3.1 Geology and Soils

3.1.1 2013 Full River Reconnaissance Study

General Description of Proposed Study

FirstLight is required by FERC to conduct a Full River Reconnaissance (FRR) Study every 3-5 years in accordance with the Northfield Mountain Project's Erosion Control Plan (ECP) and to satisfy compliance requirements associated with the Turners Falls Project and Northfield Mountain Project licenses. The next FRR is slated for November 2013 during leaf off. With the impending relicensing effort and timing of the next FRR, FERC contacted FirstLight and indicated that the 2013 FRR should be folded into the relicensing.

Prior to FERC contacting FirstLight, FirstLight had been working with the Franklin Regional Council of Government (FRCOG), Connecticut River Watershed Council (CRWC), and Landowners and Concerned Citizens for License Compliance (LCCLC) on crafting a Quality Assurance Project Plan (QAPP). The goal of the QAPP is to ensure consistency with data collection methods such that any future FRRs would allow for direct comparison. A draft version of the QAPP and FRR was circulated to the FRCOG, CRWC and LCCLC for review and comment, and a meeting was held. Since the QAPP/FRR is now incorporated into the FERC relicensing process, FirstLight developed this study plan based on the study plan criteria. However, as part of this study, stakeholders should also review Appendix D, which includes the QAPP for the FRR. This work plan reflects comments received from the Massachusetts Department of Environmental Protection (MADEP) during a meeting on March 26, 2013, and comments received from stakeholders during a Study Plan meeting on May 15, 2013.

Several stakeholder groups submitted study requests pertaining to: 1) Study of shoreline erosion caused by Northfield Mountain Pumped Storage operations and 2) Impact of Turners Falls and Northfield Mountain Project operations on sedimentation and sediment transport. Study requests related to these subjects were received from: MADEP, New Hampshire Fish and Game Department (NHFGD), New Hampshire Department of Environmental Service (NHDES), FRCOG, Franklin Conservation District (FCD), CRWC, LCCLC and the Town of Gill. Portions of these study requests were incorporated into this study, while other portions are discussed in Study No. 3.1.2 *Northfield Mountain/Turners Falls Operations Impact on Sediment Transport.*

The proposed FRR study calls for conducting a boat and land-based survey along the riverbanks of the Turners Falls Impoundment to document erosion using consistent methods and procedures to allow for comparisons of any future FRRs. It was not designed to determine the cause of erosion; that issue is addressed in Study No. 3.1.2 *Northfield Mountain/Turners Falls Operations Impact on Sediment Transport.*

Study Goals and Objectives (18 CFR § 5.11(d)(1))

The purpose of the FRR study, together with its QAPP (Appendix D), is to conduct a reconnaissance level evaluation of erosion in the Turners Falls Impoundment without reference to the cause of erosion. The goals and objectives of this study are to:

- ~~Develop a QAPP for the FRR;~~
- Document existing riverbank features and characteristics;

- Accurately map and scientifically describe all portions of the Turners Falls Impoundment where active or recent bank erosion is occurring;
- Spatially define, using a global positioning system (GPS), the transition points or end points where riverbank characteristics or features change from one classification to another;
- Map land use practices adjacent to the river (note that land use maps along the riverbanks are being developed as part of the FERC relicensing process). Describe areas that are directly observed and linked to bank erosion.
- ~~Establish permanent reference stations on the river banks~~Conduct land-based evaluations at select locations throughout the Turners Falls Impoundment (Note: detailed geotechnical evaluations and assessments will be conducted as part of Study 3.1.2. Geotechnical evaluations will not occur in the FRR).
- Develop classification techniques of observations into a definable and repeatable methodology;
- Develop distribution and summary statistics of conditions in 2013, assess change in riverbank conditions in context of the "*Erosion Control Plan for the Turners Falls Pool of the Connecticut River (ECP)*" (1999) since implementation, analyze change in condition of the riverbank since previous FRRs; and
- Develop a final report, including maps delineating features identified in the field, which will document and summarize the findings of the 2013 FRR.

Resource Management Goals of Agencies/Tribes with Jurisdiction over Resource (18 CFR § 5.11(d)(2))

As part of the current license requirements of the Northfield Mountain and Turners Falls Projects FirstLight is required to conduct a FRR every 3-5 years. Given the impending relicensing effort and timing of the next FRR (November 2013), FERC contacted FirstLight and indicated that the 2013 FRR should be folded into the relicensing.

In addition, MADEP, NHFGD, NHDES, NMFS, NHDES, and VANR, as well as stakeholder groups FRCOG, FCD, CRWC, LCCLC, and the Town of Gill, all submitted study requests pertaining to soils and geology. Study request tasks that were related directly to the goals and objectives outlined in the Study Goals and Objectives section above were incorporated in this reconnaissance level study. All other tasks were included in Study No. 3.1.2 *Northfield Mountain/Turners Falls Operations Impact on Sediment Transport* or not included in the PSP.

Resource management goals of the Agencies related specifically to this effort include documenting and describing the changes to banks upstream and downstream of riverbank restoration projects, including bank recession.

Existing Information and Need for Additional Information (18 CFR § 5.11(d)(3))

In 1998, Simons & Associates (S&A) developed the "*Erosion Control Plan for the Turners Falls Pool of the Connecticut River (ECP)*" (1999). As part of the ECP, FRR studies were conducted in 1998, 2001, 2004, and 2008 to document existing riverbank features and characteristics. The ECP and FRR studies are readily available for use as support documentation or as tools to compare past and present riverbank conditions.

Extensive research has been conducted evaluating erosion along the Connecticut River in the Turners Falls Impoundment; such research includes:

Connecticut River Joint Commissions and Trails Conservation Assistance Program of the National Park Service through the Connecticut Valley Partnership. (1996). *River Dynamics and Erosion.* Charlestown, NH: Author.

Field Geology Services. (2004). *Fluvial Geomorphology Assessment of the Northern Connecticut River, Vermont and New Hampshire.* Farmington, ME: Author.

Field Geology Services (FGS). (2007). *Fluvial Geomorphology Study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT.* Farmington, ME: Author.

New England Environmental (NEE). (2001). *Erosion Control Plan for the Turners Falls Pool of the Connecticut River*. Amherst, MA: Northeast Utilities Service Company.

New England Environmental (NEE). (2005). *Erosion Control Plan for the Turners Falls Pool of the Connecticut River, 2004 Full River Reconnaissance.* Amherst, MA: Northeast Utilities Service Company.

Simons & Associates (S&A). (1999). *Erosion control plan for the Turners Falls Pool of the Connecticut River. Prepared for Northeast Utilities*. Midway, UT: Author.

Simons & Associates (S&A). (2009). *Full river reconnaissance – 2008: Turners Falls Pool, Connecticut River*. Prepared for FirstLight Power Resources. Midway, UT: Author.

Simons & Associates (S&A). (2012a). *Analysis of Erosion in Vicinity of Route 10 Bridge Spanning the Connecticut River*. Prepared for FirstLight Power Resources, Midway, UT: Author.

Simons & Associates (S&A). (2012b). *Riverbank Erosion Comparison along the Connecticut River*. Prepared for FirstLight Power Resources, Midway, UT: Author.

Simons, D.B., Andrew, J.W., Li, R.M., & Alawady, M.A. (1979). *Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire, and Vermont*. Waltham, MA: US Army Corps of Engineers (USACE).

Western Massachusetts Electric Company, (1995), *Long Term Riverbank Plan for Connecticut River between Vernon, VT and Turners Falls, MA*. Author.

US Army Corps of Engineers (USACE). (1991). *General investigation study - Connecticut River streambank erosion*. Waltham, MA: USACE, New England Division.

Project Nexus (18 CFR § 5.11(d)(4))

The Connecticut River is an alluvial river, subject to natural processes that result in dynamics such as lateral shifting, erosion, and deposition. These natural processes and dynamic response of the river is further affected by land-use practices, modified flow/water level regime, motorized boating, and other factors. Due to a variety of factors, the riverbanks along the Connecticut River, not just in the Turners Falls Impoundment, have a history of being susceptible to erosion. In accordance with the existing license requirements of the Turners Falls and Northfield Mountain Projects, a reconnaissance survey of the Turners Falls Impoundment was conducted in 1998 to map riverbank characteristics and prioritize erosion sites to be considered for stabilization. As a result of this work, the "*Erosion Control Plan for the Turners Falls Pool of the Connecticut River (ECP)*" was developed by Simons and Associates (1999). The ECP requires FirstLight to conduct FRR studies every 3-5 years to continually monitor and evaluate erosion conditions throughout the Impoundment. As part of the FERC relicensing of the Turners Falls and Northfield Mountain Projects, the Commission has requested that the 2013 FRR be folded into a relicensing study.

