PRELIMINARY HYDRO PLANT ASSESSMENT

MINE FALLS HYDROELECTRIC PROJECT
NASHUA, NEW HAMPSHIRE

FOR:

CITY OF NASHUA
229 MAIN STREET; P.O. BOX 2019
NASHUA, NEW HAMPSHIRE

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Table of Contents

Executive Summary 1
1.0 Introduction 2
1.1 Purpose 2
1.2 Background 2
1.3 Scope 3
1.4 Qualifications 3

2.0 Description and Assessment of Current Condition 4
2.1 Water Retention Structures – Dam, Spillway, Abutments 7
2.2 Flashboards, Retaining Wall 7
2.3 Impoundment and Canal 8
2.4 Intake, Trashrack, Rack Cleaning 9
2.5 Powerhouse 9
2.6 Special Equipment, e.g. Cranes, Rigging, etc. 10
2.7 Turbines, Bearings, Gearboxes, etc. 10
2.8 Draft tubes, Tailrace 11
2.9 Generators, Controls, Switchgear, automation, Substation 11
2.10 Fire Control, Alarms 14
2.11 Fish passage Facilities 14
2.12 Plant Access 14
2.13 Manuals, Drawings, Etc. 15
2.14 Spare Equipment, Inventory(ies) 15

3.0 Description and Assessment of Project Operation and O & M 16
3.1 Current Operation 16
3.2 Power Production 16
3.3 Fish Passage Facilities 16
3.4 Minimum Flows 16
3.5 Confirmation of Operating Curves 16
3.6 Description (Verification) of elevations of impoundment, etc. 17
3.7 Project Hydrology 17
3.8 Flow Curves, Annual Flow Curve 17
3.9 Current O&M Procedures, staffing, Automation 19
3.10 Repair History (significant events) 19
3.11 Contracts for O&M, Warranties 20
3.12 Inspections 20
3.13 Scheduled Repairs, Improvements (budget and schedule) 20

Table of Contents (continued)

4.0 Description and Assessment of Project Performance 21
4.1 Historic Generation 21
4.2 Significant Outages 21
4.3 Historic Plant Operational Capacity 22
4.4 Turbine and Generator Current Efficiencies/degradation 22

5.0 Description of Project Revenues 23
5.1 Historic Revenues 23
5.2 Unrealized Revenues 23

6.0 Assessment of Remaining Life 24
6.1 Project Works 24
6.2 Electro/Mechanical 24
6.3 Anticipated Project Repairs and Costs – frequency 24

7.0 Assessment of Ability to Improve Project Performance, Revenues, Costs, etc . 25

8.0 Project Economic Feasibility Analysis 26
8.1 Hydroplant Value 26
8.2 Recommended Refurbishment/Life-Extension Schedule and Costs 26

9.0 Conclusions and Recommendations 28
9.1 Conclusions 28
9.2 Recommendations 30

10.0 List of Acronyms 31

11.0 Limitations 33

APPENDICES

Appendix A – July 16, 2015 Site Photos 35
Appendix B – Monthly Flow Duration Curves 53
Appendix C – Mechanical Assessment 66
Appendix D – Electrical Assessment 69
Appendix E – Project Drawings 73

EXECUTIVE SUMMARY

The Mine Falls Hydroelectric Project is a 3,000 kW federally licensed (FERC) hydroelectric project that the City of Nashua leases the site and water rights to Mine Falls Limited Partnership, who built the project in 1985. By terms of the lease, the City needs to decide to exercise its option to purchase in the 30 day period starting December 11, 2015 the facility for one-half of its original project cost plus the cost of certain capital expenditures made since 1985.

A preliminary assessment of the condition of the facility, its performance and likely value has been made in order to assist the City in making the decision to exercise its purchase option.

Overall, the facility was found to be in "reasonably" good condition; but it is in need of certain repairs and refurbishments to extend its service life another 25 to 30 years. The plant has exceeded its original estimated average annual generation by about 2%, or 12,838,799 kW-hrs. The price to purchase the project is estimated to be about $4,094,000, or $1,365 per kW, which is below the 2014 market selling price of $2,100 per kW for comparable hydroelectric facilities.

The assessment recommends that the City consider the purchase of the facility and conduct certain tests before the purchase closure to finalize short- and long-term costs of ownership.

1.0 Introduction

1.1 Purpose

The purpose of this preliminary assessment is to determine the condition, performance, short- and long-term capital improvement costs, and general value of the Mine Falls Hydroelectric Facility, located in the City owned Mine Falls Park. The preliminary assessment is intended to be sufficient in detail to allow the City to determine if it should exercise its option to purchase the facility in accordance with its lease with Mine Falls Limited Partnership.

1.2 Background

The Mine Falls Hydroelectric Project is a federally licensed project. The Project's license was issued to the City of Nashua and Seward Construction Company, as co-licensees, by the Federal Energy Regulatory Commission (FERC) on August 4, 1983 for a term of 40-years, as "The City of Nashua and Seaward Construction Company, Project No. 3442-001". The current license term expires on July 31, 2023.

The City of Nashua leases the Project site and water rights to its current co-licensee, the Mine Falls Hydroelectric Limited Partnership (MFLP). The current general partner of MFLP is Eagle Creek Renewable Energy, which purchased the partnership interests from the then Algonquin Power Fund, Inc., on June 29, 2013.

The current lease, as amended, expires on May 1, 2024. The terms of the lease allow the City of Nashua the right to acquire the Project's works (including improvements and betterments to the leased site) by exercising a purchase option. The City of Nashua's purchase option commences on December 11, 2015 and expires on close of business, 5:00 p.m., January 10, 2016. Unless modified, the purchase option, when exercised, provides for a closing on the Project's assets no sooner than one (1) year after the exercise of the option, and no later than two (2) years thereof. Effective as of the closing, the lease shall be deemed terminated and title to the Project works, equipment, civil structures, and improvements shall reside with the City of Nashua.

At the time of title transfer, etc., the Project's assets, in accordance with the terms of the lease, are to be in "good condition" with ordinary acceptable wear and tear, and repair of damage beyond normal wear and tear, whether by fire or other casualty.

The exercise of the City of Nashua's purchase option does not require the payment of a deposit, earnest monies, etc., to MFLP. The purchase does require that the City of Nashua and MFLP enter into a purchase and sale agreement. However, the provisions thereof are subject to numerous express and implied conditions, including, but not limited to, further due diligence with regard to the condition of Project assets. The City

of Nashua is also obligated under the lease, whether it exercises the purchase option or not, to pay at the time of transfer of title, "*the depreciated values of any capital improvements made to the Project after thirty (30) years after the Initial Date of Commercial Operation*." The Initial Date of Commercial Operation is December 2, 1985.

1.3 Scope

The scope of the investigation for the preliminary assessment included a facility visual examination, a review of available operation and maintenance (O&M) records, an evaluation of the O&M and power/energy performance against the original facility design and those of comparable hydroelectric facilities, and an evaluation and determination of short- and long-term capital improvement costs.

1.4 Qualifications

Although this facility has been in operation for 30 years, there is little in the way of "day-to-day" plant log records. Only certain historic emergency and some routine equipment testing/monitoring data were available for this investigation. Because of the schedule to complete this assessment by the end of August, there was insufficient time to conduct certain physical (plant shutdown and dewatering), turbine/generator equipment (teardown), or electrical testing to provide definitive conclusions on the exact condition of all the equipment. However, because of the assessment team's past experience with the facility, that included engineering and permitting, construction, equipment installation and early–on operations, professional judgements, weighed with comparable data from similar hydroelectric facilities, were used to determine the general condition of the facility and its equipment, and provide reliable estimates of short-and long-term project costs.

2.0 Description and Assessment of Current Condition

Mine Falls Hydroelectric Project is located on the Nashua River in Nashua, New Hampshire (Figure 1). The Project consists of a dam with overflow spillway, two stoplogged stanchion bays, a single flood sluice, power canal and intake structure, powerhouse and tailrace. The original dam was constructed in the 1820s, with subsequent modifications to its current configuration of a concrete capped, granite block, rockfill dam, with an approximately 145-feet long spillway at a permanent crest elevation of 154.77 ft NAVD 88, and 4.0 ft. high wooden flashboards maintaining a normal headpond elevation of 158.77 ft NAVD 88.

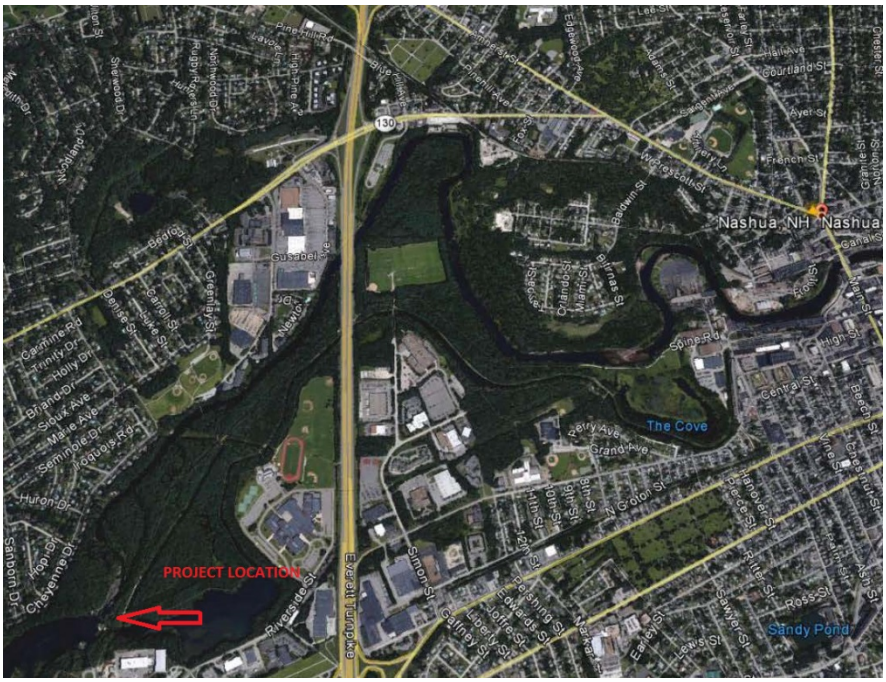


Figure 1 – Google Earth image of Project Location in proximity to downtown Nashua, New Hampshire

To the right of the concrete capped spillway (viewed facing downstream) are two, 12.5 feet-long stoplog bays and a 10-foot wide gate with a short spillway section above the gate. The stop log bays have a permanent concrete invert elevation of 145.77 ft NAVD 88, with a top of log elevation at the normal pond elevation of 158.77 ft NAVD 88. Adjacent to the stop log bays (right side facing downstream) is a single flood sluice gate, with an invert elevation of 141.77 ft NAVD 88 (Figure 2).

Figure 2 – Stoplog bays and sluice gate adjacent to Mine Falls Dam, Nashua, New Hampshire

The 22-feet wide power canal is along the right bank of the river, between the river bank and the single flood sluice gate. The canal is approximately 170 feet long, made of reinforced concrete, with an invert of 139.27 ft NAVD 88, and a top of wall elevation of 159.77 ft NAVD 88. Immediately upstream of the powerhouse intake is a waste gate and two smaller stop log bays. The river side wall of the power canal and the two stop log bays serve as auxiliary spillways during high flow periods and for sluicing trash and large debris from the canal (Figure 3).

Figure 3 – Riverside power canal wall with stoplog bays and waste gate immediately upstream of powerhouse intake

The intake structure (Figure 4) is comprised of a trash rack and mechanical raker, two roller gates, and two square to round transition openings which feed the 104 inch diameter steel penstocks. The powerhouse is a multi-level reinforced concrete structure containing the turbines, generators and controls, and auxiliary equipment. The tailrace is a channel cut into the river downstream of the powerhouse that returns discharge from the powerhouse back to the river (Figure 5). The majority of the Project components are founded on ledge, with significant sections of ledge removed by blasting in order to construct the power canal, canal wall, and powerhouse.

Figure 4 – Mine Falls Hydroelectric Plant Intake

Figure 5 – Mine Falls Hydroelectric Project Powerhouse and tailrace

The turbine-generators are two identical systems: vertical-shaft, semi-regulated Kaplan turbines with 1,750 mm diameter blades, manufactured by Allis Chalmers Corporation (now Voith Hydro), and vertical shaft, synchronous, electrical generators by Siemens-Allis Corporation, with nameplate reading of 1,500 KW each. The electrical controls and switchgear are manufactured by Powercon, and include monitoring and protective devices consistent with the Allis Chalmers standard specifications. Major auxiliary equipment includes two hydraulic pumping systems (HPUs) to adjust the turbine blade positions and inlet gates, a water turbine/generator bearing cooling system, water level controls, and station back-up battery power supply.

2.1 Water Retention Structures – Dam, Spillway, Abutments

The following are observations made during the July 16, 2015 site visit:

1. The dam is reported to be approximately 10 feet longer than depicted in the original design drawings.

2. The dam is founded on ledge, with weeps at the downstream face of the dam reported to follow the profile of the ledge. There was no water running from the weeps at the downstream face.

3. In general the concrete on the downstream face of the dam is in “good” condition. There appears to be little to no undermining at the cold joint between the concrete and the ledge.

4. The concrete abutment between the second and third bays (abutments between the wooden stop logs), has a horizontal crack in the downstream side of the abutment, approximately 10 feet down from the top of the abutment. The crack appears to be completely through the 2-1/2 foot thick abutment. There was no structural movement associated with this crack.

5. The steel support for the electric operator of the gated section of the three bays at the spillway (three bays, with two wooden stop log sections and one gated section) has 1 broken bolt and 1 missing nut on the left side and 1 broken bolt and 2 missing nuts on the right side.

2.2 Flashboards, Retaining Wall

The following are observations made during the July 16, 2015 site visit:

1. Flashboards on the concrete capped spillway are 4-feet high, with 2-3/8” O.D. pins with 3/8” wall (schedule 160 pipe).

2. In the power canal approach to the intake, there are minor vertical cracks along the south sloping face of the canal wall. There is evidence of some minor patching along the canal. None of the existing cracks are severe enough to warrant immediate patching. The canal was last drained in 2001.

3. There is some minor efflorescence on the exterior wall of the approach canal as viewed from the riverside of the wall.

4. There is an electrical conduit that runs across the overflow weir of the power canal. The electrical conduit supplies power to the spillway gate operator. The conduit is susceptible to logs and other debris should the turbine go to load rejection, causing water to spill over the canal wall. There is no other power supply to the gate operator. The gate operator does not have a manual override mode of operation.

2.3 Impoundment and Canal

The following are observations made during the July 16, 2015 site visit, aerial photos, and analysis of NRCS Soil Maps.

1. The 242 acre impoundment extends approximately 1 mile upstream of the Mine Falls Dam.

2. The banks of the Nashua River are predominantly heavily vegetated and tree-lined.

3. Open and agricultural lands are significant components within the Mine Falls Dam watershed of the Nashua River.

4. Trees and vegetation along riverbanks require more frequent maintenance for removal of leaves and debris from the trashracks of hydroelectric projects, and pose an additional risk to failing the wooden flashboards, which could result in loss or decrease in energy production.

5. Open and agricultural lands may experience increased erosion and subsequent sedimentation into the Nashua River, requiring occasional maintenance dredging of the power canal and the exercising of the single flood sluice gate to maintain functionality.

6. During the site visit the canal was free of obstructions. No deficiencies were observed.

2.4 Intake, Trashrack, Rack Cleaning

The following are observations made during the July 16, 2015 site visit:

1. The hold-down bolts for the gate operators for the power canal have missing nuts. It appears that the nuts were abandoned and either the support plate was welded to an embedment plate or the protruding anchor bolt was welded to the baseplate with a fillet weld all around.

2. The trash rake tines are bent rendering the rake virtually useless. The head of the trash rake needs to be replaced as soon as possible.

3. There is a significant vertical crack in the wall of the trash sluice just downstream of the trash rack.

4. Water was observed running from a pipe exiting the high concrete wall that runs along the river between the intake structure and the powerhouse. The source of the water is unknown. The concrete slab on grade just outside the storage room adjacent to the operations office has settled. The settlement may be related to the below grade water seeping through this area.

5. Depressed areas covered with crushed stone were observed around the penstock vent pipes. The depression at the right side vent tube was much more pronounced. This is reportedly caused from water being forced up through the vent tube as the turbine is reaching synchronous speed. This operation needs investigation and correction.

6. The condition of the 2 stoplog bays at the dam is “poor”. There is excessive leakage through and at the stoplog seals. Similarly, but not as excessive, the canal stoplogs are also leaking. Excessive leakage is occurring along the seals of the operable flood sluice gate at the dam.

7. Visual examination of the 2 intake headgates and trashrack hydraulic power systems found worn seals and operable wear on the “moving” parts.

2.5 Powerhouse

The following are observations made during the July 16, 2015 site visit:

1. The operator’s office roof needs replacement as do some of the trim boards along the edge of the roof.

2. There is a leak that was reported in the roof of the powerhouse near the downstream right side over the "exciter". The seal around some of the roof penetrations appear to be suspect. There was a section of roof edging/flashing torn off the downstream side of the roof at the northeast corner. Also a section of edging was bent up along the north side of the roof. The roof is a membrane, ballasted roof and based on the age of the roof, replacement is recommended.

3. Powerhouse concrete is in "very good" condition. There is some efflorescence visible on the interior surface of the upstream wall of the powerhouse located at the very lowest level of the powerhouse.

4. Leakage over the years has caused a significant amount of rust on the decking, around deck penetrations and on some of the floor support beams and deck support angles. Much of this corrosion is limited to the downstream corner of the powerhouse at the east side of the river. (See Fish Passage Facilities Item 2 below)

2.6 Special Equipment, e.g. Cranes, Rigging, etc.

The following are observations made during the July 16, 2015 site visit:

1. There are 2 material handling trolley beams located just inside the entrance door to the powerhouse. These two trolley beams, one extending out over the stairwell and the other 90-degrees to the first trolley, protrudes into the main area of the powerhouse. Neither beam is stamped with a capacity although the trolleys do have a placard with a 1-ton rating. For the trolley that extend into the powerhouse, the connection of the trolley beam to the concrete above the opening in the wall is suspect as to its structural capability.

