatment plant sized for the flows and loads of the existing hatchery infrastructure and production level (see Section 2). This would result in formal waste treatment prior to discharge that is not currently possible within the existing facility.

Aquaculture Water Supply
Merrymeeting Lake remains the source of culture water and the existing water distribution systems are mostly reused. New influent drum filters and UV disinfection systems are installed, and bulk liquid oxygen is provided to the existing raceways. The hatchery continues to require roughly 3,745 gpm which will also be the amount of water that needs formal waste treatment prior to discharge. Of the three alternatives outlined in this report, Alternative 1 has the highest water demand with few options to reduce the overall water needs while maintaining production levels. Proposed process flow diagram and site plan drawings are shown in Figure 3-3 and Figure 3-4.

Fish Rearing Units
The rearing units remain largely unchanged in Alternative 1 with only minor upgrades. The existing concrete is rehabilitated to improve failing areas to the extent possible, and flow baffles are installed to enhance transportation of solids towards the drains. Some of the existing circular tanks at the south end of the facility will likely need to be demolished to make room for the new effluent treatment plant. The production levels are projected to remain the same but some decrease in production may need to occur if permit limits and treatment technology require less feeding to remain in compliance. These adjustments would need to be made post-implementation as needed to match the capabilities of the treatment system with the permit requirements.

Hatchery O&M

From a fish rearing perspective O&M remains unchanged. The existing challenges related to the site layout, aging infrastructure, frequent vacuuming by staff, and manual controls remain. Minimal technical equipment is installed for the purposes of fish rearing. The flexibility, reliability, and performance of the hatchery is only marginally improved. Nevertheless, existing staff are well equipped to operate this hatchery as it's the same annual operation cycle and equipment that is currently utilized.

Effluent Treatment

Hatchery wastewater is intercepted at the existing outfalls and rerouted to the new effluent treatment plant. Having the highest flow rate, this alternative would require the largest effluent treatment equipment. Based on the production levels and permit requirements, it is anticipated that supplemental treatment equipment (chemical additions or adsorption columns) would only need to operate during the late summer when phosphorus loading is highest. For the purposes of this comparison, it was assumed that supplemental treatment would be required for four months.

Effluent O&M

O&M requirements increase with the addition of a new effluent treatment plant. The addition of advanced nutrient removal processes will require additional operator attention to maintain stable operations. It is anticipated that two full-time employees will be required to oversee effluent treatment operations and additional training will likely be required. Operators' licenses for staff may be required depending on the final operational parameters and technologies implemented. O&M requirements for alternative 1 and alternative 2 require similar levels of effort.

New Buildings

Several new buildings are required, rough square footage requirements are as follows: two 200 sq-ft intake buildings, 9,500 sq-ft effluent treatment building, and 2,000 sq-ft vehicle and chemical storage building.

Site

Apart from the effluent treatment building, the site remains largely unchanged. Roads will be reused. A bulk liquid oxygen tank will be sited in proximity to the existing raceways. The Merrymeeting spillway remains in the center of the hatchery and any redesign of the spillway will be heavily constrained by the existing hatchery footprint.

Electric and Controls

Base level instrumentation and alarming will be implemented to alert staff of very general conditions (i.e., loss of flow), and a generator will be installed in the new effluent treatment building to maintain treatment capabilities during power outages.

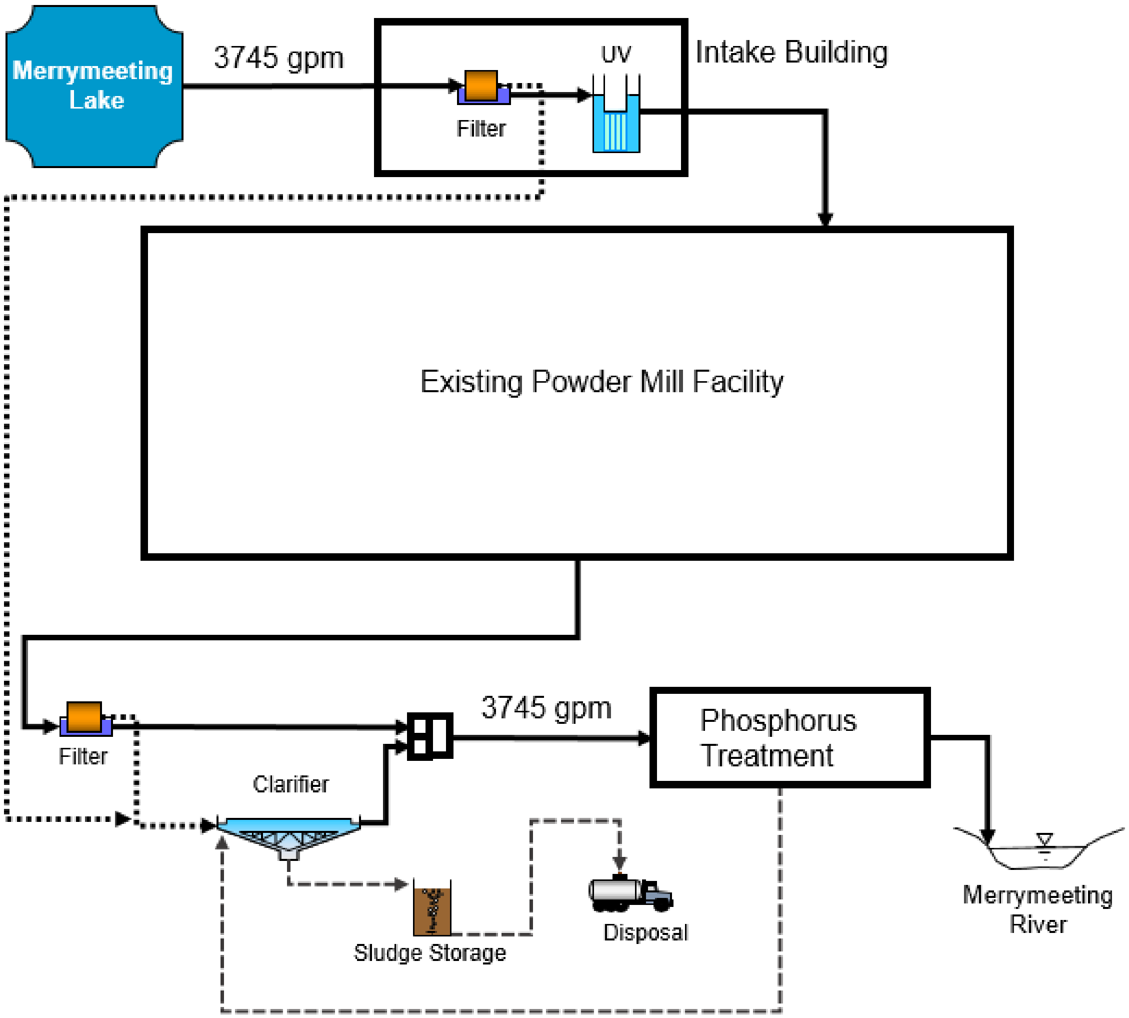

Figure 3-3 Alternative 1 Process Flow Diagram

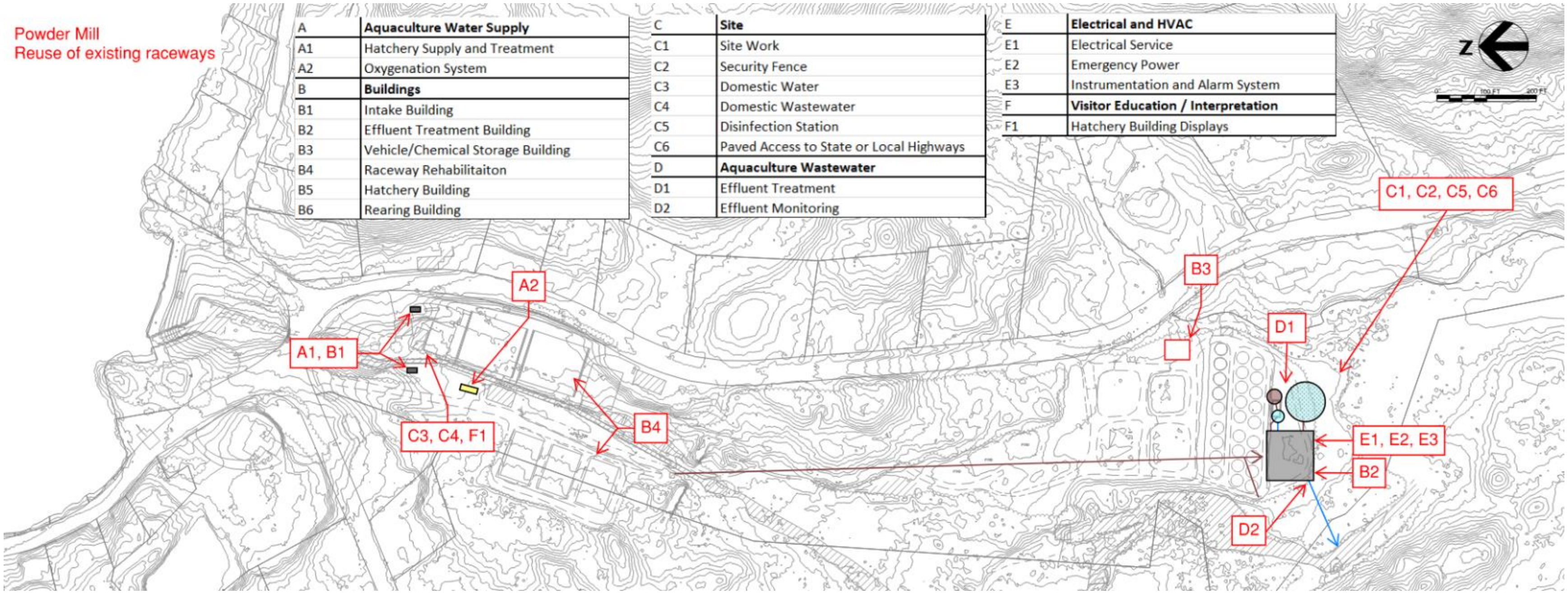

Figure 3-4 Alternative 1 Conceptual Site Plan

3.2.2 Alternative 2 – Circular Rearing Tanks with 75% Recirculation

Alternative 2 focuses on adding production flexibility and includes a slight increase in production carrying capacity over current levels to approximately 131,000 pounds annually. This alternative returns production levels back to historic highs. Conversely, the flexibility of the system also allows for a decrease in fish rearing densities with sufficient rearing space as needed to maintain current production levels observed in 2022. In this alternative, replacement of all existing raceways and circular tanks with new dual drain circular tanks is recommended. The replacement of rearing units will coincide with the addition of a partial recirculating aquaculture system (PRAS) which will recirculate up to 75% of the water in the system thus reducing the background water supply demand.

Overview
In this alternative the existing hatchery infrastructure is abandoned, and a new hatchery rearing building is constructed within the existing property. The new hatchery building utilizes a partially recirculating aquaculture system which treats and recirculates 75% of the culture water while 25% is discharged to the effluent treatment plant. While individual tank flows can usually be reduced by switching from linear raceways to circular tanks, the extensive serial reuse between raceways, and low flows at the existing hatchery result in PRAS water requirements that are only modestly reduced from the existing flows. While the flow rates are similar to the existing operation, the reuse of untreated water through multiple passes of fish is eliminated and replaced with treated water. The result is an improved rearing environment for the fish which has a positive impact on production and can result in a reduction in generated waste loads due to healthier fish over traditional systems. Flows were estimated based on fish rearing requirements in circular tanks using water once before treatment. Effluent phosphorus loads were estimated based on modelling from the required fish production and feeding levels but will require refinement prior to a detailed design.

Aquaculture Source Water
Merrymeeting Lake remains the source of culture water, but the existing intake piping is intercepted and directed to a new intake building at the southern end of the facility. New influent drum filters and UV disinfection systems will be installed. The full flowrate of the proposed rearing building is 13,868 gpm assuming 12,874 gpm for sixteen forty-foot growout tanks, 3,525 gpm for twenty twenty-foot intermediate tanks and 317 gpm for twenty six-foot early rearing tanks. When 75% recirculation is implemented, this hatchery recirculates 10,163 gpm and requires 3,388 gpm of first use water from Merrymeeting Lake, which is the middle background water required of the three alternatives. Flows are modestly reduced (10%) compared to the existing facility. This hatchery has a better ability to control water demand based on the final production targets and in turn the number of recirculation modules. Proposed process flow diagram and site plan drawings are shown in Figure 3-5 and Figure 3-6.

