Riverbank Erosion Comparison along the Connecticut River

by

Simons & associates

October 2012

prepared for

FirstLight Power Resources GDF SUEZ

Table of Contents

List of Tables

List of Figures

Appendices

Riverbank Erosion Comparison along the Connecticut River

Simons & Associates
October 2012

Executive Summary

Rivers are dynamic features meaning that lateral migration, channel shifting, and changing position are processes that occur to varying degrees along their path. The fact that channels migrate, shift, and otherwise change position translates directly into riverbank erosion. Such is the case with the Connecticut River as it flows through Vermont, New Hampshire, Massachusetts, and Connecticut. Erosion has been and is a concern for many people and groups all along the river corridor. Several studies have been conducted regarding riverbank erosion of the Connecticut River. Information and data on this subject are available from a variety of sources over a period of more than 50 years although most of the information covers the more recent decades. A review, evaluation, and comparison of riverbank erosion along the Connecticut River was conducted based on available reports from a variety of sources coupled with some recent compilation of photographic evidence of erosion in the Bellows Falls, Vernon, and Holyoke Impoundments as well as the recently completed full river reconnaissance (FRR) of the Turners Falls Impoundment (Simons & Associates, 2009). The objective of this study is to compare riverbank erosion between the various impoundments and free-flowing reaches along the Connecticut River and to draw conclusions based on the observations and comparisons.

The Connecticut River consists of several different segments ranging from un-impounded or free-flowing reaches, primarily in the northern section of the river; to a series of pools formed by dams, primarily in the middle and southern sections of the river. The study reach for this comparison of riverbank erosion extends from Pittsburg, NH in the north downstream to Holyoke Dam. Over the approximate 240 mile study reach, the Connecticut River flows through 15 currently-existing dams with associated impoundments, as well as free-flowing sections.

Riverbank features and characteristics vary considerably along the length of the river. While portions of the river consist of bedrock outcrops that are very stable, much of the riverbanks consist of hillsides or alluvial material that is formed primarily of silt to sand sized material. There are areas that consist of gravel to cobble sized material that are generally less erodible but still are alluvial or transportable by fluvial processes nonetheless. Much of the riverbanks are quite well vegetated, which generally adds to riverbank stability, although there are segments where a range of erosion and mass-wasting processes remove or damage vegetation and associated riparian land.

Riverbank erosion was compared among various reaches to the extent feasible with available data as well as through photographs taken over the years at erosion sites. The comparison reveals the following key points:

- The segment of river with the greatest extent of eroding riverbanks is the un-impounded northern reach (Pittsburg, NH down to Gilman Dam). At the time of the available study (Field, 2004), 48.4% of the riverbanks were experiencing moderate or more significant erosion. Riverbanks that had been rip-rapped covered 17.1% of the length of the river.

- Several erosion sites were identified and photographed in the Bellows Falls, Vernon, Turners Falls, and Holyoke Impoundments in 1997, and again in 2008. All of the erosion sites in 1997 in the Bellows Falls and Holyoke Impoundments and all but one of the 1997 erosion sites in the Vernon Impoundment remain in essentially the same state of erosion when photographed in 2008, many of which are significant in both size and severity. In contrast, most of the erosion sites identified in the Turners Falls Impoundment in 1998 have been stabilized and are no longer eroding as of 2008 (when previously identified erosion sites were re-photographed in 3 impoundments and when the most recent FRR was conducted in the Turners Falls Impoundment), with several additional erosion sites scheduled to be stabilized as part of the *"Erosion Control Plan for the Turners Falls Pool of the Connecticut River"* (1998, Simons & Associates) by 2012.

- In addition to direct stabilization of many of the erosion sites in the Turners Falls Impoundment that were identified in the 1998 Erosion Control Plan (ECP), there is evidence of some natural stabilization processes including increased upper bank vegetation and areas of dense low bank aquatic vegetation that are helping provide a degree of additional stability in some areas.

- Despite the fact that similar percentages of riverbank have been stabilized in the northern, free-flowing reach and in the Turners Falls Impoundment; the percentage of erosion in the Turners Falls Impoundment is only about one-third the extent of erosion that is occurring in the northern, free-flowing reach of the Connecticut River (16.7% compared to 48.4%).

- Because riverbank erosion in the Turners Falls Impoundment is significantly less than in the northern free-flowing reach, and erosion sites in other impoundments (Bellows Falls, Vernon, and Holyoke) have continued eroding from 1997 to 2008 while many erosion sites have been stabilized in the Turners Falls Impoundment along with some evidence of natural stabilization processes; it can be concluded that the riverbanks in the Turners Falls Impoundment are in the best condition (more stable and less eroding) than in any other part of the Connecticut River.

- The Turners Falls Impoundment, which experiences water level fluctuations due to a combination of run of river/peaking power and pumped-storage hydropower operations, has less riverbank erosion than the other impoundments (Wilder, Bellows Falls, Vernon, Holyoke) which only experience water level fluctuations resulting from run of river and peaking power operations and do not experience additional fluctuations due to pumped-storage operations. The Turners Falls Impoundment also experiences significantly less erosion than the northern, free-flowing reach which has no hydropower operations and associated water level fluctuations. This implies that the additional water level fluctuations due to pumped-storage operation either do not adversely affect riverbank erosion to a significant degree and/or are being successfully handled through implementation of the ECP.

- The Turners Falls Impoundment, experiences water level fluctuations due to a combination of three hydroelectric projects: Vernon and Turners Falls which operate approximately 3/4ths of the time in peaking power generation mode and when flows exceed their hydraulic generation capacity, operate the remainder of the time in a run-of-river mode; and the Northfield Mountain Pumped Storage Project which operates in a peaking power mode. The other impoundments experience water levels fluctuations due to hydroelectric projects that operate in a peaking power generation mode combined with run-of-river (when hydraulic generation capacities are exceeded). The Turners Falls Impoundment experiences less riverbank erosion than the other impoundments (Wilder, Bellows Falls, Vernon, and Holyoke) which only experience water level fluctuations resulting from run of river and peaking power operations and do not experience additional fluctuations due to pumped-storage operations. The Turners Falls Impoundment also experiences significantly less erosion than the northern, free-flowing reach which has no hydropower operations and associated water level fluctuations. This implies that the additional water level fluctuations due to pumped-storage operation either do not adversely affect riverbank erosion to a significant degree and/or are being successfully handled through implementation of the ECP.

1. Introduction

Riverbank erosion has been a long-standing issue for people having varying interests and relationships with rivers. Simons and Senturk (1991) discuss the fact that some rivers migrate laterally as much as 10s, 100s, and even 1000s of feet per year through a process of riverbank erosion. They further state that *"Stable or static alluvial channels are the exception in nature."* Such is the case for the Connecticut River to varying degrees along its length. Several erosion-related studies have been conducted along the Connecticut River and this report summarizes findings from these studies as well as information obtained by Simons & Associates (S&A) over decades of involvement along this river. It is intended to develop an understanding of erosion along the river, and compare erosion along specific reaches over time.

The Connecticut River flows out of Quebec in a southerly direction from the Connecticut Lakes in northern New Hampshire, along the border between New Hampshire and Vermont, through western Massachusetts and central Connecticut into Long Island Sound. Figure 1 shows the path of the Connecticut River as it flows through New England. On its journey through New England, the river is impounded by 15 dams, some of which are equipped with hydropower facilities. A few of the dams create impoundments that are sufficiently large to seasonally re-regulate[1] river flows. Most dams on the Connecticut River are low-head facilities which form narrow impoundments that experience generally low water velocities at low flow and higher velocities with near full riverine conditions at high flows. In the headwater reaches of the Connecticut River, it flows through a series of small dams and lakes including the Connecticut Lakes down to Canaan Dam. The river then flows through an unimpounded or free-flowing reach downstream from Canaan Dam to the upper reaches of the impoundment formed by Gilman Dam. The river flows through a couple of large storage dams (Moore and Comerford) capable of re-regulating river flow due to the seasonal storage capacity of the associated reservoirs. Downstream of Comerford Dam, the river passes through several low-head dams having relatively narrow impoundments McIndoes and Dodge Falls, Wilder, Bellows Falls, Vernon, Turners Falls, and Holyoke. Downstream of Holyoke Dam, the river is free-flowing through Connecticut and into Long Island Sound.

Except for rare segments of the Connecticut River like the French King Gorge located in the Turners Falls Impoundment which consists of an extensive rock outcrop; the Connecticut River, through a significant portion of its length, is an alluvial river. An alluvial river consists of bank and bed material that the river itself transports, deposits, or erodes. An interesting characteristic of the Connecticut River is that fairly recently (in geologic time) it used to be a large lake (Lake Hitchcock) that formed as the little ice age (approximately 18,000 years ago) was ending and melting ice was blocked by a mass of sediment pushed up by the ice (Rittenour, 1999. As a result of the formation of a large lake, into which sediment deposited over a period of approximately 3000 years, much of the riverbank material of the Connecticut River consists of fine sediment that deposited in the lake. Field (2007) commented on the nature of riverbank sediments found in a reach

[1] Dams having sufficient storage capacity to store water during periods of high flow thereby reducing flood peaks for release during the low flow season.

of the Connecticut River describing them as being "*naturally susceptible to erosion given their noncohesiveness and fine-grained texture.*" Alluvial rivers, consisting of materials

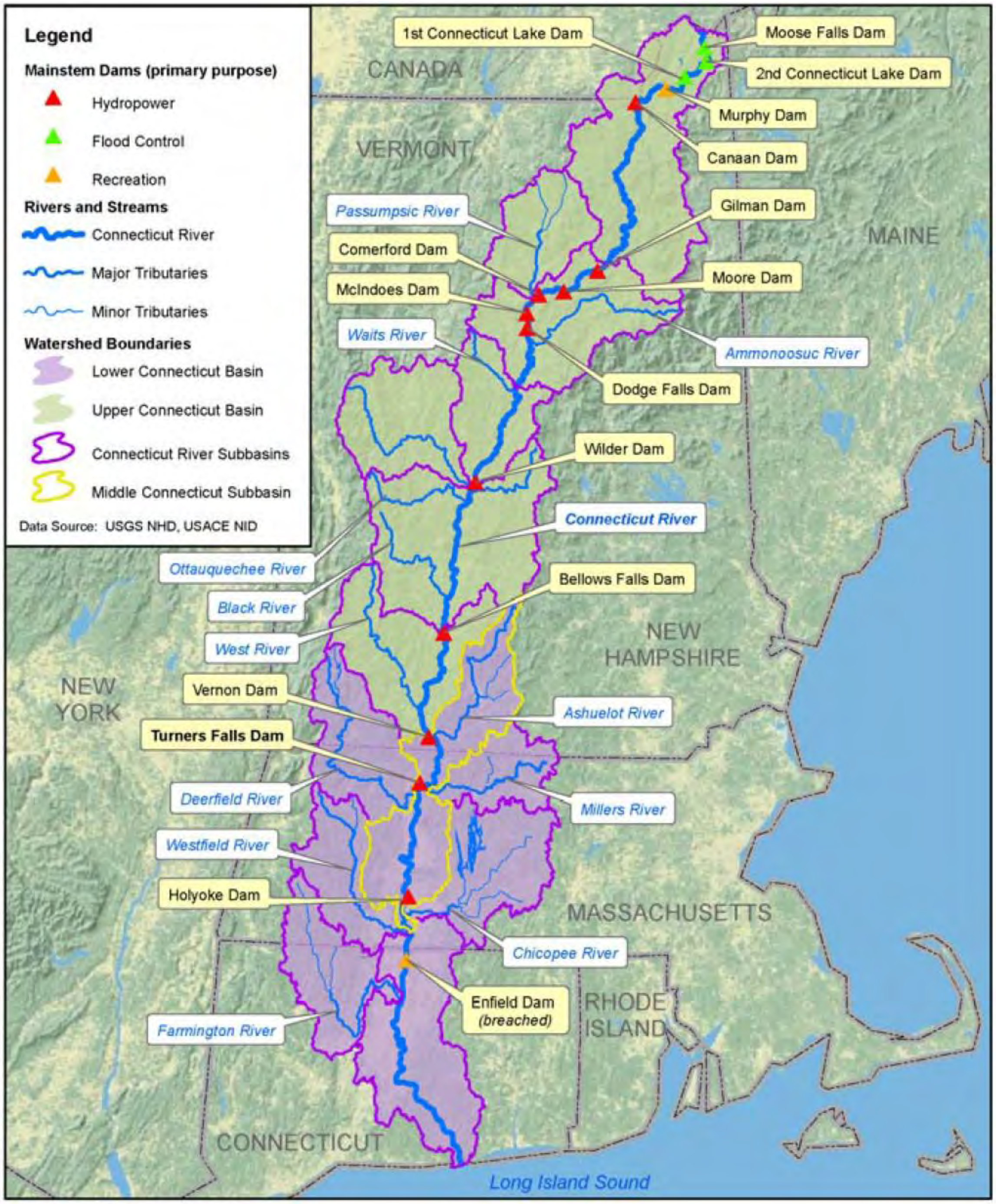


Figure 1. Connecticut River (after USGS NHD, USACE, NID)

that are periodically eroded, transported, or deposited; are – by definition, dynamic. Thus, various segments of riverbanks along the length of the Connecticut River are eroding, consistent with the dynamic nature of alluvial rivers especially considering the non-cohesive, fine-grained riverbank soils – much of which is sediment that was deposited when the Connecticut River was a lake.

Several studies of riverbank erosion along the Connecticut River have been conducted on different parts of the river and from different sources some of which are listed below.

- "Observation of Erosion on Banks of the Connecticut River Bellows Falls to Vernon September 2-3, 1954," Connecticut River Power Company, 1954

- "Connecticut River Streambank Erosion Study Massachusetts, New Hampshire and Vermont," United States Army Corps of Engineers (USACE), 1979

- "Analysis of Bank Erosion at the Skitchewaug Site in the Bellows Falls Pool of the Connecticut River," Simons & Associates, 1992

- "Bellows Falls Pond Bank Inspection," May 31, 1991, New England Power Company

- "Discussion of Erosion at Vernon Station," Simons & Associates, 1996

- "Erosion Control Plan for the Turners Falls Pool of the Connecticut River," Simons & Associates, 1998

- "Fluvial Geomorphology Assessment of the Northern Connecticut River, Vermont and New Hampshire," Field Geology Services, 2004

- "Fluvial Geomorphology Study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT," Field Geology Services, 2007

- "Full River Reconnaissance – 2008 Turners Falls Pool, Connecticut River," Simons & Associates, 2008 (Other full river reconnaissance efforts were conducted by New England Environmental in 2001 and 2004)

These reports and other available information provide sources for the evaluation of erosion along the length of the Connecticut River.

The study which covered the greatest length of the Connecticut River (USACE, 1979) included Appendix A entitled, *"Locations of Erosion Sites in the Study Reach"* confirms that erosion sites are found along the length of the river studied (Appendix A of this report presents maps showing erosion along the study reach – see numbered segments,). An example of erosion sites found along the river shows segments of river (shown by dark black lines, numbered to identify each site) in Figure 2. Erosion sites 4 through 17A are indicated on the east bank of the river and sites 302 through 305 are found on the west bank.

The distribution of erosion sites along the river from this 1979 study were as follows: 54 upstream of the Wilder Dam, 8 between Bellows Falls and Wilder Dams, 28 between Vernon and Bellows Falls Dams, 13 between Turners Falls and Vernon Dams. While the simple number of erosion sites does not fully describe the severity or length of erosion within each segment; it does, however, indicate that erosion is found along the entire length of the river that was studied. Based on the maps in the 1979 study, the total length of eroded sites for each of the impoundments was determined (see Table 1).

