# EROSION CONTROL PLAN
# for the
# Turners Falls Pool
# Connecticut River

Simons & Associates, Inc.
June 15, 1999

## Executive Summary

An Erosion Control Plan (Plan) has been developed for the licensees of the Turners Falls and Northfield Mountain Hydroelectric Projects to address riverbank erosion in the Turners Falls Pool of the Connecticut River. The licensees of these projects are the Connecticut Light & Power Company and Western Massachusetts Electric Company which are wholly owned subsidiaries of Northeast Utilities ("NU"). The Plan responds to concerns over riverbank erosion in the context of compliance with relevant articles of the Federal Energy Regulatory Commission ("FERC") licenses that govern NU's two hydropower projects operating in the Turners Falls Pool. The Plan presents the objective of minimizing soil erosion along the Turners Falls Pool as required by the relevant FERC license articles. The Plan has two distinct elements. The first element of the Plan pertains to the actual repair of eroded riverbank segments over time. The second element focuses on a proactive program of preventative maintenance measures NU will implement to minimize or prevent future erosion.

With regard to riverbank repairs, The Plan explains the approach that was taken to first classify segments of riverbank based on physical characteristics, vegetation, and erosion condition. Utilizing this classification data, these segments of riverbank were then prioritized based upon those segments that are contributing the most sediment to the river. Riverbank segments or sites will be repaired generally in the order of their ranking on this priority list. The classification and prioritization process will be repeated every several years and the Plan will be updated to incorporate changes in erosion conditions.

The Plan discusses various methodologies that will be applied in repairing a wide range of erosion conditions in the Turners Falls pool. The Plan goes on to explain that specific repair designs for each site on the priority list will be developed at least one year before commencement of repairs at that site or segment of riverbank.

The Plan also includes follow-up monitoring and evaluation of repaired sites to provide important information on the performance of various types and components of erosion protection. This knowledge will be used in improving the design, planning and construction of future sites.

Finally, the Plan outlines NU's commitment to minimize riverbank erosion in the Turners Falls Pool for the remaining 20 years of its FERC operating licenses.

# Table of Contents

## 1.0 Objective

The Turners Falls Pool serves both as the lower reservoir for NU's Northfield Mountain Pumped Storage Hydroelectric Project (FERC Project No. 2485) and as the impoundment for NU's Turners Falls Project (FERC Project No. 1889). Both projects are licensed by the Federal Energy Regulatory Commission (FERC) and subject to license articles pertaining to the minimization or prevention of soil erosion along the Turners Falls Pool. Article 20 of FERC License No. 2485 states that, *"The Licensee shall be responsible for and shall minimize soil erosion and siltation on lands adjacent to the stream resulting from construction and operation of the project."* Article 19 under FERC License No. 1889 states that, *"in the construction, maintenance, or operation of the project, the Licensee shall be responsible, and shall take reasonable measures to prevent soil erosion on lands adjacent to streams. . ."* Article 20 of License 2485 goes on to say that the Commission (FERC) *"may order the licensee to construct and maintain such preventive works to accomplish this purpose and to revegetate exposed soil surface as the Commission may find to be necessary after notice and opportunity for hearing."*

The objective of this Erosion Control Plan (Plan) is to minimize or prevent erosion in the Turners Falls Pool in compliance with the relevant FERC license articles. To meet this objective, the steps outlined below have been incorporated in the Plan:

- Classification of riverbanks and erosion sites.
- Prioritization of erosion sites.
- Application of appropriate erosion control methodologies or treatments based on prioritization.
- Monitoring and evaluation of repaired sites.
- Preventative Measures Program.

## 2.0 Classification

Portions of the riverbanks along the Turners Falls Pool are generally stable, while other portions of the riverbanks exhibit a range of severity of erosion. Classification of riverbank conditions regarding erosion or stability provides necessary information to determine the extent of riverbank potentially needing repair and a basis for prioritizing sites for repair. The goal of the classification process is to identify those erosion sites contributing the greatest amount of sedimentation to the river. These sites are to be repaired first, as later discussed in Sections 3.0 and 4.0.

## Methodology

There are several characteristics of the riverbanks themselves that play a significant role in their stability or potential for erosion. These key characteristics are listed below along with a brief explanation of how each characteristic affects the potential for erosion.