Fish Rearing Units
The existing rearing units are abandoned in place and replaced with new dual drain circular tanks in an enclosed, biosecure rearing building on site. Partially recirculating aquaculture system components include gas management towers for balancing of dissolved gas levels in the system, drum filters to remove solids, UV disinfection, and recirculation pumps. The hatchery can be operated in a much more flexible manner to meet the local and statewide

production goals while providing an opportunity to reduce effluent concentrations to meet permit goals.

Hatchery O&M

The O&M effort shifts towards mechanical maintenance compared to the current gravity operation at Powder Mill. The site layout is consolidated which improves the overall efficiency of the operation, solids removal automated rather than manually vacuumed, and the demand for manual intervention by staff is reduced by integrated controls. Additional full-time employees are likely not required but existing staff will require training on the new systems. The flexibility, reliability, and performance of the hatchery is improved greatly providing for continued production of trout and landlocked salmon for decades.

Effluent Treatment

Hatchery wastewater is routed to the new effluent treatment plant from the new rearing building. The effluent treatment plant for Alternative 2 is similar in size to the treatment plant in Alternative 1. Additionally, due to the recirculation, a higher concentration of nutrients is anticipated since a more concentrated waste stream is discharged when only 25% of the flow rate leaves the facility with solids and nutrient levels from fish metabolic waste generation.

Effluent O&M

O&M requirements increase with the addition of a new effluent treatment plant. The addition of advanced nutrient removal processes will require operator attention to maintain stable operations. It is anticipated that two full-time employees will be required to oversee effluent treatment operations and additional training will likely be required. Operators' licenses for staff may be required depending on the final operational parameters and technologies implemented. O&M requirements for Alternative 1 and Alternative 2 require similar levels of effort.

New Buildings

Several new buildings are required, rough square footage requirements are as follows; 400 sq-ft intake building, 9,200 sq-ft effluent treatment building, 2,000 sq-ft vehicle and chemical storage building, 3,700 sq-ft hatchery building and 74,000 sq-ft rearing building.

Site

The site would undergo major renovations. Roads are reused where beneficial but new roads are required to access the additional buildings and renovated site infrastructure. The Merrymeeting spillway remains in the center of the site, but the new hatchery can be sited in many locations on NHFGD owned property for flexibility in site development and to take advantage of the most advantageous layout. With consolidated facilities, the future spillway design anticipated by the state is much more flexible since the impacts to the operation of the hatchery portion would be much less than the current facility layout.

Electric and Controls

Fully modernized instrumentation and alarming is implemented meaning items like flow meters, float switches, low water alarms and a staff interface system are added to improve the operational capabilities of the system. An emergency backup generator is installed in the new effluent treatment building to support the recirculation systems and associated instrumentation in the event of a power failure. This addition safeguards the production and reduces the risk for system failure due to power outages.

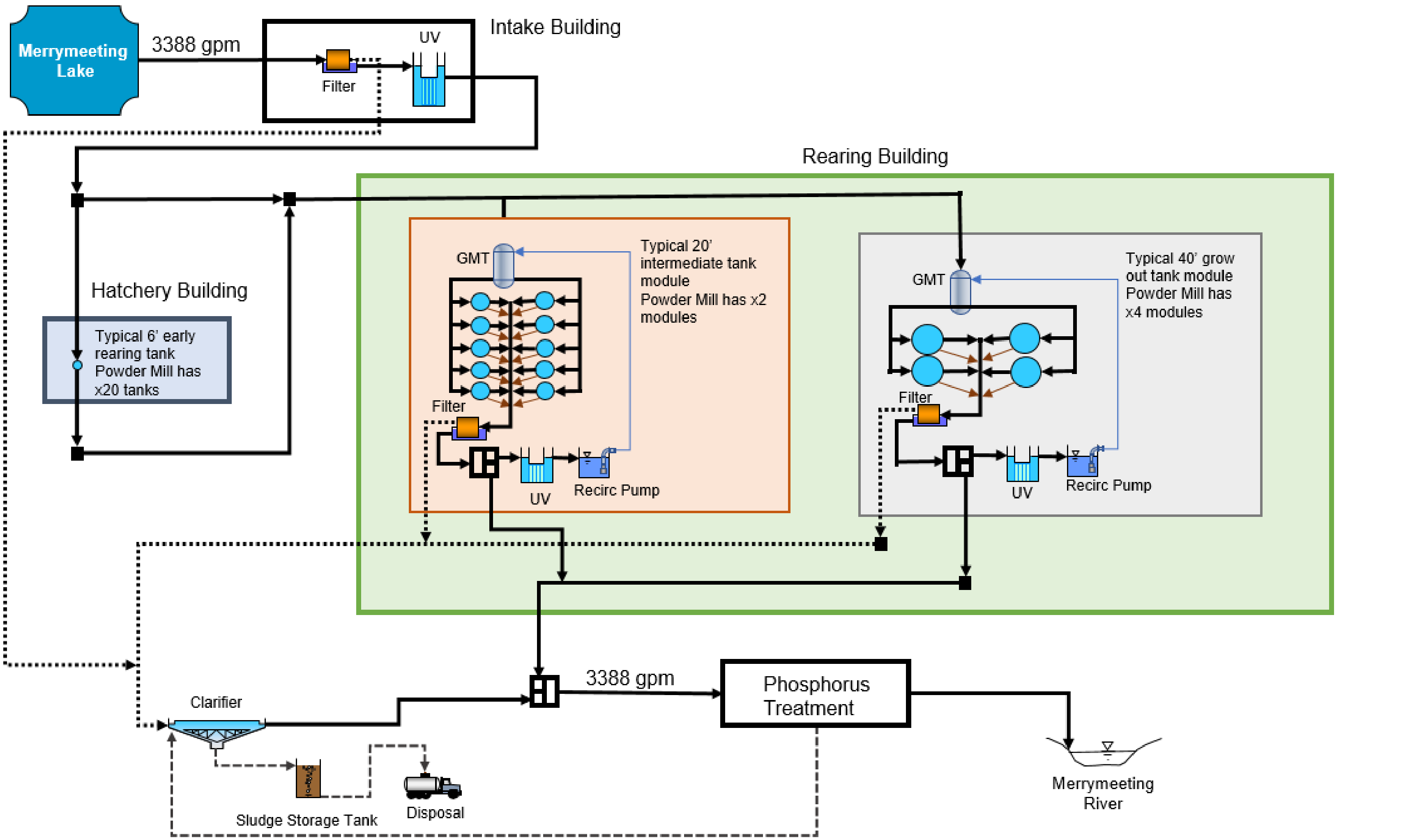

Figure 3-5 Alternative 2 Process Flow Diagram

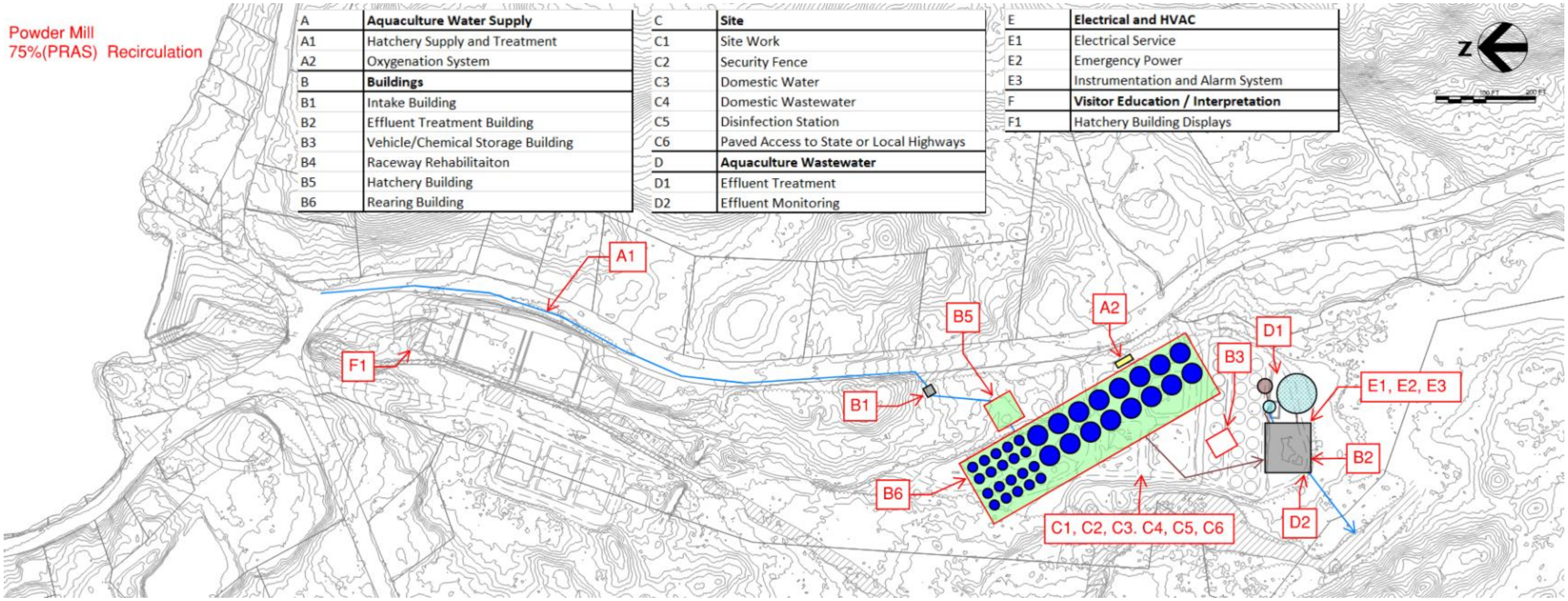

Figure 3-6 Alternative 2 Conceptual Site Plan

3.2.3 Alternative 3 – Circular Rearing Tanks with 95% Recirculation

Overview

Similar to Alternative 2, Alternative 3 includes the flexibility to increase production to approximately 131,000 pounds annually if desired. In this alternative the existing hatchery infrastructure is abandoned in place. New incoming water treatment building, enclosed rearing building, and associated infrastructure for effluent treatment are constructed within the existing property owned by NHFGD. The new hatchery utilizes a recirculating aquaculture system which reuses 95% of culture water before discharging to effluent treatment. The required water demand from Merrymeeting Lake is greatly reduced compared to Alternatives 1 and 2. Flows were estimated based on fish rearing requirements. Effluent phosphorus loads were estimated based on modelling from the required fish production and feeding levels but will require refinement prior to a detailed design.

Aquaculture Source Water

Merrymeeting Lake remains the source of culture water and the existing intake piping is intercepted and directed to a new intake building at the southern end of the facility. New influent drum filters and UV disinfection systems are installed. The full flowrate of the proposed rearing building is 13,868 gpm assuming 12,874 gpm for sixteen forty-foot growout tanks, 3,525 gpm for twenty twenty-foot intermediate tanks and 317 gpm for twenty six-foot early rearing tanks. This rate for the full building operation is the same as Alternative 2 but when 95% recirculation is implemented, this hatchery recirculates 13,175 gpm and only requires 693 gpm of first use water from Merrymeeting Lake. This level of water demand and discharge is the lowest background water required of the three alternatives. Flows are greatly reduced (80%) compared to the existing facility. Based on the final production targets, this hatchery has the ability to decrease or slightly increase water demand and in turn the number of recirculation modules. This means production can be adjusted to match the capabilities of effluent treatment and remain in permit compliance. Proposed process flow diagram and site plan drawings are shown in Figure 3-7 and Figure 3-8.

Fish Rearing Units

Similar to Alternative 2, the existing rearing units are abandoned in place and replaced with new dual drain circular tanks within an enclosed, biosecure building. Recirculating aquaculture systems are installed including gas management towers, drum filters, UV disinfection, biofilters, and recirculation pumps. This biofilter required for Alternative 3 differs from Alternative 2 and is required to approach a 95% recirculation rate. The biofilters are required to reduce toxic un-ionized ammonia levels that are toxic to fish and common in high recirculation rates.