Table 1. Total length of erosion from 1979 USACE maps

Reach of Connecticut River	Miles of Erosion (1979 USACE maps)
Wilder Impoundment	19.84
Bellows Falls Impoundment	4.05
Vernon Impoundment	9.91
Turners Falls Impoundment	3.13

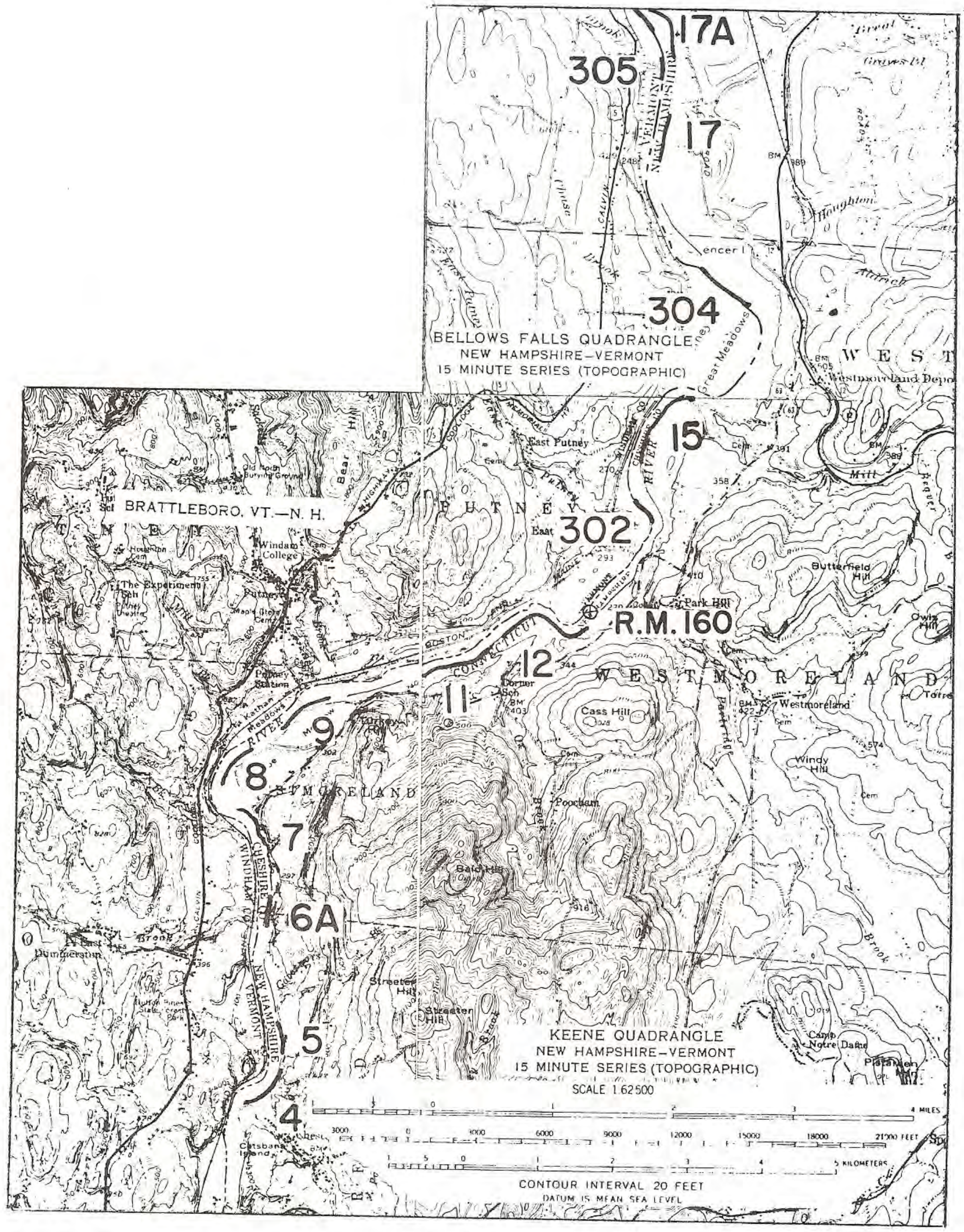


Figure 2. Erosion Sites – Keene and Bellows Falls Quadrangles, "Connecticut River Streambank Erosion Study Massachusetts, New Hampshire and Vermont," 1979

In this document, the distribution and extent of erosion along the Connecticut River is compared between the various reaches based on previous documentation of erosion from a variety of sources as well as recent and previous photographic evidence of erosion where such information is available.

2. Connecticut River Reaches

The Connecticut River includes both riverine or free-flowing reaches as well as reaches impounded by dams. Table 1 summarizes Connecticut River dams and their height, listed in order from upstream to downstream. As noted in the table, a couple of these dams are breached and no longer form upstream impoundments. River reaches in the Connecticut River are primarily defined by the existence of dams and impoundments formed by these dams.

Table 2. Dams along the Connecticut River*

Dam	Dam Height (ft)
Moose Falls Flowage	10
Second Connecticut Lake Dam	28
First Connecticut Lake Dam	56
Murphy Dam (Lake Francis)	106
Canaan Dam	27
Lyman Falls Dam	Breached
Wyoming Dam	Breached
Gilman Dam	40
Moore Dam	178
Comerford Dam	170
McIndoe Falls Dam	25
Dodge Falls Dam	28
Wilder Dam	39
Bellows Falls Dam	57
Vernon Dam	60
Turners Falls Dam	35
Holyoke Dam	60

* Information primarily from Connecticut River Joint Commissions (CRJC)

A profile of the Connecticut River for most of its length is presented in Figure 3. As shown by this profile, much of the river is impounded behind a series of dams as listed above. The longest reach that is not impounded stretches downstream from Pittsburg to the Wyoming Valley (since Wyoming dam was breached).

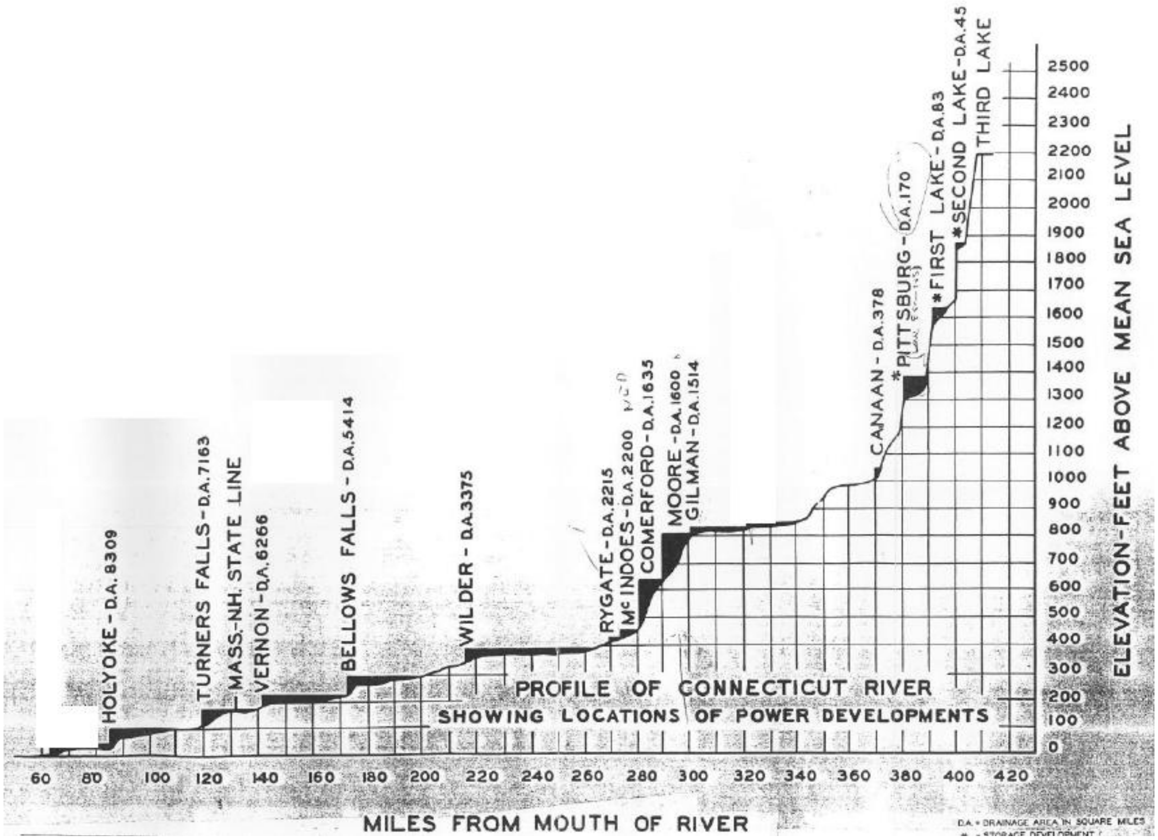


Figure 3. Connecticut River profile (after, US Generation).

Dams generally reduce the river velocity, depending on the magnitude of river flow compared to the magnitude and extent of the impoundment storage volume. In addition to the main-stem dams, several United States Army Corps of Engineers flood control dams have been constructed on tributaries to the Connecticut River to reduce peak flows and flood damage.

3. Natural Riverine Geomorphology

Except for rare segments of the Connecticut River like the French King Gorge located in the Turners Falls Impoundment, which consists of extensive rock outcrop; the Connecticut River, through a significant portion of its length, is an alluvial river. An alluvial river consists of bank and bed material that the river itself transports, deposits, or erodes. Alluvial rivers, consisting of materials that are periodically eroded, transported, or deposited are – by definition, dynamic.

The dynamic nature of rivers is described in one of the foremost and well-known textbooks, Fluvial Processes in Geomorphology (Leopold, Wolman and Miller, 1964). Chapters of interest that indicate the dynamic nature of rivers include: Chapter 1 – "The Changing Scene," Chapter 3 – "Climate and Denudational Processes," Chapter 4 – "Weathering," Chapter 10 – "Drainage Pattern Evolution," Chapter 11 – "Channel Changes with Time," Chapter 12 – "Evolution of Hillslopes." Key words of note directly discuss the fact that rivers change: changing, denudational processes, weathering, evolution, changes with time. The aftermath of Hurricane Irene in 2011 provided a recent and dramatic reminder of disruption and change that occurs in living with the dynamic nature of rivers. Leopold et al, discusses the continual adjustments of river systems through processes of aggradation, degradation, scour, deposition, and lateral migration; providing numerous examples of rivers that have historically experienced significant changes.

Even the concept of a river in equilibrium (as described below) does not mean that a river, so classified, is not changing. In discussing the concept of equilibrium in an ideal channel, Leopold et al state the following:

> *This analysis brings out an essential point. In the simplest stable natural channel with movable bed and banks, two conditions must be satisfied simultaneously – the transmission of the flow and the stability of the banks. Such a channel has been called "threshold" (Henderson, 1961, p. 112), describing the fact that each point on the perimeter is at the threshold of movement. In this hypothetical condition a channel could not transport sediment because the required increase in stress would cause erosion of the banks. In actuality a natural channel not only carries sediment but migrates laterally by erosion of one bank, maintaining on the average a constant channel cross section by deposition at the opposite bank. In this case the condition of no bank erosion is replaced by an equilibrium between erosion and deposition. The form of the cross section is "stable," meaning constant, but position of the channel is not.*

Thus, an ideal natural channel in equilibrium essentially means that the channel size generally retains an overall unchanging average size, with erosion in one place balanced by deposition in another, resulting in a channel changing its position over time. Changing position, even while retaining overall average channel geometry, necessarily means riverbank erosion occurs even in such channels that are considered to be in equilibrium.

The concept of the dynamic nature of rivers is confirmed by another eminent geomorphologist (Schumm, 1977, The Fluvial System) states,

> *Frequently environmentalists, river engineers, and others involved in navigation and flood control consider that a river should be unchanging in shape, dimensions and pattern. This would be very convenient. However, an alluvial river generally is changing its position as a consequence of hydraulic forces acting on its bed and banks.*
>
> *Archaeologists have provided clear evidence that the lateral shift of channels is completely natural and to be expected.*
>
> *In summary, archaeological, botanical, geological, and geomorphic evidence supports the conclusion that most rivers are subject to constant changes as a normal part of their morphological evolution.*

As noted by some of the world's most renowned geomorphologists, even those river reaches considered to be in "equilibrium" are expected to experience lateral movement and adjustment which necessarily involves the process of riverbank erosion. To expect otherwise contradicts reality and denies extensive historic evidence on rivers throughout the world. Erosion is a natural process, even in channels in equilibrium that cannot and should not be totally controlled.

4. Current State of Riverbank Erosion along the Connecticut River

4.1 Free-Flowing Reach

The longest free-flowing reach of the Connecticut River extends from Pittsburg, NH downstream to Gilman Dam (excluding the small reach affected by Canaan Dam, see Figure 3). A study of the condition of the Northern Connecticut River through this largely unimpounded and primarily alluvial reach (Figure 4) was conducted by Field Geology Services (2004, "Fluvial Geomorphology Assessment of the Northern Connecticut River, Vermont and New Hampshire").

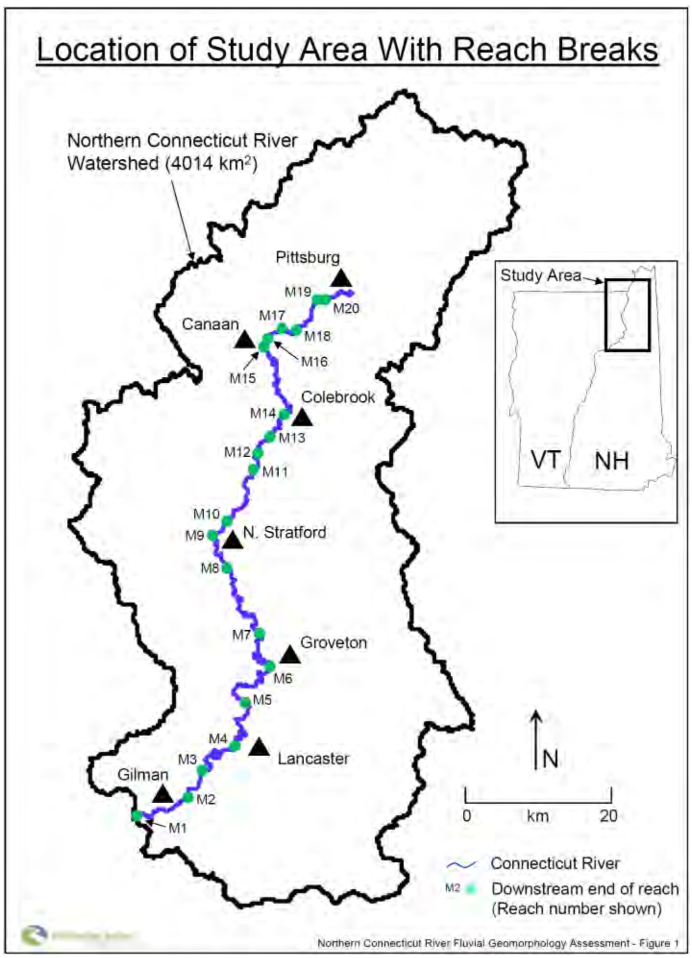


Figure 4. Northern Connecticut River (after Field, 2004)

As an integral part of this analysis, the river was evaluated regarding channel instabilities and erosion, as Field (2004) states that, *"Management of erosion problems must address, or at least recognize, the causes for erosion."* He cites six primary causes for erosion in this unimpounded reach of the Connecticut River:

> *Six of the most important human and natural causes of erosion and channel instability are discussed below: 1) channelization; 2) land clearance and other human land use intributary watersheds; 3) continuing adjustments to deglaciation; 4) agricultural practices in the riparian zone; 5) dams; and 6) reforestation of hillslopes cleared in the 18th and 19th Century.*

Field presents several figures illustrating the causes of erosion in this free-flowing reach of the river (see Figures 5-8).