2.7 Turbines, Bearings, Gearboxes, etc.

The following are observations made during the July 16, 2015 site visit:

1. Visual examination of the 2 turbine casings, water seals between the turbines and generators, and the exposed sections of the turbine shafts found some corrosion on the exterior metal casings and bolt ring attachments, and leaking water seals. (Note: At the time of the site visit Eagle Creek was in the process of re-packing these seals to stop further leakage). The short sections of the turbine shafts appeared in good condition. There was no examination of the turbine runner blades, or other interior examination of the turbine water passages including the penstocks to the intake.

2. Visual examination of the ancillary mechanical equipment including the bearing water cooling system, turbine blade hydraulic power units, and draft tube evacuation pumps found them in good working order, but exhibiting the customary normal wear from day-to-day and occasional use.

2.8 Draft tubes, Tailrace

The following are observations made during the July 16, 2015 site visit:

1. The steel grating maintenance platform over the tailrace gate slots is completely rusted out and deteriorated to the point that it is unsafe to access. The platform must be replaced.

2. About 200 feet downstream of the powerplant, rock debris from the tailrace sidewalls has partially filled the tailrace channel, restricting plant discharge flows and resulting in an impact of 6 to 10 inches to the plant tailwater elevation.

2.9 Generators, Controls, Switchgear, automation, Substation, interconnection

The following are notes from observations during the site visit on 17 July 2015

1. The single flood sluice gate at dam receives its power through a conduit secured to the top, inner wall of the station intake channel concrete. It could be subject to ice or other damage. Per Facility personnel it is a single phase powered gate motor with controls located at the platform end along the intake channel. If the conduit and wiring were to be damaged there would be no way to open the gate as there is no manual gate operator still at the unit. There would also be no power to operate the gate under those conditions. Consideration should be made to move the motor controller (not the pushbuttons) to near the gate, with local pushbuttons also at that location, and with the wiring rerouted to underground on the "land side" of the intake cannel. Consider possible provision for portable standby power for the gate near the gate, or reconfigure the operator so it can be used with the motor or manually operated at the gate location.

2. Existing electrical service originates at a pole mounted recloser located in the utility power line ROW some distance from the facility and is routed underground to the facility. It was indicated that the oil in the recloser has not been tested as regularly as that of the station step-up transformer. There is some minor cleaning and painting needed on the regulator; the oil needs to be tested. The general construction at the recloser is standard electric utility type and appears to be in good condition based on a visual only inspection. Recloser

and controls are vintage. Availability of maintenance parts; if needed, is unknown.

3. Power step-up transformer at Mines Falls facility is a McGraw Edison, Class OA, 3 phase, 34,400 Y/ 19860 - 4160 volt delta, 3750 KVA, S# C-45527-1-1, 1984 manufacture, 65 degree C. Rise, Impedance 6.1 %,@ 3750 KVA, with 2-2 1/2 % taps above and below 34,400. It has fans installed on the radiators. The top of the transformer has paint problems and some rust that needs to be addressed. The main side flanged opening near the top appears to have a gasket/seal failing as oil leakage was observed. There is an apparent stainless steel pan that has been added at some time under the transformer to contain any oil leakage from the unit (it is located directly adjacent to the river). A portable sump pump is used to remove rain water or other precipitation from the collection container, and it was indicated that any "surface oil" was skimmed off before the pump removed the remaining liquid (which is pumped overboard into the river). High and low voltage bushing and cable termination compartments could not be opened during the visit due to required special safety clothing not being available.

4. At some time the facility's original, oil filled 34.5 KV to 480/277 volt pad mounted station service transformer (that was initially located adjacent to the main step-up transformer) was removed and a new dry type, 225 KVA, 4160 to 480/277 Volt station service transformer has been installed in the facility near the station service power distribution panels (one level below the generator floor level). The power for the new station service transformer is tapped from the generator 4160 volt switchgear. Access to determine how tapped, and what circuit protection was installed was not possible because proper safety clothing was not available during the visit. Originally the facility bought the station service power from the original, separately metered outdoor transformer (meter socket is still in place inside the building). Now station service power is only purchased when station generation is less than station power use. The new transformer outwardly appears to be in good condition. Station service panelboards are vintage, but they appear to be of a make and type that is still readily available on the market. A 45 KVA, 3 phase, dry type transformer provides 208/120 volt power for receptacles, etc. and that power is distributed from one panelboard at the station service power area.

5. Site area lights at the dam are Quartz lamped. LED would use less power and should be considered for replacements as the existing units need replacement. IF they are used regularly as security lights, it would be better to change them out at an earlier time.

6. Conduits for secondary (4160 Volt) power from the main step-up transformer to the generator switchgear is apparently damaged at some location where it is underground as water has entered through it. The main junction box (near the #2 exciter) has its bottom plate fully rusted out and falling away. This apparently is an issue when the fish bypass is flooded. This needs repairs as the earliest time to minimize possible damage to the electrical equipment and controls in the building.

7. Exciters are Basler Shunt Static Exciter Regulators, Part 9177400-100, input 480 V, 50/60 HZ, 3 phase, 71.3 Amperes, Output 250 Volt, 132 Amperes continuous, both units indicate: date 9-28-84 and S# 125. Doors were not opened. Units outwardly appear to be in good condition.

8. Generator #2 Nameplate indicates: Allis Chalmers, KVA 1000 **(need to double check this),** PF 90%, 300 RPM, 4160 Volt, 3 phase, 60 HZ, 231 Amperes, Rise at 115 % load 105 degrees C. by Res. Rotor 105 degrees C. Exciter 250 Volt, 118 Ampere. Type AVW, S# 80052-2.

9. Generator #1: Same as Generator #2 except S# 80052-1

10. The generator switchgear manufacturer is Powercon. Modifications made by Algonquin (2001) that included changes to the PLC interface appear to be well documented in one set of 11x17 prints that were briefly reviewed. Modifications by the present operator are unknown; especially the installation of a new Basler BE1-700V relay that replaced the apparent original voltage and frequency relays. Those modifications were not noted in the information review.

11. It was noted that presently Unit #1 is having "phantom" trip operations (no apparent alarm annunciation record, but machine trips off line.

12. It was indicated that the existing Allen Bradley PLC is becoming obsolete and that the present operators plan to replace it at some time in the near future.

13. It was noted that the existing alarms and machine operating data are not transmitted off site, and that alarms activate an alarm dialer only to call in personnel. The replacement system would, hopefully, include making remote access to information like pond level, etc. also available.

14. Switchgear DC batteries provide power to a DC power panelboard and to controls, etc. The existing batteries are approximate 2011 vintage, and are deep discharge truck/marine type. Normal switchgear battery life is considered to be approximately 5 years, so replacement in the next year is recommended.

2.10 Fire Control, Alarms

The following are observations made during the July 16, 2015 site visit:

1. There is no permanent fire suppression system for the facility. Fire suppression is accomplished by use of portable fire extinguishers located throughout the facility.

2. It is reported that smoke alarms alert the operator and the operator contacts the emergency services.

2.11 Fish passage Facilities

The following are observations made during the July 16, 2015 site visit:

1. There is some spalling and cracking along the wall of the fish bypass channel. Most is minor in nature. A crack was observed at one of the cold joints.

2. The fish by-pass channel has not been used in years. There are reports that when the channel was run full of water in the past, a high voltage conduit running in or through the channel was taking on water. The water leaked into the conduit and flowed all the way to the high voltage junction box in the powerhouse. The bottom of the junction box was rusted out from the leaking water.

3. The roof of the fish by-pass channel has serious cracking and spalling on the exposed, exterior surface of the concrete.

4. The entire fish ladder mechanism and related equipment is non-functioning and is beyond repair. The entire system needs replacement which Eagle Creek is in the process of designing and permitting.

2.12 Plant Access

The following are observations made during the July 16, 2015 site visit, by previous unrelated site visits, and by review of aerial photographs:

1. The site is accessed from a public parking area off of Stadium Drive. A gravel road serves as access to the Project (approximately 0.15 miles from the parking area to the powerhouse). The access road continues on and is used as a trailhead for access to the Mine Falls Park trail system.

2. The access is well maintained, with large vehicular traffic on a frequent basis (trash removal from park facilities and other park maintenance vehicles).

3. The gravel access roadway provides access to the powerhouse, with adequate room for personnel parking.

2.13 Manuals, Drawings, Etc.

Available project information consists of original turbine, generator controls and ancillary equipment operations and maintenance manuals and shop drawings/schematics, and limited testing, replacement, and modification documentation performed to a large extent by Algonquin Power, and to a minor degree by the current lease, Eagle Creek. Hard copy versions of the project documentation reside at the Mine Falls plant office, Eagle Creek's plant offices at its Greggs Falls facility in Goffstown, NH and its Clement Dam facility in Tilton, NH, and at Eagle Creek's home office in Morristown, NJ.

2.14 Spare Equipment, Inventory(ies)

Minor spare parts are available locally from Eagle Creek's "spare parts pool" which it maintains for all its New Hampshire facilities. There is no spare major equipment (i.e. turbine runners/blades, shafts, generator parts, bearings, etc.).

3.0 Description and Assessment of Project Operation and O & M

3.1 Current Operation

The powerplant operates when river flows equal or exceed 130 cfs (30 cfs is devoted to the minimum by-pass release at the dam; 100 cfs is the minimum flow to start a single turbine). The hydraulic capacity of the plant (2 turbines) is 990 cfs, or a river flow of 1020 cfs. Turbine control and dispatching is maintained by electronically monitoring the headpond elevation to operate the facility in the required "run-of-river" mode and utilize all the available river flow for power production.

3.2 Power Production

Plant capacity factor (the percent utilization of all river flows at the dam) is estimated to be about 53%. The industry standard for "run-of-river" New England hydropower plants averages between 42 and 48%.

The powerplant has a maximum nameplate capacity of 3,000 kW (3MW). However; the generators have a 1.15 service factor which allows for greater capacity without sacrificing the life of the equipment.

The reported long-term, average annual energy generation estimated for the plant is 12,563,000 kW-hrs. (12.563 MW-hrs.).

3.3 Fish Passage Facilities

The entire fish ladder and related equipment is inoperable, and beyond repair. The fish bypass channel has not been used in years and is in need of repair and should not be used until repairs are made to prevent further leakage to the high voltage junction box.

3.4 Minimum Flows

Minimum by-pass flow at the Project is 20 cfs. An additional 10 cfs of inflow is required to pass through the Gatehouse to Mill Pond and the Nashua Canal. FERC records indicate the Project has complied with the minimum by-pass flow requirements.

3.5 Confirmation of Operating Curves

The Project is licensed as a "run-of-river" project, where inflow equals outflow. Any flow above the turbine(s) capacity (plus minimum by-pass flow) is spilled over the dam spillway or through the single flood sluice gate.

3.6 Description (Verification) of elevations of impoundment, etc.

Three sets of vertical datum are referenced in project documents:

1. Local Datum
2. National Geodetic Vertical Datum of 1929 (NGVD 29)
3. North American Vertical Datum of 1988 (NAVD 88)

Conversion equations are as follows:

Local Datum = NGVD 29 -90.47 feet
NAVD 88 = NGVD – 0.7 feet
Local Datum = NAVD 88 + 0.7 feet – 90.47 feet

No instrument survey was performed as part of this assessment. Project elevation data were confirmed by referencing project design drawings and "as-built" FERC orders and exhibits.

3.7 Project Hydrology

Mine Falls Dam has a 525 square mile drainage area, extending west to Greenville, N.H., and south to Worcester, M.A., and includes the Wachusett Reservoir. River flow is impacted by water withdrawals for the City of Boston drinking water supply, and regulated by hydropower production upstream. The drainage area is predominantly a mixed forest and residential, with some agricultural areas. Areas along the river tend to be more heavily populated, with current and former mill complexes in Clinton and Pepperell, MA, and the City of Nashua, NH.

The USGS maintains a stream gage downstream of the hydroelectric project in Pepperell, MA, USGS gage 01096500 Nashua River at East Pepperell, MA, with a period of record from October 1, 1935 to present. The gage has a drainage area of 435 square miles. Mean daily gage data (average flow for the respective date) was downloaded on June 30, 2015, and corrected for drainage area adjustment, a factor of 1.207. The data was then analyzed by flow to develop annual and monthly flow duration curves, presented below.

3.8 Flow Curves, Annual Flow Curve

Figure 6 below presents the annual flow duration curve for the Nashua River at Mine Falls Hydroelectric Project. Monthly flow duration curves are included in Appendix B. Algonquin Power estimated monthly average flows at the Project for the period 1936 and 2001; see Figure 7. Flow values provided in Figures 6 and 7 include environmental or minimum bypass flows, and are not representative of the net river flow available for energy generation.

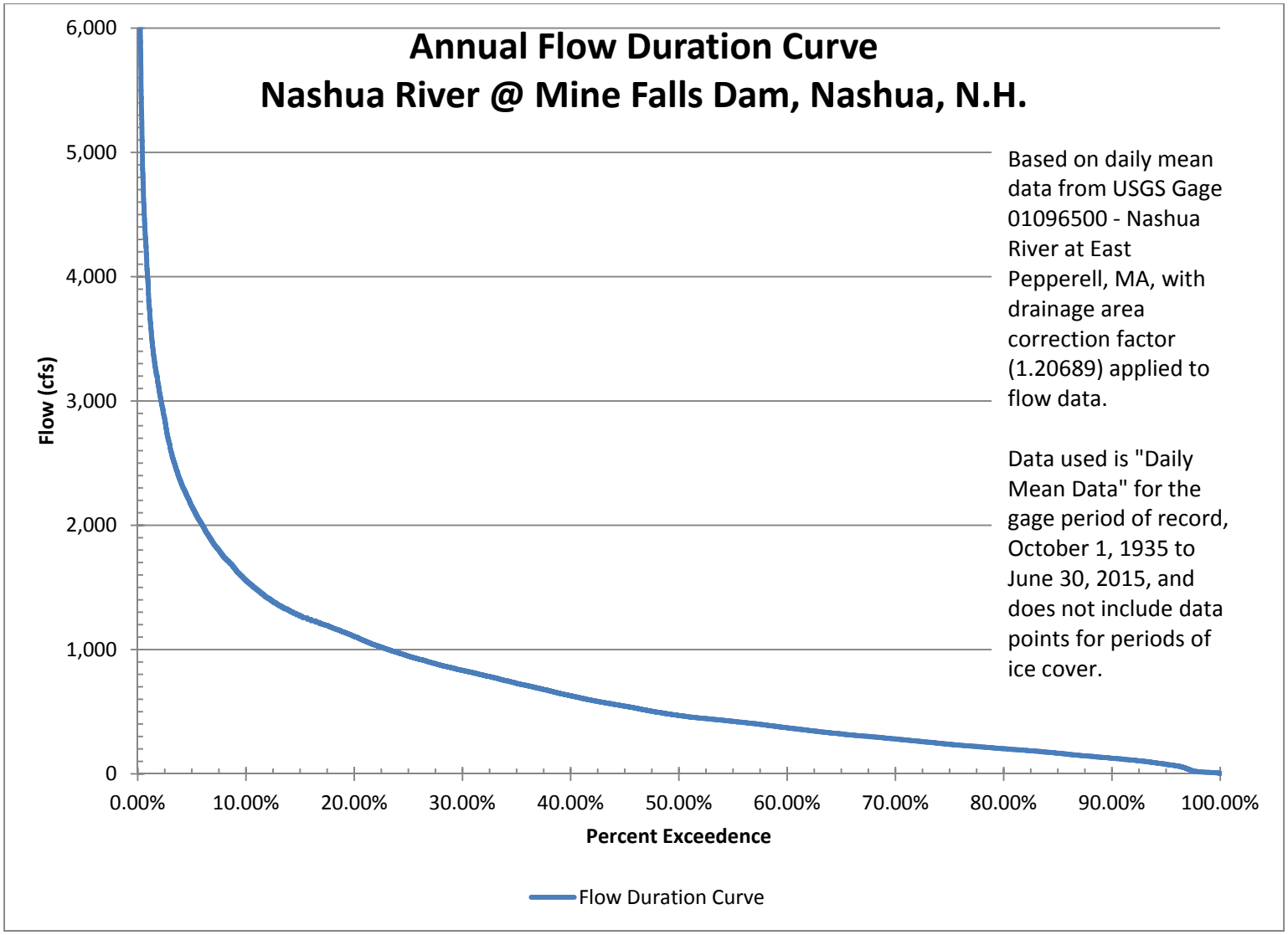


Figure 6 – Annual Flow Duration Curve for the Nashua River at Mine Falls Dam, Nashua, NH