Methodology (18 CFR § 5.11(b)(1), (d)(5)-(6))

Riverbank erosion classifications and FRR surveys were conducted in 1998 (Simons and Associates (S&A)), 2001 (New England Environmental (NEE)), 2004 (NEE), and 2008 (S&A and NEE). The 2013 FRR methodology is based in part on the 2008 FRR methodology as well as recommendations made by the CRSEC, MADEP, S&A, and NEE. The 2008 FRR methodology was based on the methodology used in 2004 combined with improvements/recommendations identified by S&A, NEE, and Field Geology Services *(Field, 2007)*. Specifically, in the report titled, "*Fluvial Geomorphology Study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT*," which was conducted for FirstLight, Field recommended:

1. Study patterns of erosion in other reaches of the Connecticut River for comparative purpose;
2. Map the distribution of terrace and floodplain surfaces relative to the position of the river channel throughout the Turners Falls Impoundment;
3. Use LIDAR surveys of the channel banks in order to more accurately monitor erosion in the future;
4. Develop a systematic and explicit method for mapping erosion in order to eliminate artifacts in the mapping process, so the full value of the collected data is realized;
5. Map the distribution of beaches throughout the Turners Falls Impoundment and study the processes that lead to their formation and preservation; and
6. Experiment with the addition of large woody debris on the beach faces as a means of bank stabilization

The methodology utilized in 2008 (both the technology and matrix of characteristics) met Field's primary recommendation regarding mapping as outlined in recommendation #4. Additionally, the 2008 methodology explicitly described important riverbank characteristics related to erosion, eliminated artifacts of some previous mapping efforts through the use of sub-meter GPS coupled with a laser rangefinder, and created a product that is spatially accurate allowing for spatial comparisons to be readily conducted. When discussing spatial comparisons, it is important to note that FRRs are internally consistent. While comparisons can be made between the percentages or lengths of the river that fall into the various categories between FRRs, this is only true when specific transition points are compared from one FRR to another. The accuracy of each particular survey methodology associated with each individual FRR and any such differences must first be accounted for before direct comparison of specific points or segments is conducted.

The mapping of beaches (recommendation #5) was accomplished by two items in the classification matrix – the lower riverbank slope and lower riverbank material as well as the documentation of any erosion resistant vegetation found thereon. Beaches are those lower riverbanks that have a flat slope. The mapping of terraces and floodplain surfaces (recommendation #2) was accomplished by utilizing existing topographic data and can be expanded upon through the land based surveys proposed below. Field's other recommendations do not apply to a FRR and therefore were not incorporated in the methodology; however, a study comparing erosion along much of the length of the Connecticut River (Field's recommendation #1) has been conducted (S&A 2012b). Additionally, the use of large woody debris for riverbank stabilization (Field's recommendation #6) has been and is being incorporated into recent and on-going stabilization efforts since 1996. The following methods will be used to document existing riverbank features and characteristics and to analyze any change in riverbank conditions since previous FRRs. Study methods will consist of the following tasks:

1) document current riverbank features and characteristics;

2) spatially define riverbank feature transition points;

3) map and develop distribution of riverbank features and characteristics including summary statistics, evaluation of conditions in 2013 in context with changes in conditions from the previous FRRs studies;

4) identify specific areas of slope instability and erosion prone reaches; and

5) develop a final report and mapping.

The establishment of permanent survey cross sections for land-based evaluations will be conducted as part of Study 3.1.2 and not as part of the FRR. Note that the task descriptions provided below are excerpts from the QAPP (Appendix D). It is recommended that stakeholders fully review Appendix D.

This study will include the entire length of the Turners Falls Impoundment from Vernon Dam to Turners Falls Dam to show the full range of conditions that are observed within this reach and to be consistent with previous FRRs. Islands within the Turners Falls Impoundment are to be included in the study.

Task 1: Document Existing Riverbank Features and Characteristics

Task 1a: Identify and Define Current Riverbank Features and Characteristics

A riverbank consists of a combination of features with a range of characteristics that either work together in resisting erosive forces, or together suffer various degrees of failure or susceptibility to erosion. Riverbanks in the Turners Falls Impoundment generally consist of an upper bank that is often above water except during high flow conditions, and a lower bank that is frequently submerged. These banks consist of a range of materials from silt or sand to solid rock. The banks support a range of vegetation conditions and a range of heights. The riverbanks experience a range of conditions of stability or erosion. This combination of features and associated range of characteristics or attributes are described in the matrix in Table 3.1-1. This matrix represents one of several approaches in understanding and evaluating the data and was developed based on input received at the 2008 CRSEC meeting and experience from previous reconnaissance efforts.

Current riverbank features and characteristics will be identified and defined through the use of a pre-determined matrix of nine riverbank criteria (see Table 3.1-2). The matrix of features and characteristics utilized in 2008 was based on experience from previous FRR efforts, including 2004, and discussion with the CRSEC. The matrix consists of 9 riverbank features that include such items as riverbank geometry (upper and lower riverbank slope and upper riverbank height), riverbank materials (upper and lower riverbank sediment), vegetation (upper and lower riverbank degree of vegetation), and erosion (mass wasting and erosion type. The same matrix of riverbank features and characteristics is proposed for the boat-based portion of the 2013 FRR providing a consistent basis for comparison with past FRR efforts (see Table 3.1-2).

The FRR report will include maps for each of the 9 riverbank features in the matrix (Table 3.1-2, vertical left-hand column) with each segment categorized as shown in the other columns (2-7). For example, in the case of upper riverbank sediment, maps will be developed showing all segments surveyed covering the length of the Turners Falls Impoundment and the particular type of upper riverbank sediment associated with each segment. A statistical summary of each riverbank feature and the extent of each characteristic within each feature will be provided. These data will allow for the evaluation of individual features (e.g. mass wasting), or for the entire spectrum of features and characteristics. The grouping approach consolidates riverbank segments into key associations that can provide insight into which features and characteristics are associated with stability and which are associated with erosion. Statistical distributions of characteristics within each group can aid in further understanding erosion and stability issues such as which combination of features and characteristics trend towards stability, and which trend toward erosion. Such information and understanding can aid in the planning process in developing appropriate approaches in addressing erosion issues.

A key aspect of the FRR is how the range of riverbank features and characteristics are classified in the field. To understand and demonstrate the classification process, photographs were taken in November 2012 during leaf-off conditions, representing similar conditions for the 2013 FRR. Appendix C of the QAPP (Appendix D) contains photographs covering the features and range of characteristics from Table 3.1-2. QAPP Appendix C also includes photographs from previous years to ensure complete coverage of the matrix.

These photographs will provide a guide as to how riverbank features and characteristics will be classified. Particular segments of the riverbank will be classified and entered into the data logger based on certain features and characteristics observed on the riverbank(s) and found in the photographs. As discussed in Task 1b, the use of geo-referenced digital video will provide a means of verifying the observed features and characteristics of any riverbank segment in comparison to the observations entered in the data-logger.

Table 3.1-1: Riverbank Characterization Groups[4]

Group	Mass Wasting	Erosion Type	Degree Upper Riverbank Vegetation	Upper Riverbank Slope	Upper Riverbank Sediment	Lower Riverbank Slope	Lower Riverbank Sediment	Upper Riverbank Height	Lower Riverbank Vegetation
1	Extensive	Overhanging to Slide	None to Heavy	Flat to Overhanging	non-Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
2	Some	Overhanging to Slide	None to Heavy	Flat to Overhanging	non-Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
3	Little/None	None	None to Sparse	Flat to Overhanging	non-Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
4	Little/None	None	Moderate to Heavy	Steep to Overhanging	non-Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
5	Little/None	None	Moderate to Heavy	Moderate	non-Rock	Moderate to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
6	Little/None	None	Moderate to Heavy	Moderate	non-Rock	Flat	Silt/Sand to Rock	Low to High	None to Heavy
7	Little/None	None	Moderate to Heavy	Flat	non-Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy
8	Little/None	None	None to Heavy	Flat to Overhanging	Rock	Flat to Vertical	Silt/Sand to Rock	Low to High	None to Heavy

[4] See Table 3.1-2 for classification defintions

Table 3.1-2: Connecticut River – Turners Falls Impoundment Riverbank Characteristics Matrix, field data logging worksheet