Figure 5. Erosion in channelized reach (after Field, 2004)

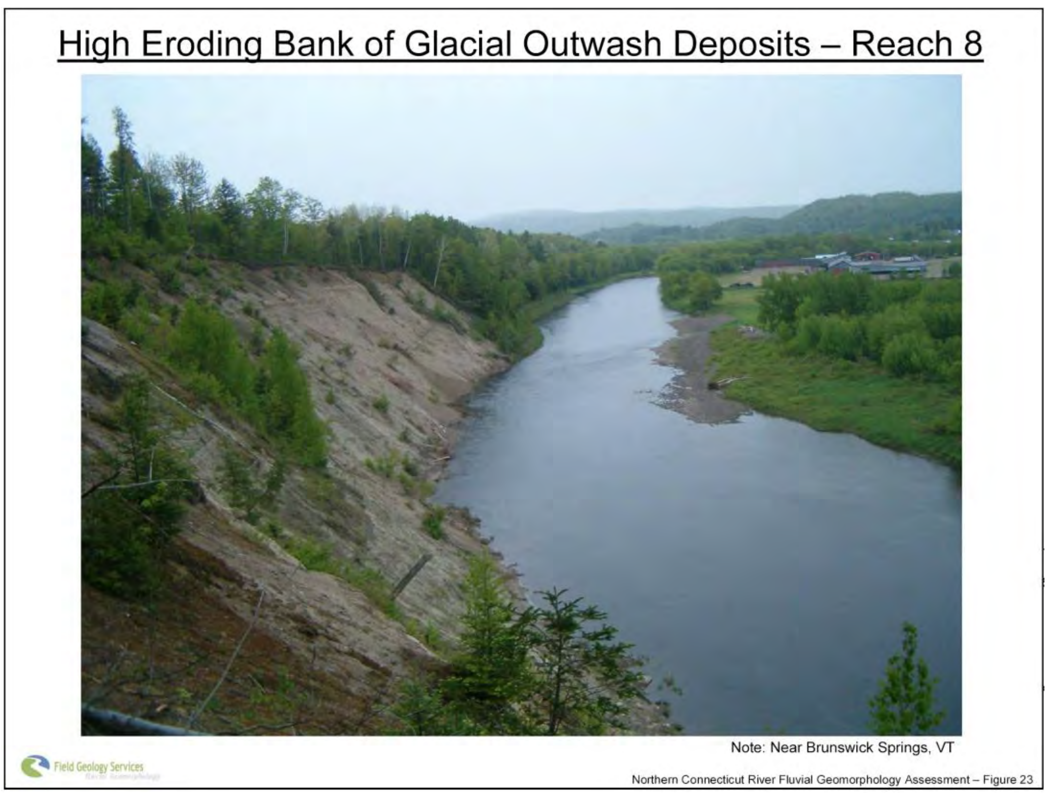


Figure 6. Erosion of glacial outwash deposit (after Field, 2004)

Figure 7. Erosion due to bar formation (after Field, 2004)

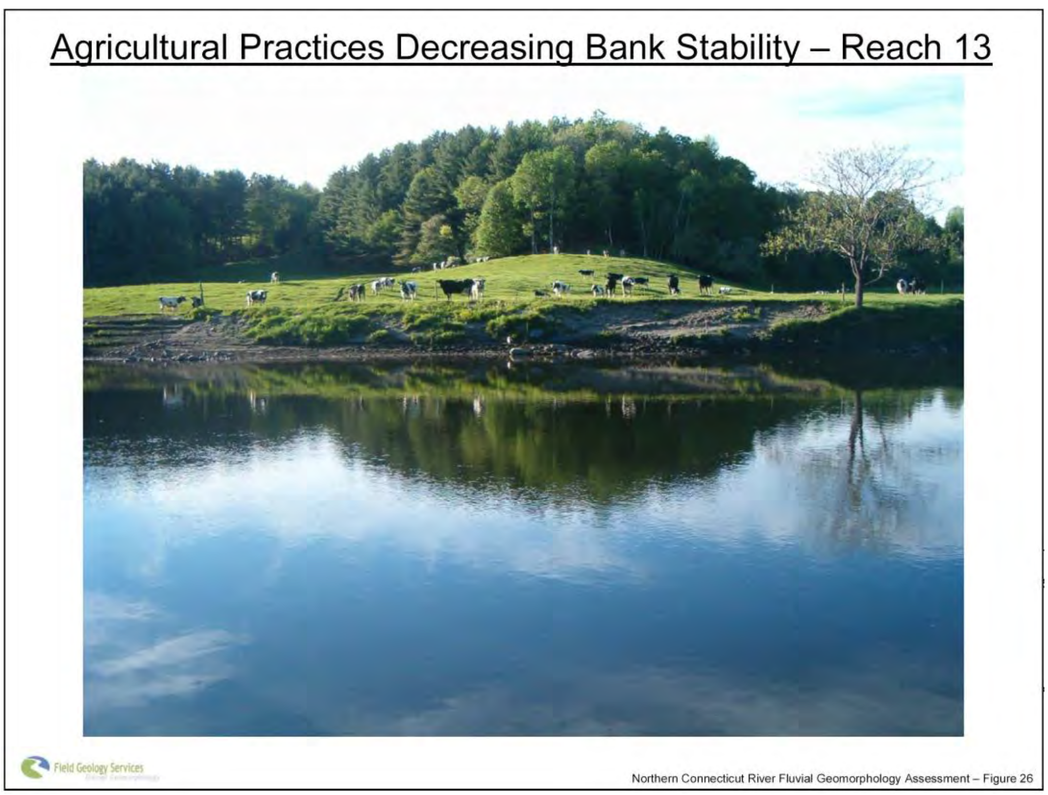


Figure 8. Erosion due to agricultural practices (after Field, 2004)

The distribution of riverbank erosion through this reach was summarized by Field as shown in Figure 9; eroding banks are shown in red.

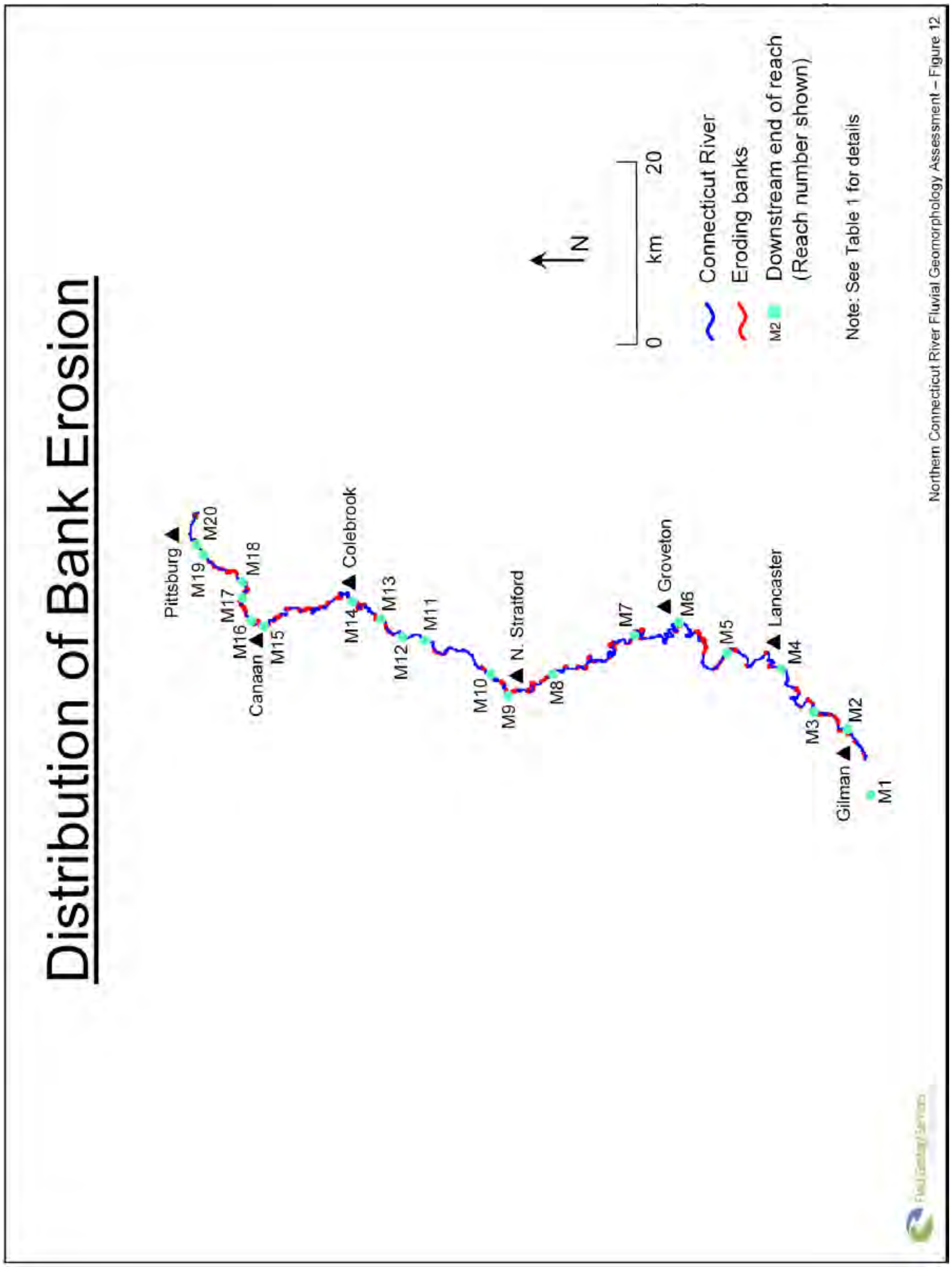


Figure 9. Riverbank erosion – Pittsburg to Gilman (after Field, 2004)

This reach of river in the study area *"is largely free flowing and unimpounded, unlike much of the river farther south.*" The report concludes:

> *A fluvial geomorphic assessment of the northern Connecticut River has revealed that 66 percent of the river's banks are either eroding, have been protected from erosion, or are susceptible to further erosion (Table 1).*

Table 1 (from the aforementioned report) provides information on bank stability indicating that 25.8 % (42.62 miles) of the length was "Eroding," and 22.6% (37.26 miles) was "Moderately eroding." Based on this information, this free-flowing reach experiences moderate or more significant erosion over almost half (48.4%, 79.88 miles) of its length. The same table shows that 17.1% (28.30 miles) of the riverbanks have been rip-rapped. The total length of both banks combined in this northern reach is 165.12 miles.

Additional maps were prepared by Field in 2005 showing riverbank characteristics and erosion. Figure 10 (after Field Geology Services, 2005) shows a portion of this free-flowing reach with the various aspects related to channel characteristics and stability or erosion. Appendix B presents other maps prepared by Field showing the riverbank conditions in this free-flowing reach.

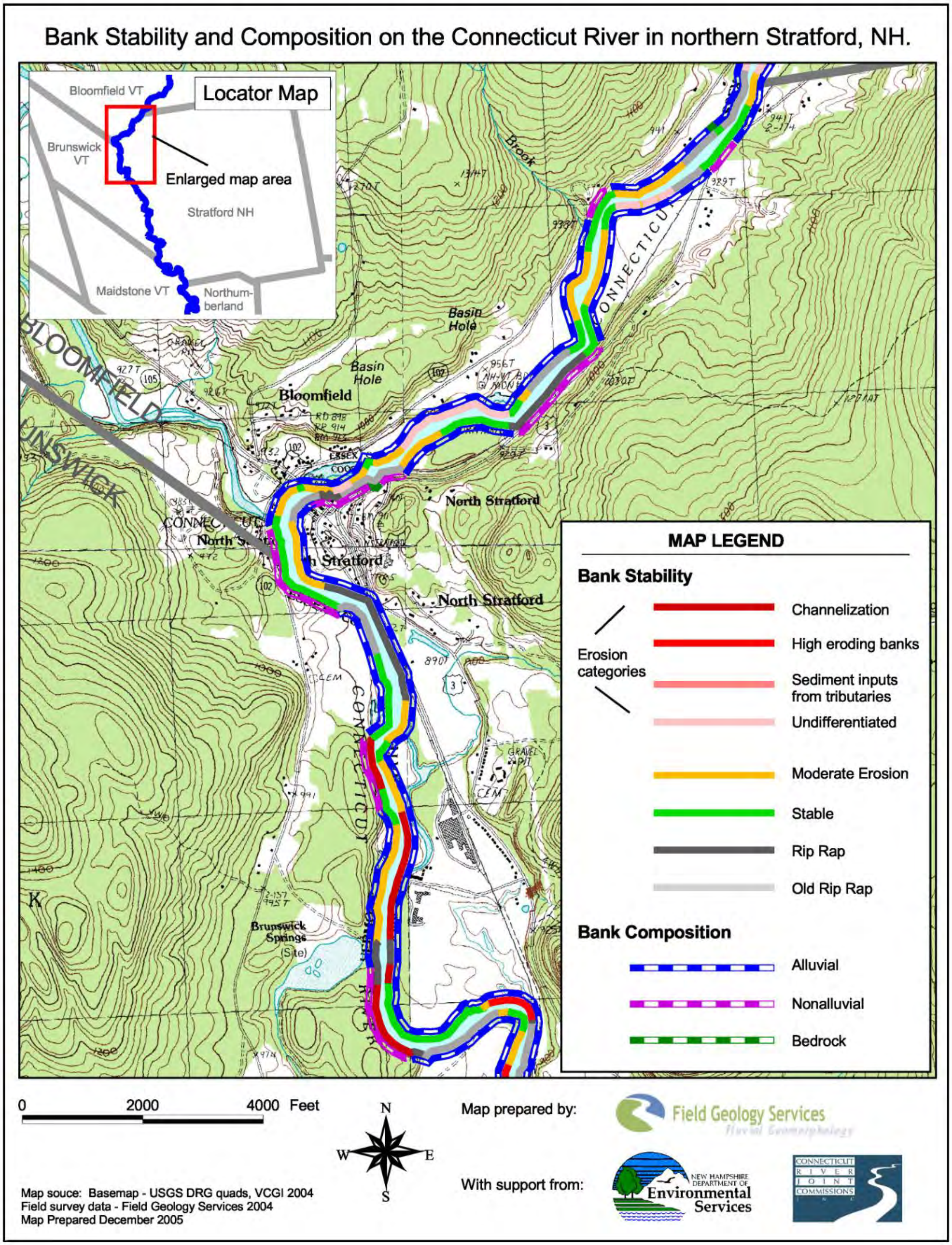


Figure 10. Example of Riverbank Characteristics – Northern, Free-Flowing Reach

4.2 Connecticut River Impoundments

4.2.1 Riverbank Erosion – Bellows Falls Impoundment

In addition to erosion sites documented by the USACE (1979) that included the Bellows Falls reach, a bank inspection was conducted in 1991 by the New England Power Company (included in this report as Appendix C). More recently, some erosion sites were identified and photographed in 1997 and again in 2008 by S&A. The location of the erosion sites are shown in Figure 11. An example comparing erosion from 1997 to 2008 is presented in Figure 12. As this example shows, the extent of erosion is similar and has continued over this 11-year time period (see Appendix D for a comparison of photos of erosion sites from 1997 to 2008 in the Bellows Falls Impoundment). The various sites where erosion was documented in 1997 were still eroding in 2008. While the full extent of erosion is not known in this impoundment in terms of mileage or percentage, geo-referenced video tapes were made of much of this impoundment that document the conditions as of 2008.