1. Bank material - The soil/sediment type and characteristics control a significant portion of the forces resisting erosion. For banks consisting predominantly of non-cohesive sediment particles (sand, gravel, cobbles, boulders), the weight of the individual sediment particles provide the resisting force. Larger sized particles with corresponding heavier weights provide greater resistance to erosion than smaller, lighter particles. For cohesive sediment (clay and silt, to some degree), electrostatic bonds provide cohesion which helps these types of material resist erosion. Sediment with greater cohesion has a greater capacity to resist erosion than those types with less cohesion.
2. Bank geometry - The geometry of a riverbank also plays a significant role in how effective the resisting forces due to the cohesion or weight of bank material can resist erosion. The key factors in bank geometry are: bank slope, bank height, and whether or not a beach exists below the upper bank. Steeper bank slopes and those with larger heights, tend to be less resistant to erosion than do flatter, shorter banks. Beaches provide a buffer zone between the higher velocity current as well as provide some dissipation of wave forces which help increase upper bank stability.
3. Vegetation - Riverbank vegetation generally increases riverbank stability with the root structure tying riverbank soils together (In some cases vegetation at the top of a tall bank with a root structure extending to the lower bank, can when undercut, topple over causing additional erosion of the upper bank). Stems, branches, and trunks help dissipate the energy of flowing water. Lack of vegetation is indicated by the percentage of barren soil exposed to the flow.
4. Erosion/stability characteristics - Indicative factors related to existence or lack of characteristics including overhanging upper banks, teetering or leaning trees, traces of continual sliding of bank material, indications of mass wasting, undercutting lower banks, and other indicative factors will be observed and documented.

A methodology was developed to document riverbank conditions and to provide information later used in ranking erosion conditions along the river. The riverbanks were delineated into a series of segments or sites for which the ranking is relatively homogeneous. To meet the classification objective of compiling a complete description of the riverbank with respect to erosion, a continuous digital image log of the riverbank at near-bank scale was collected. The method of preparing this near-bank image log involves the use of digital video camera and Global Positioning System (GPS) technology. Continuous digital video images coupled with continuous GPS were collected in July 1998 along the riverbanks of the Turners Falls Pool. Observations of riverbank conditions were recorded on one of the audio tracks of the video image. These observations included comments on bank height, bank slope, vegetation, characteristics of riverbank sediment,

and other factors which tend to indicate recent erosion or the potential for future erosion or instability.

Equipment for digital image logging and recording of observations consisted of: a boat (the floating platform for the equipment), an integrated sub-meter Differential GPS unit (Trimble ProXRS), a digital video camera linked directly to GPS, a hardware item linking the GPS and digital video image which allows recording of comments on one audio track of the videotape while the continuous GPS data stream is recorded on the other available audio track. The equipment was operated by a two-person crew along with a boat operator.

The video image/GPS/observation process was conducted on the Turners Falls Pool on July 22nd and 23rd, 1998. The information generated by this process forms the basis for the classification of riverbank conditions at this time. It is anticipated that this video image/GPS/observation process will be repeated in three years to document changes in riverbank conditions that occur from 1998 to 2001. At such time, the classification and prioritization of riverbank sites would be modified and updated as necessary to fulfill the intent of the Plan. It is anticipated that if no significant changes occur and repair efforts are successful, future riverbank classification would be timed at progressively longer intervals such as five years or longer. If, however, during intervening periods, significant flood events or other factors occur which accelerate erosion, an interim re-classification may be warranted.

## Results

Figures have been prepared documenting the field observations made in July 1998. These figures are contained in Appendix A and include the distribution of: bank height, bank slope, bank material, degree of vegetation, and risk features along the Turners Falls Pool. Figure 2.1 illustrates the observed distribution of bank height in categories of high, medium, and low. The distribution of bank slope (steep, moderate, and flat) is presented in Figure 2.2. Figure 2.3 shows the distribution of bank material (silt or sand, cohesive, gravel or cobbles, and rock outcrop). Also shown on this figure are areas that have been armored. The degree of vegetation in categories of heavily, moderately, and sparsely vegetated, as well as no vegetation is shown on Figure 2.4. The distribution of risk features including: bench formation, mass wasting, overhanging bank, seeps or springs, surficial slide, and undercut toe is shown on Figure 2.5. Figure 2.6 presents the density of risk features in terms of the number of risk features per 100 feet of riverbank along the direction of the river. The density of risk features gives an indication as to the relative level of instability.