Upper Riverbank Slope	Overhanging *>90°*	Vertical *90°*	Steep *(>2:1)*	Moderate *(4-2:1)*	Flat *(<4:1)*	
Lower Riverbank Slope	Vertical *90°*	Steep *(>2:1)*	Moderate *(4-2:1)*	Flat *(<4:1)*		
Upper Riverbank Sediment	Silt/Sand *<.062mm-2.0mm*	Gravel *2.0mm-64mm*	Cobbles *64mm-256mm*	Boulders *256mm-2048mm*	Bedrock	Clay
Lower Riverbank Sediment	Silt/Sand *<.062mm-2.0mm*	Gravel *2.0mm-64mm*	Cobbles *64mm-256mm*	Boulders *256mm-2048mm*	Bedrock	Clay
Upper Riverbank Height (above Ordinary High Water (OHW)	Low *(<8 ft.)*	Medium *(8-12 ft.)*	High *(>12 ft.)*			
Degree Upper Riverbank Vegetation	Heavily Vegetated *>50% cover*	Moderately Vegetated *26%-50% cover*	Sparsely Vegetated *11%-25% cover*	None to Very Sparse *<0%-10% cover*		
Mass Wasting (extent of erosion)[5]	Little/None	Moderate	Extensive			
Erosion Type[6]	None	Overhanging Bank	Undercut Toe	Notching	Slide	
Lower Riverbank Vegetation	None *0% cover*	Heavy *>50% cover*	Moderate *26%-50% cover*	Sparse *1%-10% cover*		

[5] Mass-wasting is defined as the movement of blocks or other large pieces of riverbank material downslope under the influence of gravity. Minor or insignificant amounts of erosion can be found in virtually all riverbanks. When a riverbank is characterized as being in the little/none category this means that only minor or insignificant to no erosion was observed. Erosion is not necessarily continuous throughout the length of any particular segment of river, particularly those segments characterized as having "some" mass-wasting.

[6] Frequently, different types of erosion occur at the same location. In these instances, the dominant type of erosion will be used when characterizing a particular segment of river.

Task 1b: Geo-referenced Video

As a means of data control and reference checking, a geo-referenced video will be taken of the riverbanks of the entire Turners Falls Impoundment. This technique allows for the capture of both digital video images and their location along the riverbank. Geo-referenced video provides a method to verify what the riverbanks looked like during the 2013 FRR as well as the locations of the video scenes along the length of the Turners Falls Impoundment. If questions arise as to how a riverbank segment was classified, the videotape can be checked to evaluate the specific features and characteristics. Video of the riverbank will be taken either before or after the riverbank classification from a boat at approximately 50 feet from the bank line.

The geo-referenced videotaping will be conducted using the Red Hen Systems equipment (which was utilized in 1998, 2001, 2004 and 2008). Red Hen Systems provide hardware and software to collect geo-referenced video and photo data in the field, and brings that data into desktops and Web-based maps for analysis and decision making processes. Red Hen Systems includes three components: the VMS-HDII (which includes the VMS-333 geo-referencing equipment); the nanoFlash video recorder from Convergent; and MediaMapper Software. Appendix D of the QAPP (Appendix D) provides detailed information on this system from the Red Hen Systems website (http://www.redhensystems.com).

Task 1c: Land-Based Observations

Both the MADEP and the CRSEC have requested future FRR surveys to include a land-based evaluation. The MADEP has suggested that the boat surveys could be eliminated in favor of a geotechnical evaluation of specific areas of slope instability within Turners Falls Impoundment. The CRSEC is in favor of the boat-based survey in addition to a land-based assessment of the entire Impoundment. It is proposed as part of this FRR Study to continue to document and map the entire Turners Falls Impoundment using the boat-based surveys, but to additionally conduct land-based evaluations in select locations. A land-based bank assessment looking at specific areas of slope instability and erosion prone areas will be implemented as part of the 2013 FRR study. The land based observations will be made on the riverbanks by walking along the top of the bank in select reaches of the Turners Falls Impoundment. Observations will be documented of any erosion or riverbank instability including geo-referenced photographs. Specific erosion phenomena observed include such items as tension cracks, gullying, lack of riparian vegetation, slopes or slides, or other erosional features.

As part of Study 3.1.2 additional land-based field work will evaluate the existing 22± river cross sections which were established in 1998 and surveyed intermittently to document bank erosion. The locations of these cross sections are included in Appendix H. Additional survey locations may be included in Study 3.1.2. Significant erosion areas, specific areas of slope instability (e.g. tension cracks or evidence of mass-wasting, and other forms of erosion) will be evaluated by the geotechnical engineer.

Table 3.1-3, provides an overview of attributes to be captured during FRR land-based observations. The location of the beginning and end points of these features will be collected via sub-meter GPS. Observations will be entered into the data-logger and backed up by geo-referenced digital photograph and/or video documentation. In order to provide information to better understand the conditions related to erosion at each observation, Table 3.1-3 also includes a "Description/Comments" column.

Table 3.1-3: Land-Based Erosion Evaluation Form

Town /East or West Bank	Coordinates Start-End	Distance from River (OHW)	Height above River (OHW)	Type of Erosion*	Description/ Comments

* Type of Erosion: Erosion types identified will include, but not be limited to, the following: tension cracks, gullies, slides, slips, slumps, falls

Task 2: Spatially Define Riverbank Feature Transitions

The locations of transition points, or end points, from one riverbank feature or classification to another will be captured via sub-meter GPS in a standard coordinate system (i.e. NAD 83 State Plane or UTM coordinates). In order to capture these locations, FirstLight will utilize standard field equipment including three field instruments: 1) a sub-meter GPS; 2) a data-logger; and 3) a laser range-finder.

The individual conducting the classification will select a point of transition from one category of riverbank to another and "shoot" this point with the laser range-finder. The features and characteristics of the next riverbank segment will be classified and verbally transmitted from the individual conducting the expert classification to the individual operating the data logger who then records the observational data while the position information (location of the GPS antenna and distance and azimuth from the laser rangefinder to the selected point on the riverbank) is automatically recorded when the trigger is pulled on the laser rangefinder. The data logger acknowledges that the positional data has been recorded and the individual operating the data logger can ensure that the observations corresponding to that point have been entered. Appendix A and B of the QAPP (Appendix D) provide specifications for the sub-meter GPS and laser range-finder models that have been selected for this survey.

The accuracy of a sub-meter GPS is assumed to be less than one meter; however, the accuracy of any GPS in the field depends on the availability of a sufficient number of satellites and the correction that is applied that ultimately defines the actual accuracy when locating a point on the ground. Prior to initiation of GPS mapping, the location/time of day of the satellites will be determined for optimal GPS readings. The GPS determines the location of the boat from where the observation of the riverbank features and characteristics is made, and the offset and azimuth to the riverbank is made using the laser rangefinder.

The position of the riverbank point will be shot from the boat using a laser rangefinder. The accuracy of a mapping grade laser rangefinder is +/- 1 foot for distance and +/- 1 degree for azimuth. Assuming the length of the shots from the laser rangefinder is 100 feet, an accuracy of one degree translates into about +/- 1.7 feet distance when projected along the length of the bank (100 times sine of 1 degree). The combination of the accuracy of the sub-meter GPS and the laser rangefinder would then be approximately +/-6 feet, with an estimated accuracy of within 10 feet for 90% of the measurements made.

Prior to initiation of the FRR mapping the positional accuracy of the GPS/laser rangefinder system will be determined via field test. A known, fixed point will be located on the bank from a slow moving boat. The GPS unit and laser rangefinder will then be used to collect the known points' location. The point will be surveyed multiple times and the difference in location will be determined.

The approach of using sub-meter GPS with laser rangefinder is a sufficiently accurate technique to map bank erosion in long river reaches, particularly given the variability of biologic and geologic identification of the specific transition points between one riverbank segment and another.

The level of discretization of riverbank segments depends on the frequency of transitions between the various features and characteristics observed in the field. There is no set distance of segmentation along the river. Previous FRRs have resulted in a range of segment lengths from 20 to over 4000 feet, with average segment lengths from 480 to 1267 feet. The 2008 FRR resulted in the smallest average segment length and greatest degree of discretization of the various FRRs compared ("*Response to Field Geology Services' 2011 'Detailed Analysis of the 2008 Full River Reconnaissance of the Turners Falls Pool on the Connecticut River,*" *July, 2012*). The 2013 FRR will result in a range of segment lengths and degree of discretization consistent with the frequency of transitions of features and characteristics found in the Turners Falls Impoundment and will likely result in a similar level of discretization as the 2008 FRR. Segments as short as 20 feet will be documented based on the observation of features and characteristics. The speed at which the survey will be conducted is dictated by the efficiency of the observer/data logging team and is constantly varied to match field conditions, including reversing the boat and passing by riverbank features again.

Task 3: Develop Maps, Summary Statistics, Evaluation of Conditions, and Analyze Changes in Condition since Implementation of ECP and from 2008 FRR

Segmentation of all riverbank features and characteristics will be developed showing the longitudinal extent and distribution along the Turners Falls Impoundment. Summary statistics quantifying the lengths of features and characteristics will be calculated. Conditions in 2013 will be evaluated based on comparisons over time of the river going back as far as the implementation of the ECP (1999).