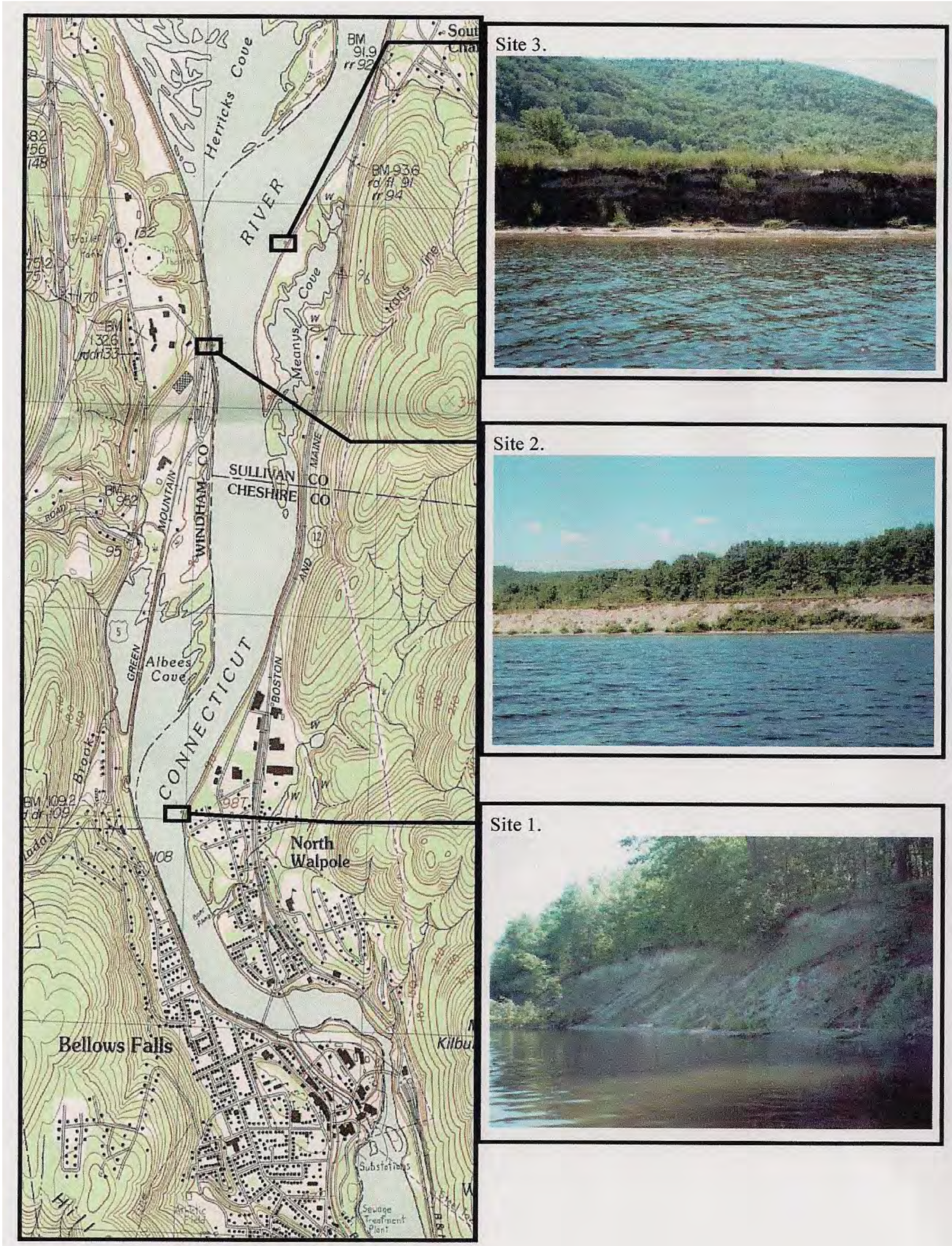


Figure 11a. Erosion Sites – Bellows Falls Impoundment, 1997

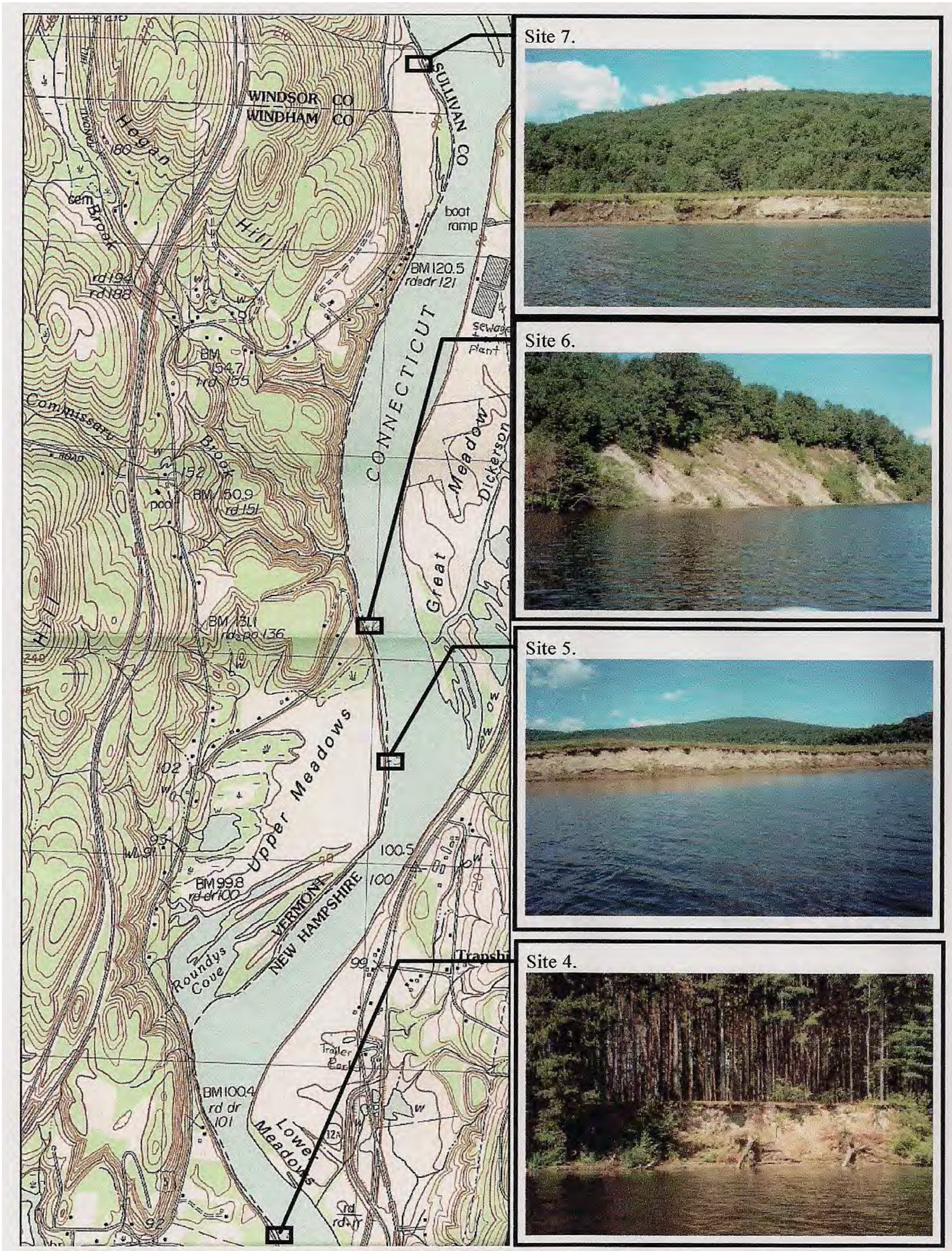


Figure 11b. Erosion Sites – Bellows Falls Impoundment, 1997

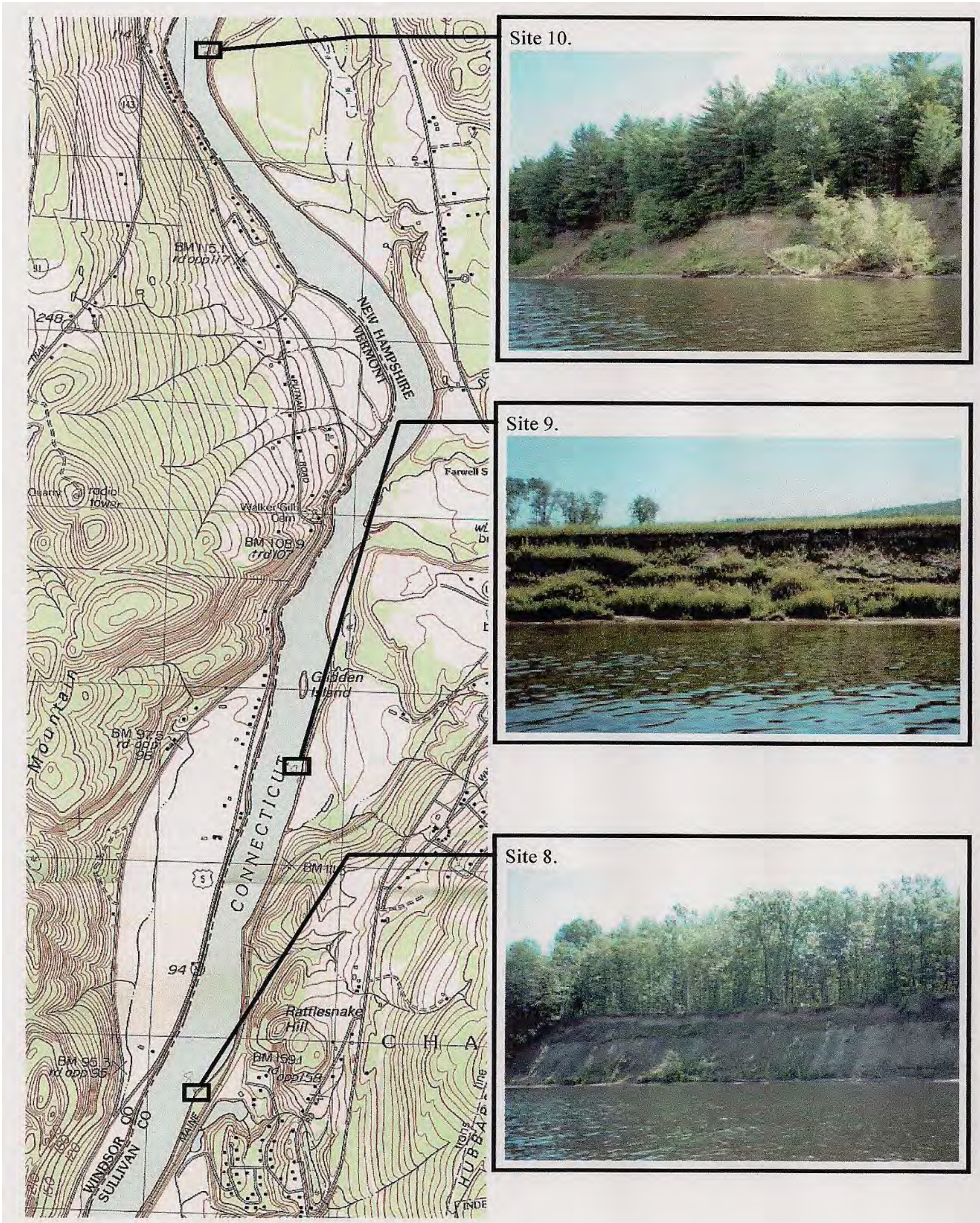


Figure 11c. Erosion Sites – Bellows Falls Impoundment, 1997

Bellows Falls Pool – Location 8

1997

2008

Figure 12. Riverbank erosion comparison, Bellows Falls Impoundment – Location 8

4.2.2 Riverbank Erosion – Vernon Impoundment

Similar to the Bellows Falls Impoundment, erosion sites along the Vernon Impoundment were also photographed in 1997 and again in 2008. The locations of the erosion sites and images of the sites are shown in Figure 13. Figure 14 presents a comparison of erosion at a location in the Vernon Impoundment in 1997 and 2008, and shows that there are similar erosion and riverbank characteristics over this decade (see Appendix E for a comparison of photos of erosion sites from 1997 to 2008 in the Vernon Impoundment). The various sites that had documented erosion in 1997 were still eroding in 2008. While no evaluation of the extent or percentage of riverbanks experiencing erosion is available, geo-referenced video tapes were taken to document riverbank conditions for this reach of river in 2008.

As listed in available references, the power company that was operating the Vernon Station during the 1950s documented erosion in the Vernon Impoundment on a periodic basis. The 1954 document discusses and shows about 50 erosion sites that were photographed. Apparently, they were monitoring erosion sites along the Vernon Impoundment over time and documenting them by noting changes and taking photographs. Figure 15 presents an example of an erosion site taken by the Connecticut River Power Company in 1954. Other examples are found in Appendix F. The existence of this document shows that erosion has been an issue of concern for over half a century.