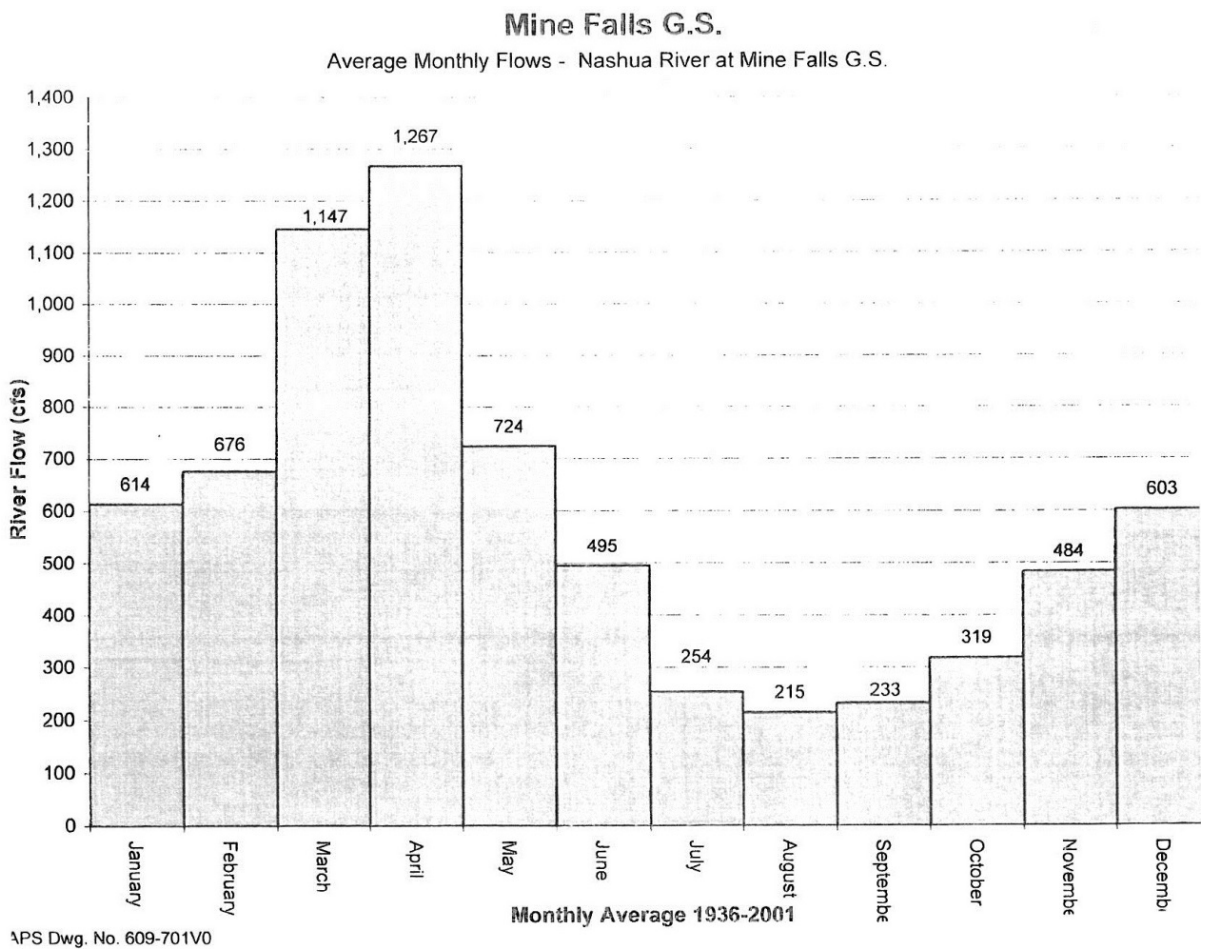


Figure 7 – Nashua River Average Monthly Flows from 1936 to 2001, for Mine Falls Hydroelectric Project - calculated by Algonquin Power

3.9 Current O&M Procedures, staffing, Automation

The powerplant has and continues to be manually operated by Eagle Creek personnel. Although the plant is capable of automatic operation, this feature has never been used. The plant is visited on most days to set turbine/generator running conditions, clean the trashracks, and conduct routine facility monitoring and maintenance. Certain times of the year (fall, spring, and high river flow conditions) warrant full-time (8-hour shifts) plant attention.

3.10 Repair History (significant events)

Based on available plant records, major repair work was performed on the turbine shafts, shaft couplings, turbine/generator bearings, and the two generators between 2001 and 2008 by Algonquin Power. There were no other records of significant repairs.

3.11 Contracts for O&M, Warranties

For the project to date, operations and maintenance has been performed by Eagle Creek and Algonquin Power personnel. It its first 15-20 years, MFLP contracted O&M to the Energy Resource Group of Farmington, NH. All warranties that existed for the plant equipment, or for any major repair work, have all expired.

3.12 Inspections

Based on the plant records for the past 15 years, only routine (operator visuals) and occasional (technical operating and maintenance staff) facility condition inspections have been conducted by Eagle Creek and Algonquin Power. From these inspections, annual maintenance and repair scopes of work and budgets were developed to maintain the facility in working order.

There were no records of any independent inspections except for certain mechanical/electrical testings and calibrations.

3.13 Scheduled Repairs, Improvements (budget and schedule)

The only significant repair/improvements that have been identified is the near-term re-construction of the fish passage facility and the powerplant controls upgrades. Repairs to the fish passage are predicated on the need to make the current facility, which is in structural disrepair, functional for the passage of river herring and eels. The FERC facility license requires the fish passage to be functional when requested by the US Fish and Wildlife Service, and the NH Department of Fish and Game. Correspondence from these two agencies requesting the functional upgrade of the fish passage extends back several years.

Currently, Eagle Creek is seeking engineering design and permitting approvals to proceed with construction. A capital cost estimate of $1.5 million has been reported for this project with construction being planned for 2015 and 2016.

Eagle Creek is also investigating the upgrade of the plant's operating controls and other pertinent electrical gear. Existing controls and the PLC are vintage; and ready access to spare parts and circuit boards is now becoming difficult. With modern electrical control equipment, turbine dispatching and enactment of the plant automation should improve operations, and to some degree, energy generation efficiency. No capital cost or timeline was reported. However, Eagle Creek expressed a desire to implement this improvement within the next 2 years.

4.0 Description and Assessment of Project Performance

4.1 Historic Generation

The Project has a nameplate installed capacity of 3,000 kW (3 MW) with a reported long-term average annual generation of 12,563 MWh. No energy generation records were found for the period 1985 (plant start-up) through 2001. From 2001 to 2008, the plant went through several long periods when the full capacity (availability of both turbines) of the plant was not being realized because of significant repairs to both turbines and generators. However, records were available for the period 2008 to 2013 when the plant was capable of full power production to provide a "snap shot" of energy performance. Table 1 is a summary of generated energy by month and year for the period 2008 to 2013.

Table 1 – Energy Production for 6 year period, 2008 to 2013

Month	2008	2009	2010	2011	2012	2013
January	1,249,318	1,780,245	1,046,404	2,227,203	1,598,402	872,774
February	2,015,799	1,412,579	1,058,537	616,571	1,232,224	986,459
March	2,288,266	2,127,713	948,505	717,109	1,296,499	1,712,458
April	1,979,931	1,875,888	1,563,993	1,810,723	880,391	1,769,000
May	1,278,347	1,424,502	1,690,378	2,004,3085	1,271,616	648,166
June	482,419	1,603,217	829,248	1,598,024	1,234,171	1,063,856
July	839,783	1,976,910	568,197	1,177,097	305,585	791,636
August	1,219,216	1,243,982	246,202	481,083	72,369	615,484
September	1,124,566	637,911	111,655	513,674	55,057	223,000
October	906,084	794,948	47,232	1,258,703	117,515	136,943
November	984,646	1,001,438	418,665	1,541,965	844,252	154,219
December	1,938,874	1,229,918	601,993	1,665,246	579,267	412,246
kW-hrs	**16,307,249**	**17,109,251**	**9,131,000**	**15,611,706**	**9,487,348**	**9,386,241**

The six year average annual energy generation (2008 to 2013) is 12,838,799 kW-hrs., which is about 2.2% higher than the original long-term estimate of 12,563 MWh. .

4.2 Significant Outages

Based on available plant records, the only significant reported plant outages occurred between 2001 and 2008 when one or both of the turbine/generators were not fully available to produce power.

4.3 Historic Plant Operational Capacity

No “day-to-day” plant operation logs were available to assess the plant’s operating capacity. However, in reviewing the annual energy generation for the period 2008 to 2013, the facility would have had to produce equal or greater nameplate capacity (3,000 kW) for a certain period of time in order to achieve the total generation reported in years 2008, 2009, and 2011.

4.4 Turbine and Generator Current Efficiencies/degradation

There are no records of any historic testing of the turbines and/or generators in order to assess their efficiency to produce power or to determine the condition of any mechanical/electrical degradation. Field tests to make exact determinations is beyond the scope of this preliminary hydropower assessment.

It is likely that over time the clearances between the outer edge of the turbine blades and its encasement have grown beyond their original machined specification causing some leakage of water around the blades resulting in some loss of mechanical efficiency. Also, the generators have also likely suffered some minor loss in nameplate performance because of age and stress to its windings due to operation at prolonged warm temperatures. But, the long-term information on plant performance, particularly since 2008, indicates the plant equipment has not suffered significantly from mechanical/electrical power losses. Overhauls of the turbines and generators will likely restore the equipment to near original efficiency and extend this condition with proper maintenance well into its next 20 years of service.

5.0 Description of Project Revenues

5.1 Historic Revenues

From 1985 through 2005, the hydroelectric project sold its energy for the PSNH contracted price of 9 cents per kilowatt-hour (¢/kWh). No records were available indicating the annual revenue realized for that time period. However, at the estimated average annual generation of 12,563,000 kWh, the hydroelectric project, on average, would have received $1,130,670 per year during its first 20 years of operation.

After 2005, PSNH paid daily market rates for the hydroelectric plant energy plus a premium for the plant capacity based on a weighted availability factor. From 2008 to 2013 the project received energy revenues at the average rate of 4.9¢/kWh for an annual average of $646,294 for this period. The average annual capacity payment was $58,960. The total annual revenue for the period was $705,254.

5.2 Unrealized Revenues

The only unrealized revenues are the energy losses attributable to facility leakages whose water is not being past through the turbines, and a loss of power head on the turbines due to slightly higher tailwater from debris partially restricting the end of the tailrace. These losses in aggregate amount to as much as 80 to 100 kW of power, or about 3888,000 kWhrs per year; 3% of the average annual peak energy generation.

6.0 Assessment of Remaining Life

6.1 Project Works

Civil works are 30 years old and in "good" condition. When built, these structures were designed and constructed to the highest industry standards for merchant grade hydroelectric facilities at that time; and meets most, if not all, of today's standards. With continued maintenance, the civil works should easily attain another 30 to 50 years of serviceable life.

6.2 Electro/Mechanical

According to DOE [(1)] and EPRI[(2)] life expectancy studies for hydroelectric facilities, the turbines, generators and some of the ancillary equipment normally has a serviceable life of 30 to 40 years, and a useful life of another 15 to 30 years with proper maintenance and scheduled overhauls. The equipment at the Mine Falls plant is in "reasonably" good condition and as such would fall into the DOE and EPRI projections for life expectancy. The exception to this being the plant controls and switchgear because the rapid advances in electronic technology makes replacing this equipment within 20 to 30 years. This is just the case for the Mine Falls plant, as Eagle Creek is in the planning stages of upgrading the controls and some of the switchgear.

6.3 Anticipated Project Repairs and Costs – frequency

See Section 8.2 - Recommended Refurbishment/Life-Extension Schedule and Costs.

(1) US Department of Energy, "Condition Performance Assessment Manuals: Hydropower Advancement Project, 2012"

(2) Electric Power Research Institute, "Hydropower Plant Modernization Guide, 1989"

7.0 Assessment of Ability to Improve Project Performance, Revenues, Costs,etc

By taking corrective actions to eliminate the water leakages at the dam and remove the "hard" debris from the end of the tailrace (an action that can be accomplished when the fish passage is upgraded), energy generation should increase, on average, by 3% annually. Other refurbishments, improvements and modernizations to the turbines, generators and controls should improve operating efficiency, and thus to some degree energy generation (1 to 2% annually).

Currently project revenues are being dictated by the day-to-day market prices at which utilities are buying power and energy from producers of electricity. These rates have dropped as low as 2 to 3 cents per kilowatt hour and now average between 4 and 6 cents per kilowatt hour. Participation in programs such as Renewable Energy Certificates (RECs) and other "green" incentives help to improve the revenue "bottom line" but only to a limit. Creative ways to use, off-set, or sell to a single/multiple high energy user may be a means to improve electricity revenues in the future; but, these all need further investigation.

The other factor to improving revenue is to reduce operating costs which is the primary activity being performed at the plant by the leasee, Eagle Creek. For the short-term energy market, aggressive operating costs reduction needs to continue to preserve the value of whatever revenues are received from the sale of hydropower electricity.

8.0 Project Economic Feasibility Analysis

8.1 Hydroplant Value

The original project cost for the Mine Falls Hydroelectric Project established on November 26, 1985 was $6,688,000. Based on the total plant nameplate capacity of 3,000 kW, the project cost is $2,229 per kW. Per the current lease with Mine Falls Limited Partnership, the City has the option to purchase the hydroplant at 50% of the original project cost ("base" price) plus "the depreciated values of any capital improvements made to the Project after thirty (30) years after the Initial Date of Commercial Operation." The Initial Date of Commercial Operation is December 2, 1985. This means the City would purchase the hydro facility for a "base" price of $3,344,000, or $1,115 per kW.

As a point of comparison, in 2014, existing hydroelectric plants in the eastern USA were sold between $2,100 and $4,300 per kW without any further consideration to capital improvement costs made during the life of these facilities. An existing hydroelectric plant in upstate New York built in 1985 with identically manufactured turbines, generators and controls to that of the Mine Falls plants was sold in 2014 for about $2,700 per kW.

Based on available information, there have been no capital improvements made to the Mine Falls Plant since its original 1985 construction. However, Eagle Creek (general partner, Mine Falls Limited Partnership) is anticipating receiving design and permit approvals for a new improved fish passage system scheduled for construction in 2015-2016. The estimated cost of this capital improvement has been reported to be $1,500,000.

If the City were to exercise the lease option to purchase the plant by the end of 2016, the City would be liable for 50% of the new fish passage cost; $750,000. This would bring the total purchase price to $4,094,000, or $1,365 per kW. At this price the facility is still below the 2014 market prices for comparable hydroelectric plants.

8.2 Recommended Refurbishment/Life-Extension Schedule and Costs

If the City decides to exercise the lease option to purchase the hydroplant, it has 12 months to close on the financial purchase agreement. It is being recommended that the City explore and timeline the scheduling of making the following short- and long-term repair, maintenance and improvement items in order to extend the life of the project another 25 to 30 years.

Type	Item	Cost
ME	TG HPUs – replace	$150,000
ME	Drain pump – redundant system	$50,000
ME	Turbine(s) – overhaul	$200,000
ME	Turbine Blade Positioning System – recondition	$100,000
ME	Ancillary – filters, crane motors, etc	$100,000
EE	Generator – refurbishment	$300,000
EE	New Station Battery System	$30,000
EE	PSNH/Eversource – New Interconnection Upgrade	$30,000
EE	Transformer – rehabilitation	$80,000
EE	Controls automation	$200,000
EE	Miscellaneous	$50,000
Civil	Fish Passage Access way	$75,000
Civil	Intake gates/trashrack – rehabilitation	$50,000
Civil	Stoplog/gate replacement	$200,000
Civil	Roof repair/EE conduit	$50,000
Civil	FERC Re-License	$400,000
	Total	$2,065,000

Although highly unlikely all the above items would be undertaken immediately upon a plant ownership transfer, if the total value of the short- and long-term project costs ($2,065,000) were to be added to the “base” purchase price of ($4,094,000), the total “inherent” cost of the hydroplant would be $6,159,000, or $2,053 per kW, which is still below the 2014 market threshold of $2,100 per kW.

9.0 Conclusions and Recommendations

9.1 Conclusions

1. Physical hydroplant was found to be generally in “good” overall condition.

2. The concrete civil works consisting of the dam, stoplog and gate section, power canal, and powerhouse, is in good condition with only minor cracking and spalling.

3. Excessive water leakage that is not being used for power production is occurring at the dam’s wooden flashboards and wooden stoplogs and gate seals. The wood stoplogs are at the end of their useful life.

4. Spalled rock debris from the tailrace sidewalls is restricting flow to some degree from the powerhouse; this is impacting power/energy production.

5. There is no redundant operating system for the dam gate leaving it vulnerable to inoperation when needed.

6. The existing fish passage facility is in total disrepair. A leak into the powerhouse from the fish passage channel is entering an electrical conduit junction box that is in close proximity to the high voltage (4160 volts) turbine exciter creating a hazardous condition.

7. The metal walkway and caged metal ladder to the draft tube gate slots on the downstream side of the powerhouse are completely corroded and unusable.

8. The mechanical trashrack cleaner has several worn parts and is in need of refurbishment.

9. The powerplant intake gates that control water from the power canal to the turbine penstocks have exhibited worn seals and deteriorating hydraulic power control that will require refurbishment.

10. The powerhouse roof is nearing the end of its useful life. Sections of the roof flashing are missing on the riverside of the roof and leaks have started to occur in the interior of the building.

11. The interior powerhouse crane and monorail rail hoist are in good condition, although the hoist rating is suspect.

12. Based on visual examination and review of O&M and repair records the turbines and ancillary hydromechanical equipment are in “reasonably” good operating condition. Turbine blades need checking for wear, and seals and bearings likely need refurbishment.

13. The generators, excites and other ancillary electrical equipment is in “reasonably” good operating condition. Given their age, it is likely that seals, bearings and other components are ready for refurbishment and/or replacement. Further field testing is needed to define the scope of this work.

14. The station DC battery system that provides back-up power has exceeded its useful life and needs replacement.

15. The controls and switchgear are aged and will likely need upgrade and modernization.

16. The plant is currently operated in manual control, although there is equipment in-place to run it automatically.

17. There is reasonable access to “everyday” spare parts through the lease, Eagle Creek.

18. An inventory list of existing project information (equipment O&M manuals, testing reports, repair records, FERC license compliance, etc.) does not exist. One should be created, and the City should make arrangements with the lease, the caretaker, to have access to the information needed.

19. FERC license compliance, which in the past has been handled by the lease, should be jointly coordinated with the City as they are the FERC co-licensee.

20. Except for leakages, and required minimum flows, the powerplant is utilizing the maximum available river flow for power/energy production. The plant factor of 53% is about 17% better than the industry expectation for other New England “run-of-river” hydropower facilities.

21. Review of limited power/energy records shows the plant has produced at or slightly in excess of its capacity of 3,000 kW when river flows are available. Additionally, the plant has surpassed its original average annual energy estimation by about 2%. The average annual energy for the plant has shown to be about 12,838,799 kW-hrs.

22. The City price to exercise its option to purchase the facility per the lease agreement with MFLP is estimated to be about $4,094,000, or about $1365 per kW. This price is below the 2014 market selling price of $2,100 per kW for comparable hydroelectric facilities.

23. The facility is 30 years old. With an investment in certain refurbishments, overhauls and upgrades the facility should have another 25 to 30 years of serviceable life.