Once all field efforts, post-processing, and development of the spatial segmentation of riverbanks are completed, analysis of the 2013 field data will be conducted to develop summary statistics of the riverbank classification. Maps showing all riverbank features and characteristics within each feature will be developed in ArcGIS showing results of the 2013 FRR. Geo-referenced video from the boat-based field work and geo-referenced photographs from the land-based field work will be available in documenting and analyzing the condition of riverbanks. Comparisons of riverbank conditions will be made back to the time of the initial FRR (in 1998 as part of the ECP) and other FRRs using overall summary statistics of riverbank features and characteristics and photography. A comparison of the 2013 FRR will be made to the previous FRRs using summary statistics and analysis in ArcGIS, accounting for any differences in methods and considering the accuracy of the technology utilized in collecting the spatial component of the data. Comparison efforts may include analyzing changes in the length of riverbank shoreline experiencing erosion, severity of erosion, length of riverbank stabilization, success of erosion remediation efforts, identification of new erosion areas, etc.

The FRR will include mapping and description of riverbank features and characteristics where active or recent bank erosion is occurring at the time of the field work. Areas of erosion adjacent to previous bank stabilization will be identified and discussed in context of the type of stabilization utilized. Additionally, land-use practices that are related to riverbank erosion processes will be mapped as part of the land-based component of the FRR.

Maps showing location and extent of the range of sediment types will be generated based on the sediment classifications of the upper and lower riverbanks included in the matrix of features and characteristics. Sediment classification is sub-divided into 6 key categories ranging from clay, silt/sand, up through boulders and bedrock; allowing for easy understanding of which areas consist of erodible soils and which are not – including the location and extent of bedrock.

“Sensitive Receptors” identifying the location of important wildlife habitat use on or near the river banks (e.g. bank swallow colonies, kingfisher nests, eagle nests, prime odonate and mussel habitat, etc.) will be mapped.

A Land Use map will be developed showing the current land uses (e.g. forest, agriculture, conservation, utility, developed, etc. and the width of the undisturbed forested riparian zone.

A map will be developed of all restoration projects within the Turners Falls Impoundment completed since 1996, as well as the location of previously restored areas including rip-rap, vertical structures, and Corps projects. The FRR will provide a summary of each of the restoration projects constructed as part of the ECP. Descriptions of the successes and failures of each design, construction implementation, revegetation and invasive species concerns as well as long term maintenance recommendations will be included in Study 3.1.2. A map denoting recommendations for potential future stabilization projects will be included in the final report of the FRR.

Task 4: Develop Final Report, Mapping, and Recommendations

Following post processing and analysis of field data, a final report documenting the methodology and results of the 2013 FRR study will be generated, including discussion of summary statistics and comparisons over time with previous FRRs. In addition, summary maps and maps delineating all features and characteristics captured during field efforts will be generated in ArcGIS. Maps will be made available digitally as well as in the final report. The FRR will be completed in two phases. The initial land-based surveys, river bank mapping, and assessments will be completed during the summer, fall, and early winter of 2013.

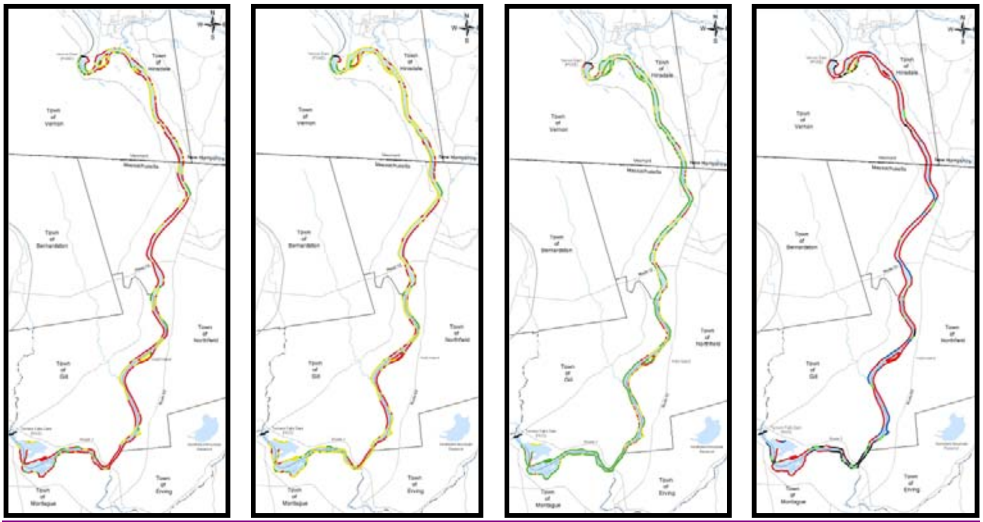
The following deliverables will be included in the 2013 FRR report:

Deliverables:

1. Upper riverbank slope map;
2. Lower riverbank slope map;
3. Upper riverbank sediment map;
4. Lower riverbank sediment map;
5. Upper riverbank height map;
6. Degree of upper riverbank vegetation map;
7. Lower riverbank vegetation map;
8. Degree of mass-wasting (erosion) map;
9. Erosion type map;
10. Riverbank group features and characteristics map;
11. Adjacent land-use map;
12. Sensitive receptors map;
13. Riverbank stabilization project site map;
14. Recommendation of potential future stabilization project map;
15. Geo-referenced video; and
16. Report (Including: summary statistics of riverbank features and characteristics; data-logging and field forms; photographs ; overall assessment of erosion within the Turners Falls Impoundment and long term trends; evaluation of existing stabilization projects; sediment deposition at stabilization sites; and recommendations for future preventative maintenance and bank stabilization work.

Examples of the map details from the 2001 FRR mapping are included in Figure 3.1-1. 2013 FRR mapping will follow previous FRR mapping styles so that data are comparable.

Figure 3.1-1: 2001 FRR maps for Height, Slope, Vegetation, and Material



Level of Effort and Cost (18 CFR § 5.11(d)(6))

FirstLight believes the proposed level of effort defined above is adequate to conduct a comprehensive full river reconnaissance study. The estimated cost for this study is between $200,000- $250,000.

Study Schedule (18 CFR § 5.11(b)(2) and (c))

FirstLight is proposing to initiate land-based studies in the summer of 2013 and the full river mapping in the fall (mid November 2013) during leaf-off conditions. Based on the ILP schedule, and assuming there is no dispute with this particular study, FERC would issue its study plan determination letter by September 12, 2013. This would allow sufficient time to conduct the November 2013 FRR. FirstLight is seeking to file the final report in September 2014 to match the timeline for filing other relicensing studies and will request FERC to provide an extension from the current April 2014 due date. If FERC grants the extension, if an agency with mandatory conditioning authority disputes this particular study, FERC would not issue its study plan determination letter until December 11, 2013. Thus, FirstLight would have to delay conducting the 2013 FRR until 2014.

3.1.2 Northfield Mountain/Turners Falls Operations Impact on Sediment Transport

General Description of Proposed Study

This study was requested by the MADEP; however, several other stakeholders (FRCOG-2[7], CRWC-2, FCD-2, Town of Gill-2, and LCCLC-2a) had a similar study request containing many of the same study objectives and elements as the MADEP. The latter group requested the same study entitled: "*Study the Impact of Operations of the Northfield Mountain Project and Turners Falls Dam on Sedimentation and Sediment Transport in the Connecticut River*". FirstLight is addressing many of their study objectives/elements in this study; however, those study objectives/elements not proposed are summarized in Section 4.0 Studies Not Included in the PSP- see Study No. 4.1.2.

The study calls for evaluating the causes of erosion in the Turners Falls Impoundment, determining if they are related to project operations, and identifying measures to stabilize the sites. In addition, the study calls for evaluating options to minimize sediment transport through the upper reservoir and power canal.

Study Goals and Objectives (18 CFR § 5.11(d)(1))

The study goals include:

- Assess management measures available to minimize sediment transport through the Turners Falls Canal and from the Upper Reservoir at Northfield Mountain during and after maintenance drawdowns; and

- Conduct a focused investigation of bank instability in the Turners Falls Impoundment in those areas where there is a causative relationship between the presence of fine-grained soils susceptible to instability due to water level fluctuations associated with hydropower operations.

The study results should provide information sufficient to understand current and proposed effects of water level fluctuations, both natural and anthropogenic, and to identify sites where biostabilization techniques or other measures may be beneficial to water quality. The purpose of the study is to focus attention and resources on select sites ~~that fraction remaining as per the PAD of the river banks~~ within the Turners Falls Impoundment which are scientifically established to be susceptible to erosion due to repeated soil wetting and drying.