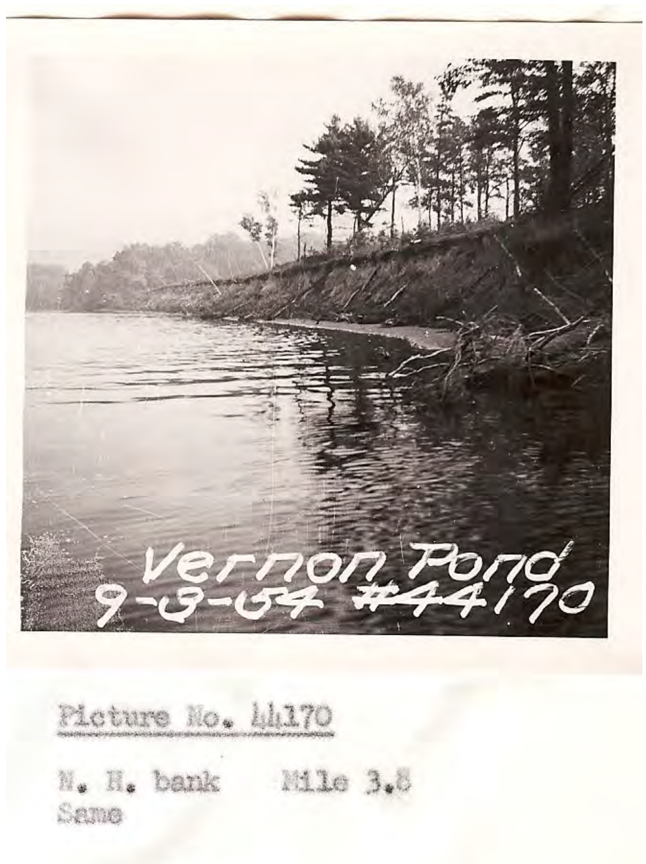


Figure 15. Erosion in Vernon Pool, 1954

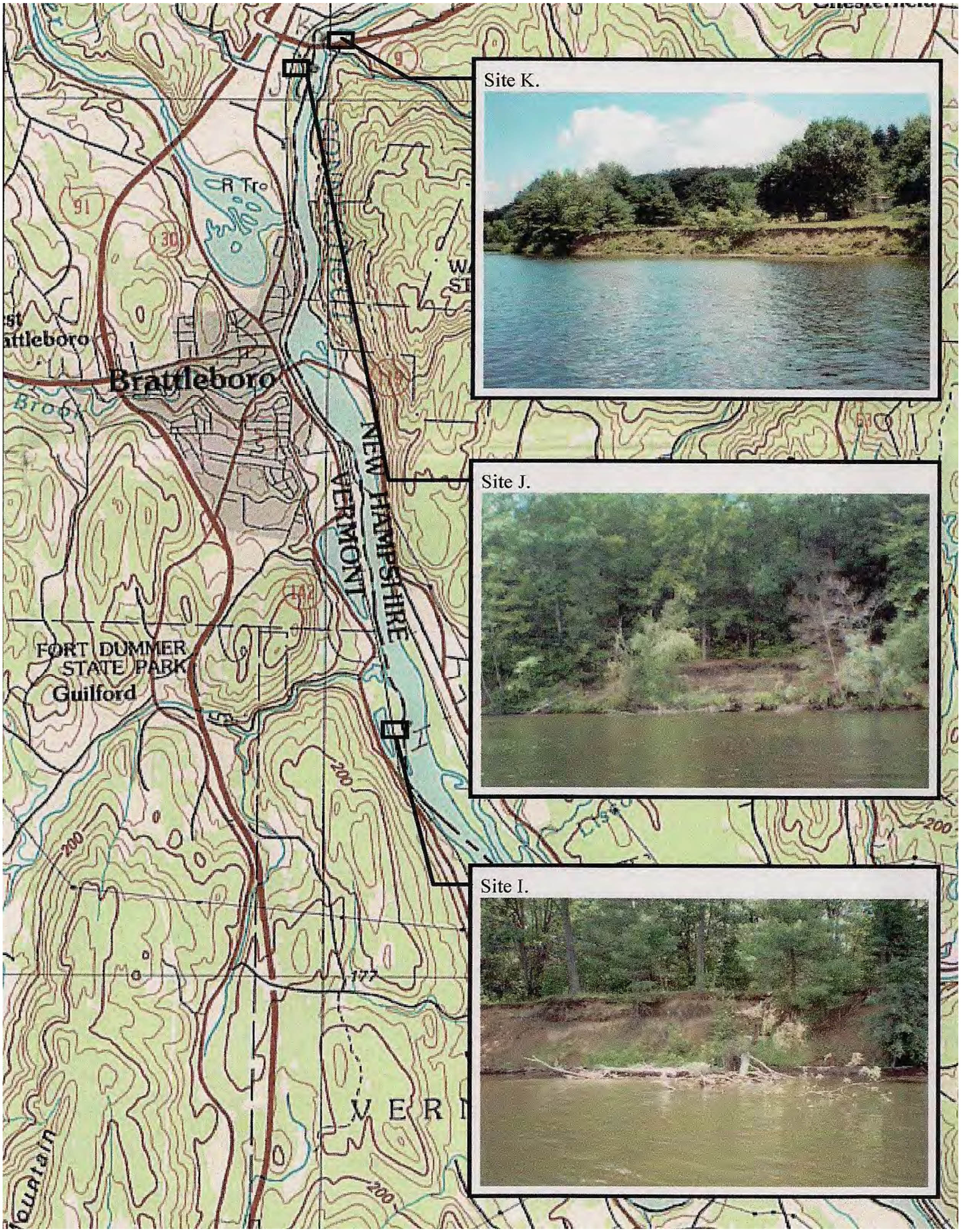


Figure 13a. Erosion Sites – Vernon Impoundment, 1997

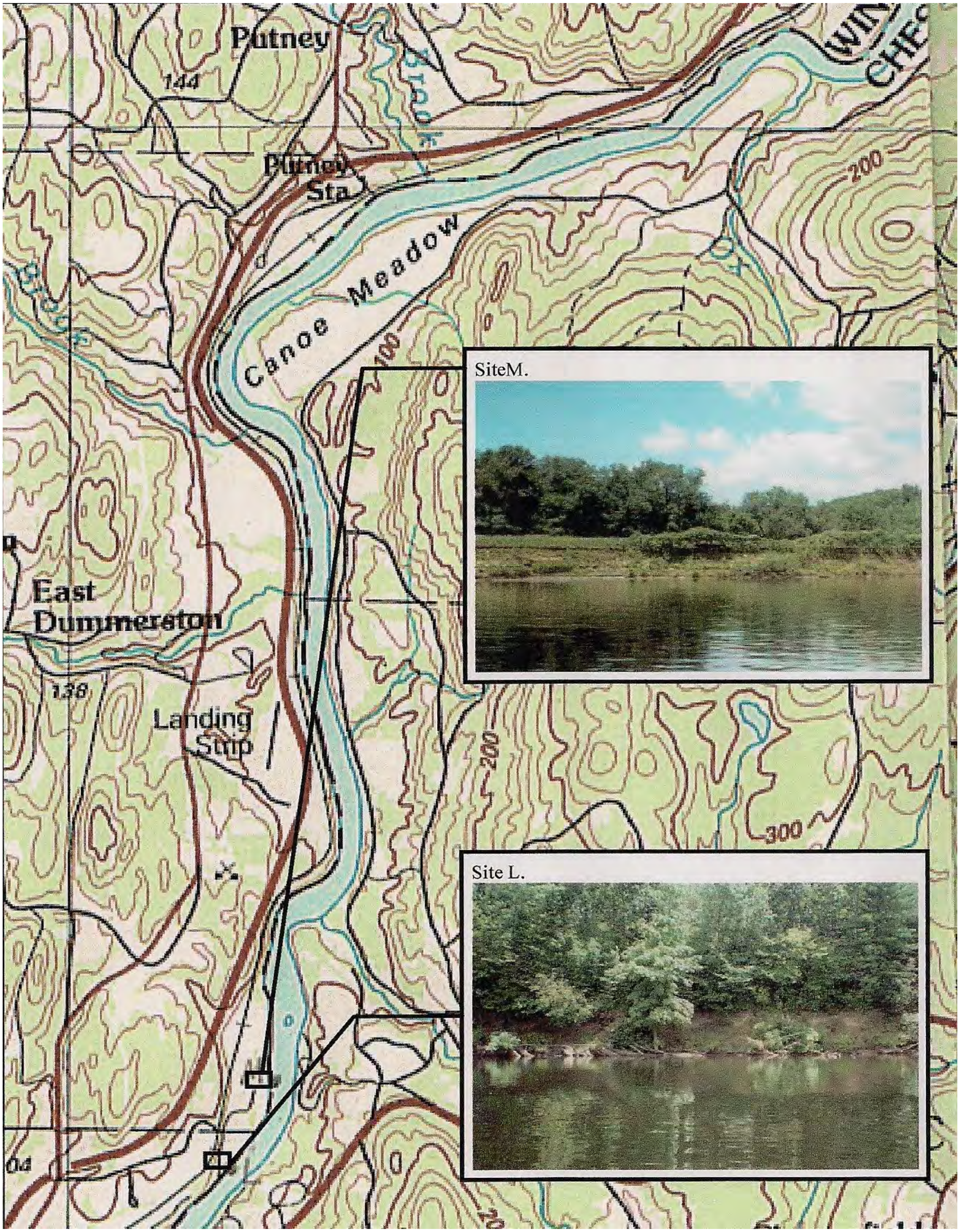


Figure 13b. Erosion Sites – Vernon Impoundment, 1997

Vernon Pool – Location I

1997

2008

Figure 14. Riverbank erosion comparison, Vernon Impoundment, 1997-2008, Location I

4.2.3 Riverbank Erosion – Turners Falls Impoundment

Riverbank erosion in the Turners Falls Impoundment has also been studied and monitored for several decades. In 1998 an Erosion Control Plan (Simons & Associates, 1998) was developed for the Turners Falls Impoundment which mapped riverbank features and characteristics to select 20 sites to be considered for stabilization. As part of the Federal Energy Regulatory Commission (FERC) license for the Northfield Mountain Pumped Storage Project and Turners Falls Hydroelectric Project, the Licensee is required to conduct full river reconnaissance (FRR) surveys of the Turners Falls Impoundment every 3-5 years to document erosion areas and the results of stabilization measures that have been implemented. An FRR was conducted in 2008 (Simons & Associates, 2009). The report provides documentation of the distribution of riverbank features and characteristics in the form of detailed maps of riverbank sediment types, slope, height, vegetation, severity and type of erosion. In addition to the maps showing the detailed breakdown of features and characteristics, summary maps were developed that delineated riverbank conditions into 8 broad groups of combination of features and characteristics related to stability or erosion (Table 2). An example of the results of the 2008 FRR (Simons & Associates, 2009) is shown in Figure 16. Segments of riverbank marked with hot pink, red, orange, and yellow are experiencing the most significant erosion while segments of river marked in blues, brown, green, and black exhibit stability. Appendix G presents the summary maps for the 2008 FRR. Detailed maps of all features and characteristics are found in the 2008 FRR report (Simons & Associates, 2009).

The score or group of characteristics in the 2008 Turners Falls Impoundment reconnaissance is explained in the following table.

Table 3. 2008 FRR Summary Groups

Group/Score	**Characteristics**
1	Extensive mass wasting (erosion)
2	Some mass wasting (erosion)
3	None to sparse upper bank vegetation
4	Moderate to heavy vegetation with steep to overhanging banks
5	Moderate to heavy vegetation with moderate upper bank slope and moderate to steep lower banks
6	Moderate to heavy vegetation with moderate upper bank slope and flat lower bank slope
7	Moderate to heavy vegetation with flat upper bank slope and flat lower bank slope
8	Rock

Results of the 2008 FRR showed that 83.3% of the riverbanks showed little to no erosion, while some erosion was found for 16.1% of the reach and extensive erosion was found in 0.6% of the Turners Falls Impoundment.

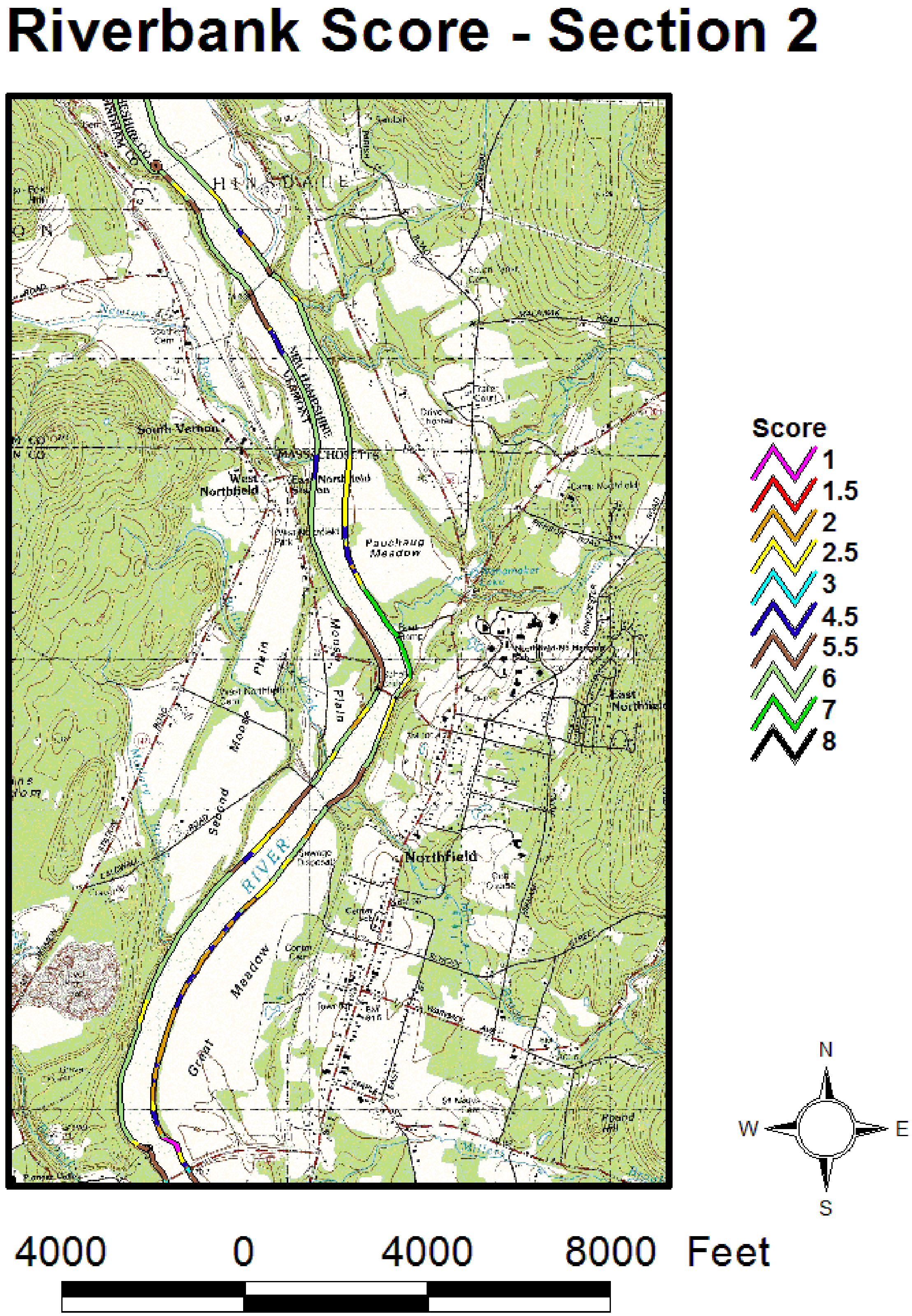


Figure 16. Example of Full River Reconnaissance Map – Turners Falls Impoundment

Photographs are available at several erosion sites in the Turners Falls Impoundment taken before and after riverbank stabilization projects that have occurred with implementation of the ECP. Many of the erosion sites identified in the ECP have been stabilized by a range of measures including placement of rock at the toe of the slope, coir logs, placement of large woody debris, various fabrics, and planting of vegetation including riparian and aquatic. Some re-shaping of riverbanks has also been conducted at some sites. An example of the transformation from an unstable, eroding riverbank to a stabilized riverbank is shown in Figure 17. As shown by this comparison of photos from before 2004 to 2008, the eroding bank has been stabilized by placing relatively small rock at the toe of the slope and planting vegetation above the rock on the formerly eroded bank. The 2008 photo shows the transformation from erosion to stability accomplished by this effort. Appendix H provides other examples of riverbank stabilization efforts in the Turners Falls Impoundment. From the commencement of implementation of the ECP to the present, approximately 14,000 feet of riverbank have been stabilized in the Turners Falls Impoundment.

In addition to stabilization of erosion sites, natural stabilization processes as a result of increasing expansion of vegetation has been observed over the period from 1998 to 2008. Areas of increased vegetation on upper riverbanks – both relative to density as well as height have been observed over this time period. Some areas of dense aquatic vegetation on lower riverbanks have also been observed. An example of natural stabilization processes is shown in Figure 18 where ongoing erosion processes are evident in 1996 with numerous trees that have fallen down, other trees tipping and on the verge of falling along with fresh erosion scars. This area of erosion is located immediately downstream of Vernon Dam on the east side of the Connecticut River. In 2008, there are no recently fallen trees, very few tipping trees, and an increased band of trees and other vegetation is growing in the transition area between the steep upper bank and the flatter lower bank where beach formation is evident. Less fresh erosion scarring can be seen. Other examples of these natural stabilization processes through increasing vegetation expansion in the Turners Falls Impoundment are shown in Appendix I. Additional expansion of vegetation was also noted during a field trip observing riverbank conditions taken in the fall of 2009.

Site 6 – Skalski, prior to 2004

Site 6 – Skalski, 2008 (from Maintenance Inspection Report)

Figure 17. Comparison of Skalski Site pre 2004 to 2008


1996 – Eddy-induced erosion downstream of Vernon Dam


2008 – Eddy-induced erosion downstream of Vernon Dam

Figure 18. Natural stabilization processes 1996-2008 downstream of Vernon Dam

4.2.4 Riverbank Erosion – Holyoke Impoundment

Erosion sites identified in the Holyoke Impoundment were photographed in 1997 and again in 2008. The locations of the erosion sites are shown in Figure 19. An example of riverbank erosion in the Holyoke Impoundment from 1997 to 2008 is shown in Figure 20. The extent and severity of erosion is similar and has continued over this 11-year time period (see Appendix J for a comparison of photos of the various erosion sites from 1997 to 2008 in the Holyoke Impoundment). The various sites eroding in 1997 were still eroding in 2008. While no evaluation of the extent or percentage of riverbanks experiencing erosion is available, geo-referenced video tapes were taken to document riverbank conditions for this reach of river in 2008.