Hatchery O&M

The O&M effort shifts towards mechanical maintenance similar to Alternative 2 given the complexity of operating with pumped system with multiple levels of water treatment in the recirculation system. The site layout is consolidated, solids removal automated, and the demand for manual intervention is reduced by integrated controls. Additional full-time employees are not likely required but existing staff will require training on the new systems. Out of the three alternatives the hatchery O&M effort is highest for this hatchery due to additional technical processes and mechanical equipment, but the flexibility, reliability, and performance of the hatchery is improved greatly. These enhancements not only improve worker safety and fish health but can also play a role in reducing effluent levels due to system efficiency.

Effluent Treatment
Hatchery wastewater is routed to the new effluent treatment building from the new rearing building. In this alternative bio reactors are required to remove nitrogen and maintain a healthy rearing environment. Those bio reactors can be further investigated during detailed design to optimize for phosphorus removal as well. Due to the recirculation, a higher concentration of nutrients is anticipated.

Effluent O&M
O&M requirements increase with the addition of a new effluent treatment plant. The addition of advanced nutrient removal processes will require operator attention to maintain stable operations. It is anticipated that two full-time employees will be required to oversee effluent treatment operations and additional training will likely be required. Operators' licenses for staff may be required depending on the final operational parameters and technologies implemented. Lower flowrates associated with Alternative 3 allow for a significantly smaller treatment system, so while many of the same tasks will be required the equipment will be more easily managed than that with Alternatives 1 or 2.

New Buildings
Several new buildings are required, rough square footage requirements are as follows; 400 sq-ft intake building, 5,500 sq-ft effluent treatment building, 2,000 sq-ft vehicle and chemical storage building, 3,700 sq-ft hatchery building and 74,000 sq-ft rearing building.

Site
The site undergoes major renovations. Roads are reused where beneficial but new roads are required. The Merrymeeting spillway remains in the center of the site, but the new hatchery can be sited in many locations on NHF&G owned property. With consolidated facilities the future spillway design is much more flexible.

Electric and Controls
Fully modernized instrumentation and alarming is implemented similar to Alternative 2 which greatly enhances the user interface with the management of the system. An emergency backup generator is installed in the new effluent treatment building.

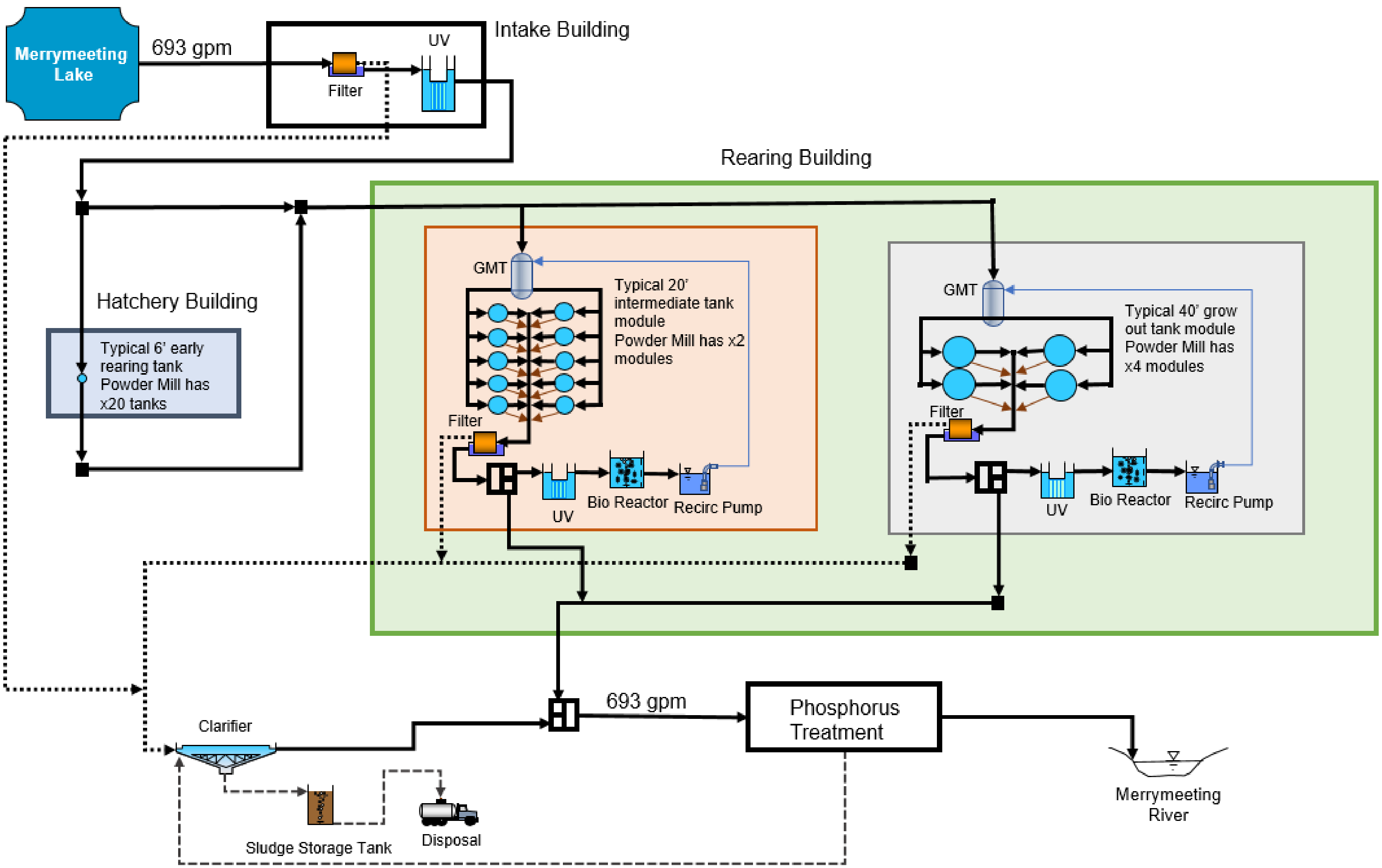

Figure 3-7 Alternative 3 Process Flow Diagram

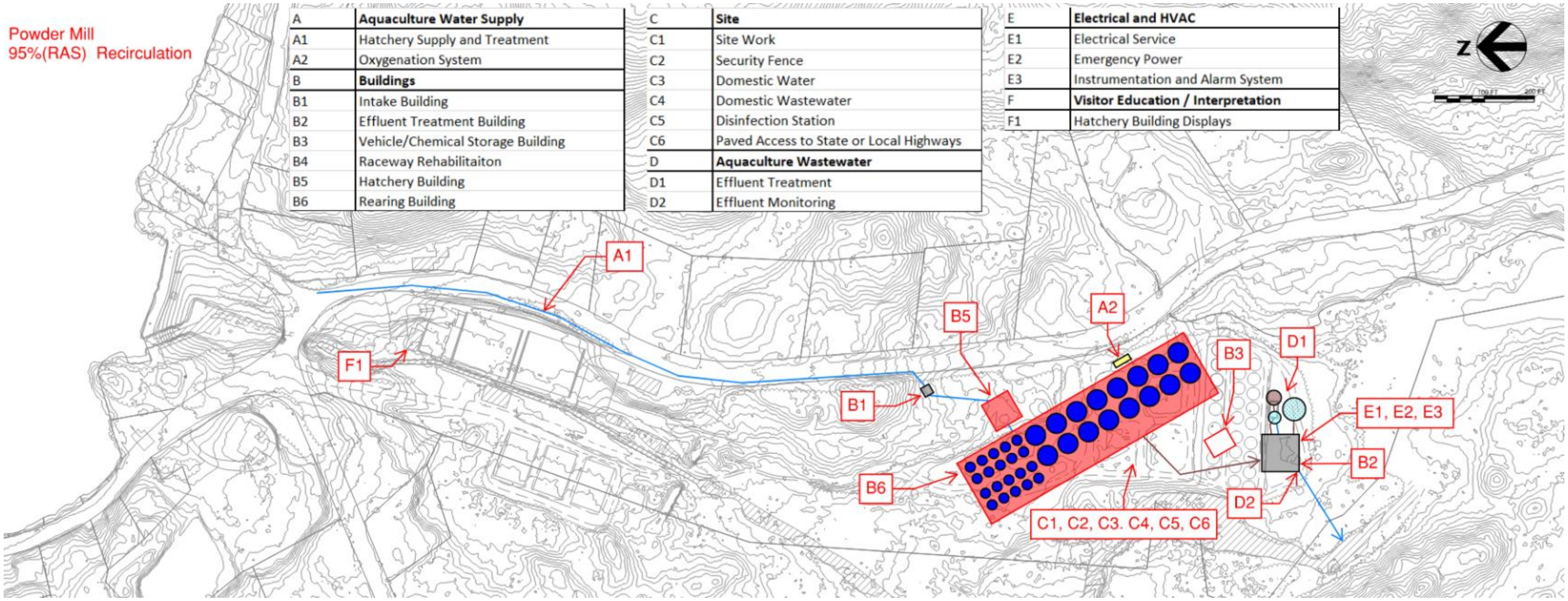

Figure 3-8 Alternative 3 Conceptual Site Plan

3.3 Combined Alternatives Summary

Three hatchery modernization alternatives combined with two phosphorus treatment alternatives result in six overall alternatives as shown in Table 3-1. This section outlines the differences in required components, chemical usages, and processes between the alternatives.

Table 3-1 Summary of Alternative Combinations

	Alternative 1A	**Alternative 1B**	**Alternative 2A**	**Alternative 2B**	**Alternative 3A**	**Alternative 3B**
Hatchery Alternatives (1, 2, and 3)	Existing Raceways with Aquaculture Upgrades	Existing Raceways with Aquaculture Upgrades	Circular Rearing Tanks with 75% Recirculation	Circular Rearing Tanks with 75% Recirculation	Circular Rearing Tanks with 95% Recirculation	Circular Rearing Tanks with 95% Recirculation
Effluent Treatment Alternatives (A and B)	Membrane Filtration with Chemical Dosing	Membrane filtration Followed by Adsorption	Membrane Filtration with Chemical Dosing	Membrane filtration Followed by Adsorption	Membrane Filtration with Chemical Dosing	Membrane filtration Followed by Adsorption

While six alternatives are possible, the improvements are reflected in two primary features within the hatchery modernization and the effluent treatment as follows:

- Hatchery Modernization – Use of existing infrastructure versus implementation of recirculating technology
- Effluent Treatment – Addition of membrane filtration with either chemical dosing or adsorption

Hatchery Alternative 1 is based on the existing hatchery infrastructure and does not change the source water flow rate or the anticipated effluent phosphorus concentration. Hatchery Alternatives 2 and 3 implement recirculation technology which reduces the source water demand and subsequently the effluent flow rate required to be treated.

3.3.1 Phosphorus Loadings

A key difference between Alternative 1 options and the Alternative 2 and 3 options is new dual flow circular rearing units for fish production. The proposed dual drain circular units are rapidly self-cleaning due to their operational features. Fish generated solids are removed before they have a chance to break down into soluble and harder to treat forms of phosphorus compared to the large particulate forms. The estimated effluent flow rates, phosphorus concentrations, and phosphorus loads for each hatchery alternative are summarized in Table 3-2 to illustrate the impact of applied technologies. It should be noted that the recirculation options increase the instantaneous phosphorus concentration because less flow rate is discharged with similar mass loadings. This underscores the importance of utilizing mass loadings as concentrations can be highly variable for similar mass loading. For the comparison of alternatives, the overall mass loadings for Alternatives 2 and 3 are lower in this example due to a modeled feeding efficiency possible in the modernized facility over the existing operation's feeding levels.

Table 3-2 Estimated Effluent Flows and Phosphorus Loads

	Hatchery Alternative 1	Hatchery Alternative 2	Hatchery Alternative 3
Effluent Flow, gpm	3,745	3388	693
Estimated TP Concentration in Hatchery Effluent, mg/L	0.081	0.059	0.289
Effluent TP Loading, lb/day	3.65	2.41	2.41

3.3.2 Effluent Treatment Chemical Usage

There will be chemical consumption in all alternatives attributed to the membrane filtration unit required in the effluent treatment portion of the renovations. Citric acid, Sodium Bicarbonate, and Sodium Hypochlorite are required for the membrane recovery process. Typical values for the chemical consumption were provided by the membrane manufacturer and are presented in Table 3-3.