Objectives related to the specific goal of investigating a causative relationship between the presence of fine-grained soils susceptible to instability due to water level fluctuations associated with hydropower operations include:

a. Utilize the 2013 FRR mapping[8] to select areas of detailed study ("study area") as related to the hydraulic, geomorphic, and geotechnical aspects of erosion, including identifying the causes of and contributors to erosion in the study area; ~~Accurately map and scientifically describe that portion of the Turners Falls Impoundment where active or recent "bank" "erosion" is occurring (maybe as much as 18% of the banks in the Turners Falls Impoundment, based on the 1979 USACE study) – all terms should be precisely defined, and linked to jurisdictional definitions, whenever possible~~;

[7] The "-2" refers to the stakeholders' study request number.

[8] The 2013 FRR will accurately map and scientifically describe that portion of the Turners Falls Impoundment where active or recent bank erosion is occurring.

b. Based on the 2013 FRR, note the areas of active or recent bank erosion that have been the locus of prior bank stabilization and identify the method of stabilization implemented at that locus;

c. Within the mapped study area (i.e., areas of active or recent bank erosion as identified in the 2013 FRR) establish and designate fixed, recoverable transects. Transects should be representative of various reaches and utilize, to the extent practicable, existing data. Additionally, if applicable, evaluate the existing 22+ river cross sections established in 1998 and surveyed intermittently over time to document bank erosion;

d. Analyze soils (classification, structure, parent materials, texture, hydric regime, position on landscape, chemistry, and most importantly engineering dynamics such as susceptibility to slope failure) at each transect;

e. Along these same transects collect cross-section data related to bathymetric and riverine hydrology, most especially as they relate to jurisdiction and water level fluctuation. Determine the precise elevation of the Ordinary High Water Mark (OHWM), normal impoundment elevation, and maximum and minimum daily range elevations. Evaluate the subsurface hydrology at each transect, but above OHWM, to account for groundwater influences on soil slumping;

f. Once the initial data is collected and organized, a geotechnical engineer and fluvial geomorphologist/hydraulic engineer will evaluate field data plotted at each cross section on various transects to analyze conditions of slope instability and erosion. This analysis will focus on slope conditions, relative susceptibility of bank failure due to repeated wetting and drying. Soil engineering analysis e.g. slope stress, failure planes, shear stress, "Plasticity Index" and "Erosion Factors", would help guide direction of the stabilization efforts. Of special concern is to analyze all causes for slope instability, and to separate out those locations where repeated wetting and drying is a primary factor. This analysis should investigate site soils within the range of daily fluctuation of water levels extending up to and including the capillary zone. All water level data and soil hydrology should be plotted on cross sections to allow for proper analysis;

g. Utilize the land use practices mapping conducted as part of the 2013 FRR at areas of active or recent erosion to determine if the erosion in that area is partially or fully attributable to the adjacent land use practices. Identify areas for employment of best management practices where necessary; ~~Map land use practices that are observationally linked to bank erosion directly beneath and/or proximate to them, and identify areas for employment of best management practices;~~

h. Superimpose on the portion ~~18%~~ of the impoundment which comprises the "study area" a "sensitive receptors" overlay. This overlay will map in detail the position of bank-nesting bird species, rare species occurrences, "vegetated shallows," and other sensitive and agreed to factors which might make such sites less preferable as locations for biostabilization~~, in favor of less sensitive sites~~;

i. Transects will be periodically revisited and data collected for use in determining progression of relative erosion at each, the effectiveness of biostabilization at transects where this technique has been employed, and potential differences in soil profiles at different transects to withstand repeated, daily wetting and drying; and

j. Determine through accurate, repeatable, scientifically based mapping what fraction of the banks of the impoundment within the study area are susceptible to or experiencing erosion due to repeated wetting and drying of the soil column due to hydropower operations. Eliminate all other "banks" within the impoundment from further erosion study, including areas in which bedrock predominates; soils/substrates are presently stable; or where hardscape stabilization has already been installed.

Resource Management Goals of Agencies/Tribes with Jurisdiction over Resource (18 CFR § 5.11(d)(2))

The 2012 Integrated List of Waters shows the segment from VT/NH state line to the Turners Falls Dam (MA34-01 and MA34-02) as impaired and considered "*Water Requiring a TMDL*" due to "*Other flow regime alterations*", "*Alteration in stream side or littoral vegetative covers*" and "*PCB in Fish Tissue*". In addition, the segment below the Turners Falls Dam to the confluence with the Deerfield River (MA34-03) is also shown as impaired by these causes as well as total suspended solids. MADEP notes that the requested studies will assist it in issuing a Water Quality Certification that complies with the State and Federal Clean Water Acts.

Existing Information and Need for Additional Information (18 CFR § 5.11(d)(3))

Extensive research has been conducted evaluating the causes and effects of erosion along the Connecticut River in the Turners Falls Impoundment; such research includes:

Connecticut River Joint Commissions and Trails Conservation Assistance Program of the National Park Service through the Connecticut Valley Partnership. (1996) *River Dynamics and Erosion.* Authors.

Field Geology Services. (2004). *Fluvial Geomorphology Assessment of the Northern Connecticut River, Vermont and New Hampshire.* Farmington, ME: Author.

Field Geology Services. (2007). *Fluvial Geomorphology Study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT*. Farmington, ME: Author.

Simons & Associates. (1998). *Erosion Control Plan for Turners Falls Pool of the Connecticut River (Draft).* Western Massachusetts Electric.

Simons & Associates. (1998). *Long Term Riverbank Plan for the Turners Falls Pool of the Connecticut River.* Author.

United States Army Corps of Engineers. (1979). *Connecticut River Streambank Erosion Study Massachusetts, New Hampshire, Vermont.* Author.

Woodlot Alternatives. (2007). *Connecticut River Hydraulic Analysis Vernon Dam to Turners Falls Dam.* Author.

In addition, the following information is available to help inform this study:

- Bathymetric mapping of the Turners Falls Impoundment was completed in 2006 and bathymetric mapping of the upper reservoir was completed in 2010, 2011 and 2012.

- On January 22, 2013, FirstLight filed with FERC plan maps showing the location of 22 transects located in the Turners Falls Impoundment. Also provided were cross-section plots of these transects that have been surveyed twice annually since 1998. It is unclear at this juncture whether any of the 22 transects could be used as part of this study as further assessment is needed to determine if any of the 22 transects are in locations where erosion is caused by water level fluctuations due to hydropower operations.

- Section 4.2.3 of the PAD contains a discussion of soil types and mapping from Vernon Dam to the Cabot tailrace including the identification of the ten most common soil series found in the Project boundary (PAD Table 4.2.3-1). Soils maps along the riverbanks were included in the PAD. Included as part of FERC's AIR (see Section 2.0) for the top ten most common soils, FirstLight has included in Appendix C[9] the following other data that will help support study objective (d):

  - Relative to soil chemical properties: depth, cation-exchange capacity, effective cation-exchange capacity, and pH.

  - Relative to soil physical properties: percent sand, silt, and clay, moist bulk density, saturated hydraulic conductivity, shear and compressive strength, available water capacity, linear extensibility, organic matter and erosion factors (Kw, Kf, and T).

- FirstLight maintains paper copies of their log sheets that include hourly data on flows, water elevations and generation. For the period 2000-2010, FirstLight has converted the paper copies to electronic data. The following data is available that will be of assistance in this study:

  - Relative to flows, FirstLight has Vernon discharges, and adds to this USGS flows as recorded at the Ashuelot and Millers River to estimate total inflow. FirstLight also has estimated flows passed through the gatehouse and estimated flows passed over the Turners Falls Dam.

  - Relative to water levels, FirstLight maintains water level recorders on the same vertical datum in the Turners Falls Impoundment at the following locations a) immediately below Vernon Dam, b) directly below the Northfield Mountain tailrace, c) at the boat barrier buoy line approximately 1,500 feet upstream of the Turners Falls Dam and d) at the Turners Falls Dam (see Figure 4.3.1.3-1 in PAD for locations).

- FirstLight also maintained water level recorders on the same vertical datum for approximately the period May 1 through mid-August at two additional locations in the Turners Falls Impoundment --at West Northfield Road (near the VT/NH/MA border) and at the Route 10 Bridge (see Figure 4.3.1.6-1 in PAD for locations).

- Two hydraulic models of the Turners Falls Impoundment are available using the 2006 bathymetry including a steady-state one-dimensional HEC-RAS model and a two-dimensional RIVER2D model. FirstLight recently used the HEC-RAS model to evaluate at what flow hydraulic control of the river shifts from the Turners Falls Dam to the French King Gorge. The analysis also demonstrated that the upstream influence of the Turners Falls Project extends to approximately 9,000 feet below the Vernon Dam. This analysis was filed with FERC on February 22, 2013.