9.2 Recommendations

Based on the conclusions that the facility is in "reasonably" good condition, its "better-than-average" energy generating performance, and its low price versus market value, the City should seriously consider exercising its lease option with Mine Falls Limited Partnership to purchase the Mine Falls hydroelectric project.

During the one-year period before purchase closing, the City should invest ($75,000) in certain physical and electrical testing to determine the exact scope and costs for short- and long-term repairs and refurbishments that will extend the service life of the facility another 25 to 30 years.

10.0 List of Acronyms

LIST OF ACRONYMS AND ABBREVIATIONS

ac-ft	acre-feet
¢/kWh	cents per kilowatt hour
CFR	Code of Federal Regulations
cfs	cubic feet per second
CWA	Clean Water Act
DOE	Department of Energy
DOI	Department of the Interior
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
°F	degrees Fahrenheit
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
ft.	feet
GIS	Geographic Information System
GWh	gigawatt hour
Hz	Hertz
I.D.	Inside diameter
kV	kilovolt
KVA	kilovolt amp – 1000 volt amps
kW	kilowatt
kW-hrs	kilowatt hours
L&D	lock and dam
LIHI	Low Impact Hydropower Institute
MFLP	Mine Falls Limited Partnership

msl	mean sea level
MW	megawatt
MW-hrs	megawatt hours
MWh	megawatt hours
NAVD	North American Vertical Datum of 1988
NGVD	National Geodetic Vertical Datum of 1929
NHDES	New Hampshire Department of Environmental Services
NHDHR	New Hampshire Division of Historical Resources
NRCS	Natural Resources Conservation Service
O.D.	Outside Diameter
O&M	Operations and Maintenance
PAD	Preliminary Application Document
PF	Power factor
PSNH	Public Service of New Hampshire (formerly) now Eversource
RECs	Renewable Energy Certificates
RM	river mile
ROR	run-of-river
rpm	revolutions per minute
sq. mi.	square mile
STDV	standard discharge volume
USACE	U.S. Army Corps of Engineers
USDA	United States Department of Agriculture
USDOI	United States Department of Interior
USGS	U.S Geologic Service
VAC	Volts, AC

11.0 Limitations

1. The observations described in this report were made under the conditions stated herein. The conclusions presented in the report were based solely on the services described therein, and not on scientific tasks or procedures beyond the scope of described services, or the time and budgetary constraints imposed by the City of Nashua, NH (Client).

2. In preparing this report, The H.L. Turner Group Inc. (TTG) has relied on certain information provided by the Client and other parties referenced therein. TTG has also relied on certain information contained in the files of the Client and other parties that were available to TTG at the time of report preparation. Although there may have been some degree of overlap in the information provided by these various sources, TTG did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this work.

3. In reviewing this report, it should be realized that the reported condition of the hydro-facility is based on observations of field conditions during the course of this study along with data made available to TTG. The observations of conditions at the facility reflect only the situation present at the specific moment in time the observations were made, under the specific conditions present. It may be necessary to re-evaluate the conclusions and recommendations of this report when subsequent phases of evaluation, or repair and/or improvement provide more data.

4. It is important to note that the condition of the hydro-facility and its appurtenant structures depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the hydro-facility and its appurtenant structures will continue to represent the condition of the hydro-facility at some point in the future. Only through continued care, monitoring, and inspection can there be any chance that unsafe conditions may be detected.

5. No survey was performed by or for TTG during the preparation of this report. Elevations and dimensions described herein are based on previously reported values and rough measurements in the field. The level of accuracy of these measurements is no more than implied by these approximate methods.

6. TTG based any hydraulic analysis on existing conditions based on the site plans made available to TTG as of the date of this report or upon field reconnaissance. In the event that any changes to the hydro-facility or its appurtenant structures are planned, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report modified or verified by TTG.

7. Any TTG hydrologic analysis presented herein is based on standard statistical analysis of data obtained from public sources, including USGS flow records. TTG did not independently verify this data.

8. Opinions of Cost estimates prepared for this study are approximate only and meant for planning purposes by the Client. Actual costs of design, equipment, and construction may vary based on conditions encountered, economic circumstances, and final scope of work and supply. In preparing the cost estimates, TTG has relied upon typical unit costs and historic data which may vary over time and between projects.

9. Estimates of revenue or other avoided costs contained in this study are based upon the specific flow and head conditions stated, as well as efficiency information provided by the Client or their assigns. Actual project benefits in any particular year may vary based on hydrologic conditions, regulatory constraints, and other factors.

10. This report has been prepared for the use of the Client, under the terms of an agreement for services dated June 23, 2015, in accordance with generally accepted engineering practices. No other warranty, express or implied, is made.

11. This report is for the Client's broad evaluation and management purposes only and is not sufficient, in and of itself, to prepare construction documents, or an accurate bid.

Appendix A – July 16, 2015 Site Photos

Overview of dam, note white PVC weeps at bottom of downstream face of dam; the weeps are just above the rock and follow the profile of the ledge

The left abutment of the dam appears to be in very good condition with no signs of cracking, spalling or undermining

Close up of downstream face of dam, note vertical cold joint along sloping face, appears to be in good condition

View of downstream face of dam shows several areas where the toe of the concrete is starting to spall slightly where the concrete meets the ledge

Typical flashboards and pins – Pins are 2-3/8” OD with .375 wall

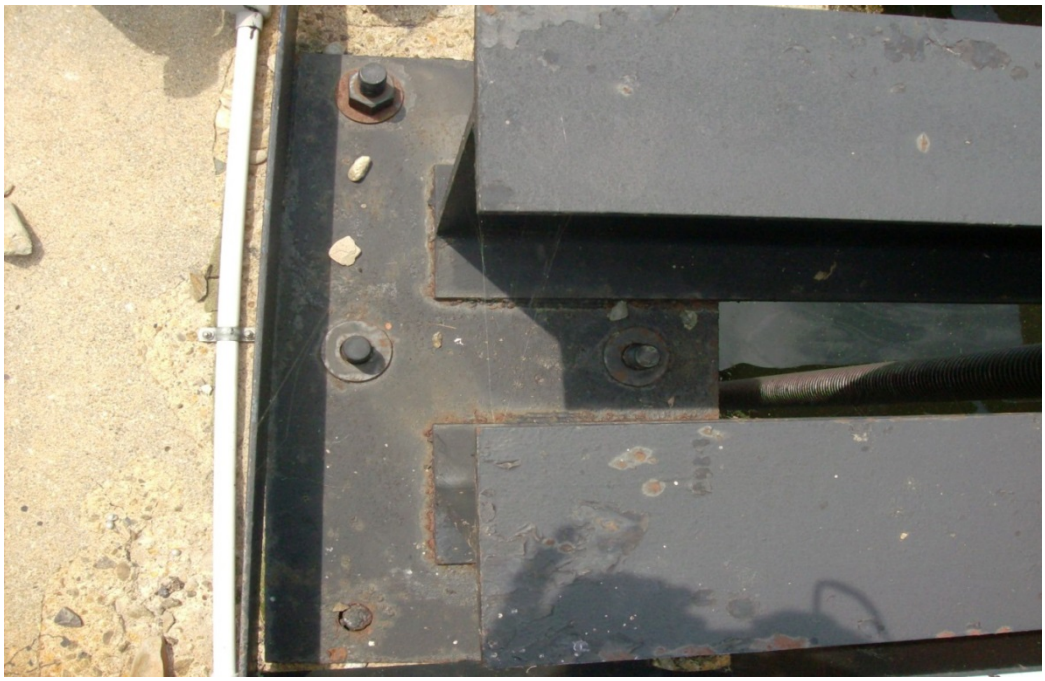
Bearing pad and anchor – perhaps left from the original construction

Downstream abutment for gate structure – north side of buttress between the two wood stop log gates

Downstream abutment for gate structure – south side of buttress between the two stop log gates

Vertical wall of power canal on river side – note some slight efflorescence

Several year old concrete patch under left bearing plate for gate operator - Note one missing nut



Right side of spillway gate operator – note two missing nuts and a broken anchor bolt stud

Some minor spalling on the right side training wall at the power canal approach

Power canal overflow crest – note power cable for gate operator is exposed to damage during a canal spillover event

Vertical cracks along the sloping face of the power canal, note past attempts at patching some spalled areas

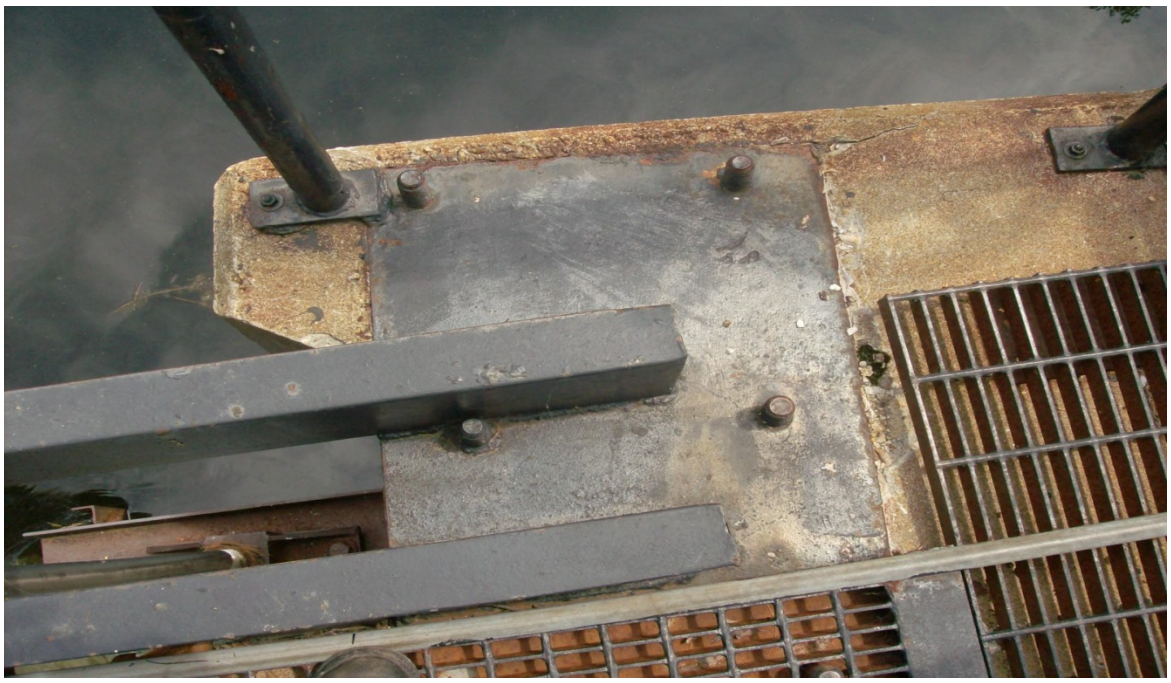
Close-up of power canal wall cracks at sloping wall

Area subject to subsidence near penstock vent as it is affected by spillover from vent

Trash rake tines are at the end of their useful life

Vertical crack in downstream face of wall of trash sluice channel

Valve operator welded to support frame



Valve support frame baseplate – fillet welds around anchor bolts in lieu of nuts

Water seeping through PVC weeps in wall along river between powerhouse and intake

Slab subsidence adjacent to vertical wall at site of water seepage

Roof slab over fish canal is spalled and cracked in numerous areas

The steel grating catwalk over the tailrace gate slots is totally deteriorated and must be replaced as are all the components for the original fish ladder, located to the right of the powerhouse (when looking down river)

Damaged roof edging along downstream edge of powerhouse

Missing edging at northeast corner of powerhouse roof

Hanger connection for 1-ton trolley is anchored into minimal concrete spanning wall opening (there is a question as to what's supporting the concrete at the edges of the opening.)

4160 volt junction box is rusted out from water leaking in from conduit that runs or passes through the fish by-pass channel

Composite decking is rusted all around 4160 volt conduit

Rusted beam support at downstream wall of powerhouse – supports main powerhouse equipment floor

Deteriorated composite decking around vent pipe from gas heater

Rusted deck support angle at lowest level of powerhouse

Efflorescence forming on wall of powerhouse just below penstock flange

Efflorescence on wall of powerhouse between turbines at lowest level

Appendix B – Monthly Flow Duration Curves

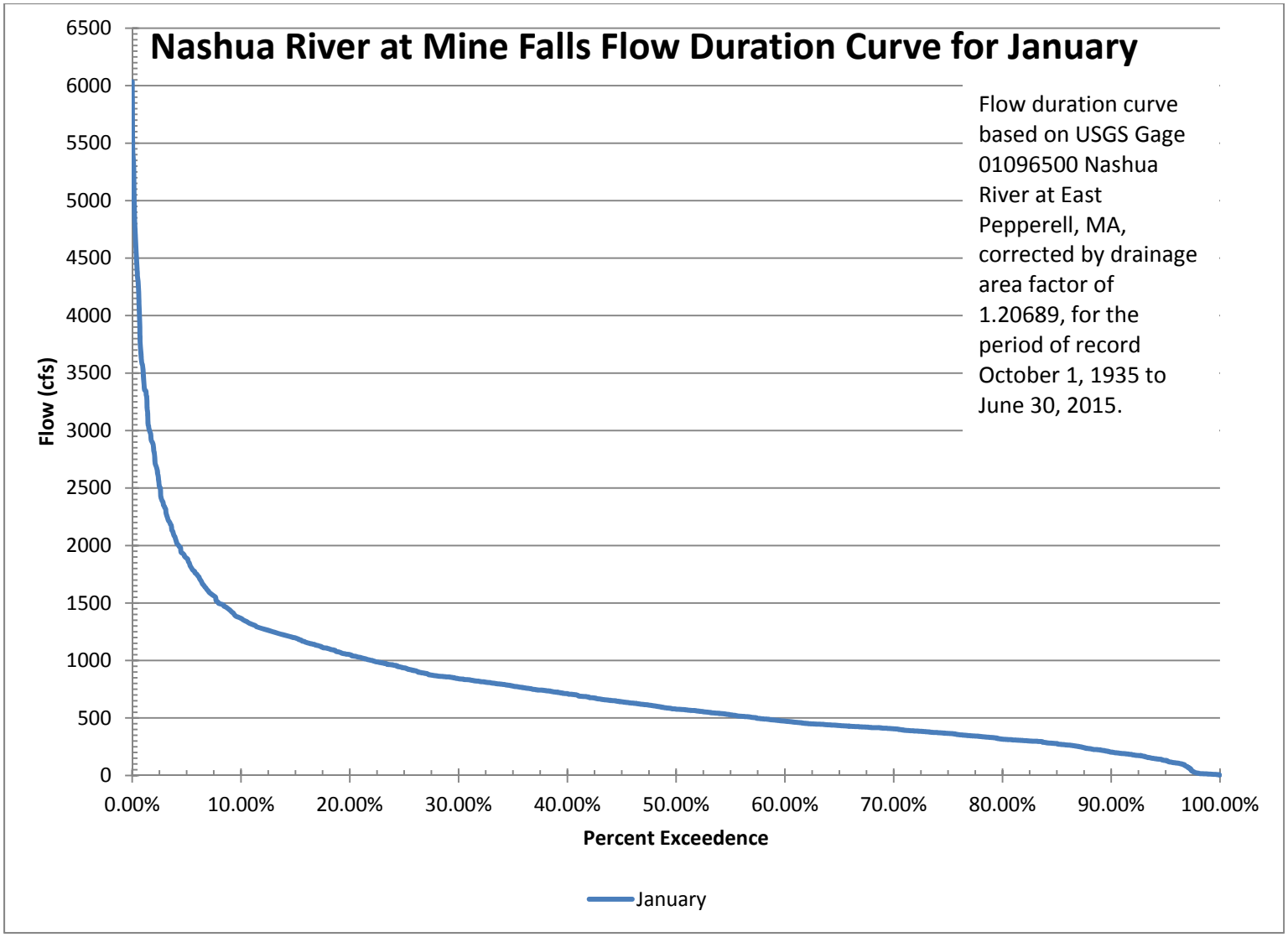


Figure 8 – January Flow Duration Curve for Nashua River at Mine Falls Dam, Nashua, NH

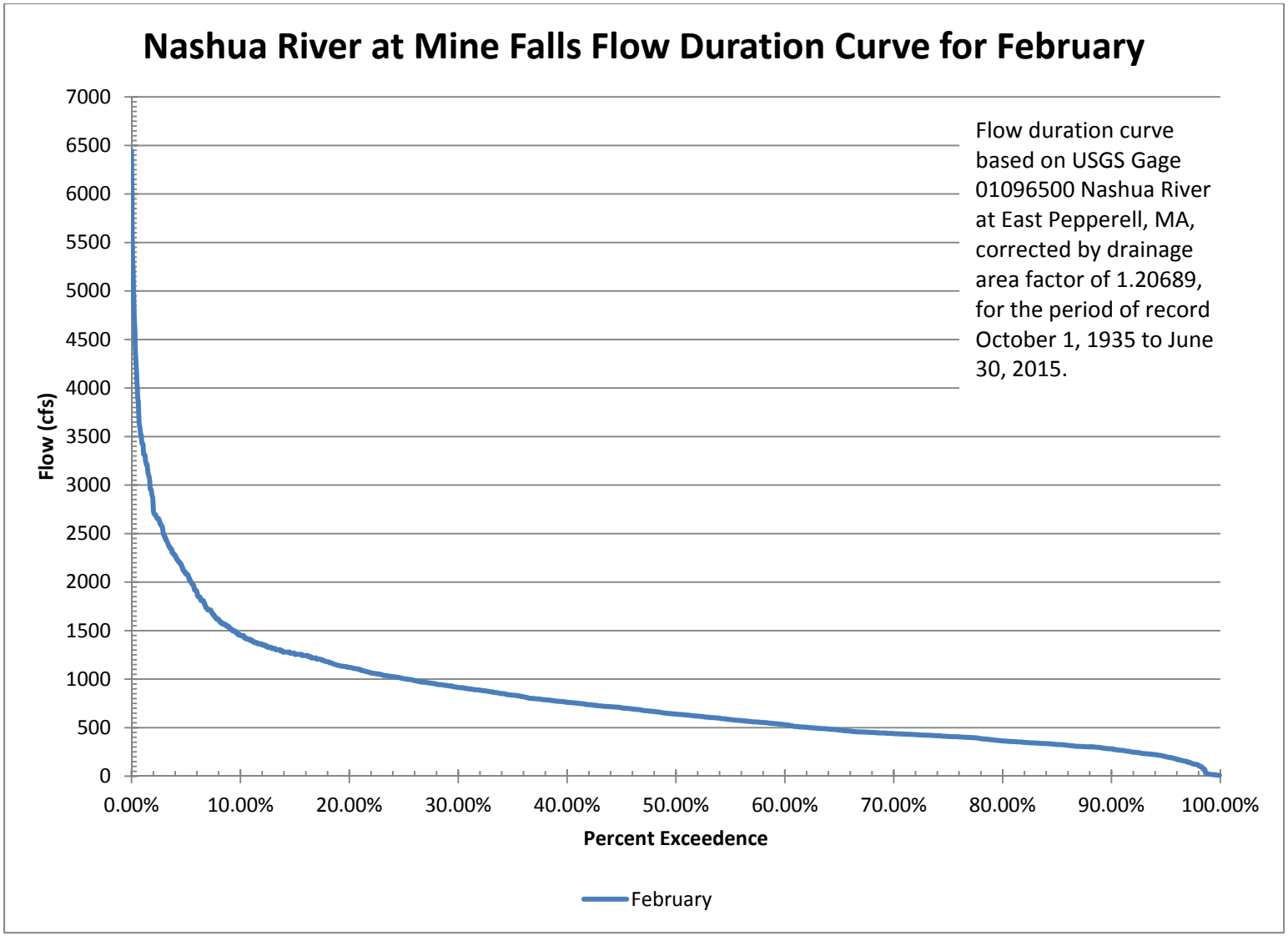


Figure 9 – February Flow Duration Curve for Nashua River at Mine Falls Dam, Nashua, NH