Table 3-3 Summary of Required Chemicals for Membrane Cleaning

	Alternative 1A	Alternative 1B	Alternative 2A	Alternative 2B	Alternative 3A	Alternative 3B
Sodium Hypochlorite Usage (gal/yr)	18,300	18,300	18,300	18,300	6,900	6,900
Citric Acid Usage (gal/yr)	38,500	38,500	38,500	38,500	14,500	14,500
Sodium Bisulfate Usage (gal/yr)	4,400	4,400	4,400	4,400	1,700	1,700

Additionally, metal salt will be dosed upstream of the membrane filtration in alternatives 1A, 2A and 3A to reduce effluent sRP concentrations. The attributed dosage rates depend on the hatchery effluent phosphorus loadings. For this effort, alum was considered as a low cost and readily available coagulant, however, selection between alum vs ferric is pending. Additionally, since both alum and ferric consumes alkalinity, sodium hydroxide is dosed to replace it. A summary of each individual alternative shown in Table 3-4.

Table 3-4 Summary of Required Chemical Additions for Coagulation

	Alternative 1A	Alternativ e 1B	Alternative 2A	Alternative 2B	Alternative 3A	Alternative 3B
48% Alum Dose (lb/hr)	45	0	29	0	31	0
48% Alum Usage (gal/yr)	12,000	0	8,000	0	8,000	0

	Alternative 1A	Alternative 1B	Alternative 2A	Alternative 2B	Alternative 3A	Alternative 3B
25% Sodium Hydroxide Dose (lb/hr)	38	0	24	0	26	0
25% Sodium Hydroxide Dose (gal/yr)	10,000	0	7,000	0	7,000	0

3.3.3 Solid Handling

Due to recommended hatchery improvements, solids will be automatically transported out of rearing units and into the drains in Alternatives 2 and 3 but will still need to be manually removed in Alternative 1. Solids handling equipment will be required to remove those solids from the effluent stream in all three alternatives to maintain permit compliance. Drum filters will be deployed at the end of the hatchery process in Alternative 1A and 1B (Figure 3-1) and in the recirculation systems in Alternatives 2A, 2B, 3A and 3B (Figure 3-3 and Figure 3-5) as standard PRAS and RAS equipment utilizing 40 to 60 micron mesh drum filters. Further solids removal will be done downstream in the effluent treatment plant via .04-micron membrane filtration. The solids recovered from the drum filters and the membranes will be sent to a clarifier for thickening. The sludge from the clarifier's underflow will be transferred to a storage tank and subsequently hauled off the facility by truck. Unit processes of solids handling include effluent drum filters, clarifiers, and sludge storage are shown in Figure 3-9.

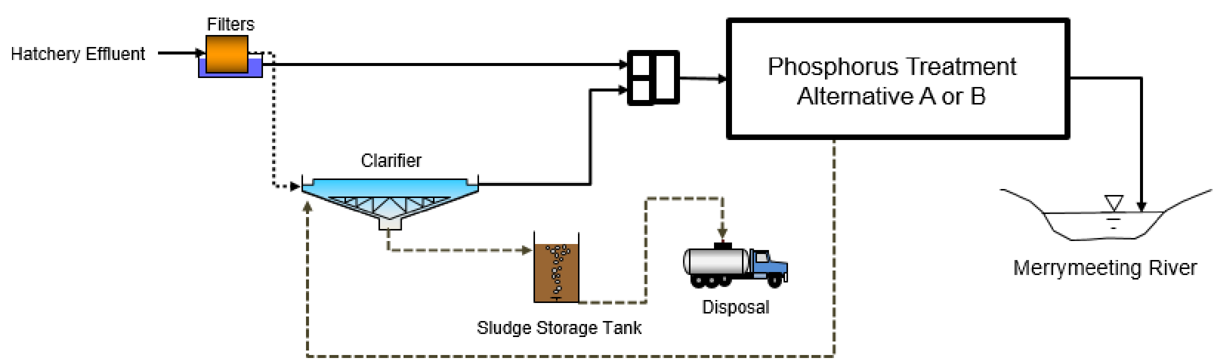

Figure 3-9 Solids Handling Schematic

In addition to the hatchery effluent solids, chemical sludge will be formed in Alternative 1A, 2A and 3A as a result of coagulant addition and will be wasted into the clarifier along with the membrane clean recovery process water. Preliminary quotes on the membrane units indicated a relatively poor recovery rate of just over 90 percent meaning that 10 percent of flows sent to the membranes will be rejected and in turn become a significant side stream. In detailed design, that side stream will require investigation to determine if the primary membranes can be operated with a more favorable recovery rate. Otherwise, that side stream will require additional treatment. Some treatment options include increasing the primary membrane capacity or installing a dedicated membrane. Suitable disposal options must be identified and evaluated for the sludge that is generated. Based on the composition of the solids, land application, landfill, and incineration can be considered. The selected method of disposal may necessitate dewatering the sludge.

The estimated sludge production, required storage tank, and frequency of hauling for each alternative are presented in Table 3-5. Sludge storage tank sized for 6-month storage capacity during winter.

Table 3-5 Clarifier and Sludge Storage Tank Sizing

	Clarifier Diameter (ft)	Clarifier Depth (ft)	Sludge Storage Tank Diameter(ft)	Sludge Storage Tank Depth (ft)
Alternative 1	30	8	30	7.5
Alternative 2	40	8	30	7.5
Alternative 3	40	8	25	7.5

3.3.4 Treatment Process Monitoring and Analysis

Effluent treatment process monitoring will include automated flow meters and online phosphorus analyzer. The data provided by the monitoring equipment will be used by a control system to estimate required chemical dosage in real-time. The control system will prevent underdosing or overdosing the chemicals and optimize the process performance and chemical cost.

Treatment influent and effluent samples should be collected frequently and analyzed for total phosphorus to ensure compliance. Measuring total phosphorus below 50 μg/L comes with poor accuracy in upwards of +/-50% towards below 20 μg/L. This poses some practical challenges that were discussed at length in the Technical Memorandum titled, Pilot and Bench Testing Results and Recommendations completed as part of this contract.

The low limit and analytical variability will require daily samples; at a minimum 20 samples per month. This would allow the analytical variability to average out and permit the plant to make up occasional excursion. Online monitoring relies more on consistency than accuracy as operators can include offsets and/or fine tune the process control in other ways based on verified performance.

We recommend pilot testing online analyzers like the Hach 5500sc as part of the predesign. Further, we recommend that Powder Mill continue to run total phosphorus samples with the DR 3900 spectrophotometer and TNT 843 test kits on split samples that are sent to a commercial lab such as the University of New Hampshire (UNH) lab as part of routine monitoring. This will give hatchery staff time to fine tune the sampling and analysis to where the measured values can inform day to day operation decision if online monitoring is not reliable or cost efficient.

3.4 Site Improvements

The following discussion identified areas where improvements are suggested. These improvements correspond to numbered items identified on the site drawings (Figure 3-4, Figure 3-6, and Figure 3-8) and the opinions of probable construction cost in Section 4. It is suggested that the reader refer to the keyed notes on the drawings to become familiar with the location and scope of improvements discussed in this section of the report.

3.4.1 A. Aquaculture Water Supply

A.1. Hatchery Supply Distribution
Improvements to the water supply distribution will be needed to accommodate the new facilities. These improvements include additional water supply piping and accessories to distribute the water supply to the entire hatchery considering new upgrade on rearing units for each alternative.

A.2. Oxygenation System
One of the highest impact methods to improve fish production and growth is to increase the supply of oxygen to the fish. Currently, the facility is contending with lower than optimal oxygen levels as the water is reused multiple times in the system.

Low Head Oxygenators (LHO's) are proposed for the raceway oxygenation equipment. LHO's generally can operate with minimal drop and depending on how much oxygen is applied, they can produce supersaturated oxygen concentrations while displacing other dissolved gases like nitrogen. LHO's operate by dropping water through an orifice plate into a multi-chamber oxygen rich cavity. High purity oxygen is supplied to fill the LHO cavity and when the water passed through, oxygen displaces nitrogen in the water increasing the dissolved oxygen level while decreasing the nitrogen level in the water.

Liquid oxygen (LOX) is commercially available and is typically stored in an insulated cryogenic container on site which can either be rented or purchased. Because LOX has a very low boiling point that requires storage under high pressure, it must be vaporized and used as a high-pressure gas. A typical LOX system includes components such as a storage tank, vaporizer, piping, and pressure regulators. LOX systems are generally very reliable and the gas itself is economical. The major advantage of utilizing LOX is the ability to consistently achieve high DO concentrations with little or no noticeable noise. Furthermore, LOX systems are functional during power outages since there is no power required to contact the water with oxygen.

3.4.2 B. Building and Rearing Units

The current layout of the Powder Mill Fish Hatchery has various buildings and rearing units spread out across the entirety of the developed site. This arrangement takes advantage of gravity flow and allows for multiple uses of the water throughout the facility. The three Alternatives summarized in 3.2 above outline potential use of new buildings at the existing property owned by NHFGD. The scope of work for renovating or adding buildings to the site varies between the three alternatives ranging from simple building renovations to major indoor rearing building additions. For Alternative 1, the scope of work for the existing buildings and rearing units will be limited to the rehab work necessary to keep the buildings and raceways operational, such as concrete spall and crack repairs. In Alternatives 2 and 3, the existing rearing units will all be replaced with new rearing tanks in a new Rearing Building, and the existing raceways will be abandoned.

B.1 Intake Building
A new Intake Building housing surface water treatment drum filters and UV units will be included in each of the alternatives. The intake will accommodate filtration and disinfection of up to approximately 4,000 gpm influent therefore reducing exposure to debris and pathogens leading

to a more biosecure water source. Alternative 1 requires two intake structures, to accommodate for the split between rearing areas on both sides of the Merrymeeting River.

B.2 Effluent Treatment Building

An Effluent Treatment Building will be included in each alternative before the effluent monitoring and outfall location back into the Merrymeeting River. Due to the local climate, all of the effluent treatment facilities shall be located indoors.

The Effluent Treatment Building will be a simple concrete or masonry and steel structure sized to fit the effluent treatment equipment with necessary circulation and maintenance space.

B.3 Vehicle/Chemical Storage Building

The existing Chemical Storage Building, which is located adjacent to the north entrance on top of the hill, is in poor condition and cannot be used as intended for the storage of large vehicles and chemical supplies. Since this building is not in stable or safe condition, it is recommended this building be demolished as part of each of the alternatives and be replaced with a new Vehicle / Chemical Storage Building.

The new Vehicle/Chemical Storage Building will be larger than the existing building in order to accommodate the vehicle storage needs along with the increased chemical storage needs related to the new effluent treatment plant. The new building will be designed with proper fire separation between the vehicle and chemical storage areas, and with proper ventilation and spill containment.

The location of the new Vehicle / Chemical Storage Building varies depending on the alternative based on the location of the Effluent Treatment Building, so the chemicals needed in the effluent treatment plant are located to minimize the need to transport the chemicals around the site.

B.4 Raceway Rehabilitation

The quiescent zones at the tail end of the raceways and the boxes at the circular tanks have been vacuum cleaned weekly with a portable vacuum and hauling tank to reduce the amount of solids and associated phosphorous in the hatchery effluent. This process is very labor intensive and physically demanding on hatchery staff. Rapid removal of the solids is essential to achieving the permitted P concentrations. When solids accumulate in the rearing environment, they breakdown into smaller particles and also release soluble P which are both harder to remove. Given the extremely low level of phosphorus allowed, solids must be collected and extracted from the tanks as quickly as possible via an automated process.