- Past reports contain significant background information on the geomorphic history of the Connecticut River, which provides some context.

- Pressure transducers were used to measure water level fluctuations in the river and groundwater near Bennett Meadow on the west bank just below the Route 10 Bridge. One transducer was placed in the river, and three (52 ft, 65 ft and 210 ft from the river) were placed in monitoring wells along a line perpendicular to the riverbank. The field work was conducted from mid-July

[9] The soil information was obtained from the United States Natural Resources Conservation Service.

1997 through February 1998. These data provide information on the groundwater elevation and hydraulic gradient.

- Hydraulic (near shore velocity), bank material sampling, and suspended sediment sampling was conducted over a range of flow conditions from 1997 through 2011. These data provide information on velocity, hydraulic shear stresses, particle size distributions, and sediment transport.

- Data on boat waves was collected on July 12-13, 1997 and July 26-27, 2008. At several locations, temporary staff gages were installed to document wave amplitude and frequency using videotape. Suspended sediment samples were also collected in the area where the waves impacted the shoreline.

- Two reports addressing riverbank erosion were filed with FERC on January 8, 2013 as follows:

  - Simons & Associates. (2012). *Riverbank Erosion Comparison along the Connecticut River*. Prepared for FirstLight. Midway, UT: Author.
  - Simons & Associates. (2013). *Analysis of Erosion in Vicinity of Route 10 Bridge Spanning the Connecticut River*. Prepared for FirstLight. Midway, UT: Author.

One goal of this study is an assessment of management measures to minimize sediment releases from the upper reservoir during maintenance drawdowns. As discussed in the description of Task 8 below, On July 15, 2011, FirstLight filed a *Sediment Management Plan* for the Northfield Mountain Project. The plan was filed in response to FERC's directive requiring measures to avoid or minimize entrainment of silt into the project's works during drawdown of the upper reservoir. The original plan has since been modified, in consultation with the MADEP and FERC, and calls for FirstLight to continuously record suspended sediment concentrations at the Route 10 Bridge and at the Northfield Mountain Project (both water used in pumping and generating). In addition, the plan called for annual bathymetric mapping of the upper reservoir to document changes in sediment accumulation or transport. At the end of each year FirstLight files with the FERC the study findings. The most recent report was filed with FERC on November 30, 2012. FirstLight is implementing the plan over a 4-year period, concluding with a final report to FERC by December 1, 2015. Based on the study findings, FirstLight will evaluate alternatives for sediment management in the upper reservoir during maintenance drawdowns. The suspended sediment concentration data and bathymetric surveys of the upper reservoir are available for this study. Sediment Transport through the Turners Falls Canal is addressed as part of Task 9 below.

Project Nexus (18 CFR § 5.11(d)(4))

The Connecticut River in the Turners Falls Impoundment is impacted by three hydroelectric projects which discharge or draw water from the river for hydropower generation. These Projects are (from downstream to upstream): the Turners Falls Project, Northfield Mountain Project, and Vernon Hydroelectric Project. All three Projects can operate as peaking facilities when flows are within the hydraulic capacity of the facilities, which can directly impact water level fluctuations in the Turners Falls Impoundment. When flows exceed the hydraulic capacity of the Vernon and Turners Falls Projects, the projects are operated as a run-of-river project.

Methodology (18 CFR § 5.11(b)(1), (d)(5)-(6))

Task 1: Data Gathering and Background Mapping

Data Gathering

Extensive research and data gathering efforts have been conducted within the Turners Falls Impoundment over the past several decades which will assist in this study. Existing data includes: hydrology, water elevation data, suspended sediment measurements, hydraulic modeling, and previous FRRs. A full list of available data for use in this study is included in the section of this study plan titled "Existing Information and Need for Additional Information (18 CFR § 5.11(d)(3)).

Background Mapping

Prior to conducting any field work, geo-referenced aerial imagery of the Turners Falls Impoundment will be developed in GIS and uploaded to pentop computer so that the geographic extents of active or recent bank erosion can be noted directly in the field. Also, separate GIS layers showing soil mapping and land use classification will be loaded along with the aerial imagery to allow personnel conducting the field assessment with quick reference data.

Task 2: Geomorphic Understanding of Connecticut River

It is important that the study include background of the geomorphic setting of the Connecticut River. This task would entail summarizing, as part of a larger report, the historic and modern geomorphology of the Connecticut River to provide readers with context. In addition, it would include background on the dynamic nature of alluvial rivers. More specifically, FirstLight will document causes of riverbank erosion that occur within a river corridor even if the river is not subject to rising and falling water levels due to hydropower operations. Causes or erosion include natural processes such as naturally high flow events as well as anthropogenic influences unrelated to hydropower operations.

Task 3: Evaluation of Water Elevation and Flow Data

The purpose of this task is to document the normal, maximum and minimum Turners Falls Impoundment elevation using the six water elevation monitoring locations in the impoundment- at the four long term (2000-2010) water level recording locations (historically collected on an hourly time step) and at two water level recording locations selected in 2012 (collected every 15 minutes). This task is not intended to fully replace Objective (e) of the study that requests minimum, maximum and critical elevation data along the transects where active or recent erosion is field-documented. Rather it will provide a sense of the timing, magnitude, and duration of water level fluctuations that is occurring at these locations in the impoundment due to hydropower operations and naturally high flows.

Below is a summary of the graphs and statistics that will be developed for the water level recorders in the Turners Falls Impoundment. FirstLight proposes to develop two types of water level data to help determine the range of water level fluctuations due to project operations and those attributed to naturally high flows. The maximum flow that can be regulated in the Turners Falls Impoundment is when Northfield Mountain is generating at its maximum hydraulic capacity of 20,000 cfs. FirstLight proposes to ~~parce~~parse the water level data at the four long term and two short term water level recorders as follows:

a) Include water elevation data only when flows less than 20,000 cfs

b) Include water elevation data only when flows are greater than 20,000 cfs

c) Include water elevation data over the entire range of flows

The following tables and graphs will be developed

- For items a)- c) above, tables will be developed showing the monthly (and annual) minimum, maximum, median and average impoundment elevation at the six monitoring[10] locations;
- Elevation duration curves have already been developed using the 2000-2010 data for the four long-term monitoring locations (see Section 4.3.1.6 and Appendix E of the PAD). The elevation duration curves provide background on the range of fluctuation;
- Eleven hourly graphs will be developed for each year between 2000 and 2010 at the four long-term gages and hourly graphs will be developed for 2012 at the two short-term gages. Each graph will include the hourly (or 15-minutes for the short term gages) water elevation for the four locations along with the flow estimated at the dam (which will be a sum of the flow passed to the gatehouse and that passed below the Turners Falls Dam, as recorded on the log sheets). Also shown on these same graphs will the flow as recorded at the USGS gage in Montague City, MA. This will provide background information on the relationship between the magnitude of streamflow and impoundment elevations.
- To understand the approximate daily fluctuation in the TF impoundment elevation at the four long-term gages between 2000 and 2009[11], for each day over the period when flows are less than 20,000 cfs, the maximum and minimum elevation will be computed from the hourly data. The maximum and minimum elevations will be subtracted to yield the approximate fluctuation over the day due to hydropower operations. For example, if the maximum and minimum elevation at the Northfield tailrace on January 1, 2000 was 181 feet and 179 feet respectively, the maximum fluctuation on this particular day would be 2 feet (the "delta"). Using the resultant delta data, a maximum daily fluctuation duration curve will be developed on a monthly basis. The same analysis will be applied to the short term gage as well. In addition, the understand the range of fluctuation due to naturally high flows, the same analysis will be applied to both the short-term and long-term gages.

In addition to water elevation data, the following flow information will be evaluated:

- Flow data from the Montague City USGS gage will be used to provide context on the magnitude, timing, frequency and duration of flows. Mean daily flows from this gage will be prorated, based on a ratio of drainage areas, to represent flow at Turners Falls Dam. As shown in the PAD, annual and monthly flow duration curves have been developed. FirstLight will develop a mean daily average annual hydrograph for the period after several USACE flood control facilities were constructed, to understand the magnitude of flow throughout the year, relative to the hydraulic capacity to the Project. In addition, using the post-USACE instantaneous peak flow data, a flood frequency analysis (Log Pearson Type III) will be conducted to predict the 2-, 10-, 50- and 100-year flood flows at the Turners Falls Dam. This information will be used for the hydraulic modeling assessment as described below.