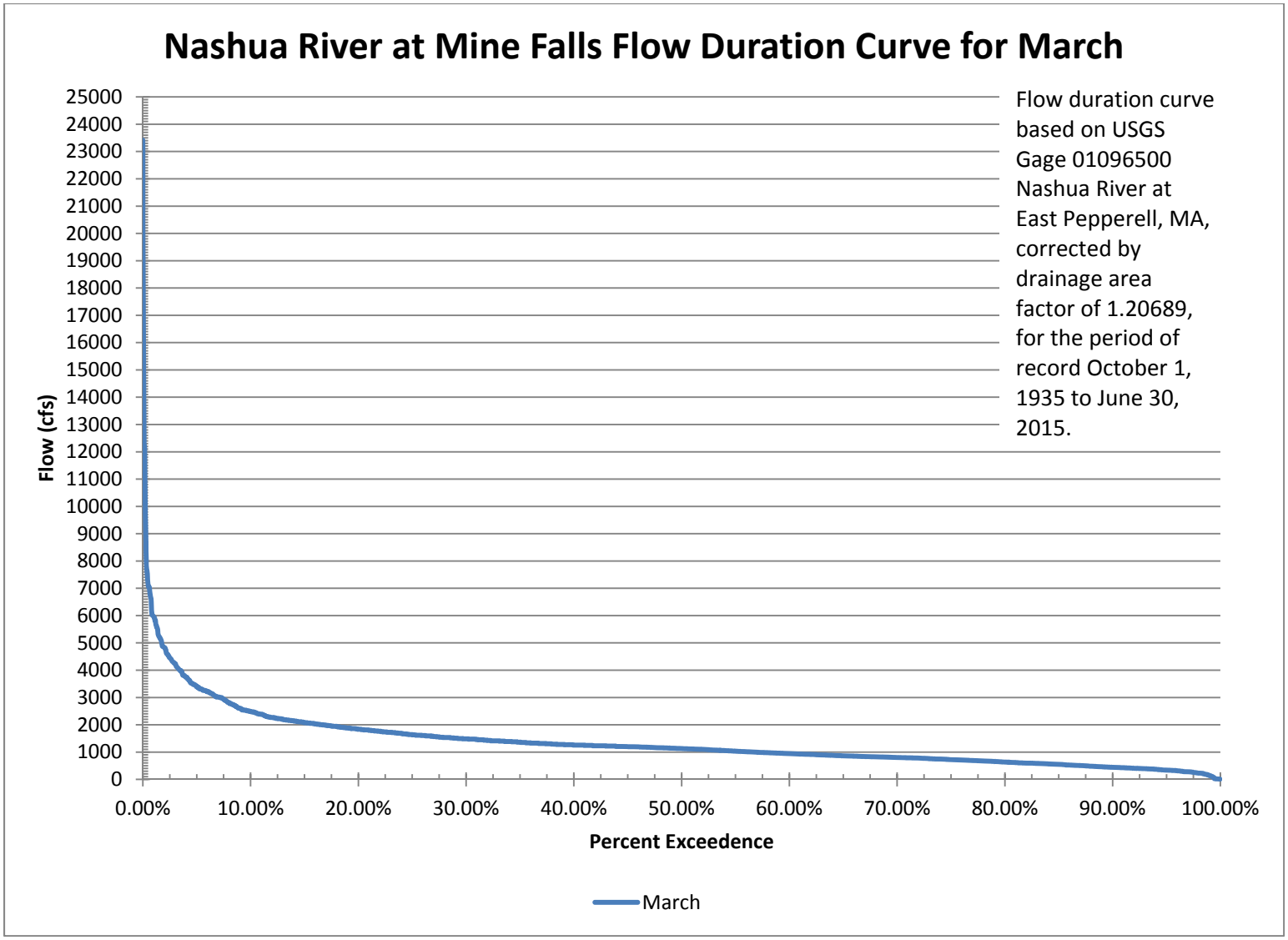


Figure 10 – March Flow Duration Curve for Nashua River at Mine Falls Dam, Nashua, NH

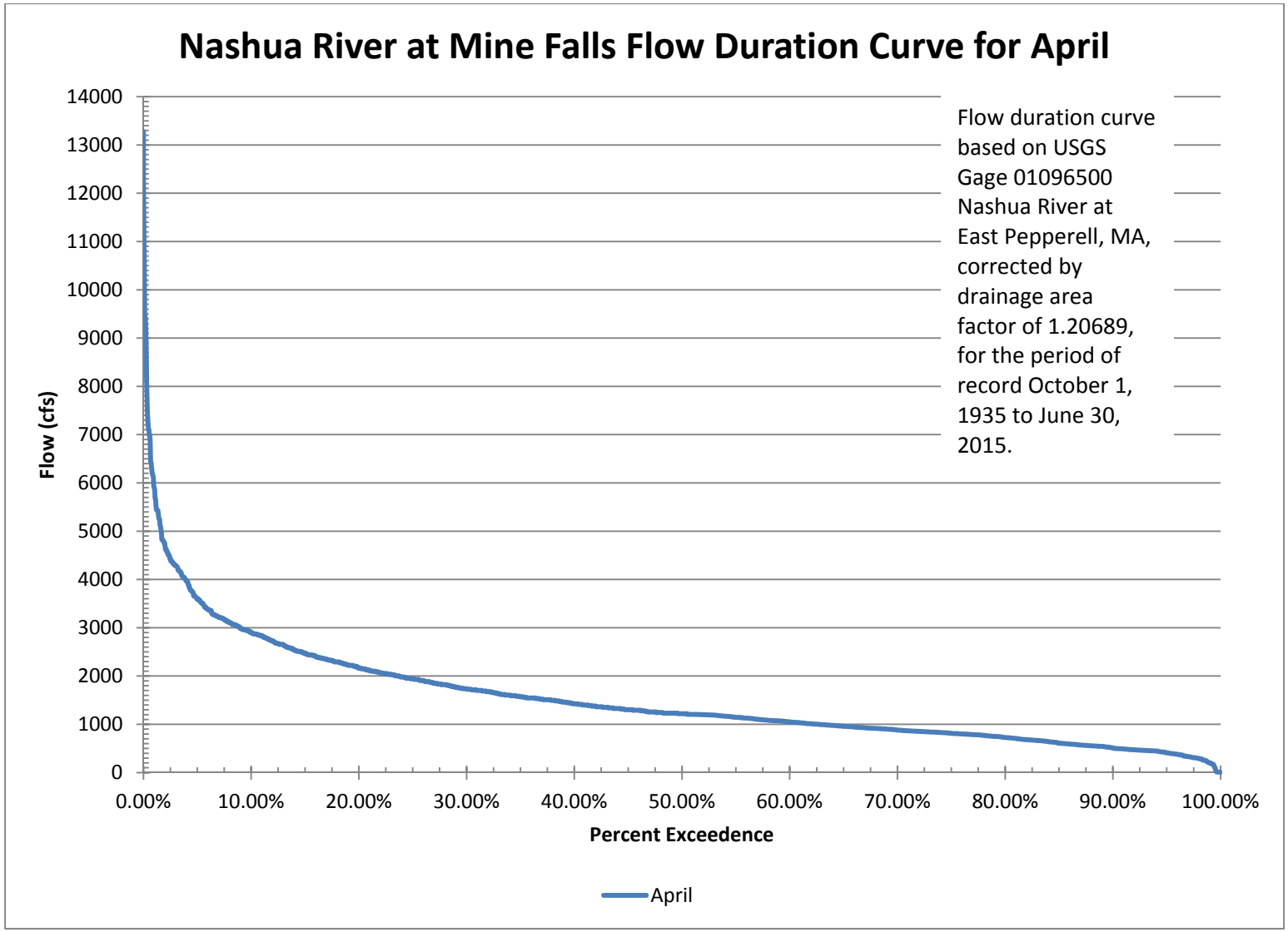


Figure 11 – April Flow Duration Curve for Nashua River at Mine Falls Dam, Nashua, NH

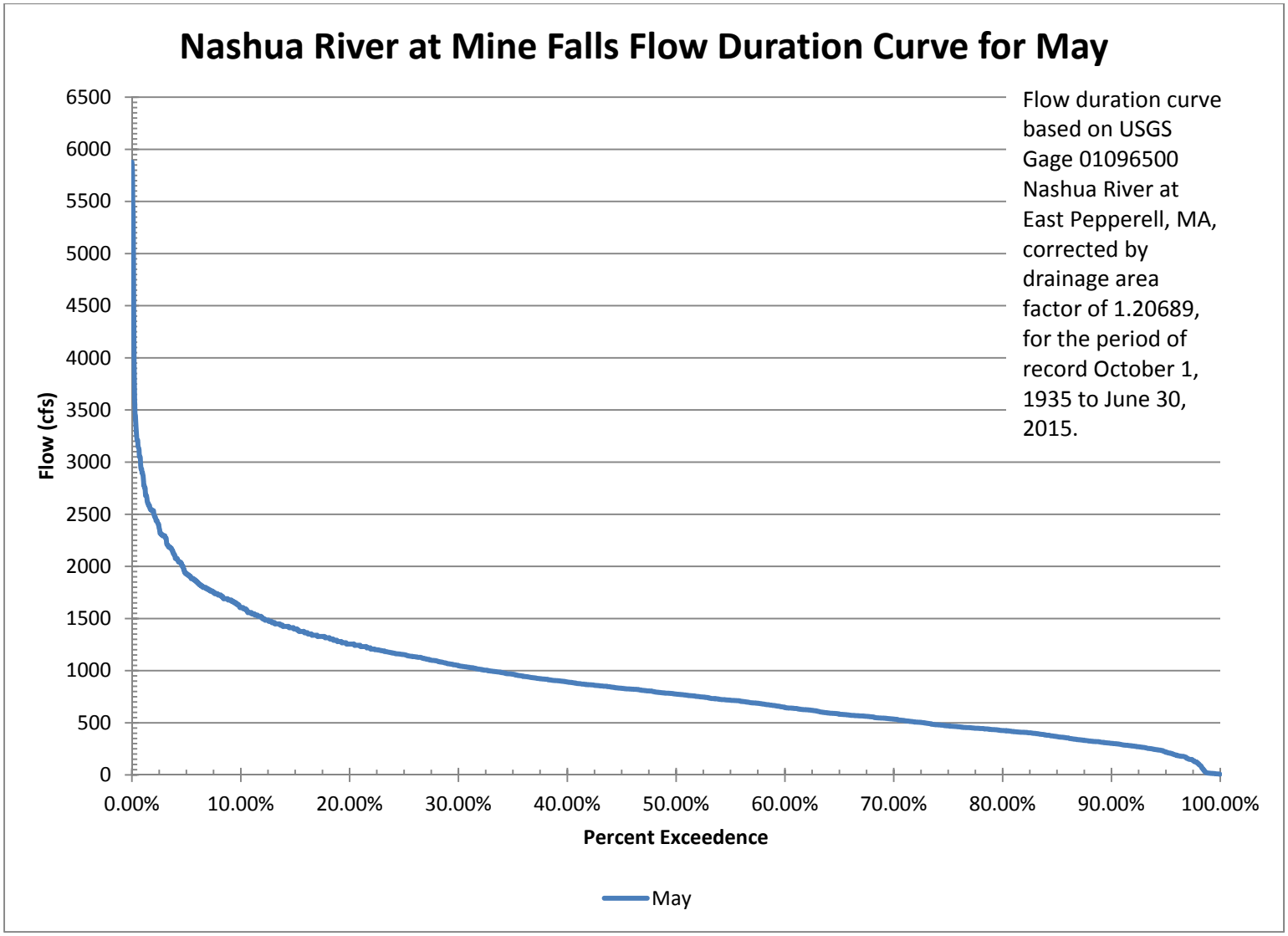


Figure 12 – May Flow Duration Curve for Nashua River at Mine Falls Dam, Nashua, NH

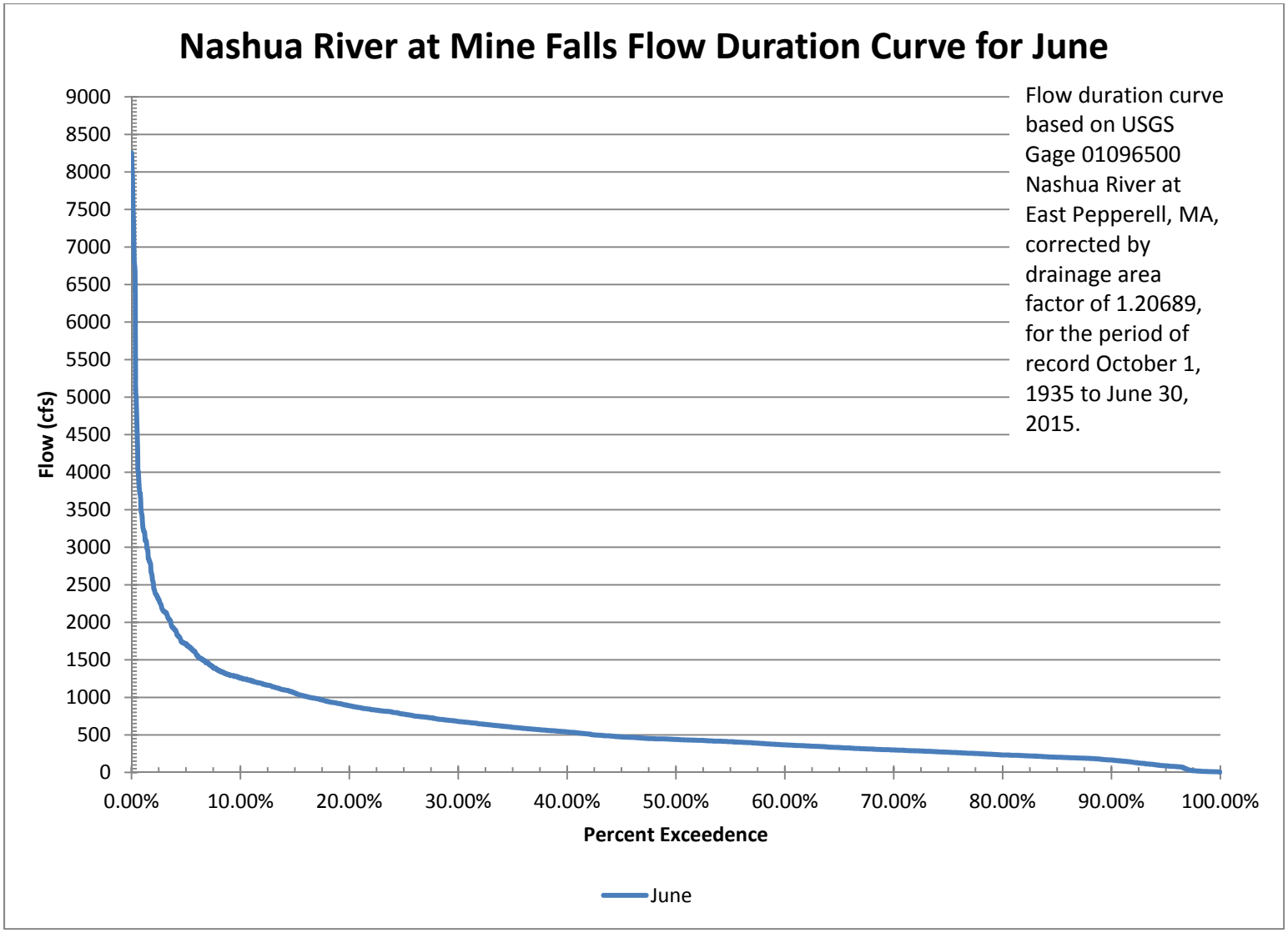


Figure 13 – June Flow Duration Curve for Nashua River at Mine Falls Dam, Nashua, NH