Within raceways, automated processes similar to the dual drain circular tanks are not possible. To aid in improving the sweeping velocities in the raceways, which would move generated solids more efficiently, flow baffles are recommended. Flow baffles are a solid aluminum plate that is anchored to the wall of the raceway. The solid panel extends above the water column and a gap is created where the baffle meets the floor of the raceway. The gap is provided to allow fish movement but is also where water flow is forced and solids are pushed. The solid plate of the baffle forces flow under the baffle through the gap thus creating higher velocities along the floor. When baffles are used, raceways are not cleaned (broomed) on a regular basis since most solids sweep to the quiescent zones (QZ). The quiescent zones must be routinely vacuumed to remove accumulated solids but the system is more efficient and moving solids to the QZ to be managed than traditional raceways with no flow baffles. In a typical arrangement, baffles are recommended to be placed at intervals equal to 1.0 to 1.5 times the width of the raceways. This spacing allows for the floor velocities to remain connected between baffles and solids to be efficiently pushed to the QZ. The State of Michigan routinely utilizes flow baffles in their linear raceways to improve solids movement to QZ zones and is an example of a State operation.

Alternative 1 proposes retaining the existing rearing structures with the necessary rehabilitation work including concrete spall and crack repairs in raceways B through G, demolish and fill in raceway A, and Baffle flow installation to improve solid drainage and cleaning procedure in raceways.

B.5 Hatchery Building

The existing Hatchery Building is 40-ft by 22-ft concrete masonry and wood frame structure that houses the early rearing tanks and incubation trays (not currently operated). Under Alternative 1, this existing Hatchery Building would remain with a few minor upgrades or modifications, while Alternatives 2 and 3 propose a new building to be constructed that will house the incubation and early rearing tanks along with the Growout tanks. In addition, administrative spaces that are currently located in the historic Office / Garage Building, including staff office space, break room, locker and boot storage room, showers, and staff bathrooms will be incorporated into the new building in Alternatives 2 and 3.

The new building that is proposed under Alternatives 2 and 3, would be designed and constructed as a pre-engineered steel frame structure on concrete foundations, and will be fully enclosed with proper insulation, HVAC, ventilation, electrical and lighting. The new Hatchery Building will either be an independent building located adjacent to the new Rearing Building or could be constructed as a part of the rearing building with the administrative, incubation and early rearing spaces being separated spaces within the footprint of the Rearing Building.

B.6 Rearing Building and Circular Tanks

The Powder Mill Fish Hatchery does not currently have an enclosed rearing environment so the fish are routinely exposed to predation and sunlight which can increase stress and reduce feeding efficiency thus generating more waste. Outside of the Hatch House all rearing takes place in exterior raceways, ponds, and circular tanks. Alternatives 2 and 3, propose to construct a new Rearing Building to consolidate all of the rearing tanks and associated equipment and processes within a single large structure.

As part of Alternatives 2 and 3, the new Rearing Building would replace all of the existing raceways and circular tanks that are currently spread out across the site and consolidate all of the rearing into a single structure. The new Rearing Building is proposed to be a pre-engineered steel frame structure that is fully enclosed and insulated with proper electrical, lighting, HVAC, and ventilation. Within the pre-engineered building, there would be separate rooms or spaces for the RAS process equipment, storage spaces, and other mechanical, electrical and HVAC equipment. As noted in Section 3.4.2, the spaces and rooms that make up the Hatchery Building may also be included within the footprint of the Rearing Building in order to minimize the overall site impact of multiple new buildings by allowing for combined MEP (Mechanical, Electrical & Plumbing) equipment spaces.

The transition to recirculating circular tank modules is supported by the following:

- Improved operational efficiency is achieved by utilizing modern circular tanks with appropriate flow rates and dual drain technology. Circular tanks require less flow compared to traditional linear raceways to achieve the optimal velocities for solids management, water mixing and fish health. This means that by utilizing circular tanks solids management and fish health are enhanced while utilizing less water during grow out phase than previously used with linear raceways. It should be noted that Powder Mill is currently flow limited when utilizing linear raceways, does not operate with ideal velocities for solids management, and employs extensive serial reuse meaning the water utilized to rear the fish is reused multiple times without treatment to remove fish generated waste. The staff have made all possible adjustments to improve within the limitations of the existing infrastructure. Switching to circular tanks with optimal flows alone would allow for a more efficient use of available water, improve waste removal, and improve tank velocities.

- When operating with a partial or full recirculating aquaculture system, a percentage of culture water is treated and recycled back to the fish rearing environment. This means a larger portion of the water can remain within the system to improve overall flow rates while reducing the water required from Merrymeeting lake compared to a system without recirculation. This also can reduce the size of an effluent treatment facility as less water is leaving the system compared to the same system operating at a non-recirculated rate. By recirculating a percentage of the culture water, a new hatchery can be designed to match the existing flows available while increasing the individual flow rate within the rearing tanks. Depending on the recirculation percentage selected, the water use from Merrymeeting Lake could also be significantly reduced while maintaining production levels.

- In the proposed scenarios, recirculation modules are operated independently from each other thereby allowing increased flexibility in production numbers, control over rearing environments, and control over culture water requirements. For example, the proposed layouts reflect four independent growout modules of four tanks each that are independent systems from each other. This is a biosecurity and operational enhancement not possible in the current system that utilizes mostly the same water through several groups of fish.

- Reduced culture water requirements may allow for the phosphorus concentrations leaving the treatment plant to be greater than 12 µg/L when mixed with lake water prior to the permitted sampling point. This would allow the treatment plant to remove the cumulative phosphorus load to the prescribed limit then incorporate fresh water to achieve the permitted concentration through a permit approved dilution factor. Such a mixing zone could be incorporated within the facility or in the Merrymeeting River. It should be noted that for this effort outlined in this study, no dilution factor was considered, and the main driver of the treatment plant design was achieving the 12 µg/L concentration of phosphorus in the treatment plant effluent during the months of peak phosphorus production.

- It is believed that upcoming hydraulic and hydrologic studies for the evaluation of the discharge capacity of the Merrymeeting Dam will show that the dam overtops by several feet during the design flood. This will also mean that the lake overflow channel is also under designed and will require expansion to carry the new design flows. The existing lake overflow channel carries flows from the lake through the center of the hatchery to its outlet near Outfall 001 (see Figure 1-1) and is in poor condition. This channel will likely require complete replacement due to its condition as well as it's likely insufficient capacity.
- The use of a natural channel is desired to be able to handle the conveyance of the increased flows as well as the excess lake water not required to flow through the facility once new circular rearing units have reduced the required culture water. A natural channel within the center of the facility could provide a central educational opportunity for learning about the local ecosystem including fish, plants, animals, and insects. Additionally, this natural channel could also possibly be ecologically engineered to provide an environment for trout to migrate to the upstream lake and provide natural spawning opportunities.
- Since a natural waterway will require a larger footprint than a concrete channel to carry the same amount of flow, more space will be required in the middle of the facility to accommodate the new waterway, taking space currently occupied by Raceways A-D.

3.4.3 C. Site

Improvements to the site will be needed to accommodate the new facilities. These improvements will be the least extensive under Alternative 1, with only minor grading and roads needed to locate, construct, and access the facilities. Most of this work will take place at the lower end of the site related to the effluent treatment plant, as shown in Figure 3-4. Under Alternative 2 and 3 much more extensive improvements are needed, as shown in Figure 3-6 and Figure 3-8. In addition to the effluent treatment plant, the lower end of the site will need extensive demolition and grading to accommodate the large Rearing Building. Also, the location is in close proximity to the river, its floodplain and potential wetlands so there may be aquatic resource considerations and mitigation needed.

3.4.4 D. Aquaculture Wastewater

D.1 Effluent Treatment
New effluent treatment will be needed to accommodate the new TP limit. Two effluent treatment alternatives recommended in section 3.2 are based on the pilot study results.

D.2 Effluent Monitoring
Effluent monitoring equipment is required for effluent treatment. Flow measurement equipment and composite samplers for each effluent treatment alternative will be needed.

3.4.5 E. Utilities

The new Hatchery and Rearing Buildings in Alternatives 2 and 3 will need potable water to service bathroom and kitchen facilities. This will either be piped from the existing system servicing the existing hatchery building at the upper end of the site or from a new well at the lower end of the site. New domestic wastewater systems will be provided. Telephone and cable internet will need to be extended from the existing hatchery building to the lower end of the site or newly serviced from Merrymeeting Road.

Electrical service to the hatchery facilities is currently provided from the utility distribution line that runs along Merrymeeting Road. This utility line is single-phase, and therefore is not capable of providing the facility with 3-phase power. The project will coordinate with the utility to extend a 3-phase line from the nearest source in order to provide a new 3-phase service for new facility loads at the lower part of the site.

The hatchery does not currently have backup power capability. A new propane generator will be installed along with a propane storage tank and automatic transfer switch(es). The generator will be sized to provide backup power to critical hatchery loads for 72 hours minimum. The generator status will be monitored and connected to an auto-dialer for remote notification of loss of power.

Site security lighting will be installed at site entrances, along Merrymeeting road, and elsewhere where required to deter trespassers and mitigating predation at the raceways. Site lighting will be dark-sky compliant to minimize light pollution to the extent possible. Lighting controls will be installed to meet all required energy codes.

3.4.6 F. Visitor Outreach

There are several alternatives for how to improve the visitor areas of the facility to provide accessible amenities and an improved visitor experience. These alternatives include: (1) renovate the basement of the existing office building; (2) renovate the existing hatchery building; (3) construct a new visitor center over the existing Raceway A; (4) construct a new visitor's center as part of a new hatchery / rearing building.

The first alternative involves gutting the basement of the existing Garage / Office Building and renovating the space to include an updated visitor's center / display area where the current lab / wash area is located, so that the rear door can be converted into the main entrance. Designated accessible parking spaces will need to be added at the parking area along with a new accessible walkway from the parking spaces to the entrance at the rear of the building. This option for the visitor amenities works best in conjunction with Alternative 1, in which the existing raceways and hatchery building are upgraded in place. In this option, viewing areas could be created with views into the hatchery building.

The second visitor's center alternative involves gutting the existing hatchery building and converting it into a visitor's center. This option for the visitor's center works for Alternatives 2 and 3, as those alternatives create new hatchery buildings, which would leave this space available to be converted. Similar to the first alternative, designated accessible parking would be provided in the parking area along with an accessible walkway to the entrance door to the hatchery. Within the hatchery, all of the equipment will be removed along with abatement of the existing asbestos wall and ceiling panels. New insulation and interior wall finishes will be installed, along with a new entry door, new accessible entrance and ramp, new insulated windows, new lighting, and new HVAC system.

The third alternative for the visitor’s center would be to construct a new visitor’s center over Raceway A, adjacent to the existing hatchery building. The new building would be constructed of a concrete foundation with a lightweight metal stud framing and exterior finishes that complement the existing Garage / Office and Hatchery Buildings. This visitor’s center option could be implanted with any of the 3 overall alternatives. If this were used for Alternative 1, the new visitor’s center could be designed with viewing areas into the existing Hatchery Building. As with the first 2 visitor center alternatives, this option would require designated accessible parking spaces and an accessible route to the entrance.

The fourth alternative for the visitor’s center would incorporate the new visitor’s center into the new Hatchery / Rearing Building as part of Alternatives 2 or 3. In this visitor’s center option, the visitor’s center would be designed as a cohesive space within the new Hatchery / Rearing Building and could include views into the hatchery or rearing area.

For Alternative 1, it is recommended that new guardrails be provided around the existing raceways B, C, and D to allow visitors to safely view the raceways.

The existing show ponds can be maintained for each of the Alternatives, with a new accessible walkway from the parking area, along with a viewing platform for safe and accessible viewing.

4 Cost Analysis

Conceptual Opinion of Probable Construction Cost (OPCC), Operation and Maintenance (O&M) cost, and a life-cycle analysis were developed for each of the alternatives. Cost and quantities for equipment were developed based on information obtained from suppliers and historical project data. Costs for contingencies are included in the estimate for each individual process area and cost of escalation to midpoint of construction and market volatility adjustment are included in subtotal cost of all process area. O&M cost was estimated based on annual replacement cost, chemical costs, electricity costs, and labor cost for each alternative in below sections. The life-cycle analysis was estimated using a 20-year Net Present Value (NPV) analysis based on capital cost and O&M cost. The 20-Year NPV was used to prepare a Triple Bottom Line (TBL) analysis, which was used to aid in determining the alternative most suited for the project. Detailed OPCCs for each process area is included in Appendix E. A summary of OPCC for each alternative is provided in the following sections:

4.1 Opinion of Probable Construction Cost

OPCCs were estimated based on estimated quantities and unit costs for the outlined items in each of the three alternatives. These opinions were prepared to the standards of the Association for the Advancement of Cost Engineering (AACE) International Class 4 estimate which outlines an added construction contingency of fifty percent (50%) for conceptual level studies of this nature. The OPCC presented in the sections below is broken down by process area and numbering for each Alternative. The numbering within the figures is matched to the text and the OPCC.