Visual examples that tie the classification ranges of the various categories of riverbank conditions to actual images of the riverbanks are shown in the following figures which are contained in Appendix B:

- Figures 2.7 - 2.9: high bank, medium bank, and low bank
- Figures 2.10 - 2.12: steep slope, moderate slope, flat slope
- Figures 2.13 - 2.17: silt or sand, cohesive soil, gravel or cobbles, rock outcrop, armored bank
- Figures 2.18 - 2.20: heavily vegetated, moderately vegetated, sparsely vegetated
- Figures 2.22 - 2.27: bench formation, mass wasting, overhanging bank, seeps or springs, surficial slide, undercut toe

## 3.0 Prioritization

This Plan establishes two criteria for prioritizing erosion sites in the Turners Falls Pool. The first and primary criterion deals with the potential and imminent threat to structures due to the close proximity of an eroding riverbank to a structure. Based on the July 1998 reconnaissance and classification of the riverbanks in the Turners Falls Pool, it was observed that there are no sites that fall under the first criterion at this time.

The second criterion relates to those sites that contribute the greatest quantity of sediment to the river. With regard to this second criterion, the use of historic aerial photographs for quantification of erosion trends was initially evaluated. Available aerial photographs of the Turners Falls Pool were examined over a period of time from the 1970's to the recent past. Because of the scales involved, scale differences, seasonal factors (foliage versus no foliage), unknown dates and therefore unknown flows, an evaluation of these factors indicated that reliable quantitative information on bank erosion would not be feasible to obtain through analysis of the available aerial photographs.

As a result of the deficiencies with using aerial photographs, an alternative approach to quantifying riverbank erosion was used. This approach involved applying a quantitative ranking system based on the riverbank characteristics observed during the classification process. An example of such an approach is found in Rosgen[1] (1996). The riverbank characteristics deemed most relevant are bank height and slope, riverbank material, degree of vegetation, and observation of ongoing or active erosion or indicators of instability. Utilizing these factors, a simple formula was developed to prioritize the various sites being considered for erosion protection. In general, those with the highest score have the highest priority for repair.

[1] Rosgen, Dave; 1996; Applied River Morphology; Wildland Hydrology, Pagosa Springs, Colorado.

First the potential sites were scored on the criteria presented in Table 3.1. .

Table 3.1
Riverbank Classification Scoring

| Riverbank Sediment | Non-Cohesive Coarse grained 2 | Cohesive 3 | Non-Cohesive Fine grained 4 | Score 1[1]-4 |
|---|---|---|---|---|
| Bank Height | Low (<4ft) 1 | Medium (4-8ft) 2 | High (>8ft) 4 | 1-4 |
| Bank Slope | Flat (>4:1) 1 | Medium (4-2:1) 2 | Steep (<2:1) 6 | 1-6 |
| Degree of Vegetation | Heavily Vegetated 1 | Moderately Vegetated 2 | Sparsely Vegetated 6 | 1-7[2] |
| Erosion Indicators[3] | One 1 | Two 2 | Three or More 3- Number of Indicators | 0-Number of Indicators |
| Total Score | | | | 4-21+ |

[1]Rock outcrops and armored banks have a score of 1.
[2]No vegetation has a score of 7.
[3]Erosion Indicators include such factors as observed active or ongoing erosion, overhanging banks, undercut toe, mass wasting, superficial slides, seeps or springs. The linear density of these factors per 100 ft of bank (one, two, or three or more) serve as a basis for the score in this category.