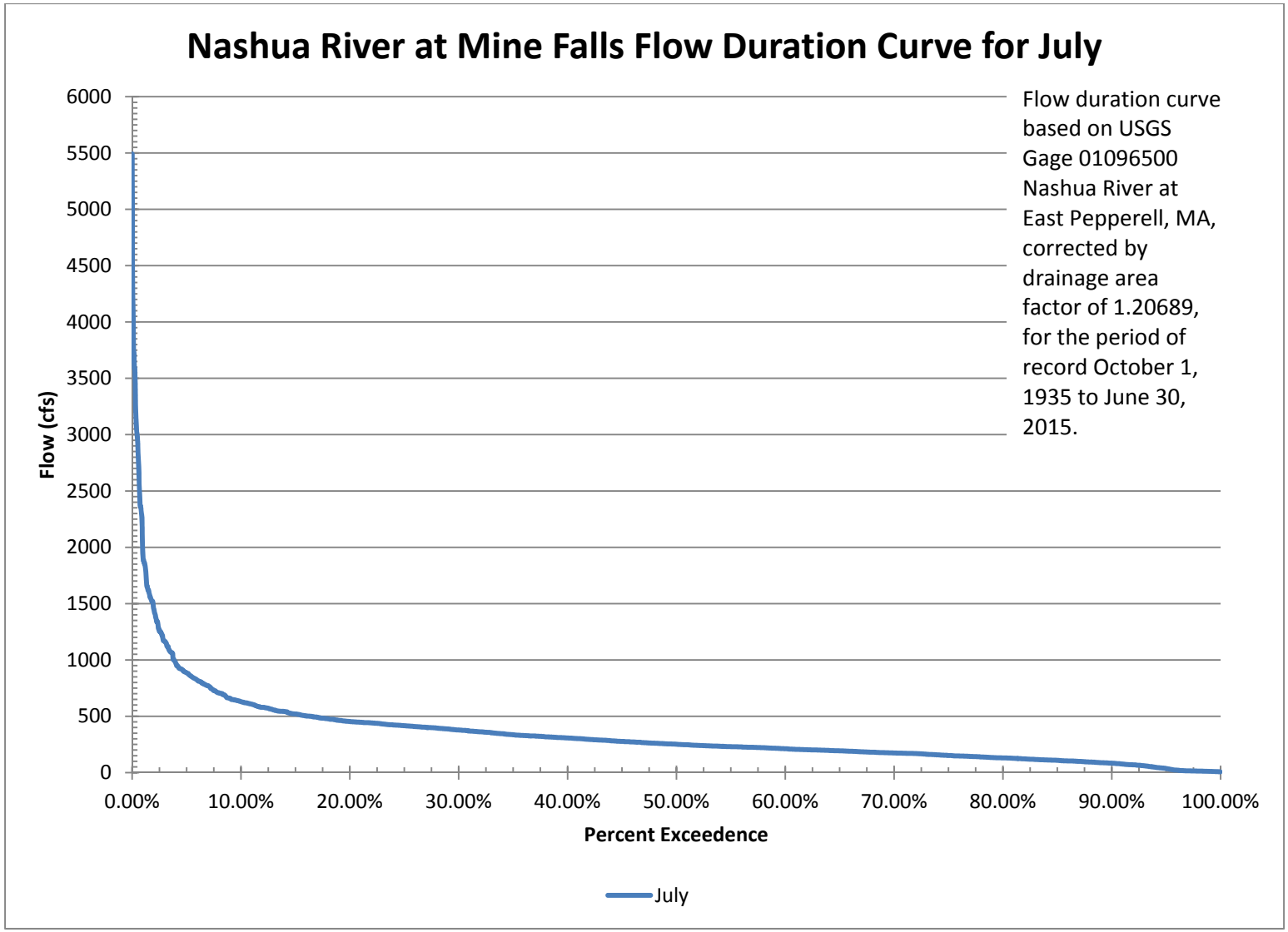


Figure 14 – July Flow Duration Curve for Nashua River at Mine Falls Dam, Nashua, NH

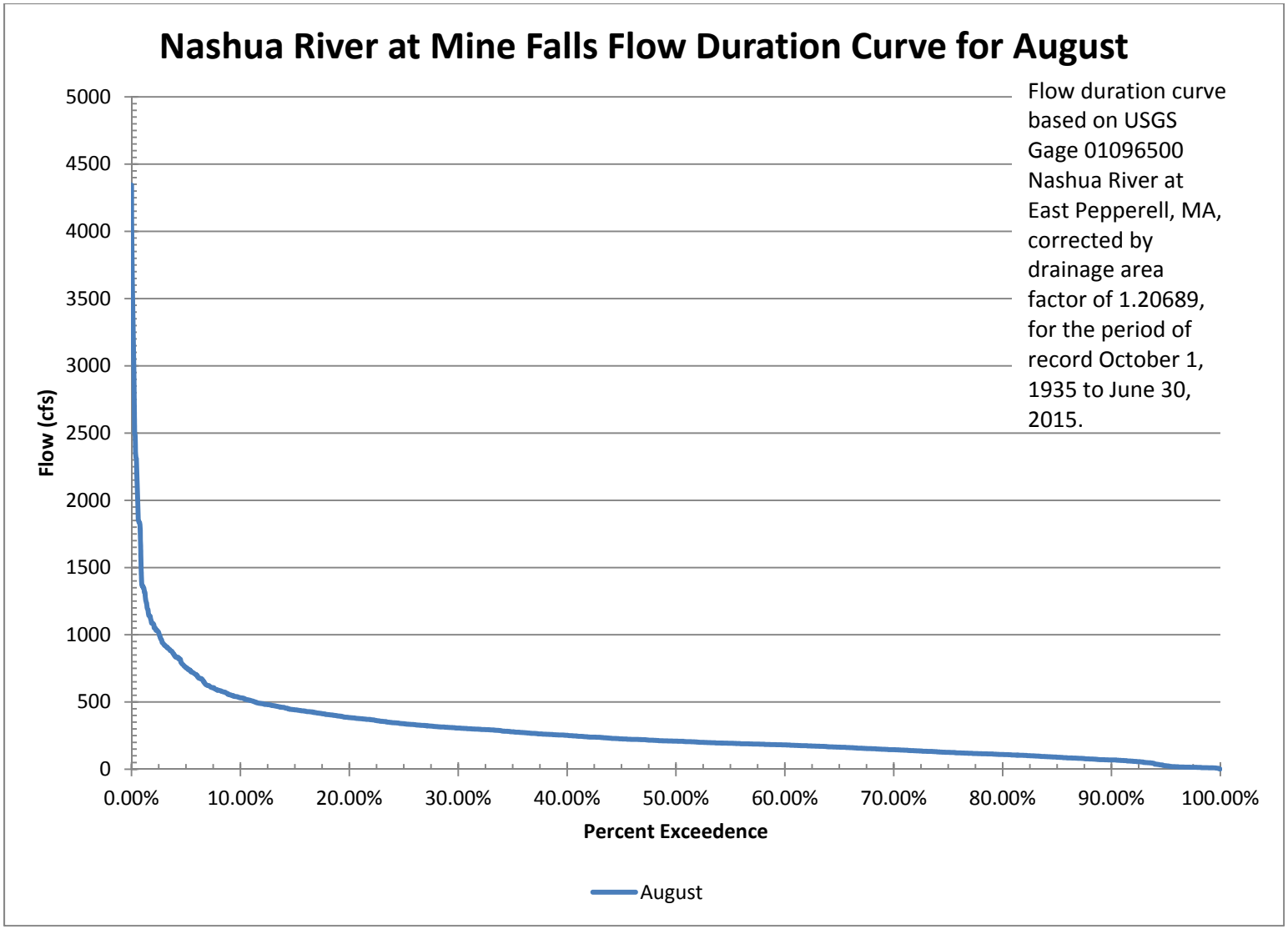


Figure 15 – August Flow Duration Curve for Nashua River at Mine Falls Dam, Nashua, NH

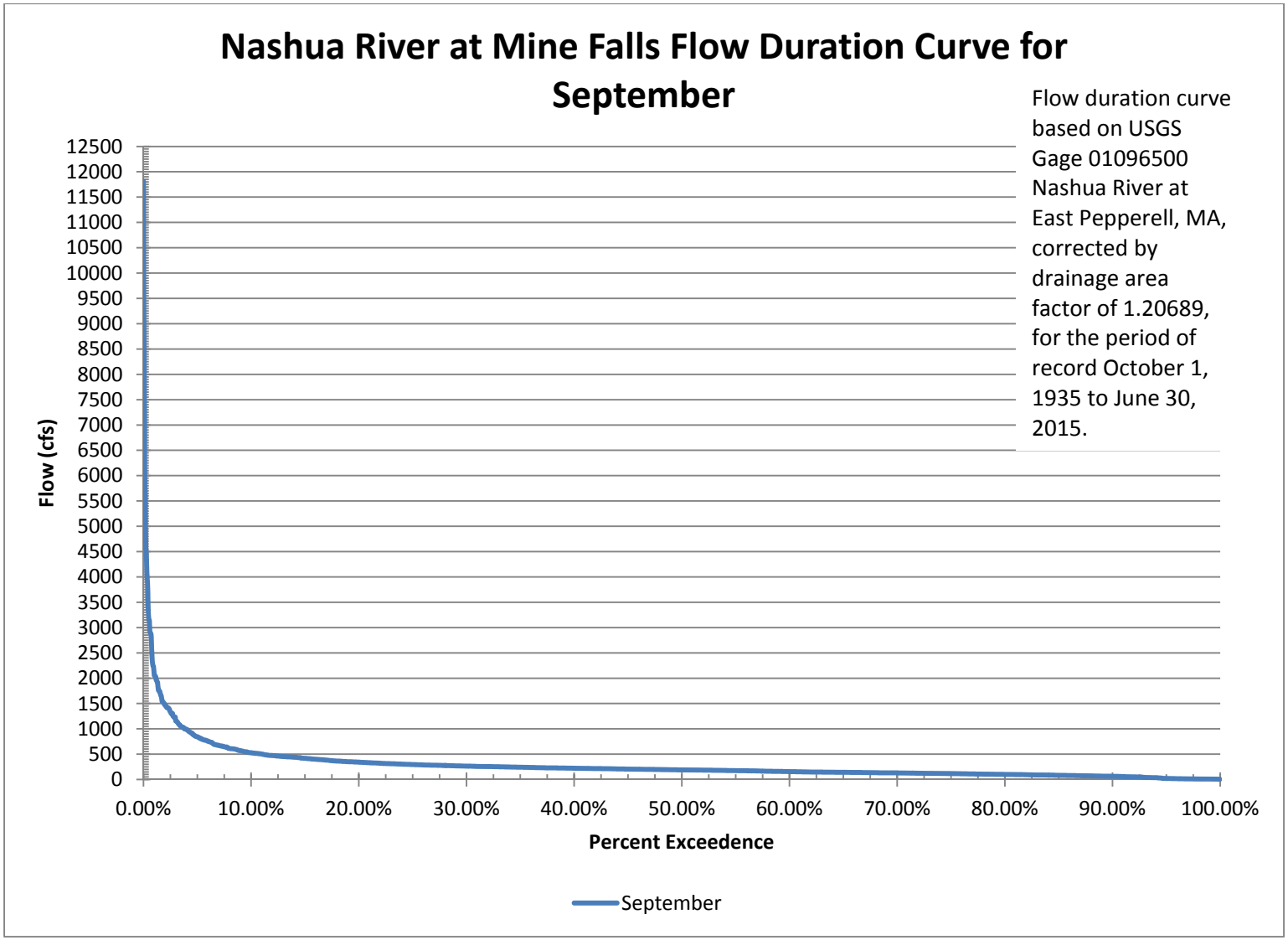


Figure 16 – September Flow Duration Curve for Nashua River at Mine Falls Dam, Nashua, NH

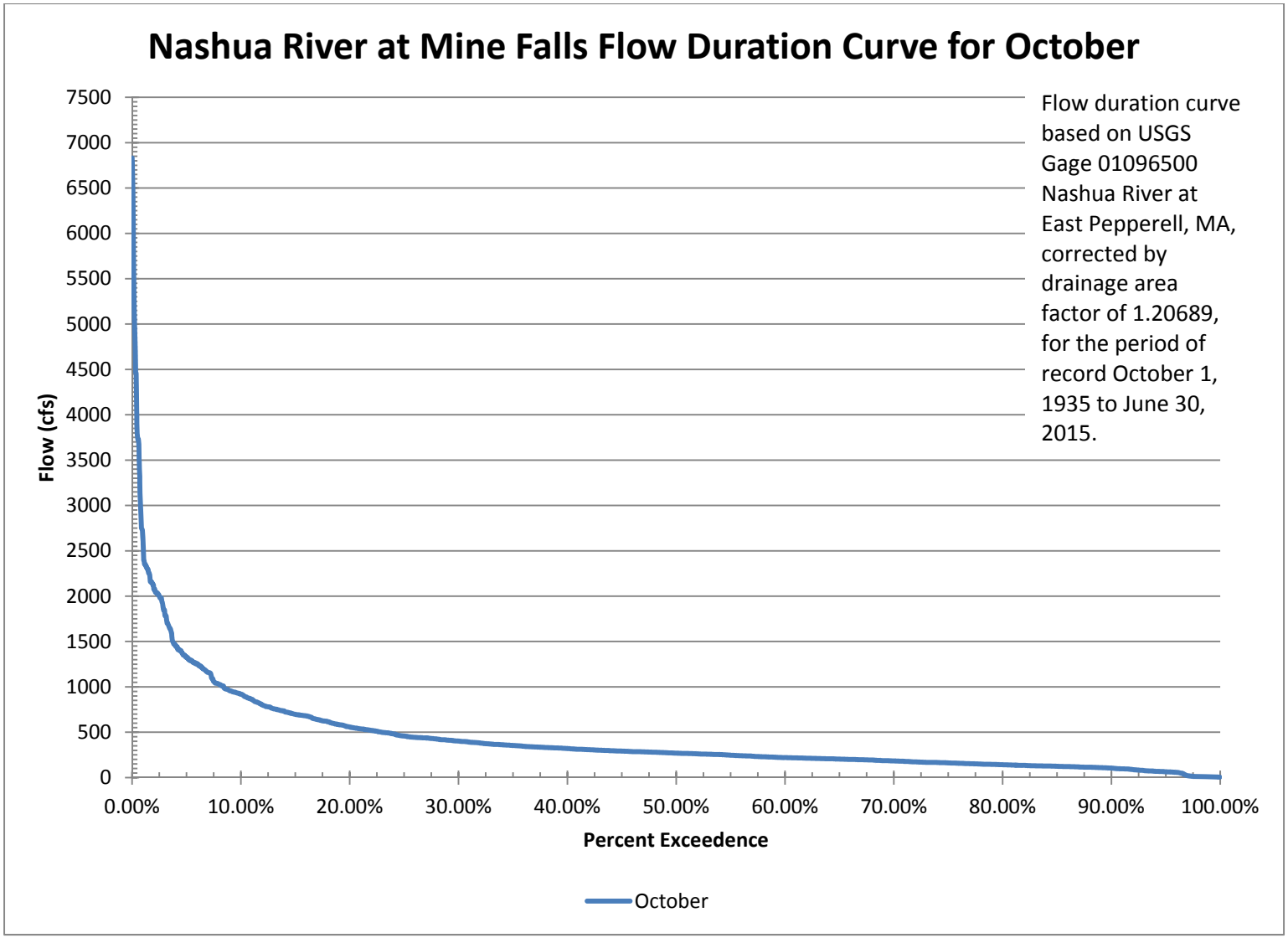


Figure 17 – October Flow Duration Curve for Nashua River at Mine Falls Dam, Nashua, NH

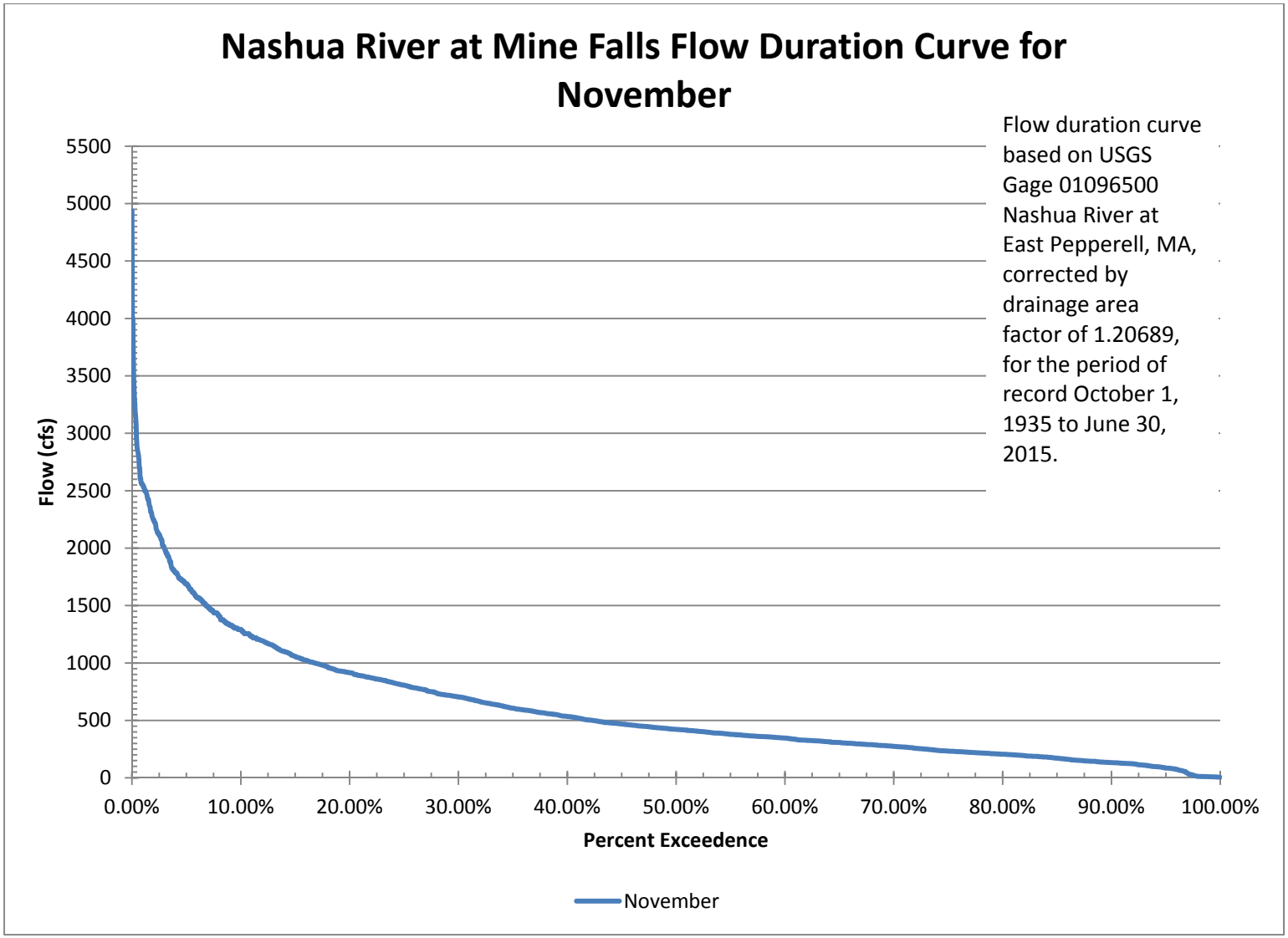


Figure 18 – November Flow Duration Curve for Nashua River at Mine Falls Dam, Nashua, NH