4.1.1 Alternative 1 – Existing Raceways with Aquaculture Upgrades

The summary of OPCCs for Alternative 1A and 1B are presented in Table 4-1 and Table 4-2. Detailed OPCCs for each process area is included in Appendix E.

Table 4-1 Alternative 1A Opinion of Probable Construction Cost

Powder Mill New Facility Summary Opinions of Probable Cost		
ITEM	**DRAWING I.D. #**	**ROUNDED TOTAL COST[a]**
New Facility Features		
Hatchery Supply	A1	$9,000
Oxygenation System	A2	$322,000
Intake Building	B1	$1,624,000
Effluent Treatment Building	B2	$3,379,000
Vehicle/Chemical Storage Building	B3	$705,000
Raceway Rehabilitation	B4	$465,000
Site Work	C1	$1,004,000
Security Fence	C2	$7,000
Domestic Water	C3	$50,000
Domestic Wastewater	C4	$100,000
Disinfection Station	C5	$23,000
Effluent Treatment	D1	$26,674,000
Effluent Monitoring	D2	$65,000
Electrical Service	E1	$190,000
Emergency Power	E2	$217,000
Instrumentation and Alarm System	E3	$348,000
Hatchery Building - Displays	F1	$222,000
Subtotal		**$35,404,000**
Escalation to Midpoint of Const. @ 5%/yr for 5 years		$1,770,000
3% market volatility adjustment		$1,062,120
Total Cost		**$38,236,000**

[a] Rounded Total Costs (or Costs needed to Budget) include 50% Class 4 AACE expected accuracy range).
Costs do **NOT** include: Design Reimbursables (Variable); State Agency Administrative Fee; and land acquisition or lease.

Table 4-2 Alternative 1B Opinion of Probable Construction Cost

Powder Mill New Facility Summary Opinions of Probable Cost

ITEM	DRAWING I.D. #	ROUNDED TOTAL COST[a]
New Facility Features		
Hatchery Supply	A1	$9,000
Oxygenation System	A2	$322,000
Intake Building	B1	$1,624,000
Effluent Treatment Building	B2	$3,379,000
Vehicle/Chemical Storage Building	B3	$705,000
Raceway Rehabilitation	B4	$465,000
Site Work	C1	$1,004,000
Security Fence	C2	$7,000
Domestic Water	C3	$50,000
Domestic Wastewater	C4	$100,000
Disinfection Station	C5	$23,000
Effluent Treatment	D1	$31,444,000
Effluent Monitoring	D2	$65,000
Electrical Service	E1	$190,000
Emergency Power	E2	$217,000
Instrumentation and Alarm System	E3	$348,000
Hatchery Building - Displays	F1	$222,000
Subtotal		**$40,174,000**
Escalation to Midpoint of Const. @ 5%/yr for 5 years		$2,009,000
3% market volatility adjustment		$1,205,220
Total Cost		**$43,388,000**

[a] Rounded Total Costs (or Costs needed to Budget) include 50% Class 4 AACE expected accuracy range).

Costs do **NOT** include: Design Reimbursables (Variable); State Agency Administrative Fee; and land acquisition or lease.

4.1.2 Alternative 2 – Circular Rearing Tanks with 75% Recirculation

The summary of OPCCs for Alternative 2A and 2B are presented in Table 4-3 and Table 4-4. Detailed OPCCs for each process area is included in Appendix E.

Table 4-3 Alternative 2A Opinion of Probable Construction Cost

Powder Mill New Facility Summary Opinions of Probable Cost		
ITEM	**DRAWING I.D. #**	**ROUNDED CONST COST[a]**
New Facility Features		
Hatchery Supply	A1	$247,000
Intake Building	B1	$1,624,000
Effluent Treatment Building	B2	$3,292,000
Vehicle/Chemical Storage Building	B3	$656,000
Hatchery Building	B5	$4,230,000
Rearing Building	B6	$30,152,000
Site Work	C1	$836,000
Security Fence	C2	$4,000
Domestic Water	C3	$50,000
Domestic Wastewater	C4	$100,000
Disinfection Station	C5	$23,000
Paved Access to State or Local Highways	C6	$378,000
Effluent Treatment	D1	$25,490,000
Effluent Monitoring	D2	$65,000
Electrical Service	E1	$190,000
Emergency Power	E2	$217,000
Instrumentation and Alarm System	E3	$348,000
Hatchery Building - Displays	F1	$818,000
Subtotal		**$68,720,000**
Escalation to Midpoint of Const. @ 5%/yr for 5 years		$3,436,000
3% market volatility adjustment		$2,061,600
Total Cost		**$74,218,000**

[a] Rounded Total Costs (or Costs needed to Budget) include 50% Class 4 AACE expected accuracy range).

Costs do **NOT** include: Design Reimbursables (Variable); State Agency Administrative Fee; and land acquisition or lease.

Table 4-4 Alternative 2B Opinion of Probable Construction Cost

Powder Mill New Facility Summary Opinions of Probable Cost

ITEM	DRAWING I.D. #	ROUNDED CONST COST[a]
New Facility Features		
Hatchery Supply	A1	$247,000
Intake Building	B1	$1,624,000
Effluent Treatment Building	B2	$3,292,000
Vehicle/Chemical Storage Building	B3	$656,000
Hatchery Building	B5	$4,230,000
Rearing Building	B6	$30,152,000
Site Work	C1	$836,000
Security Fence	C2	$4,000
Domestic Water	C3	$50,000
Domestic Wastewater	C4	$100,000
Disinfection Station	C5	$23,000
Paved Access to State or Local Highways	C6	$378,000
Effluent Treatment	D1	$29,255,000
Effluent Monitoring	D2	$65,000
Electrical Service	E1	$190,000
Emergency Power	E2	$217,000
Instrumentation and Alarm System	E3	$348,000
Hatchery Building - Displays	F1	$818,000
Subtotal		**$72,485,000**
Escalation to Midpoint of Const. @ 5%/yr for 5 years		$3,624,000
3% market volatility adjustment		$2,174,550
Total Cost		**$78,284,000**

[a] Rounded Total Costs (or Costs needed to Budget) include 50% Class 4 AACE expected accuracy range).

Costs do **NOT** include: Design Reimbursables (Variable); State Agency Administrative Fee; and land acquisition or lease.

4.1.3 Alternative 3 – Circulation Rearing Tanks with 95% Recirculation

The summary of OPCCs for Alternative 3A and 3B are presented in Table 4-5 and Table 4-6. Detailed OPCCs for each process area is included in Appendix E

Table 4-5 Alternative 3A Opinion of Probable Construction Cost

Powder Mill New Facility Summary Opinions of Probable Cost		
ITEM	**DRAWING I.D. #**	**ROUNDED CONST COST[a]**
New Facility Features		
Hatchery Supply	A1	$247,000
Intake Building	B1	$1,624,000
Effluent Treatment Building	B2	$1,960,000
Vehicle/Chemical Storage Building	B3	$656,000
Hatchery Building	B5	$4,230,000
Rearing Building	B6	$31,952,000
Site Work	C1	$836,000
Security Fence	C2	$4,000
Domestic Water	C3	$50,000
Domestic Wastewater	C4	$100,000
Disinfection Station	C5	$23,000
Paved Access to State or Local Highways	C6	$378,000
Effluent Treatment	D1	$10,979,000
Effluent Monitoring	D2	$65,000
Electrical Service	E1	$190,000
Emergency Power	E2	$217,000
Instrumentation and Alarm System	E3	$348,000
Hatchery Building - Displays	F1	$818,000
Subtotal		**$54,677,000**
Escalation to Midpoint of Const. @ 5%/yr for 5 years		$2,734,000
3% market volatility adjustment		$1,640,310
Total Cost		**$59,051,000**

[a] Rounded Total Costs (or Costs needed to Budget) include 50% Class 4 AACE expected accuracy range).
Costs do **NOT** include: Design Reimbursables (Variable); State Agency Administrative Fee; and land acquisition or lease.

Table 4-6 Alternative 3B Opinion of Probable Construction Cost

Powder Mill New Facility Summary Opinions of Probable Cost

ITEM	DRAWING I.D. #	ROUNDED CONST COST[a]
New Facility Features		
Hatchery Supply	A1	$247,000
Intake Building	B1	$1,624,000
Effluent Treatment Building	B2	$1,960,000
Vehicle/Chemical Storage Building	B3	$656,000
Hatchery Building	B5	$4,230,000
Rearing Building	B6	$31,952,000
Site Work	C1	$836,000
Security Fence	C2	$4,000
Domestic Water	C3	$50,000
Domestic Wastewater	C4	$100,000
Disinfection Station	C5	$23,000
Paved Access to State or Local Highways	C6	$378,000
Effluent Treatment	D1	$12,233,000
Effluent Monitoring	D2	$65,000
Electrical Service	E1	$190,000
Emergency Power	E2	$217,000
Instrumentation and Alarm System	E3	$348,000
Hatchery Building - Displays	F1	$818,000
Subtotal		**$55,931,000**
Escalation to Midpoint of Const. @ 5%/yr for 5 years		$2,797,000
3% market volatility adjustment		$1,677,930
Total Cost		**$60,406,000**

[a] Rounded Total Costs (or Costs needed to Budget) include 50% Class 4 AACE expected accuracy range).

Costs do **NOT** include: Design Reimbursables (Variable); State Agency Administrative Fee; and land acquisition or lease.

4.2 Capital, O&M, and NPV Comparison

4.2.1 Capital Cost Comparison

The OPCC for each Alternative is shown in Table 4-7. A breakdown of each OPCC is presented in the Appendices.

Table 4-7 Comparative Capital Costs

Alternative	Capital Cost
Alternative 1A	$ 38,236,000
Alternative 1B	$ 43,388,000
Alternative 2A	$ 74,218,000
Alternative 2B	$ 78,284,000
Alternative 3A	$ 59,051,000
Alternative 3B	$ 60,406,000

4.2.2 O&M Cost Comparison

Estimated O&M costs for each Alternative are presented in Table 4-8. O&M cost comparisons include chemical, electricity, labor, and repair and replacement costs on an annual basis. A breakdown of the O&M costs for each Alternative are included in the Appendices.

Table 4-8 Comparative O&M Costs

Alternative	O&M Cost
Alternative 1A	$ 2,401,000
Alternative 1B	$ 2,631,000
Alternative 2A	$ 3,033,000
Alternative 2B	$ 3,288,000
Alternative 3A	$ 2,059,000
Alternative 3B	$ 2,114,000

4.2.3 20-Year NPV Comparison

NPV analyses were developed as 20-year values, which include the effects of inflation, capital, and O&M costs to provide one value to evaluate each Alternative. The results of the NPV calculations are shown in Table 4-9, and a breakdown of the NPVs for each Alternative is included in the Appendices. All NPV estimates are based on the following criteria:

- NPV Cost year basis: 2023.
- O&M Expenditures Escalation Rate:
  - 6% per year for years 2023 through 2026.
  - 3% per year for years 2027 through 2042.
- R&R Maintenance Cost:

- 6% per year for years 2023 through 2026.
- 4% per year for years 2027 through 2042.
- 5% SRF rate per year.

- Interest (discount rate): 5% per year.

Table 4-9 Comparative 20-Year NPV

Alternative	20-Year NPV
Alternative 1A	$ 89,801,000
Alternative 1B	$ 100,092,000
Alternative 2A	$ 137,644,000
Alternative 2B	$ 147,073,000
Alternative 3A	$ 100,906,000
Alternative 3B	$ 103,600,000

A comparison of the capital, O&M, and 20-year NPV costs for each Alternative is shown in Table 4-10.