[10] For the four long term gages, the statitics (min, max, mean, and median) will be based on hourly data. For the two short term gages, the statistics will be based on 15-minute data.

[11] The year 2010 was eliminated because Northfield Mountain was not operating for much of the year.

- FirstLight records on an hourly basis the Vernon Dam discharge and the magnitude of generation or pumping (MW) at the Northfield Mountain Project. The Northfield pumping and generating data will be converted to flow based on MW versus cfs curve. For select periods of record representing high and low flows, weekly graphs (on an hourly basis) will display the flow at these two locations, along with the water elevation data recorded at the four long-term water monitoring gages for the same period of record. The purpose of this evaluation is to gain a better understanding of the contributions of water level fluctuations in the impoundment due to Vernon discharges, Northfield Mountain Project operations and both facilities.

Task 4: Hydraulic Model of Turners Falls Impoundment

A hydraulic model (HEC-RAS) of the Turners Falls Impoundment is available to assist with this study and can provide valuable information. In Objective (e), the precise elevation of the minimum, maximum and normal impoundment elevations, OHWM, and min/max daily ranges at those locations where erosion is occurring is sought. FirstLight believes that the hydraulic model, once calibrated to observed elevations as recorded at water level monitoring locations, could be used to predict the min/max, and normal pond elevations, recognizing that it will not fully replace field-based physical measurements.

As described in Study No. 3.2.2 *Hydraulic Study of Turners Falls Impoundment, Bypass Reach and below Cabot Station*, FirstLight is proposing to calibrate the existing hydraulic model to observed Turners Falls Impoundment elevation data. Specifically, the goal is to simulate a few steady flow conditions (high flow and low flow) where flow throughout the length of the impoundment remains relatively stable and compare the model predicted elevation at the four long-term monitoring locations (and two gages installed in 2012) with observed elevation data. If the model reasonably reflects the observed water surface profile along the impoundment, it could be used to simulate a range of flows and range of downstream boundary conditions- in this case the water elevations at Turners Falls Dam.

In addition to the HEC-RAS model, the RIVER2D model yields information on the relationship between flow and near-bank velocity. RIVER2D modeling will be used to analyze near-bank velocity to determine shear stress along the bed and banks of the river. Analyzing near-bank velocity will be particularly useful in any future stabilization designs in areas identified in the field as active or recent bank erosion.

Task 5: Map and Describe Active or Recent Bank Erosion

FirstLight proposes to engage the following personnel to conduct the study: a) a fluvial geomorphologist and professional engineer having specific expertise in hydrology, hydraulics, fluvial geomorphology, and sediment transport, b) a geotechnical professional engineer having specific experience with riverbank stabilization projects, c) an environmental scientist having experience with habitat needs for bank swallows and identifying “sensitive receptors”, and d) other support staff. This field team will boat the Turners Falls Impoundment shoreline to conduct the following:

- Utilize the results of the 2013 FRR to identify ~~Accurately map~~ the start and end of any active or recent bank erosion sites (Objective (a)).

- Based on the results of the 2013 FRR, ~~Document~~ note any areas of bank erosion that have been the locus of prior bank stabilization and identify the method of stabilization implemented. The intent here is to learn from potential past stabilization projects that were unsuccessful such that future stabilization on river banks with similar features considers alternative methods (Objective (b)). A detailed review of all previously stabilized sites will be conducted. Specifically, several thousands of feet of shoreline have been stabilized over the decade using various techniques, some considered experimental. FirstLight wants to know what stabilization measures have or have not been successful. Based on this, it will help inform any potential future stabilization projects identified as part of this field study.

- Within the mapped areas of active or recent bank erosion, establish fixed, recoverable transects (Objective (c)). This will require establishing vertical and horizontal control at two benchmarks set back from the top of bank. By establishing monumented controls on the left and right banks, the endpoints will be fixed and, future cross-section surveys can be readily compared. Additionally, if applicable, evaluate the existing 22+ river cross sections which were established in 1998 and surveyed intermittently over time to document bank erosion.

- Utilize the land use practices mapping conducted as part of the FRR at areas of active or recent bank erosion, ~~Within the mapped areas of active or recent bank erosion, map land use practices that are observationally linked to erosion directly beneath and/or proximate to them (Objective (g)). D~~to determine if the ~~active or recent bank~~ erosion is partially or fully attributable to land management practices adjacent to the river banks (Objective (g)).

- Utilize the location of "sensitive receptors" areas identified during 2013 FRR mapping to document ~~Within the mapped areas of active or recent bank erosion, document any "sensitive receptors" such as~~ specific locations of bank-nesting bird occurrences, "vegetated shallows" and other sensitive factors (Objective (h)). There may be instances where erosion is occurring, but stabilization may or may not the best option if the eroded area provides particular types of high value habitat.

- At each of the transects within the active or recent bank erosion site, analyze the soils including: classification, structure, parent materials, texture, hydric regime, position on landscape, chemistry and most importantly engineering dynamics such as susceptibility to slope failure. Much of the information listed above can be obtained from previous sources; however, the fluvial geomorphologist and geotechnical engineer must collectively document observed soils in area of erosion (Objective (d)).

Task 6: Causes of Erosion

The fluvial geomorphologist and geotechnical engineer will collectively evaluate the cause or causes of riverbank erosion throughout the Turners Falls Impoundment generally and at each transect and erosion site documented. Causes of erosion throughout the study area could be due to a single source or combination of sources. Potential causes of erosion could include:

- Hydraulic shear stress due to flowing water;
- Water level fluctuations due to hydropower operations;
- Boat and wind waves;
- Land management practices;
- Seepage and piping;
- Freeze-thaw;
- Ice or debris ;
- Animals such as nesting burrows; and
- Anthropogenic influences to the riparian zone (e.g., removal of riparian vegetation, cattle grazing to the river's edge, heavily traveled recreation trails

In the final report, the potential causes of erosion will be discussed and summarized. Through analyses of site-specific data, the fluvial geomorphologist and geotechnical engineer will determine if the susceptibility to bank failure is due to: a) water level fluctuations due to hydropower operations; b) a combination of water level fluctuations due to hydropower operations with other causes; or c) other causes (Objective (f)).

Data analysis will focus on forces that cause erosion, forces that resist erosion, observations of erosion, the elevation range over which the forces act on the riverbanks, and the duration of time that the various forces act on riverbanks in the Turners Falls Impoundment. According to *"Sediment Transport Technology, Water and Sediment Dynamics"* (Simons, D.B. and F. Senturk, 1992):

> *"An alluvial river generally is continually changing its position and shape as a consequence of hydraulic forces acting on its bed and banks and related biological forces interacting with these physical forces. . . Until sufficient forces are exerted on the boundary of alluvial channels, the particles comprising the boundary remain stationary and the system behaves as a rigid channel. However, once the critical shear stress has been exceeded for the size of particle comprising the channel boundary, initiation of motion begins."*

When erosive forces exceed resisting forces, an imbalance of forces exists resulting in potential erosion. Erosion may occur due to particle by particle transport or by mass-wasting when blocks of sediment, typically due to gravitational forces, break loose and move vertically down the slope. Such blocks of sediment may remain relatively intact or may break apart and can then be further eroded and transported in a particle by particle mode.

Shear stresses due to the tractive force of flowing water are calculated as a function of the velocity of flow and compared to critical shear stress based on particle size using the Shield's relationship as explained in numerous texts such as the previously referenced Sediment Transport Technology and *"River Engineering for Highway Encroachments, Highways in the River Environment,"* (Hydraulic Design Series Number 6, Publication No. FHWA NHI 01-004, 2001, E.V. Richardson, D.B. Simons and P.F. Lagasse). Hydrodynamic forces due to water level fluctuations will account for the rate of change of water level over time and the range of the overall fluctuations. The rate of change in water level in the soil matrix will also be factored into the analysis of overall forces resulting from the water level changes in the river itself using the rates of water movement related to seepage.

Evaluation of hydrodynamic forces due to boat waves will utilize both the horizontal and vertical velocity of water movement as well as energy and tractive force approaches compared to the energy of the streamflow itself. Two studies will be utilized as a basis for conducting this evaluation: *"Hydrodynamic Impacts of Commercial Jet-Boating on the Chilkat River, Alaska,"* (D.F. Hill, M.M. Beachler, P.A. Johnson Department of Civil & Environmental Engineering, The Pennsylvania State University, 2002) and *"Boat-Wave-Induced Bank Erosion on the Kenai River, Alaska,"* (Stephen T. Maynord, David S. Biedenharn, Craig J. Fischenich, and Jon E. Zufelt, 2008, Engineer Research and Development Center, USACE). These studies developed and applied an approach to compare the energy from boat waves to the energy of streamflow. An energy comparison will be utilized to analyze and evaluate the effect of boat waves along with observation of wave dynamics and erosion as observed in the Turners Falls Impoundment.