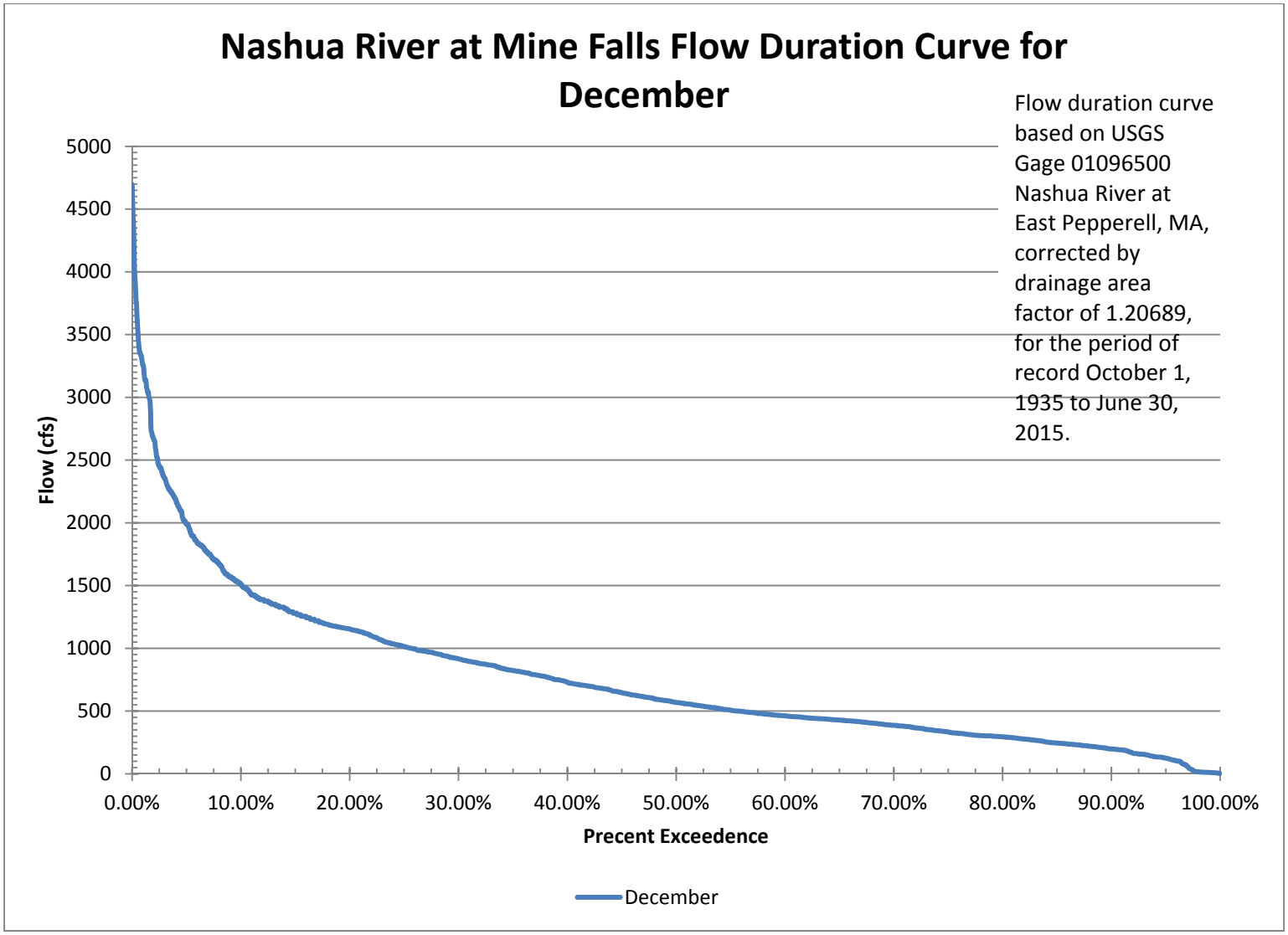


Figure 19 – December Flow Duration Curve for Nashua River at Mine Falls Dam, Nashua, NH

Appendix C – Mechanical Assessment

Mine Falls Mechanical Observations
Energy Resources Group, Inc.
to:
JLavigne
07/27/2015 02:13 PM
Cc:
b.dall, ergincorp
Hide Details
From: "Energy Resources Group, Inc." <ergincorp@aol.com>
To: JLavigne@hlturner.com,
Cc: b.dall@energyresourcesgroup.us, ergincorp@aol.com
History: This message has been replied to.

John,

As we've learned, after Algonquin took over ownership and operation from ERG and subsequently sold it to Eagle Creek, there was little maintenance documentation in between. We and Eagle Creek have been forthcoming with what we can remember but there seems to have been only emergency repairs performed by Algonquin.

Accordingly, ERG is providing expected and worst case estimate for the subject components. We can better define these with generator testing, dewatering, etc.

The hydraulic power units are 30 years old and have always been a maintenance headache. We expect to replace the hoses and parts such as aged seals and gaskets. A thorough flushing of the system and adding filtration is worthy; this will cost an estimated $50,000. If we also need to replace old shuttle valves, clean and paint the tank internal, replace motors etc. the worst case estimate is $150,000.

The drain pump system is critical. Thru these few electric pumps and single steel piping run flows all in leakage. Failure of this system will result in flooding of the powerhouse. Adding redundancy may cost $50,000.

The generators have not been disassembled and inspected in 30years. Industry standard is 10 years. The dirt and contaminants provide thermal insulation on the electrical windings causing them to run hotter than designed. For every 10°C increase in temperature, the generator's life is cut in half.

Accordingly, we highly recommend removal, transportation to a shop and refurbishment. This will probably cost $200,000 and if slip rings, etc. need to be replaced, this becomes $300,000 for the repair.

The turbines had events causing the blades to strike the casing (coupling broke), after the generators are removed, the turbines should be removed, blades reprofiled etc. to provide reliability and efficiency. Bearings should be replaced, welted parts epoxy painted, etc. This is expected to cost $200,000.

The blade positioning components should be disassembled, inspected and wear parts/seals replaced with turbine removed and in shop this will probably cost an additional $100,000 but worst case could be $200,000.

The ancillary in building mechanical components such as filters crane, etc. will also require some maintenance from which $100,000 should be budgeted.

John, how would you like us to expand on this?

Regards,
Keith Frisbee

This email has been scanned by the Symantec Email Security.cloud service.
For more information please visit http://www.symanteccloud.com

Appendix D – Electrical Assessment

Notes from Mine Falls Hydroelectric Facility site visit on 17 July 2015

The following data was noted during the subject site visit.

1) Headgate to waste at dam receives its power through a conduit secured to the top, inner wall of the station intake channel concrete. It could be subject to ice or other damage. Per Facility personnel it is a single phase powered gate motor with controls located at the platform end along the intake channel. If the conduit and wiring were to be damaged there would be no way to open the gate as there is no manual gate operator still at the unit. There would also be no power to operate the gate under those conditions. Consider a modification to move the motor controller (not the pushbuttons) to near the gate, with local pushbuttons also at that location, and with the wiring rerouted to underground on the "land side" of the intake cannel. Consider possible provision for portable standby power for the gate near the gate, OR reconfigure the operator so it can be either motor or manually operated at the gate location.

2) Existing electrical service originates at a pole mounted recloser located in the utility power line ROW some distance from the facility and is routed underground to the facility. It was indicated that the oil in the recloser has not been tested regularly as that in the station step-up transformer. There is some minor cleaning and painting needed on the regulator, the oil needs to be tested. The general construction at the recloser is standard electric utility type and appears to be in good condition based on a visual only inspection. Recloser and controls are assumed to be the vintage of the service. Availability of maintenance parts , if needed is unknown.

3) Power step-up transformer at Mines Falls facility is McGraw Edison, Class OA, 3 phase, 34,400 Y/ 19860 - 4160 volt delta, 3750 KVA, S# C-45527-1-1, 1984 manufacture, 65 degree C. Rise, Impedance 6.1 %,@ 3750 KVA, with 2-2 1/2 % taps above and below 34,400. It has fans installed on the radiators. The top of the transformer has paint problems and some rust that needs to be addressed. The main side flanged opening near the top appears to have a gasket/seal failing as oil is obviously leaking from it. There is an apparent stainless steel pan that has been added at some time under the transformer to contain any oil leakage from the unit (it is located directly adjacent to the river). A portable sump pump is used to remove rain water or other precipitation from the collection container, and it was indicated that any "surface oil" was skimmed off before the pump removed the remaining liquid (which is pumped overboard into the river). High and low voltage bushing and cable termination compartments could not be opened during the visit due to required special safety clothing not being available.

4) At some time the facility original oil filled 34.5 KV to 480/277 volt pad mounted station service transformer (that was initially located adjacent to the main step-up transformer) has been removed and a new dry type, 225 KVA, 4160 to 480/277 Volt station service transformer has been installed in the facility near the station service power distribution panels (one level below the generator floor level). The power for the new station service transformer has been tapped from the generator 4160 volt switchgear. Access to determine how tapped, and what circuit protection was installed was not possible because proper safety clothing was not available during the visit. Originally the facility bought the station service power from the original , separately metered outdoor transformer (meter socket is still in place inside the building). Now station service power is only purchased when station generation is less than station power use. New transformer outwardly appears to be in good condition. Station service panelboards appear to be vintage of the facility, but also appear to be of a make and type that is still readily available on the market. A 45 KVA, 3 phase, dry type transformer provided 208/120 volt power for receptacles, etc. and that power id distributed from one panelboard at the station service power area.

5) Site lights at the dam are Quartz lamped. LED would use less power and should be considered for replacements as the existing units need replacement. IF they are used regularly as security lights, it would be better to change them out at an earlier time.

6) Conduits for secondary (4160 Volt) power from the main step-up transformer to the generator switchgear is apparently damaged at some location where it is underground as water has entered through it. The main junction box (near the #2 exciter) has its bottom plate fully rusted out and falling away. This apparently is an issue when the fish bypass is flooded. This needs repairs as the earliest time to minimize possible damage to the electrical equipment and controls in the building.

7) Exciters are Basler Shunt Static Exciter Regulators, Part 9177400-100, input 480 V, 50/60 HZ, 3 phase, 71.3 Amperes, Output 250 Volt, 132 Amperes continuous, Both units indicate : date 9-28-84 and S# 125. Doors were not opened. Units outwardly appear to be in good condition.

8) Generator #2 Nameplate indicates: Allis Chalmers, KVA 1000 **(need to double check this),** PF 90%, 300 RPM, 4160 Volt, 3 phase, 60 HZ, 231 Amperes, Rise at 115 % load 105 degrees C. by Res. Rotor 105 degrees C. Exciter 250 Volt, 118 Ampere. Type AVW, S# 80052-2.

9) Generator #1: Same as Generator #2 except S# 80052-1

10) Generator Switchgear: Powercon. Modifications made by Algonquin (2001) to include PLC interface appear to be well documented in one set of 11x17 prints that were quickly reviewed. I need a copy of those drawings for the facility report, if at all possible. Loss of the data on those drawings would be very expensive to recreate. Whether modifications by the present operator are noted is unknown, if there were any beyond the installation of a new Basler BE1-700V relay that replace the apparent original voltage and frequency relays. Those modifications were not noted in my quick review of the information.

11) It was noted that presently Unit #1 is having "phantom" trip operations (no apparent alarm annunciation record, but machine trips off line.

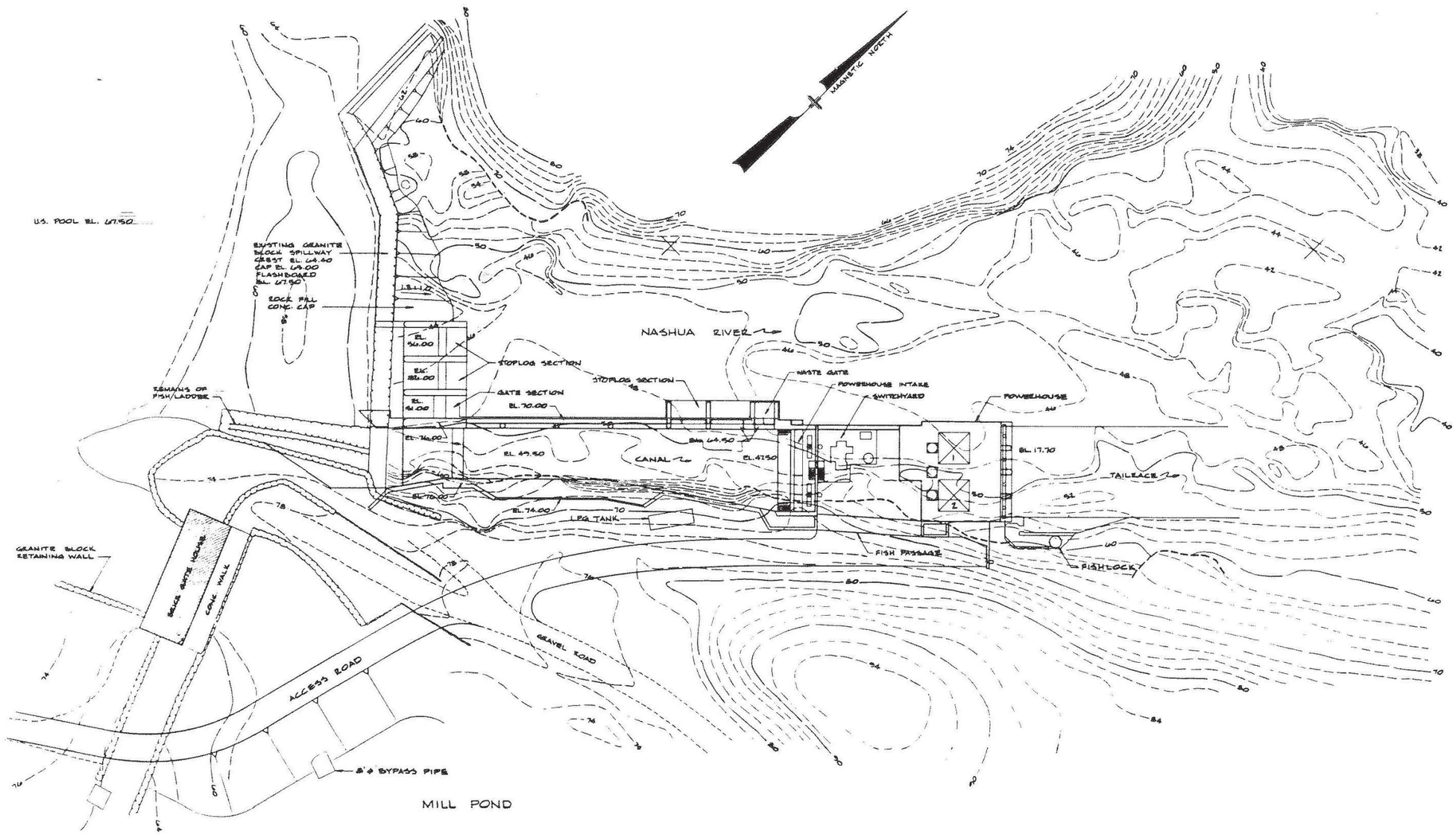
12) It was indicated that the existing Allen Bradley PLC is becoming obsolete and that the present operators plan to replace it at some time in the near future.

13) It was noted that the existing alarms and machine operating data are not transmitted off site, and that alarms activate an alarm dialer only to call in personnel. The replacement system would, hopefully, include making remote access to information like pond level, etc. also available.

14) Switchgear DC batteries provide power to a DC power panelboard and to controls, etc. The existing batteries are approximate 2011 vintage, and are deep discharge truck/marine type. Normal switchgear battery life is considered to be approximately 5 years, so replacement in the next year is recommended.