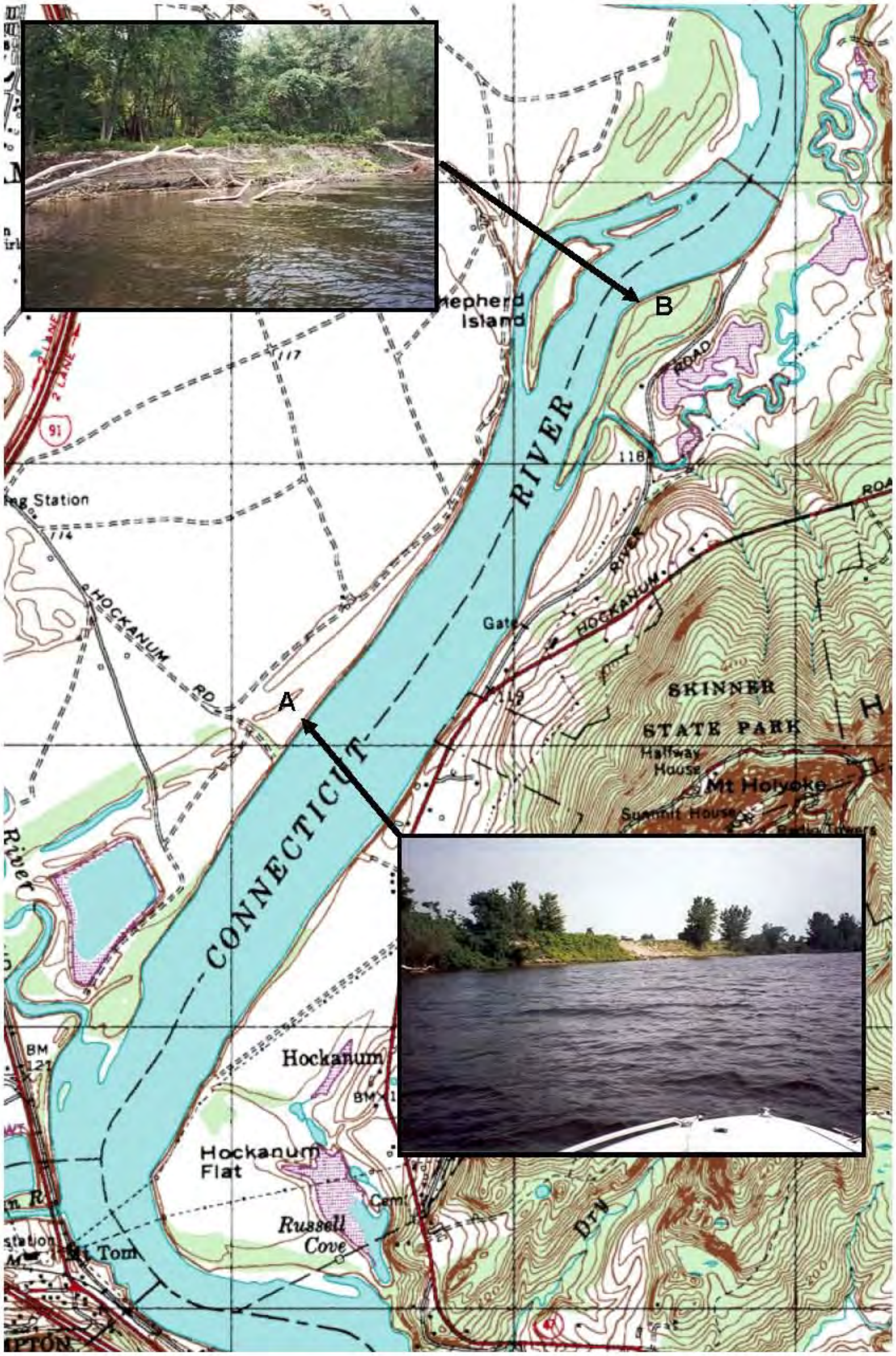


Figure 19a. Location of Erosion Sites – Holyoke Impoundment, 1997

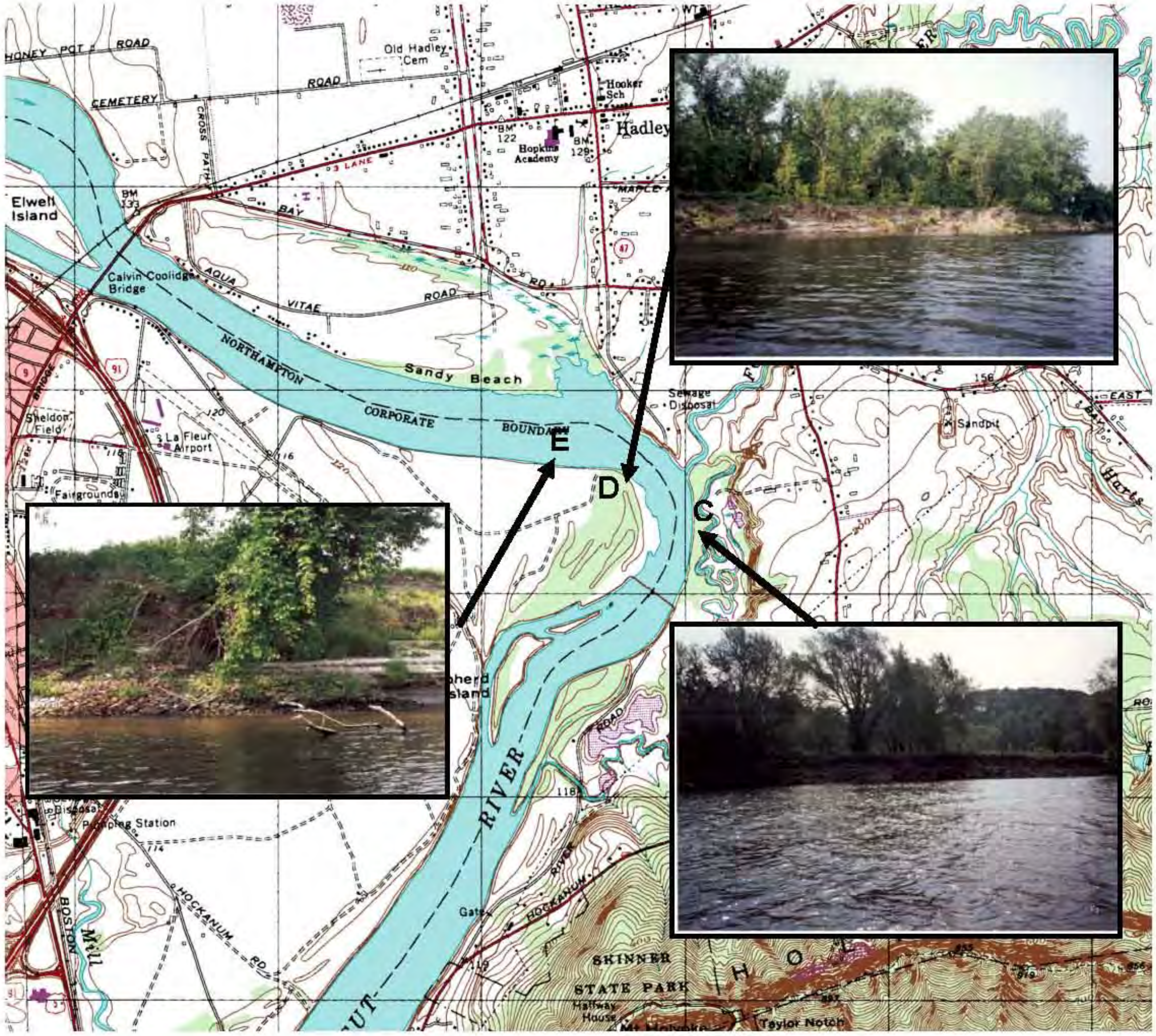


Figure 19b. Location of Erosion Sites – Holyoke Impoundment, 1997

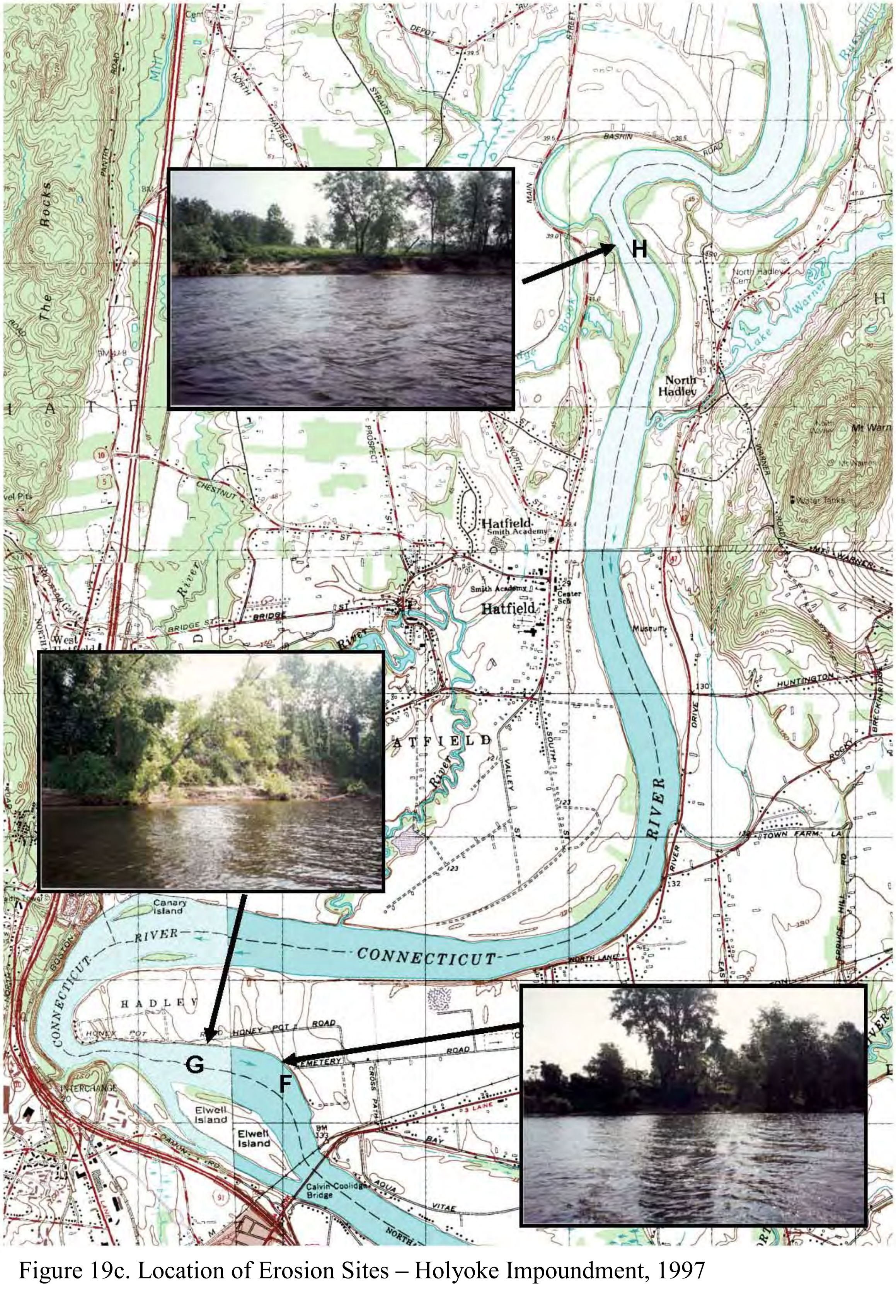


Figure 19c. Location of Erosion Sites – Holyoke Impoundment, 1997

Holyoke Pool – Location D

1997

2008

Figure 20. Riverbank Erosion Holyoke Impoundment, Site D 1997-2008

5. Discussion of Erosion along the Connecticut River

Information from a variety of sources was compiled regarding riverbank erosion along the Connecticut River. Available information covers most of the Connecticut River including from many of the low-head hydropower impoundments including Bellows Falls, Vernon, Turners Falls, and Holyoke Impoundments as well as from the longest free-flowing reach from Pittsburg to Gilman. The reaches not covered by the available information include: a) the uppermost reach from its origin to Canaan Dam, b) the seasonally fluctuated storage reservoirs (Comerford and Moore Reservoirs), and from Holyoke Dam to Long Island Sound. Information from approximately 240 miles of river was obtained representing 59% of the overall river length. A wide range of flow/operation conditions occur in these reaches for which riverbank erosion information was obtained.

Riverbank erosion occurs in the reaches described above whether free-flowing or impounded for hydropower operations. The ubiquitous nature of riverbank erosion in the Connecticut River provides yet another example of the dynamic nature of rivers explained in the scientific literature. The scientific literature (Leopold, et al, 1964) states that even under ideal conditions in the so-called "equilibrium" channel in real-world conditions:

> *In actuality a natural channel not only carries sediment but migrates laterally by erosion of one bank, maintaining on the average a constant channel cross section by deposition at the opposite bank. In this case the condition of no bank erosion is replaced by an equilibrium between erosion and deposition. The form of the cross section is "stable," meaning constant, but position of the channel is not.*

Furthermore, Schumm (1977) states that,

> *Frequently environmentalists, river engineers, and others involved in navigation and flood control consider that a river should be unchanging in shape, dimensions and pattern. This would be very convenient. However, an alluvial river generally is changing its position as a consequence of hydraulic forces acting on its bed and banks.*
>
> *Archaeologists have provided clear evidence that the lateral shift of channels is completely natural and to be expected.*
>
> *In summary, archaeological, botanical, geological, and geomorphic evidence supports the conclusion that most rivers are subject to constant changes as a normal part of their morphological evolution.*

The fact that erosion is found in all reaches and all conditions encountered in the alluvial sections of the Connecticut River is to be expected as a natural part of alluvial channel geomorphology.

As demonstrated by the available information, riverbank erosion occurs in all reaches of the Connecticut River. Beyond this basic fact, there are differences in hydraulics and hydrology – some reaches are subject to peaking hydropower operations and others not that provide insight into the potential effect on riverbank erosion. The Connecticut River is separated into three types of reaches including: a free-flowing reach from Pittsburg to Gilman; low-head hydropower impoundments that operate in both run of river and peaking power modes (Wilder, Bellows Falls, Vernon, and Holyoke[2]); and low-head hydropower impoundment that operates in run of river and peaking power modes plus pumped-storage mode (Turners Falls). The following points can be made based on the available information and observation of these three types of reaches.

The free-flowing reach (Pittsburg to Gilman):

- This reach responds to a relatively natural seasonal hydrograph and associated natural water level variations.
- The velocity of flow in this free-flowing reach is generally higher than impounded reaches. The channel bed slope of the river is generally steeper resulting in increased velocities.
- Based on Field's (2004) evaluation, the primary causes of erosion are: *"1) channelization; 2) land clearance and other human land use in tributary watersheds; 3) continuing adjustments to deglaciation; 4) agricultural practices in the riparian zone; 5) dams; and 6) reforestation of hillslopes cleared in the 18th and 19th Century."*
- Significant riverbank stabilization and erosion protection has been constructed with 17.1% of the riverbanks being rip-rapped.
- Erosion in some unprotected areas was attributed to erosion protection in adjacent segments of riverbank.
- Observations indicate boat use in this free-flowing reach is predominantly smaller boats (fishing, duck hunting) rather than larger boats that typically are used in impounded reaches.
- Field's (2004) study showed that 25.8% of the riverbanks were eroding, 22.6% were moderately eroding for a total of 48.4% of the riverbanks experiencing erosion.

The low-head hydropower reaches with run of river/peaking operation (Wilder, Bellows Falls, Vernon, and Holyoke):

- These low-head dams create relatively narrow impoundments with decreased velocities through a range of flows.
- These hydropower plants generally operate either as run-of-river, when flows exceed the hydraulic generating capacity of the project; or as a peaking project, when flows are within the hydraulic generating capacity of the project. Peaking power operations result in fluctuations in water level in the impoundment upstream of the dam and fluctuations in flow and water level in the impoundment

[2] While Holyoke is technically a daily cycle hydropower operation, the storage capacity of the upstream reservoir is so limited that it essentially operates as a run-of-river facility.

downstream of the dam. Multiple boat launches exist along these impoundments and motorized boats resulting in waves are used on these impoundments.
- While some localized riverbank stabilization exists, almost all erosion sites identified in 1997 appeared to be in essentially the same condition in 2008 indicating that these sites of significant erosion continue to experience erosion.

Turners Falls Impoundment with low-head hydropower impoundment operating in both run-of-river and peaking power mode plus pumped storage:

- This low-head dam creates a relatively narrow impoundment that generally decreases velocities through a range of flows. The French King Gorge (a narrow, rocky gorge) located a relatively short distance upstream of the Turners Falls Dam creates a pinch-point (natural hydraulic control) such that hydraulic conditions at moderate to high flows in the river upstream of the gorge are controlled by the natural resistance to flow and restriction of the flow through this narrow gorge. Thus, this reach operates as an impoundment at low to moderate flows, but from moderate to high flows; the reach upstream of French King Gorge operates as a river being controlled by this natural constriction.
- Turners Falls Hydroelectric Project operates as a run-of-river project when flow exceeds the facility's turbine capacity and generally in a peaking mode when flows are below the turbine capacity. Hydroelectric operations at the upstream end of the impoundment follow the same modes (peaking when the flow is less than hydraulic generating capacity and run-of-river when the flow is greater than the hydraulic capacity) due to operations at Vernon Dam. Additionally, the Northfield Mountain Project operates as a peaking project, typically generating during the day and pumping water to the upper reservoir at night. Water level fluctuations in the Turners Falls Impoundment are the result of operations at Vernon which propagate flow and water level fluctuations through the impoundment as well as due to operations at the Turners Falls and Northfield Mountain Projects. These operations and analyses of hourly data are found in Simons & Associates, 2012. Multiple boat launches exist along the impoundment and powerboats are used on this impoundment.
- Many erosion sites identified in the 1990s have been stabilized through implementation of the ECP.

The fact that riverbank erosion exists in a variety of conditions (free-flowing and impounded) along the Connecticut River with different operations (run of river/peaking power, pumped storage) and responses provides an opportunity to learn from this range of conditions and differences or similarities between the various reaches. Various points can be made based on a comparison of these reaches of river.

- The greatest percentage (48.4%) of erosion occurs in the northern unimpounded, free-flowing reach from Pittsburg to Gilman. This is consistent with the 1979 USACE analysis where a theoretical comparison of hydraulic forces associated with various causes of erosion showed that *"the presence of pools reduces bank erosion on the order of 34 percent compared to the natural river,"* because of reduced velocities and shear stresses which outweighs increased forces due to pool fluctuations in the analysis of forces.

- The least percentage (16.7%) of erosion is found in the Turners Falls Impoundment (with run of river/peaking power and pumped storage hydro operations). This is likely due to somewhat decreased riverine forces as a result of a lower natural longitudinal slope and impoundment, implementation of the ECP, and some natural stabilization processes observed in this reach.
- Even without the 14,000 feet of stabilization through the ECP in the Turners Falls Impoundment which represents about 7% of the length of both sides of the river, the percentage of erosion in this reach would be much less (at 16.7 +7 = 23.7%, 10.44 miles) than the percentage (48.4%,) of erosion documented in the northern, free-flowing reach (especially considering that 17.1% [28.3 miles] of the northern reach has been rip-rapped and 10.5 %, [4.91 miles] of the Turners Falls Impoundment has been rip-rapped).
- The 1979 study showed 19.84 miles of eroded bank in the Wilder Impoundment, 4.05 miles in Bellow Falls, 9.91 miles in Vernon, and 3.13 miles in Turners Falls. While no percentage or length information is available of current erosion sites in the low-head hydropower impoundments (Wilder, Bellows Falls, Vernon, and Holyoke) as of 2008, the upstream impoundments had the greatest number of erosion sites based on the 1979 study (which did not include the northern, unimpounded reach). Based on the 2008 inspection in Bellows Falls, Vernon, and Holyoke all but one of 23 erosion sites identified in 1997 were in essentially the same eroding state in 2008.