Erosion Ranking = Total Score

The ranking system was then correlated to actual data of riverbank erosion that has been surveyed since 1990 at 15 transects along the Turners Falls Pool to verify the general applicability of the approach. To illustrate, several examples are provided comparing ranking to erosion. On the eroded end of the spectrum, the Flagg site has experienced significant erosion over the past several years. The ranking at this site (Transect 6A, right bank - looking downstream) is on the high side of the spectrum, 19-22. Transect 5B - left bank has also experienced significant erosion and has a rank of 17-22. On the opposite end of the spectrum, there are a few transects with riverbanks where virtually no erosion has occurred, primarily due to the existence of rock outcrops or armoring and existence of vegetation. Examples of riverbanks with these characteristics are found at Transects: 1 - right bank, 5B - right bank, 5C - left bank, 7 - right bank (using the convention of looking downstream). Rankings at these locations range from 8 to 10. These examples support the correlation between rank and erosion where low rankings are associated with virtually no erosion and high rankings being associated with significant erosion.

Figure 3.1 (Appendix C) displays results of combining the various components of the ranking/scoring system. It shows the distribution of the rankings along the riverbanks of

the Turners Falls Pool. A high numerical score/ranking is indicative of either recent or on-going erosion, or the potential for continued erosion. A low numerical score/ranking is indicative of stability, lack of evidence of erosion, or relatively low potential for erosion.

It is expected that changes in riverbank conditions and erosion trends in the Turners Falls Pool will occur over time (i.e. that some erosion sites may stabilize while other sites may worsen with time). A provision has been added to the Plan to periodically repeat the classification and prioritization process in order to be responsive to these changes over time. This process would be repeated on 3 to 5 year intervals during the remaining term of the FERC licenses. Accordingly, the prioritized list of sites to be repaired would also be periodically revised to reflect any changes in erosion trends over the intervening years.

With this in mind, the Plan provides an initial list of twenty sites at this time (See Table 3.2). These 20 sites constitute the highest ranked sites which cover a total length of river of about 15,000 feet. The location of these sites and their associated ranking are displayed in Figure 3.2 (Appendix C). Following the next classification effort which will occur in 2001, Table 3.2 will be revised to not only reflect appropriate changes, but to eliminate sites that have been repaired in the intervening years as well as add sites not previously identified.

Table 3.2
Selected Erosion Control Sites

| Site # | Score[1] | Length (ft) |
|---|---|---|
| 1 | 21.8 | 827 |
| 2 | 21.0 | 20 |
| 3 | 20.0 | 100 |
| 4 | 19.83 | 1150 |
| 5 | 19.77 | 730 |
| 6 | 19.71 | 1640 |
| 7 | 19.70 | 2180 |
| 8 | 18.94 | 630 |
| 9 | 18.77 | 260 |
| 10 | 18.62 | 500 |
| 11 | 18.19 | 690 |
| 12 | 18.0 | 20 |
| 13 | 18.0 | 20 |
| 14 | 17.78 | 230 |
| 15 | 17.76 | 210 |
| 16 | 17.71 | 4000 |
| 17 | 17.61 | 560 |
| 18 | 17.59 | 700 |
| 19 | 17.38 | 450 |
| 20 | 17.33 | 480 |

[1]A detailed description of the scoring system follows:

(a) Riverbank segments (some as short as 10 feet) were each assigned a score, according to the values in Table 3.1 of this report.

(b) Segments with scores >=15 (red/yellow range) were grouped with other segments meeting the same criterion if they were either adjacent or within 100 ft of each other. Such a group of segments is called a site.

(c) A length-weighted score was then calculated for each site, i.e. [ (100ft x score20) + (50ft x score17) ] / (100ft + 50ft) = score19

(d) The sites were ranked by sorting in descending order by length-weighted score.

(e) The top twenty were selected.

Figures have been prepared showing a representative image from the digital video tape for each of the 20 selected sites. These figures are presented in Appendix D.

An evaluation of sites for which erosion control is not considered reasonably practical will also developed. The evaluation will be based on an assessment of the fact that extreme measures may be required to repair some sites, which may not be feasible either in terms of long-term stability of an extreme measure or excessive cost of such repairs. For such sites, no erosion control is recommended.

Simple statistical analyses were conducted on the distribution of the scores for the various riverbank segments. Segments with scores ranging from 20 to 25 represent about 3.4% of the Turners Falls Pool riverbank length (8340 feet or 1.58 miles). Another 13.1% of the riverbank (31,740 feet or 6.01 miles) have scores ranging from 15 through 19. Evaluation of the condition of the riverbanks with scores less than 15 indicates that erosion control is not warranted in these areas because these types of riverbanks generally have few erosion indicators, if any, and tend to have characteristics in the stable portion of the spectrum of the various categories in Table 3.1. Visual observation of areas with scores less than 15 indicate that erosion protection would not be needed.