An approach to develop a combined understanding of fluvial and geotechnical processes regarding riverbank erosion is the Bank-Stability and Toe-Erosion Model (BSTEM) developed by the USDA-ARS, National Sedimentation Laboratory. This approach was described as follows:

> *BSTEM evaluates the force-equilibrium factor of safety of either planar- or cantilever-shear failure in a layered streambank. The resisting forces comprise the cohesive and frictional strengths of the soil, forces due to positive and negative porewater pressures and a component of the hydrostatic confining force afforded by water in the channel. The*

> *driving forces comprise the weight of the failure block reduced by a component of the hydrostatic confining force. A global search algorithm was employed to search for the minimum factor of safety. An advanced root-reinforcement model based on fiber-bundle theory was applied to quantify the increase in bank strength due to assemblages of riparian vegetation. The hydraulic-erosion component of BSTEM estimates the applied shear stress along the bank toe and bank face and to erode these surfaces perpendicular to the existing geometry.*

BSTEM was developed by the National Sedimentation Laboratory ("*Iterative Bank-Stability and Toe-Erosion Modeling for Predicting Streambank Loading Rates and Potential Load Reductions*," 2010, Andrew Simon, Research Geologist, USDA-ARS, National Sedimentation Laboratory, Oxford, MS, Natasha Bankhead, Research Geologist, USDA-ARS, National Sedimentation Laboratory, Oxford, MS, and Robert Thomas, Research Associate, Department of Civil and Environmental Engineering, University of Tennessee, Knoxville, TN). This approach, as well as other traditional geotechnical analysis tools, will be utilized in the analysis of riverbank stability in the Turners Falls Impoundment.

Water level fluctuation data, velocity data, and suspended sediment sampling data has been collected with additional water level data and suspended sediment sampling to be collected in various components of the proposed studies. Approximately 10 years of hourly water level and flow data are available which show the range and variations in flow and water level at a number of locations over time. Hydraulic modeling also is being conducted of the Turners Falls Impoundment utilizing cross-sections spaced at 500 foot intervals along the length of the impoundment. The combination of site-specific data and hydraulic modeling results will be utilized to develop necessary hydraulic information at any sites selected in the sediment transport study by interpolation of hydraulic modeling results between the nearest cross-sections to any selected location along the impoundment. The accuracy of such modeling will be quantified through the calibration and verification process.

Some causes of erosion cannot be readily related to forces, but instead can be evaluated spatially. For example, the riparian vegetation zone has been altered by land clearing which affects riverbank stability. This and other effects that are localized to specific reaches of the impoundment will be analyzed based on the length of where such phenomena have affected the riverbanks of the impoundment using available aerial photography and the results of the 2013 FRR.

The 1979 study conducted by the U.S. Army Corps of Engineers ("Connecticut River Streambank Erosion Study, Massachusetts, New Hampshire and Vermont") analyzed riverbank erosion utilizing a tractive force or shear stress approach whereby the various causes of erosion were evaluated by comparing them to the tractive force due to the flow. The USACE report states:

> *"The tractive force method described by Chow (1959) was utilized by the New England Division of the U.S. Army Corps of Engineers to evaluate bank erosion on the Connecticut River. This method is basically sound and has been widely used to design and evaluate the stability of alluvial channels."*

The relative magnitude of forces associated with the various causes of erosion as well as the length of time or duration over which the forces act were developed into a matrix to evaluate the causes of erosion. *"The relative magnitude (M_B) and relative duration (D_B) of the forces causing bank erosion for non-cohesive and stratified bank materials have been assessed qualitatively."* In addition to evaluation of the magnitude and duration of forces, the study also considered the portion of the riverbank where the various forces attacked the bank:

"In order to more clearly focus on the major causes of bank erosion, it is perhaps worthwhile to subdivide these forces in relationship to where they act. Many geologists, engineers and laymen alike miss the main point when they consider major causes of bank erosion. One must consider that the forces acting on the bank can be broken into two categories: (1) those forces that act at or near the surface of the water associated with pool fluctuations, related piping, groundwater, wind waves, boat waves, ice, lack of or removal of vegetation, and so forth, and (2) those forces acting on the full height of the submerged bank."

The study then discussed the vertical distribution of tractive forces acting on the riverbank associated with flowing water which acts over the entire submerged bank face, but with greatest forces acting about two-thirds of the depth below the water surface. The 1979 USACE study is similar to, and provides a basis for, the sediment transport study that is proposed to be conducted on the Turners Falls Impoundment. The fluvial geomorphologist/hydraulic engineer and geotechnical engineer will collectively look at all of the available data gathered above (plasticity index, particle size distributions, soils shear and compressive strength, soils maps, water level data, flow velocity data, hydraulic modeling, suspended sediment sampling, etc.); as well as apply analysis methodologies as described above to make the determination as to whether the slope instability and/or erosion is caused (in whole or in combination with other factors) by hydropower operations. The analysis will include quantifying forces associated with the various causes of erosion; accounting for ranges, rates and frequency of flow and water level fluctuations; durations of flow and water levels; and consideration of where on the riverbank the various forces act.

Task 7. Identify Potential Bank Stabilization Locations

Based on the information obtained for the field study and in-house work, FirstLight will identify potential bank stabilization locations within the Turners Falls Impoundment where a causal relationship to water level fluctuations due significantly to hydropower operations can be determined.

Task 8: Upper Reservoir Drawdown Sediment Transport

As noted above under the Existing Information section, FirstLight is currently in the process of conducting a 4-year study as part of its *Sediment Management Plan*. The study includes a) continuously measuring suspended sediment concentrations at the Route 10 Bridge and at the Northfield Mountain Project (both water used in pumping and generating), and b) annual bathymetric mapping of the upper reservoir to document changes in sediment accumulation or transport. Suspended sediment monitoring is being performed seasonally (spring-fall) within the Northfield Mountain tailrace, and seasonally (spring-fall) in the Connecticut River. The most recent report was filed with FERC on November 30, 2012. Additional reports are anticipated to be filed on December 1 2013 and 2014. Per the *Sediment Management Plan* the final report will be filed with FERC by December 1, 2015. In the final report, FirstLight will evaluate practical strategies to minimize the release of accumulated sediment through the Northfield Mountain Project works during upper reservoir dewatering activities.

Task 9: Turners Falls Power Canal Sediment Transport

To drawdown the power canal, FirstLight uses the Cabot turbines; the Cabot spillway gates or log sluice are not used. FirstLight has not observed sediment releases due to using the Cabot turbines to lower the canal elevation. However, other stakeholders have requested a study to evaluate the impact of using the Cabot spillway on re-suspending sediment located in the Connecticut River – likely at the base of the Cabot spillway-- on sturgeon spawning habitat. Two separate studies addressing these issues are included as Study No. 3.3.12 *Evaluate Frequency and Impact of Emergency Water Control Gate Discharge Events and Bypass Flume Events on Shortnose Sturgeon Spawning and Rearing Habitat in the Tailrace and*

Downstream from Cabot Station and Study No. 3.3.18 *Impacts of the Turners Falls Canal Drawdown on Fish Migration and Aquatic Organisms.*

Comment [mwamser1]: Are stakeholders okay with deleting this task since it is addressed in other studies? Ken Hogan raised this question at the May 15 meeting.

Task 10: Report

A comprehensive report will be developed. It is anticipated the final report will include the following sections:

- Executive Summary
- Introduction
- Geomorphology of the Connecticut River
- Evaluation of Water Level and Flow Data
- Evaluation of Boat Wakes
- Hydraulic Modeling
- Soil Mapping
- Field Study and Mapping
- Erosion Processes
- Causes of Erosion Attributable to FirstLight's Hydropower Operations
- Identify Bank Stabilization Project Attributable to FirstLight's Hydropower Operations
- Upper Reservoir *Sediment Management Plan* (note this study will not be completed until December 2015

Level of Effort and Cost (18 CFR § 5.11(d)(6))

FirstLight believes the proposed level of effort is between approximately $180,000 and $220,000.

Study Schedule (18 CFR § 5.11(b)(2) and (c))

The cover letter outlines the PSP meeting schedule. The purpose of the Study Plan Meeting will be to resolve any outstanding issues with respect to FirstLight's PSP and the study requests filed by stakeholders, and to clarify the PSP and any information gathering and study requests. A portion of the field work may be conducted in 2013 along with the FRR. However, it is likely that the bulk of this study will be conducted during leaf-off in 2014.

Study reporting will be conducted in accordance with FirstLight's Process Plan and Schedule (18 CFR § 5.6(d)(1)), as provided in the PAD, and the FERC's SD1.