As shown in Figure 21 (from the USACE study, 1979), water level fluctuations are largest in the Turners Falls Impoundment due to the pumped storage facility in addition to the run of river/peaking power operation compared to other hydropower impoundments. More recent data (9/1/2012 – 10/23/2012) from USGS stations at Dalton, West Lebanon, North Walpole, and at Montague City present the gage height hydrographs. The Dalton gage (Figure 22) is in a free-flowing reach upstream of the Wilder Impoundment, West Lebanon (Figure 23) is located in the Bellows Falls Impoundment a short distance downstream of the Wilder Dam, North Walpole (Figure 24) is in the Vernon Impoundment a short distance downstream of the Bellows Falls Dam, and Montague City (Figure 25) is downstream of the Turners Falls Dam in the Holyoke Impoundment. Dalton represents a free-flowing reach of river while the other gages show the typical fluctuations associated with peaking power operations in their respective impoundments. Fluctuations are in the 3 to 4 foot range at West Lebanon (Bellows Falls Impoundment – also affected by inflow from Wilder), predominantly 3 feet at North Walpole (Vernon Impoundment – also affected by inflow from Bellows Falls), and 4 to 5 feet in the Holyoke Impoundment – also affected by releases fromTurners Falls. These recent data show that fluctuations are approximately one foot larger in amplitude downstream of the Turners Falls Impoundment (in the Holyoke Impoundment) compared to fluctuations in upstream impoundments, which appears to be a smaller increase in fluctuations associated with Turners Falls as also demonstrated in Figures 26 through 28. These figures compare water level fluctuations that result from peaking power operations due to Vernon at the upstream end of the Turners Falls

Impoundment to fluctuations at the Northfield Mountain Tailrace. Water level fluctuations at the upstream end of the Turners Falls Impoundment are due to peaking power operations at Vernon Dam and typically range from about 2 to 4 feet in amplitude in the examples from July 1997 and December 2000. At the Northfield Mountain Tailrace, water level fluctuations ranged from about 2 to 4 feet in July 1997 and approximately 2 to 5 feet in December 2000. Thus, water level fluctuations in the Turners Falls Impoundment are similar to or up to about 1 foot larger in amplitude compared to fluctuations in other impoundments.

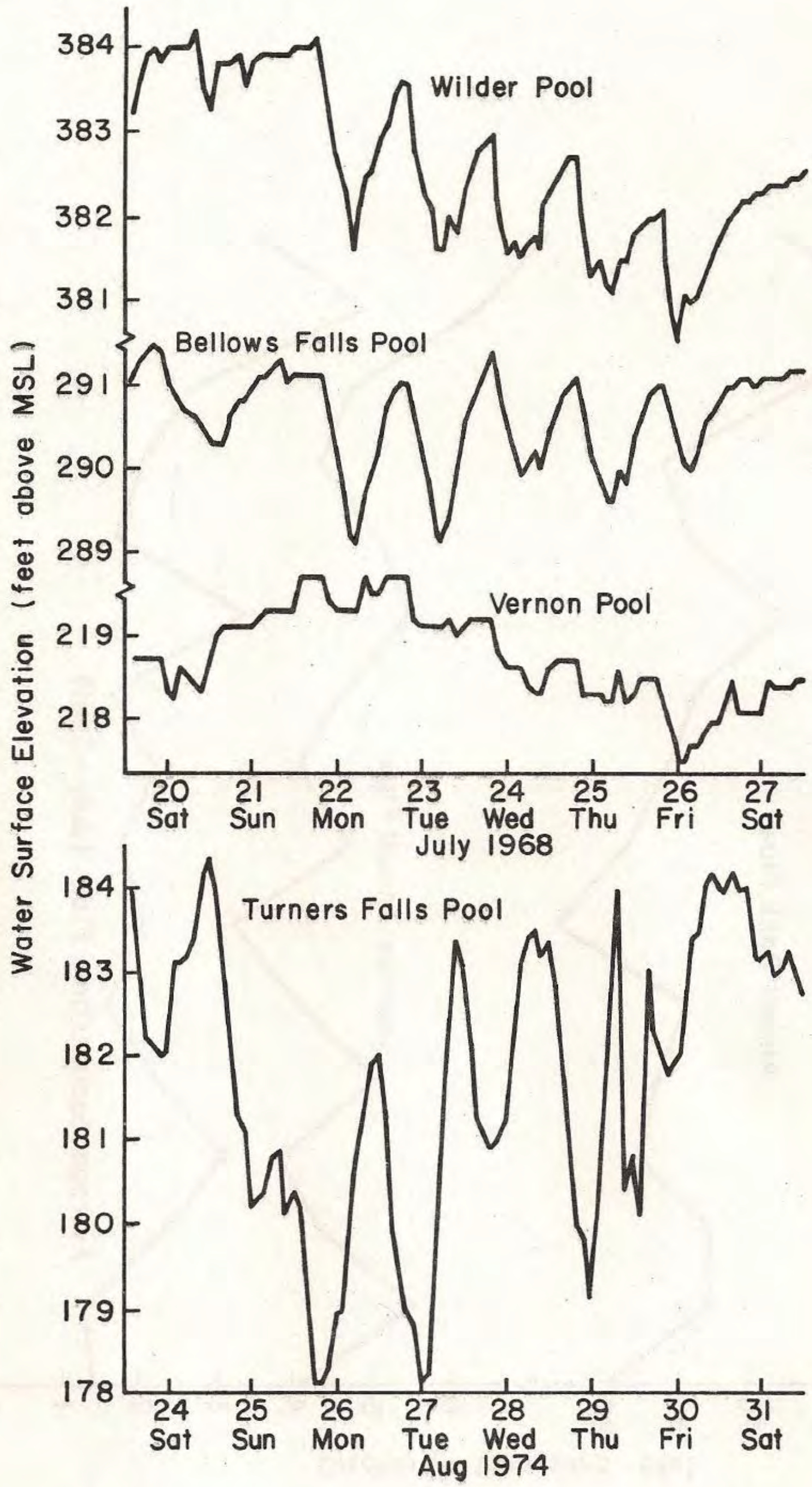


Figure 9. Pool stage compared to time at the four study reaches.