Table 4-10 Comparative Capital, O&M, and 20-Year NPV Costs

Alternative	Capital Cost	O&M Cost	20-Year NPV
Alternative 1A	$ 38,236,000	$ 2,401,000	$ 89,801,000
Alternative 1B	$ 43,388,000	$ 2,631,000	$ 100,092,000
Alternative 2A	$ 74,218,000	$ 3,033,000	$ 137,644,000
Alternative 2B	$ 78,284,000	$ 3,288,000	$ 147,073,000
Alternative 3A	$ 59,051,000	$ 2,059,000	$ 100,906,000
Alternative 3B	$ 60,406,000	$ 2,114,000	$ 103,600,000

4.3 Triple Bottom Line Analysis

A TBL analysis was performed to aid in determining the alternative most suited for the project. TBL analyses are utilized to expand the traditional cost analysis framework beyond measuring simply capital, O&M, and NPV data to include non-monetary variables such as environmental, social, logistical, safety, performance, and reliability impacts. By focusing on comprehensive variables along the intertwined dimensions of cost, people, and the planet, the TBL tool is a valuable marker of the value of a particular Alternative in comparison to others. While the TBL analysis is an accounting and reporting tool, it is also a means of thinking about the future for any particular Alternative. Criteria for each area were applied and weighted for each Alternative and scored to determine the total weighted score and benefit ratio of each.

The general criteria used for the TBL analysis are included in Table 4-11.

Table 4-11 TBL Scoring Criteria and Descriptions

Criteria	Description	Relative Weight
Flexibility / Performance / Reliability - Hatchery	Is the alternative flexible enough to successfully adjust to changing conditions. Are there adjustable controls, process options, and/or equipment features available for operators to respond as needed?	1
Flexibility / Performance / Reliability - Effluent Treatment	Is the alternative flexible enough to successfully adjust to changing conditions. Are there adjustable controls, process options, and/or equipment features available for operators to respond as needed?	1
Ease of O&M - Hatchery	How easily can the Facility Staff operate and maintain the equipment and processes.	1.5
Ease of O&M - Effluent Treatment	How easily can the Facility Staff operate and maintain the equipment and processes.	1.5
Layout	How well does the alternative fit on the site, require land, and impact the site? Does the facilities lay out in an orderly fashion and is access to each facility maintained?	0.5
Social Impacts	How well does the alternative prevent off-site impacts to public perception such as noise, odor, and visual aesthetics and can these impacts be easily mitigated?	0.5
Environmental Impacts	How well does the alternative minimize the impact to the environment in terms of construction impacts, carbon footprint, (during and after construction), ecosystem quality, and resource use?	0.5
Production Capacity	What production capacity and expanded capacity is the facility capable of regularly achieving with the selected alternative?	1.5
Safety / Staff Considerations	How well does the alternative minimize safety risks to the facility Staff and the public and can the risks be mitigated?	2
Cost	What are the capital and O&M costs?	N/A

4.3.1 Criteria Weighting and Scoring

A score for each Alternative was then determined based on the 1 to 10 scale for each category. Table 4-12 contains the summary of the weighted scores for each Alternative, the relative weight factors, and the scoring scale for each Alternative. The total score for the Alternative was then summed to determine the Alternative with the highest TBL score as shown in Table 4-12.

Table 4-12 Triple Bottom Line Analysis

Criteria	Relative Weight	Alternative 1A		Alternative 1B		Alternative 2A		Alternative 2B		Alternative 3A		Alternative 3B	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Flexibility / Performance / Reliability - Hatchery	1	3	3	3	3	7	7	7	7	8	8	8	8
Flexibility / Performance / Reliability - Effluent Treatment	1	5	5	7	7	5	5	7	7	7	7	9	9
Ease of O&M - Hatchery	1.5	8	12	8	12	7	10.5	7	10.5	6	9	6	9
Ease of O&M - Effluent Treatment	1.5	6	9	8	12	4	6	6	9	7	10.5	9	13.5
Layout	0.5	6	3	6	3	9	4.5	9	4.5	9	4.5	9	4.5
Social Impacts	0.5	7	3.5	7	3.5	8	4	8	4	8	4	8	4
Environmental Impacts	0.5	7	3.5	8	4	4	2	6	3	6	3	7	3.5
Production Capacity	1.5	5	7.5	5	7.5	8	12	8	12	9	13.5	9	13.5
Safety / Staff Considerations	2	6	12	7	14	7	14	8	16	7	14	8	16
Total Weighted Score			58.5		66		65		73		73.5		81

4.3.2 Cost and Benefit Scoring

The total weighted score for each Alternative was used to determine the Benefit Ratio. The weighted score for each Alternative was divided by the highest weighted score of all of the Alternatives. The Benefit Ratio was used with the NPV for each Alternative to determine the NPV/Benefit Ratio value. Table 4-13 contains the cost comparison for each Alternative based on the NPV/Benefit Ratio analysis.

Table 4-13 Alternative Cost Comparison

Criteria	Alternative 1A	Alternative 1B	Alternative 2A	Alternative 2B	Alternative 3A	Alternative 3B
Total Weighted Score	58.5	66	65	73	73.5	81
Benefit Ratio	0.72	0.81	0.80	0.90	0.91	1.00
NPV (20-year)	$89,801,000	$100,092,000	$137,644,000	$147,073,000	$100,906,000	$103,563,000
NPV / Benefit Ratio	$124,400,000	$122,900,000	$171,600,000	$163,200,000	$111,300,000	$103,600,000

5 Summary of Finding and Recommendation

This section summarizes the evaluation and provides recommendations for NHFGD to consider at Powder Mill but also within the overall system. As noted in other documents provided within the overall work effort for NHFGD, the six hatcheries in the state operate in unison as one larger system supporting the stocking needs for New Hampshire. The recommendations for Powder Mill are provided to enhance the operation of the largest producer by volume of the six hatcheries but also to consider alternatives for re-purposing of the hatchery to provide other critical functions for the system. The recommendation summary is focused on three primary Alternatives, including:

- Alternative 1 – Reuse of existing rearing units with aquaculture upgrades
- Alternative 3 – Addition of a new circular rearing tank building with 95% water recirculation and aquaculture upgrades
- Additional Considerations – Re-purposed approach to meeting statewide production and stocking goals.

5.1 Alternatives Discussion

With the primary purpose of the study focused on treatment, of phosphorus in particular, the costs of treating the water to acceptable permit limits is the primary consideration. At this level of cost opinion development, the difference between effluent treatment Alternatives A (chemical dosing) and B (adsorption) is less than 10%. Trends between the two treatment Alternatives scale in the same manner when flows and loads change, meaning no significant advantage is gained on A versus B between varying flow rates. Averaging the OPCCs and O&Ms for Powder Mill, adsorption runs about 8% higher on equipment cost and 6% higher on annual O&M than B. Final effluent treatment technologies will be selected during design and be based on more in-depth cost opinions matched to available budget as well as O&M preferences and local industry support. As this evaluation shows only a small difference between the two treatment alternatives, the following discussion focuses on decision points for the hatchery side of the alternatives. More detailed discussions and additional information on the treatment Alternatives can be found in the Pilot and Bench Testing Results and Recommendations Report, HDR 2022, completed as a separate document within this contract effort.

Based on the results of the OPCCs, 20-Year NPVs, and TBL analysis, Alternative 2 (75% PRAS hatchery with advanced effluent treatment) is not recommended and will not be considered moving forward at the Powder Mill Hatchery. Discussion on Alternatives 1 and 3 are presented below.

5.1.1 Alternative 1- Existing Facility Infrastructure

Alternative 1 includes a new 3,750 gpm (5.4 MGD) effluent treatment plant to service the existing hatchery with minimal upgrades to the fish rearing systems. Alternative 1 has the lowest capital cost of all the Alternatives with about 85% of the investment (roughly $30 million) being directly associated to the effluent treatment plant requirements and about 7% of the investment (roughly 2.5 million) being directly associated with hatchery related improvements. The remaining 8% of costs are largely attributed to site work/improvements. This alternative does not modernize the existing conditions of the hatchery and only provides minor upgrades to sustain failing infrastructure. As is discussed in the Powder Mill Condition Report completed as a separate document, there are many deficiencies at the existing facility due primarily to the age of the infrastructure in place and the available fish culture technology at the time of the original construction. Most deficiencies pertain to aging buildings and fish rearing infrastructure that does not permit the staff to operate efficiently. Additional investment will be required to extend the useful life of the hatchery in addition to making investments in effluent treatment technology.

Due to its age, many “modern retrofits” to the rearing facilities are likely to run into significant design and construction challenges such as structural integrity and hydraulic grade concerns. Additionally, this Alternative has the higher O&M cost of the Alternatives evaluated for new equipment and processes, and most of which is attributed to effluent treatment. For comparison, the required effluent treatment plant would be similar in capacity to Portsmouth’s Pierce Island Wastewater Treatment Facility (3,333 gpm or 4.8 MGD as reported on their website). While designed average flows would be similar, the wastewater characteristics and limits at a Powder Mill facility would necessitate a different design. NHFGD is not currently equipped to own and operate a treatment plant of this type with the dedicated treatment plant staff. A decision to move forward with this Alternative must consider the implications of investing a large portion of the total budget on a brand-new treatment plant to service a facility that is beyond its design life. Decisions to make a large investment in effluent treatment must be weighed against the overall goals of the department, production goals and overall return on investment for the fish produced.

5.1.2 Alternative 3 – 95% Recirculation

Alternative 3 includes a new 95% RAS hatchery building as well as a new 693 gpm (1.0 MGD) effluent treatment plant. Alternative 3 has the higher capital cost with about 25% of the investment (roughly 14 million) being directly associated to the effluent treatment plant and 60% of the investment (roughly $34 million) being associated to the new rearing facilities. The remaining 15% of costs are largely attributed to site work/improvements. This Alternative replaces the existing hatchery rearing units and aims to slightly increase production capacity and provide improved flexibility within current production levels. The deficiencies of the existing hatchery would be addressed and improved upon. The new hatchery layout represents a replacement of the total production from Powder Mill into a single enclosed and biosecure building occupying a fraction of the current space. Since this Alternative requires a low background water demand from Merrymeeting Lake and compact site layout, the new hatchery does not need to be built on the current Powder Mill land and in turn discharge to the Merrymeeting River. The new rearing facilities could be built on undisturbed land or be incorporated into a separate hatchery site where the environmental effects of a state fish hatchery are not as impactful and standard effluent treatment is sufficient. This Alternative still requires advanced effluent treatment, albeit a smaller treatment plant would be required in comparison to Alternative 1. The staffing and operation of the plant would be a significant challenge for the NHFGD. The decision to move forward with this Alternative must consider making large investments in a facility that currently has the lowest phosphorus limit in the country.

5.1.3 Re-purposed Approach

Alternatives exist for the overall NHFGD fish production program and a role that Powder Mill could play in a re-purposed approach if the costs for treatment are deemed too high for the return on investment to the facility. A re-purposed role could include three options:

1- Broodstock and Egg Take Facility - Powder Mill could serve as the primary broodstock and egg take facility for a portion of the NHFGD program. Several states operate a similar broodstock and egg take facility as it focuses the facility's efforts on producing high quality and biosecure eggs for the rest of the program while other facilities focus on production. For example, the Crystal River facility operated by the State of Colorado operates in this manner. The facility maintains four broodstock strains on station. Annually, the facility spawns the strains of fish and incubates the eggs until they reach an eyed-egg stage and are stable enough for shipment to other facilities. Once received by the other facilities, the final incubation and growout phases occur. If water quality to serve in this capacity is deemed acceptable, Powder Mill could provide primary broodstock and egg production capabilities on an annual basis. In such a role, Powder Mill's egg incubation capabilities would need to be expanded and raceway repairs to a small set of raceways to house broodstock would be needed. With this adjustment in mission, the overall feeding impact and subsequent effluent levels could be reduced, because the total biomass of fish to be fed on station would be reduced. This option is presented for consideration if the previously discussed treatment and recirculation facilities are too costly. It maintains the facility, the investment in the infrastructure already made, and investment in staff, and provides the state with a much-needed primary brood and egg station. If completed at Powder Mill, incoming lake water disinfection would need to be addressed to target pathogens such as *Ichthyophthirius multifiliis* (Ich or White Spot Disease). A backup brood program would still be required at another facility to avoid interruption of egg production due to a system failure. This option could preserve a large amount of NHFGD's available renovation budget to build a new RAS-based facility in another area of NHFGD land where effluent limits would not require such aggressive (therefore expensive) treatment strategies.