Based on a preliminary evaluation of particular sites in Table 3.2, no erosion control is proposed for the following sites:

Site #1 (because of extreme conditions regarding hydraulic forces and measures that would be required to control erosion at this location, coupled with the fact that this site is located immediately downstream of Vernon Dam and adjacent to one of its spillway gates)

Sites #2, #3, #12, #13 Due to their short length, these sites were removed from the official process of planning and designing site-specific erosion control. It is the intent of the Plan that small sites and short segments could be repaired under the preventative maintenance program of the Erosion Control Plan.)

Site #5 The erosion which is taking place at this site on the east bank of the river immediately upstream of the Route 10 Bridge appears to be due to an unusual hydraulic condition at this location which results in a relatively strong and large eddy circulation. According to Simons & Associates analysis, the erosion which is currently taking place is attributable to modifications which have been made in association with previous bridges. Restoration of this area may involve changes to the existing bridge and accordingly it can be argued that any such work should be the responsibility of the entity that constructed and maintains the bridge.

## 4.0 Development of Appropriate Erosion Control Methodologies

Over the past several decades, there have been a variety of erosion control techniques that have been applied to the banks of Turners Falls Pool. These include traditional rock

stabilization, as well as experimental techniques implemented by the Corps of Engineers including tires tied together in various configurations and articulated concrete blocks. Observation and classification of the sites where these techniques have been applied show that all of these techniques have controlled erosion as evidenced by the stability exhibited at these sites.

Bioengineering erosion control demonstration projects have also been constructed at three of the five sites that were previously selected for construction and evaluation. While the completed demonstration projects have and will provide useful information regarding the performance of these types of erosion protection and at these types of erosion sites, other erosion conditions exist in the Turners Falls Pool and other stabilization techniques may be more appropriate and effective considering the actual conditions of riverbanks and hydraulic stresses exerted on the riverbanks.

Based on the availability of a wide variety of erosion control techniques (See Appendix E) and a diversity of riverbank conditions found in Turners Falls Pool (shown by the classification results), appropriate techniques for erosion control in the Turners Falls Pool will be determined on a site by site basis. Specific erosion control techniques for each selected site will be developed in detail approximately one year prior to the proposed construction at that site. This will allow the design of each successive site repair to benefit from the valuable information and lessons gained from the monitoring and performance evaluation of all previously constructed sites.

Within the realm of potential erosion protection measures lie a host of possible applications ranging from what can be considered heavy approaches including large scale bank re-shaping by earth moving equipment, placement of stone, geotextile fabrics, coir logs, large woody material, and planting of various types of woody and herbaceous vegetation to much lighter techniques. Lighter techniques would focus to a greater degree on vegetation, less on rock, and would take advantage of abundant woody debris available on most of the riverbanks in the Turners Falls Pool. In a lighter treatment, earthmoving would be limited where possible, resulting in a less uniform and more natural appearance. Lighter treatments might consist only of planting vegetation, placement of erosion control fabrics, and placement/anchoring of large woody material. Various types of toe treatments would be considered, ranging from erosion control fabric, to lighter types of rock treatments. A range of treatments from light to heavy will be considered on a variety of riverbank conditions to provide for the achievement of reasonable long-term riverbank stabilization.

## 5.0 Monitoring and Evaluation

Monitoring of sites where erosion protection is placed will occur on a periodic basis. The primary goal of such monitoring is to provide information regarding the performance of the various types and components of erosion protection. This knowledge will also increase our understanding of erosion in the Turners Falls Pool and ensure that appropriate and effective erosion control measures are implemented into the future. The

frequency of monitoring will vary through the life of each site. Monitoring will generally occur at the following times: after construction, after (or near the end of) the initial and second growing seasons, after the first and second spring freshets or other high flow events. Thereafter, monitoring will occur on a less frequent basis, i.e., annually for the next three years.