END OF NOTES

Appendix E – Project Drawings



MINE FALLS HYDROELECTRIC PROJECT

NASHUA, NEW HAMPSHIRE

NO.	REVISION	DATE	CHK'D	NO.	REVISION	DATE	CHK'D

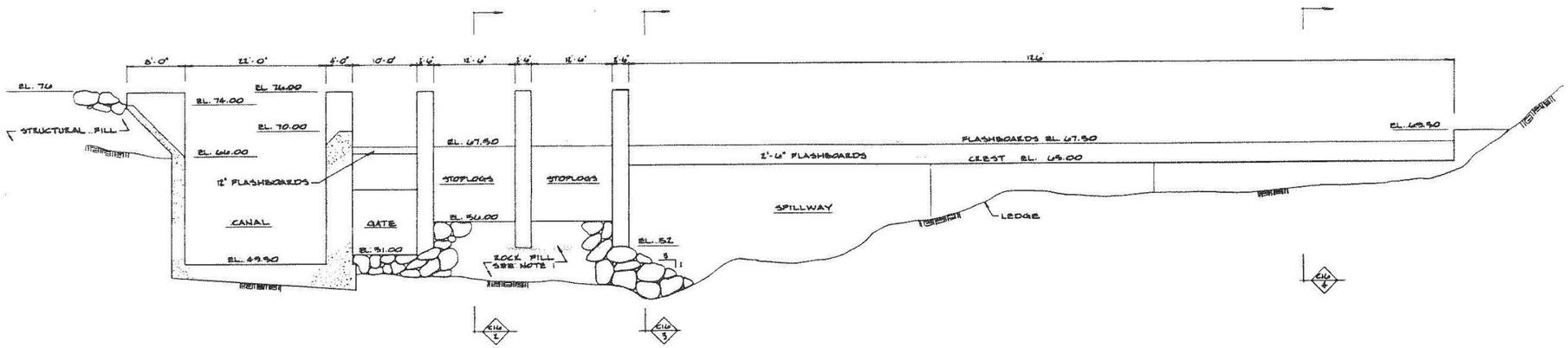
DESIGNED ____ SCALE 1" = 20'
DRAWN ____ DATE 11/17/85
CHECKED ____ DATE ____
APPROVED ____ DATE ____

SITE PLAN

RIVERS ENGINEERING CORPORATION
CONSULTING ENGINEERS
LONDONDERRY, NEW HAMPSHIRE

SHEET C1

TURNER GROUP



ELEVATION — C16 1
SCALE — 1" = 8'

NOTES

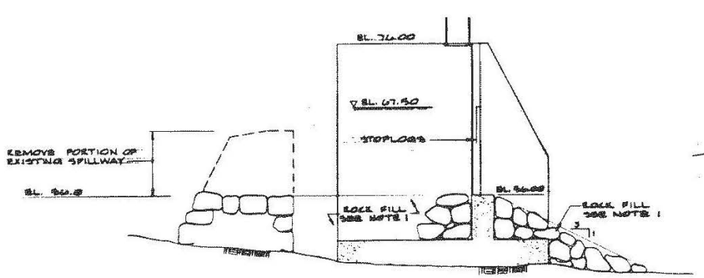
1) EXPOSED ROCK FILL DOWNSTREAM OF THE SPILLWAY AND WHERE NOTED SHALL CONFORM TO THE FOLLOWING GRADATION:

STONE SIZE	PERCENT OF TOTAL WEIGHT SMALLER
2000 lb.	100
1400 lb.	80
700 lb.	50
40 lb. NOT TO EXCEED	10

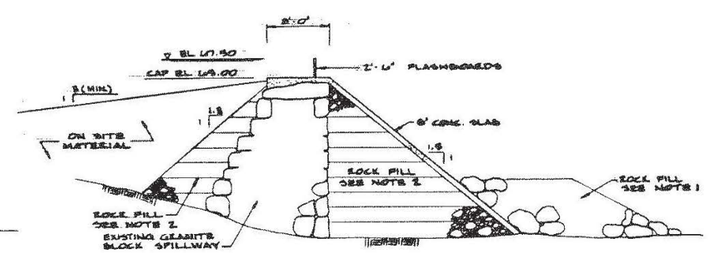
2) ROCK FILL ON THE UPSTREAM AND DOWNSTREAM SIDES OF THE EXISTING GRANITE BLOCK SPILLWAY AND THE CORE WALL SHALL BE COMPACTED IN 2 FT. LIFTS AND CONFORM TO THE FOLLOWING GRADATION:

SIEVE SIZE	PERCENT PASSING BY WEIGHT
2'	100
1'	70 - 100
6"	50 - 95
1"	15 - 75
No. 4	0 - 50
No. 20	0 - 20
No. 200	0 - 10

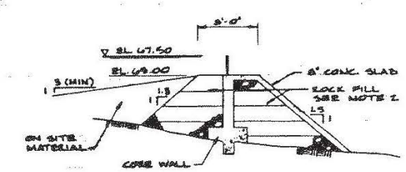
3) REFER TO MILLER ENGINEERING & TESTING, INC. REPORT TITLED "STABILITY RECOMMENDATIONS" DATED MARCH 15, 1985



STOPLOG SECTION
SECTION — C16 2
SCALE — 1" = 8'



SECTION — C16 3
SCALE — 1" = 8'



SECTION — C16 4
SCALE — 1" = 8'

NO.	REVISION	DATE	CHK'D	NO.	REVISION	DATE	CHK'D

DESIGNED SJW SCALE 1" = 8'
DRAWN JJB DATE 6/1/89
CHECKED JAG DATE 5/19/85
APPROVED SJW DATE 5/3/85

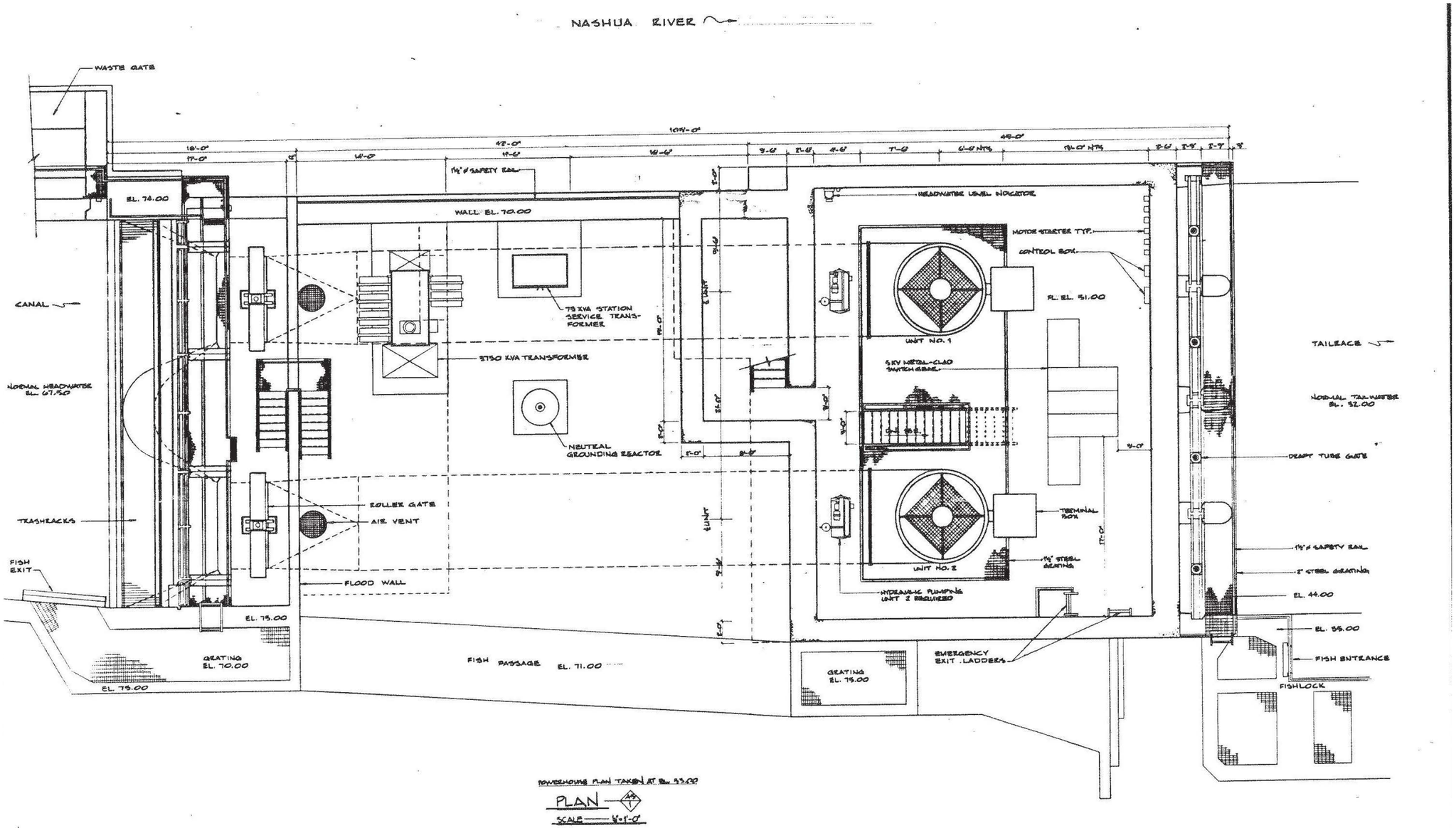
MINE FALLS HYDROELECTRIC PROJECT
NASHUA, NEW HAMPSHIRE

SPILLWAY MODIFICATIONS ELEVATION & SECTIONS

RIVERS ENGINEERING CORPORATION
CONSULTING ENGINEERS
LONDONDERRY, NEW HAMPSHIRE

SHEET C16

TURNER GROUP



NO.	REVISION	DATE	CHK'D	NO.	REVISION	DATE	CHK'D
1	CHNG POOL ELEV.	4/1/85	EJG				
2	ADD FISH FACILITY	11/1/85					

DESIGNED ____ SCALE 1/8"=1'-0"
DRAWN ____ DATE 8/8/84
CHECKED ____ DATE ____
APPROVED ____ DATE ____

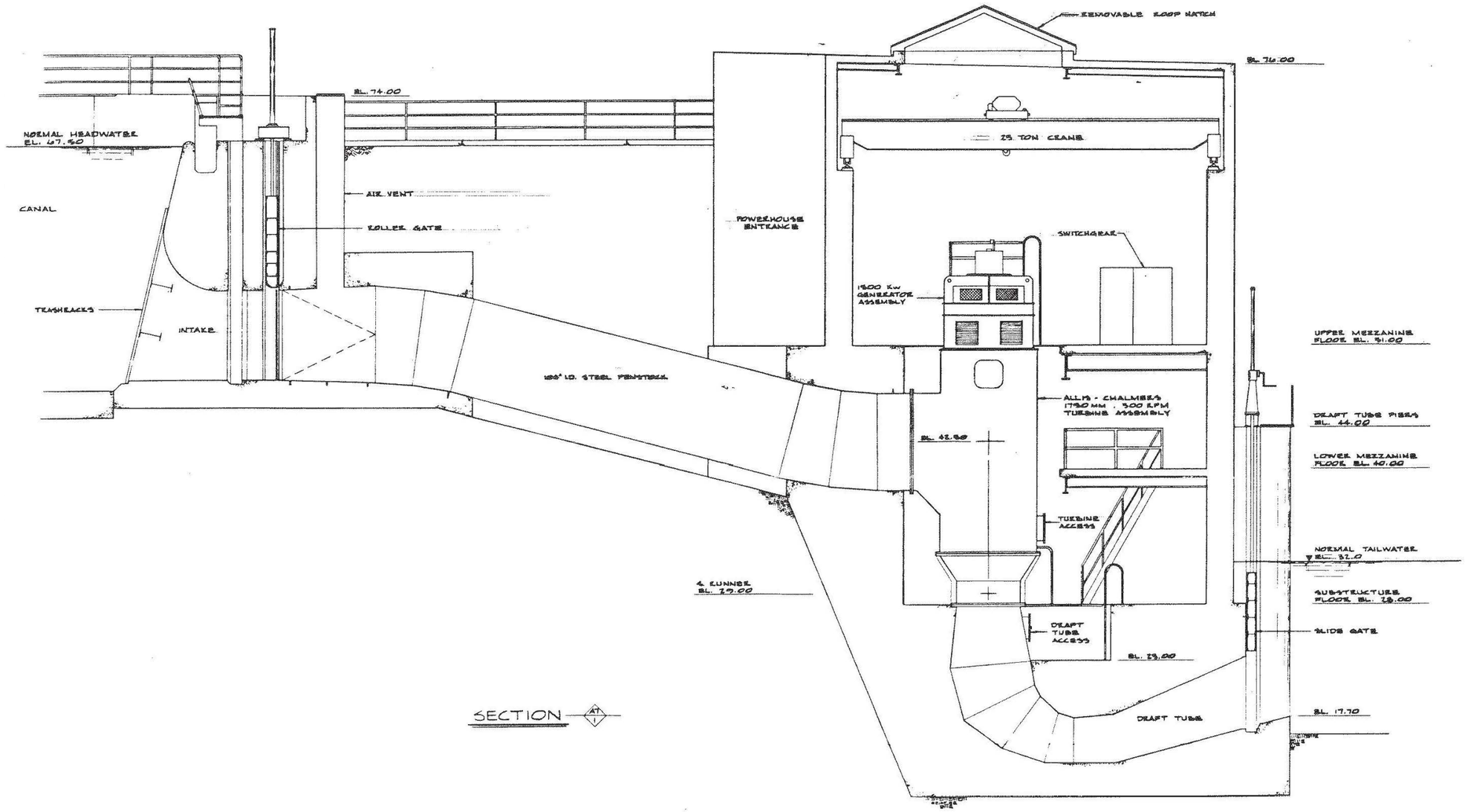
MINE FALLS HYDROELECTRIC PROJECT
NASHUA, NEW HAMPSHIRE

POWERHOUSE PLAN

RIVERS ENGINEERING CORPORATION
CONSULTING ENGINEERS
LONDONDERRY, NEW HAMPSHIRE

SHEET A5

TURNER GROUP



MINE FALLS HYDROELECTRIC PROJECT

NASHUA, NEW HAMPSHIRE

NO.	REVISION	DATE	CHK'D	NO.	REVISION	DATE	CHK'D
1	CHANGE POOL ELEV.	4/7/85	EJB				

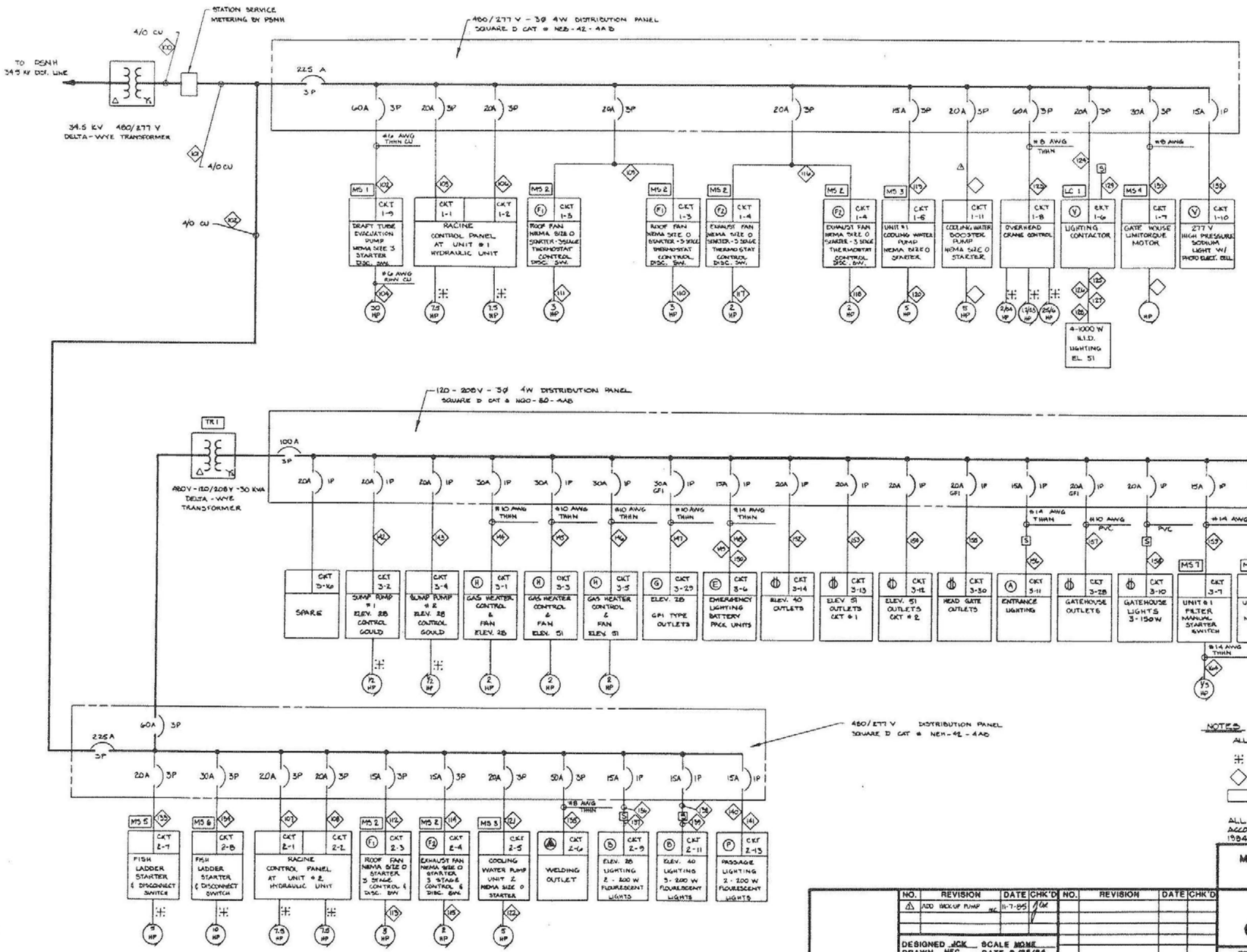
DESIGNED _____ SCALE 1/4" = 1'-0"
DRAWN EJB DATE 3/19/85
CHECKED _____ DATE _____

POWERHOUSE SECTION

RIVERS ENGINEERING CORPORATION
CONSULTING ENGINEERS

SHEET A7

TURNER GROUP



NOTES:

ALL WIRE IS # 12 THHN UNLESS OTHERWISE NOTED

DENOTES MANUFACTURER'S INTERCONNECTION

DENOTES CABLE NO. SEE CABLE SCHEDULE

DENOTES EQUIPMENT MARK. SEE BILL OF MATERIAL

ALL ELECTRICAL WORK IS TO BE DONE IN ACCORDANCE WITH NATIONAL ELECTRICAL CODE, 1984 EDITION.

NO.	REVISION	DATE	CHK'D
1	ADD BACKUP PUMP	11-7-85	

DESIGNED JCK SCALE NONE
DRAWN HEG DATE 8/28/84
CHECKED JCK DATE 9/25/84
APPROVED JCK DATE 9/25/84

MINE FALLS HYDROELECTRIC PROJECT
NASHUA, NEW HAMPSHIRE

STATION SERVICE ONE LINE DIAGRAM

RIVERS ENGINEERING CORPORATION
CONSULTING ENGINEERS
LONDONDERRY, NEW HAMPSHIRE

SHEET E 7

TURNER GROUP

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