2- Re-purposed Production Level - As noted in multiple documents within this study effort, feed is the primary driver linked to phosphorous production at a fish hatchery. Feeding at a hatchery is proportional to the total biomass on station. The more fish pounds carried, the more feed is needed and subsequently more fish-generated byproducts are created, including phosphorus. In order to achieve permit compliance without treatment or recirculation options, the biomass carried at Powder Mill could be reduced so that less phosphorus production would occur at the facility each month due to the reduction in feed required.

   To analyze the theoretical amount of fish that can be carried and still maintain permit compliance, several factors including background Merrymeeting Lake total phosphorus levels, flow rate to Powder Mill, fish size and quantity, feeding rates, and water temperature were considered. Utilizing known metabolic byproduct generation rates relative to phosphorus, the production level possible to remain under the 12 µg/L limit can be calculated. To estimate production levels, 4 µg/L of total phosphorus was assumed to come from Merrymeeting Lake and 0.005 lb of phosphorus per pound of feed fed (Willoughby, Larsen and Bowed 1972) was applied to predict the fish-generated total phosphorus production rate utilizing the following equation:

$$\mu g/L = \frac{0.005\ total\ phos.generated\ x\ total\ feed\ per\ day}{0.000001\ kg\ per\ mg\ x\ 8.34\ lb\ per\ gal\ x\ 1440 \min per\ day\ x\ flow\ gpm} \text{ x 1000 µg per mg}$$

Feeding rate based on fish energy requirements and protein-to-energy ratios within the diet can be found in the literature. This rate is much lower than the feed manufacturer's percent of body-weight (%BW) based method of determining feed rate. Westers claims that computed feeding levels can be 20%-40% lower than feed manufacturer recommended levels (Wedemeyer 2001). The feeding rate is calculated based on the fish size and the temperature of the water, utilizing the following equation from Westers (Wedemeyer 2001):

$$\%BW\ Feed = \frac{2.0\ x\ Water\ Temp\ (c)}{Length\ of\ fish\ (cm)}$$

Where:2.0 represents a constant for unit growth and feed conversion per Westers (2002)

For the combined outfall, the peak flow in June, 2020 was 4,065 gpm. At 4,065 gpm, a maximum of 78 pounds of feed can be fed per day to remain in compliance. Translating the total pounds of feed to fish biomass can be variable depending upon the size of the fish and the temperature of the water, but estimates can be made. For June, the average temperature was 52.6F and according to the 2020 records, fish on hand were approximately four inches, which corresponds to approximately 40 fish-per-pound. Applying Wester's calculations, the theoretical maximum pounds of four-inch fish that can be carried without exceeding the phosphorus discharge limit is 3,525 pounds, or 141,000 fish at 2.2 %BW feed. It should be noted that this is the total pounds of four-inch fish that can be on hand for the entire station to not exceed the 12 µg/L limit with no margin for sampling error. In a typical year, an overlapping year class could also be on station at this time, meaning Year-0 fish (RT0, EBT0, etc.) are coming into the facility as Year-1 fish (RT1, EBT1, etc.) are finishing to target size ahead of stocking. Table 5-1 below assumes that all fish are at the same size and the total feed reflects all feeding that can occur on station to remain at or below 12 µg/L. The table also assumes the first three to four inches of fish growth has occurred at another station prior to transfer to Powder Mill.

Table 5-1 shows theoretical production levels for a combined outfall utilizing the Westers calculated feed method.

Table 5-1: Theoretical Production Levels

Month	Flow (gpm)	Temperature (F)	Fish Length (in)	Fish per Pound	Feed Rate (%BW per day)	Pounds of Feed per Day	Pounds of Fish Possible
Jun	4,065	52.6	4.1	38.2	2.2%	78	3,525
Jul	3,499	57.6	5.2	18.7	2.2%	67	3,090
Aug	3,975	58.8	6.2	11.1	1.9%	76	4,036
Sep	3,571	55.5	6.9	8.0	1.5%	69	4,602
Oct	3,464	54.6	8.2	4.8	1.2%	67	5,510
Nov	3,717	51.1	8.4	4.4	1.0%	71	7,201
Dec	3,858	42.0	8.7	4.0	0.5%	74	14,682
Jan	3,890	36.9	8.9	3.7	0.2%	75	31,083
Feb	3,929	34.5	9.0	3.6	0.1%	75	37,721
Mar	3,689	36.3	9.1	3.5	0.2%	71	34,343
Apr	3,811	44.3	9.2	3.4	0.6%	73	12,512
May	3,471	49.1	9.4	3.2	0.8%	67	8,393

Note - Data averaged from 2020 Powder Mill charts provided by NHFGD. Fish per pound reflects Brook Trout condition factor of 0.0003793

As shown in the table, the facility could carry up to 37,721 pounds of 9-inch fish in February. This is based on the lower temperature of the water, low energy demand by the fish for that time of the year and resulting low %BW of feed required. This is a theoretical maximum assuming feeding is tailored to maintain phosphorus discharge at 12 µg/L without a safety factor. In months with warmer temperatures, the fish energetics increase, resulting in higher feed demand. In April a higher feed rate is required which would increase the phosphorus in the discharge. To feed at the April 0.6% BW rate, only 12,512 pounds of 9.2 inch fish could be carried. Under this scenario, the options for NHFGD would be to stock the fish early to reduce the pounds of fish at the facility.

An alternative method for forecasting phosphorus compliance is to utilize the amount of feed pounds per unit of water supply flow as a guideline. By utilizing this approach, the amount of flow required to dilute the generated phosphorus to 12 µg/L would require 52 gpm for each pound of feed fed on a daily basis. The rate of 52 gpm per pound of feed could be utilized as a tool to estimate production maximums. As noted above, this number is the maximum up to 12 µg/L and assumes 0.005 pounds of phosphorus is generated per each pound of feed fed. The numbers assume a traditional diet versus a low phosphorus diet. A safety factor should be employed, and results monitored the first few years of reduced production levels to verify that actual performance corresponds sufficiently to the theoretical calculations. Fine-tuning may be needed based on actual results, but the number provides a practical guideline to estimate potential production at Powder Mill based on feeding and flow.

Overall, production could be maintained at Powder Mill at a reduced level and in a similar range to the current levels at Warren and Twin Mountain. While reduced, the level of production possible is a positive impact to the overall statewide production target. Production decreases of 75% over the 2016-2021 average production are likely needed to achieve permit compliance. A 75% decrease in production would result in approximately 30,000 pounds of annual production from Powder Mill compared to the current average of 117,000 pounds. This would also require moving fish off station in March before rising water temperatures drive increased feeding rates, resulting in a 9-inch fish versus the targeted average of 9.5-inch fish. These reductions would result in approximately 100,000 9-inch fish available for stocking annually versus the current 344,000 9.5-inch fish.

The numbers outlined in this preceding section approximation utilize modeled data and historic results. These numbers should be discussed within NHFGD along with continued sampling results to refine the assumptions. Adjustments to reduce or increase the 100,000 fish (30,000 lbs) may occur with additional post-reduction sampling data. The data could be utilized to calibrate the guideline of 52 gpm per pound of food fed. Additionally, the calibration could be used to adjust for low phosphorus diets which could slightly increase the amount of pounds that can be carried within compliance.

3- Stockable Fish Staging Location

A third alternative for the Powder Mill facility would be to refocus the facility to eliminate rearing for growth and use the facility as a staging location for stocking only. If other hatcheries in the system could increase production to account for the reduced Powder Mill production, fish could be transferred in as they near the stocking target size. Once transferred to Powder Mill, minimal maintenance feeding would be employed for a short duration until the fish are stocked from this location. Maintenance feeding would be small amounts of feed per day necessary to maintain fish health ahead of stocking rather than production level feeding for adding fish growth. Stagging fish would likely occur for only a week or two at a time while making stocking trips to targeted water bodies.

As stated previously, Powder Mill provides the largest annual quantity of fish for NHFGD's public stocking program so loss of production from this facility has the largest potential for impact to the fishing public. Without compensation for the lost production, a significant reduction of stocked fish would occur. Two potential locations for compensating the lost production are New Hampton and Milford. New water sources and discharge points would need to be analyzed to confirm suitable conditions, but locations outside of the existing discharge points utilizing river water, which must be treated for incoming debris and pathogens via UV, potentially exist in these two locations. If this approach is employed, the majority of available dollars could be expended on fish production facilities rather than effluent treatment facilities.

5.2 Alternative Recommendation

Of the six alternatives evaluated in the TBL analysis as part of this evaluation, Alternative 3B received the highest rating. The renovated facility would protect the over 75-year investment in the property and location, allow for the continued use of the Merrymeeting Lake water supply, and would maintain the production of NHFGD's largest producing facility. Current practice at the hatchery is that almost all flow from the source water (Merrymeeting Lake) to the river is utilized by the hatchery to rear fish. Thus, there is no dilution factor that can be considered, making the effluent limits the same as the instream target. Alternative 3A and 3B would significantly reduce the flow rate required from the source water and thus the effluent discharge. The recirculated water used for fish rearing is conditioned before reuse by treating for solids and ammonia. In effect, the total source water flow through in the hatchery would reduce from 6 MGD to approximately 1 MGD. This opens an opportunity for the NPDES to be modified to allow for a minimum dilution factor of 2 where the hatchery effluent could be diluted with the lake water in a dilution zone before being discharged to the river. Thus, the instream target would be disconnected from the effluent limit and could allow for potential permit modification to increase the hatchery average monthly effluent limit up to 24 µg/L. Consequently, the required TP removal would decrease from 90% to 70% in peak loadings summer months, eliminating the need for chemical sequestration or adsorption unit and reducing metal salt addition significantly. With such permit modification, a more sustainable and cost-effective treatment solution would be possible.

While each Alternative meets current production goals and average monthly effluent TP permit compliance of 12 µg/L, it is unlikely that they represent the most effective investment for the NHFGD at this time. To maximize the benefits from investment, upgrades at each hatchery must be considered together. With significant infrastructure investment needs within the hatchery system across the state, allocating a large percentage of the total available capital budget to maintain current production at just one facility may be difficult to justify. The potential risks associated with designing, building, owning, and operating a "first of its kind" hatchery effluent treatment plant are significant. Evaluations at each of the other state hatcheries must be completed to consider how overall production can be relocated. Sites that are best suited to handle phosphorus loads, where typical effluent treatment practices are sufficient must first be fully utilized. Comparison of alternatives that increase production at other facilities may lead to abandoning Powder Mill or entirely re-purposing the site to deliver on different production goals like brood stock.

It is recommended that NHFGD discuss the alternative approaches outlined in 5.1.3 within the agency to consider the impacts. Specifically, Powder Mill can play a vital role in the statewide production goals by producing fish at a re-purposed level of 100,000 fish (30,000 lbs) annually as outlined in 5.1.3.2. While a significant reduction in historic production, the production level maintains positive capacity within a facility that is already in place with knowledgeable staff and an appropriate water supply. Under a re-purposed production level, another location would need to be sized to provide the lost Powder Mill production. This includes the loss of up to 87,000 pounds annually but also the associated stocking trips currently completed from Powder Mill. Despite this loss of production, the Powder Mill facility is recommended to continue at the reduced level provided permit levels continue to be met with the reduced production.

Based on the substantial capital and O&M costs required to maintain operations and permit compliance at the Powder Mill Facility, it is strongly recommended that further evaluation of Powder Mill's role in the statewide hatchery program should be conducted in the context of a reduced production scenario. Continued operation of the facility at a reduced production level has value to the overall NHFGD system.

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Appendix A Existing Site Maps and Hydraulic Profile

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Appendix B Proposed Site Layouts

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Appendix C Equipment Vendor Proposal Information

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Appendix D Process Calculations

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Appendix E Capital Cost, O&M, and NPV Breakdowns

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