Monitoring will consist of observing each site and noting the condition of these components. One or more general photographs of the site will be taken, as supplemented by close-up photographs of any components which display signs of failure or damage. The following information will be obtained for each component of the erosion protection:

1. Fabric: note any loose or torn areas in the fabric.
2. Anchored woody debris/coir logs: note the stability of anchored material.
3. Stone: note displacement of stone, exposure of fabric or soil through layer of stone
4. Live Stakes/other vegetation: note survival/mortality of vegetation, estimate percent survival.

Documentation will consist of written notes of observations of the components of the erosion control system referring to photographs of the various components as well as general photographs of the site. The written material will include discussion of performance of the system components and overall effectiveness of the system based on the observations. Suggested repairs will also be noted. The date of any observations and photographs will be recorded.

## 6.0 Preventative Maintenance Program

Preventative maintenance measures will be undertaken along the Turners Falls Pool as an integral part of the Erosion Control Plan. This preventative maintenance program consists of several items including the following:

- Seasonal observation of riverbanks
- Reporting of any special areas of concern which have occurred during the seasonal observations
- Identification of and scheduling of specific maintenance items to be conducted
- Supervision of specific maintenance measures and documentation of progress

The objective of preventative maintenance program is to proactively undertake low-key maintenance measures that will minimize or prevent future erosion in the Turners Falls Pool. For example, this program would attempt to stabilize selected bank areas that are characterized as being overhanging banks with trees that are in the process of falling over. Such trees add stress to the riverbank, threatening to bring down significant quantities of sediment into the river. Periodically, a maintenance crew will cut down a minimal number of leaning trees to reduce stress to the overhanging banks, thereby reducing the potential for sediment delivery to the Turners Falls Pool. Where appropriate, these trees could then

be utilized to help stabilize the riverbanks. This can be done by placing the trees along the riverbank below the overhanging banks and anchoring these trees into the bank using cables and duck anchors. These trees can then add stability by holding soil in place and by providing a buffering influence between the river current at high flows and the soil on the riverbank.

In addition, this program would include the selective planting of shrubs (primarily willows using live-stakes) and possibly other forms of vegetation in small isolated areas of bank erosion to reduce or prevent future erosion in these areas.

Documentation of work performed in accordance with this Section of the Plan will consist of the location of each selected maintenance site, a brief description of work conducted, photographs before and after maintenance work, as well as follow-up photographs on an annual basis for two years.

## 7.0 Long-Term Erosion Control

Appropriate erosion control applications will be planned, permitted, and constructed in accordance with the periodically updated prioritization schedule. Such applications and the preventative maintenance program will continue through the remaining term of the license to satisfy the requirements of the relevant FERC license articles regarding erosion. Sufficient expenditure will be made each year to satisfactorily remedy the erosion in a reasonable manner.

It is expected that changes in riverbank conditions and erosion trends will occur over time. In order to be responsive to these changes, the Plan provides for periodic changes to the priority list of sites needing repair. It is the intent of the Plan to schedule specific sites for repair in 4 to 5 year increments. Initially, the Plan proposes to conduct erosion control work at the Flagg site (Site 7) in 1999 and 2000 as was previously scheduled. In 2001, work will begin on the sites listed in Table 3.2, starting with Site 4 in 2001. Work on Site 6 will commence in 2002. Following a reclassification effort in the year 2001, an updated priority list will be used to establish a schedule for the sites to be repaired over the following four to five years . This process will be repeated through the remaining term of the licenses which expire in 2018.

The licensees will include an ad hoc erosion committee to serve as an advisory group in planning the work to be done under this Plan. The licensees and the ad hoc committee will meet on sufficient intervals to evaluate and prioritize the following years erosion control work. Any changes to the Plan, after it has been approved by the FERC, will be done only with FERC's approval. All work to be done under this Plan will be submitted for approval to the FERC's headquarters and their New York Regional Office.

It needs to be recognized that to the extent sites which have been repaired are later damaged by events including, but not limited to, high flow conditions, spring freshets, ice

damage or severe weather conditions, these sites will not be automatically repaired. In cases where erosion controls have been compromised due to such events, the licensees will document observations of the site and review each site and situation with the FERC to determine whether the bank should be reclassified and returned to the prioritization list or whether it should be left alone. This evaluation process will ensure that financial resources are not wasted on sites that may be prone to failure.