Figure 21. Water level fluctuations at four hydropower impoundments

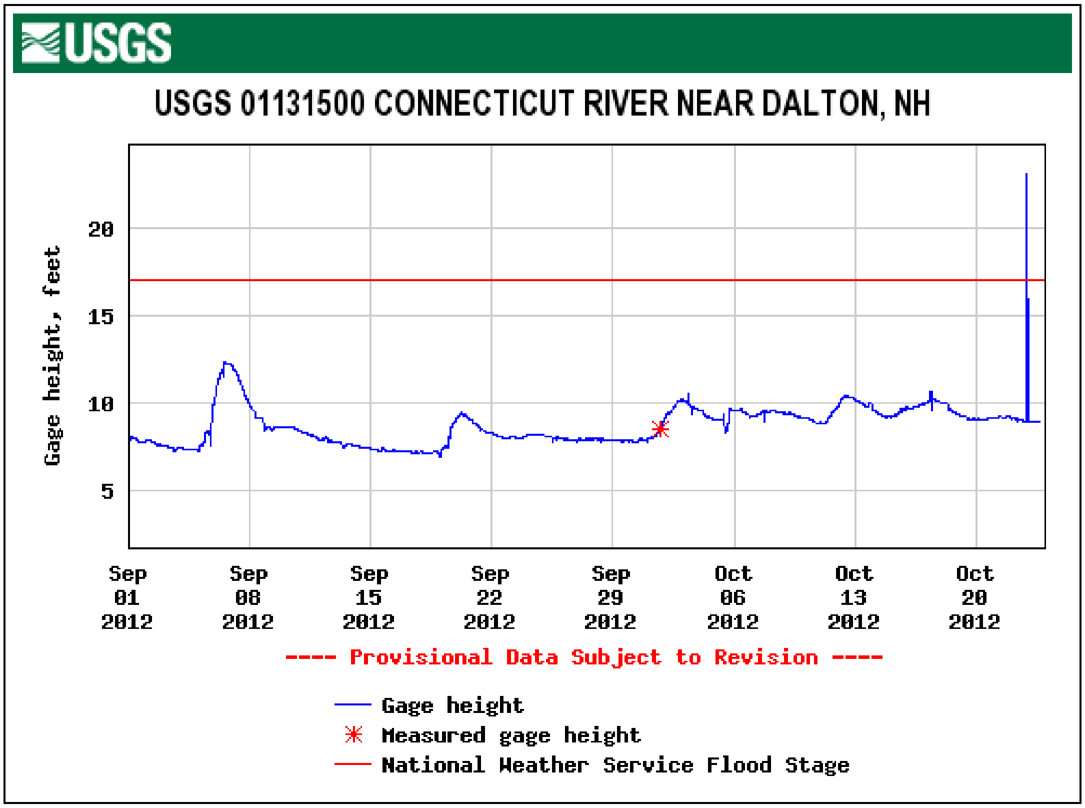


Figure 22. Gage height near Dalton, NH 9/1/2012-10/23/2012

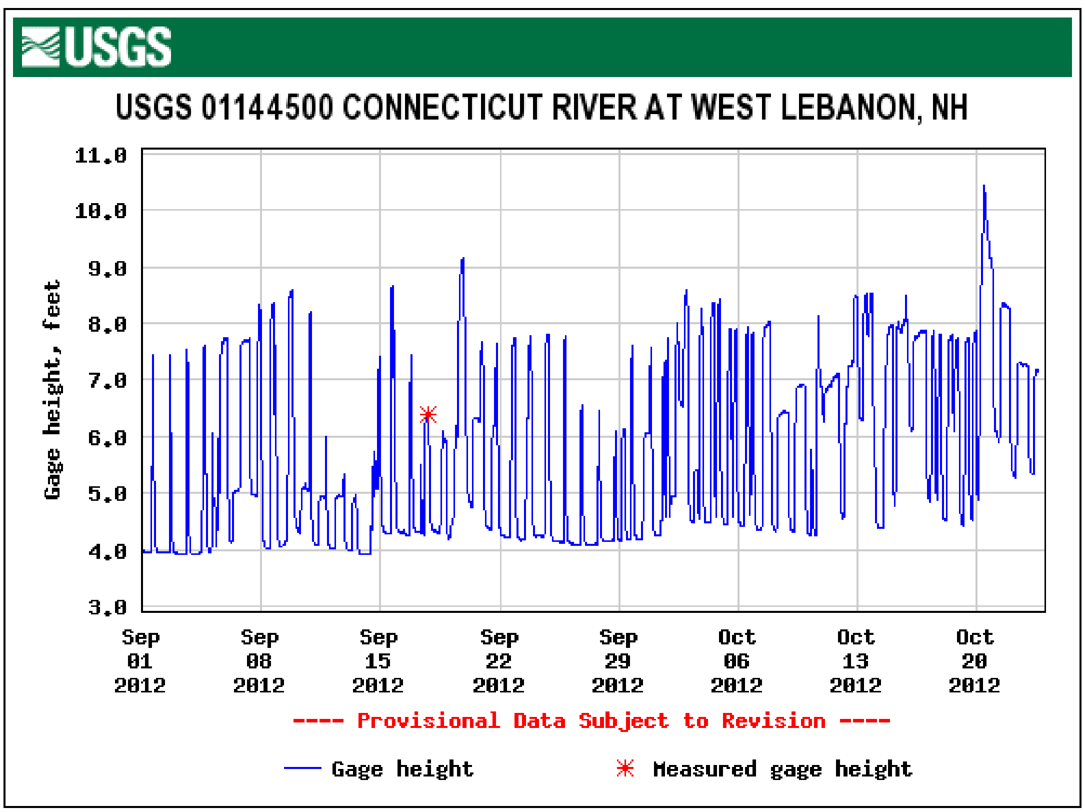


Figure 23. Gage height at West Lebanon, NH 9/1/2012-10/23/2012

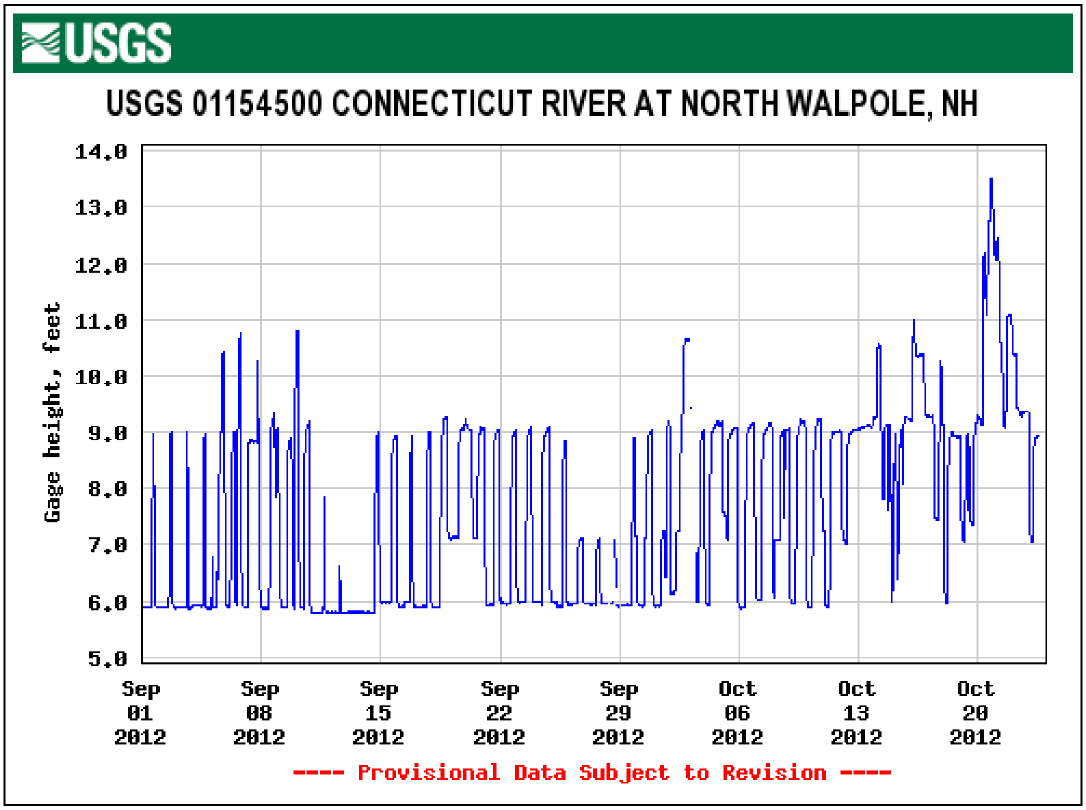


Figure 24. Gage height at North Walpole, NH 9/1/2012-10/23/2012

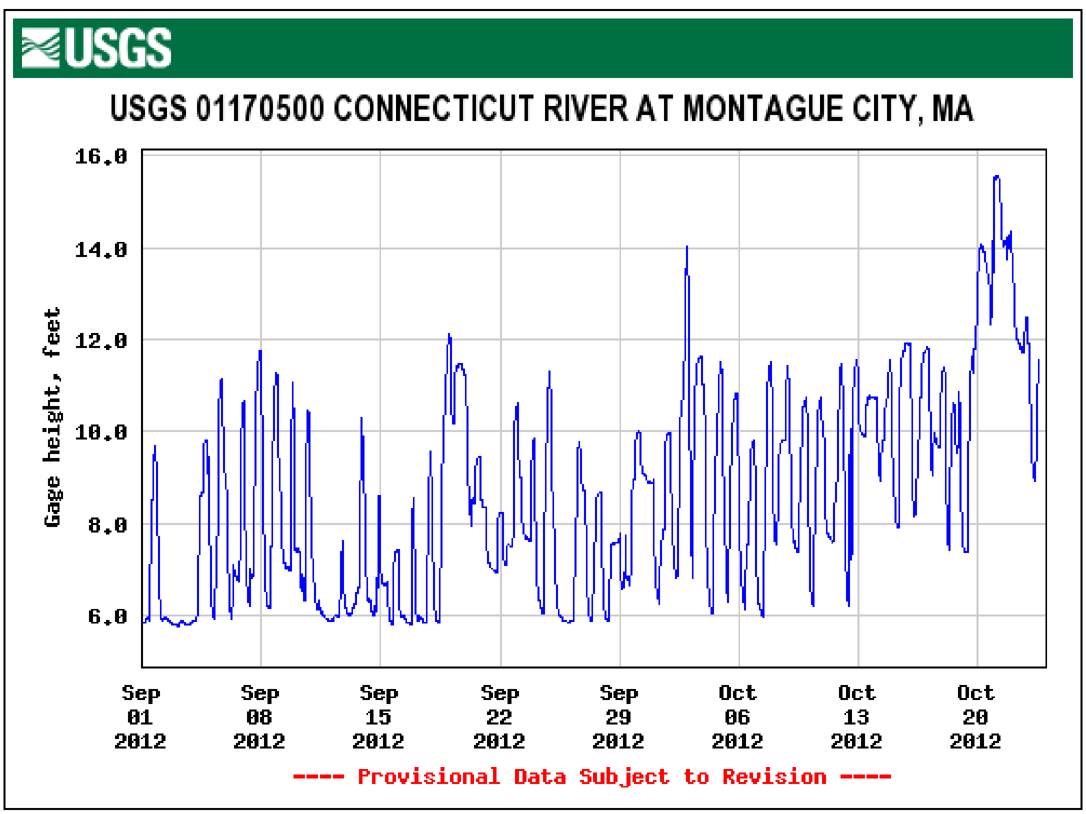


Figure 25. Gage height at Montague City, MA 9/1/2012-10/23/2012

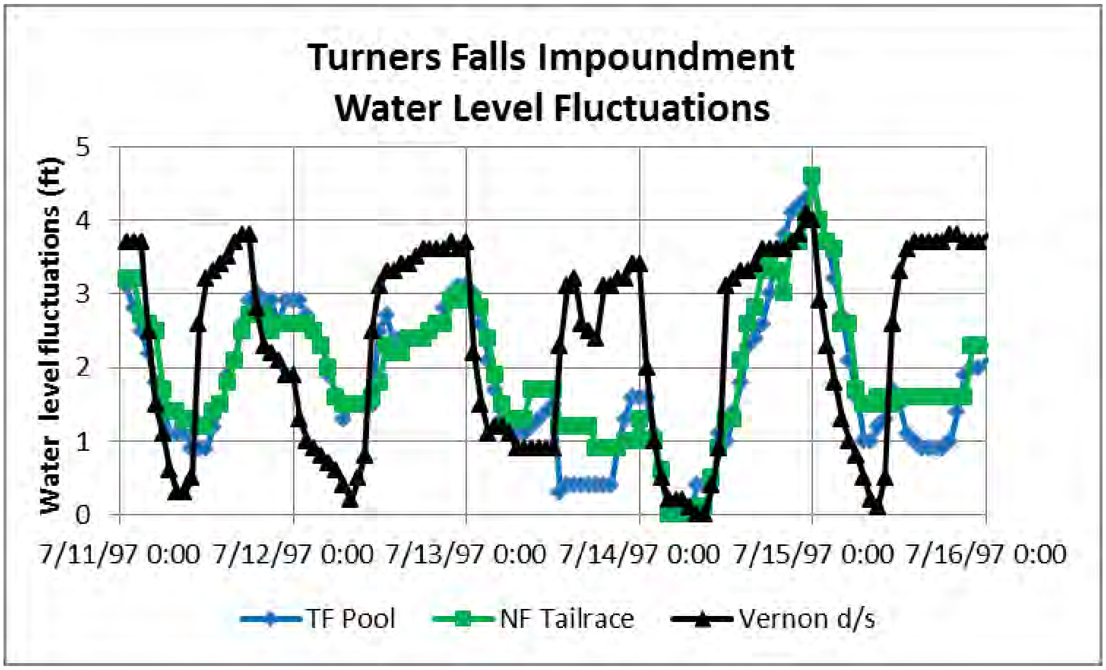


Figure 26. Water Level Fluctuations in Turners Falls Impoundment, 7/11-16/1997

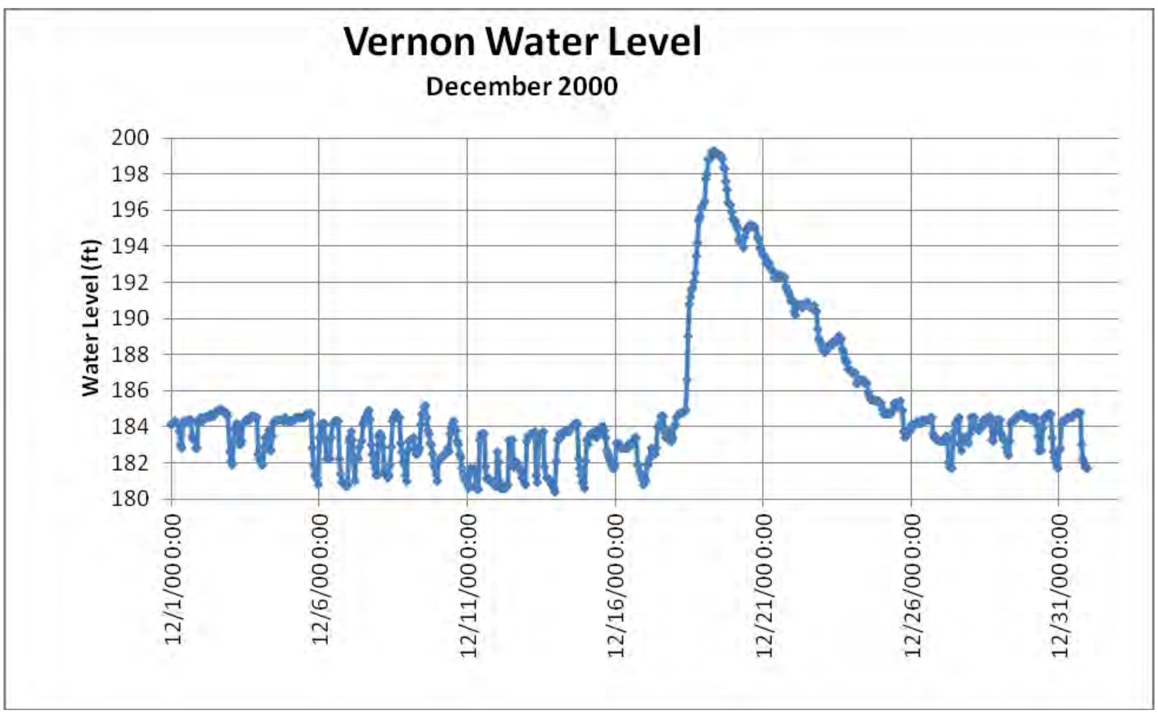


Figure 27. Water level fluctuations in upper Turners Falls Impoundment due to operations at Vernon, December 2000

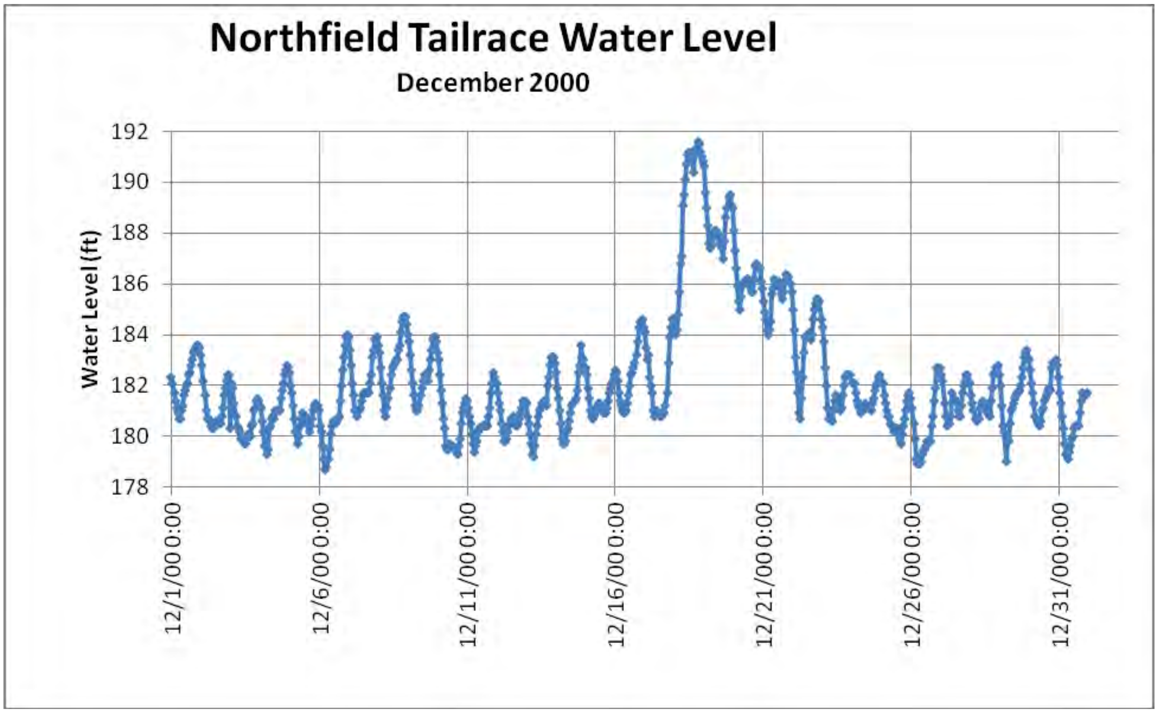


Figure 28. Water level fluctuations at Northfield Mountain Tailrace, December 2000

The greatest extent of erosion is found in the reach of river that has the greatest extent of stabilization and minimal to no water level fluctuations due to hydroelectric operations. Within reaches that are impounded for hydroelectric operations, the impoundment with somewhat larger water level fluctuations experiences the least erosion. Comparison of erosion with respect to water level fluctuations suggests that the water level fluctuations do not play a significant role in the riverbank erosion process.

Stabilization efforts have been conducted in various reaches of the Connecticut River. While stabilization projects can reduce the severity and extent of erosion, riverbank erosion resulting in channel change and lateral shifting is a natural geomorphic process as discussed in the scientific literature. A benchmark of natural alluvial river processes can be seen in rivers located in national parks where hydropower, powerboats, agriculture, and riverbank stabilization is not typically allowed. Riverbank erosion in rivers located in national parks is readily evident as shown in the example photographs below (Figures 29 and 30). Appendix K presents additional examples of significant riverbank erosion occurring in national parks. The fact that erosion of rivers in areas without significant human influence clearly demonstrates the natural dynamics of alluvial rivers as previously explained in the scientific literature.

Figure 29. Yellowstone River – Yellowstone National Park

Figure 30. Middle Fork of the Flathead River – Glacier National Park

Given the dynamic nature of alluvial rivers, complete control of erosion is impossible without taking extreme measures resulting in an unnatural channel and would contradict natural geomorphic processes. In analyzing the Connecticut River, Field (2007) commented on the nature of riverbank sediment found in the Turners Falls Impoundment reach of the Connecticut River.

> *Most of the riverbank sediments in the Turners Falls Pool are naturally susceptible to erosion given their noncohesiveness and fine-grained texture.*

Observation of other reaches of the Connecticut River indicates similar erodible sediments consistent with deposition in old Lake Hitchcock that extended through much of the length of the river.

Furthermore, Field stated (2007),

> "*Erosion is a naturally occurring phenomenon that is present even on rivers in equilibrium where erosion is offset by an equal amount of deposition in adjacent areas.*

Field (2004) in evaluating the best approach to *"help preserve surrounding farmland"* he discussed ill-advised erosion protection and the need to allow some degree of erosion before the river will shape itself into a more stable pattern.

> *Completely stopping the erosion with riprap or other bank armoring techniques, however, will lock the channel instabilities in place and potentially transfer the erosion processes further downstream.*

He then advises to *"identify how far the erosion will extend"* stating that even an aggressive erosion protection technique *"riprap to fail and allow the erosion to continue"* and allow the river to erode by simply planting a buffer zone of riparian vegetation until *"reaching this more natural configuration."* He also supports the approach to *"acquire conservation easements in order to reduce human conflicts."*

Field (2007) discussed a potential problem riverbank stabilization projects noting that, *"both riprap and bioengineering projects, could lead to increased erosion elsewhere."*

This material from Field recommending not to "fix" every erosion issue along the Connecticut River is consistent with the approach taken by the Vermont Agency of Natural Resources (VANR). Natural rivers, even those in "equilibrium," are expected to experience changes in position through processes of riverbank erosion and lateral shifting. Artificially constraining the river's position via erosion protection or stabilization projects can adversely affect riverbanks upstream, downstream or across the river and it raises the question as to the role, objective, or extent of such stabilization projects. The VANR suggested an alternative approach in their 2007 "River Corridor

Planning Guide to Identify and Develop River Corridor Protection and Restoration Projects." Their river corridor concept is based on the concept of dynamic equilibrium of rivers where *"Streams in equilibrium may still erode their banks, migrate over time across their valleys, and periodically experience small-scale lateral and/or vertical adjustments."* They advocate *"Defining and protecting the meander belt width corridor that will accommodate equilibrium conditions may be the most important aspect in any river restoration project."* In other words, enough room needs to be allowed for a river to move and adjust within the concept of dynamic equilibrium. Or, as stated by Sharon Francis, (Executive Director - Connecticut River Joint Commissions), *"A wise public must give the river room to be a river."* This concept is reinforced by the VANR when they state that, *"In nearly every Vermont watershed, there will be a need to reduce or remove constraints to the lateral adjustment of the stream channel."* In other words, give the river room to be a river. They explain further,

> *"Restoration projects have traditionally attempted to resolve conflicts by 'fixing,' and often re-fixing, the location of the channel. Inevitably, when the restoration planner ignores the channel evolution process, the energy of a large flood brings another round of traditional channel works perpetuating the conflicts at the restoration site or exacerbating the conflicts somewhere downstream."*

This concept has been developed and utilized in other states including Montana, New Mexico, and Ohio and was studied by the Federal Emergency Management Agency (FEMA), 1999, "Riverine Erosion Hazard Areas - Mapping Feasibility Study,"

While riverbank stabilization and erosion protection can be successful in reducing erosion, examples of the adverse consequences of such activities exist on the Connecticut River. The fact that the VANR and the CRJC (as well as other states and agencies) have expressed concern over constraining rivers beyond their natural dynamic nature to the extent that documents and regulations have been written to accommodate lateral migration and channel shifting (which necessarily means allowing some degree of riverbank erosion). The fact that rivers cannot be completely controlled must be considered carefully in future evaluation and planning for such projects.

6. Conclusions

Some erosion of riverbanks is occurring along the length of the Connecticut River, both in free-flowing reaches and within reaches impounded by dams. Erosion has been occurring along the Connecticut River over a long period of time, likely since the draining of Lake Hitchcock and on to the present; and for as long as observations have been documented, as shown in available material as early as a half-century ago in the 1950s. The fact that some erosion is occurring is consistent with the fact that rivers are dynamic; meaning that they experience lateral migration, and continually change in dimension, shape, and pattern. Other than reaches consisting of bedrock or other materials and characteristics that are resistant to erosion, or have been stabilized; erosion or the potential for erosion is ubiquitous throughout the various reaches or segments of the Connecticut River. Erosion exists in all of the impoundments as well as in free-flowing reaches of the river.

Despite the fact that there has been similar extent of erosion control or riverbank stabilization in the northern, free-flowing reach of the Connecticut River compared to the Turners Falls Impoundment (17.1% rip-rapped for the northern, free-flowing reach vs. 10.5% rip-rapped plus 7% bio-engineered stabilization through the ECP for the Turners Falls Impoundment); the reported percentage of eroding river in the northern, free-flowing reach is approximately triple (48.4% to 16.7%) compared to the Turners Falls Impoundment. The fact that erosion is greater in the free-flowing reach compared to an impounded reach is consistent with the analysis presented in the 1979 USACE report because an impounded reach generally experiences reduced velocities and reduced shear stresses which outweighed impoundment fluctuations in causing riverbank erosion.

While no recent quantitative assessment of the riverbanks in the Bellows Falls, Vernon or Holyoke Impoundments is available at this time; individual erosion sites found in 1997 were re-visited and photographed in 2008. From a qualitative perspective, based on the comparison of photos of erosion sites from 1997 to 2008, in these three other impoundments all but one of the erosion sites in 1997 continues to experience virtually the same degree of erosion in 2008. Many of these erosion sites are significant both in size and severity. In contrast, most of the severely eroded sites in the Turners Falls Impoundment found in 1997 have been stabilized by 2011 through implementation of the ECP. Some natural stabilization processes of increased upper bank vegetation and areas of dense low bank aquatic vegetation have also been observed in the Turners Falls Impoundment.

Despite somewhat larger pool fluctuations as a result of the combination of fluctuating discharges from upstream releases at Vernon, fluctuations in water level due to peaking power operations at the Turners Falls Dam (Cabot Station), and water level fluctuations due to peaking power operations due to the pumped-storage facility (Northfield Mountain); these fluctuations have not resulted in greater erosion in the Turners Falls Impoundment compared to other reaches along the Connecticut River. This may be because impoundment fluctuations do not play a large role in eroding banks as suggested by the 1979 USACE study which attributed 15-18% of the cause of erosion to impoundment fluctuations, the buffering effect of impoundments which tend to slow river velocities, natural stabilization, and/or stabilization efforts at most of the severely eroded sites through implementation of the ECP. Whatever the reason (or combination of reasons), there is no evidence to support the argument that impoundment fluctuations resulting from a combination of hydropower projects cause greater erosion in the Turners Falls Impoundment because riverbank erosion is less severe and/or less extensive compared to any other reach of the Connecticut River.

7. References

Connecticut River Power Company, 1954 "Observation of Erosion on Banks of the Connecticut River Bellows Falls to Vernon September 2-3, 1954,"

Federal Emergency Management Agency, "Riverine Erosion Hazard Areas – Mapping Feasibility Study," 1999

Field Geology Services, 2004, "Fluvial Geomorphology Assessment of the Northern Connecticut River, Vermont and New Hampshire"

Field Geology Services, 2007, "Fluvial Geomorphology Study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT"

Leopold, L.B., M.G. Wolman and J.P. Miller, 1964, Fluvial Processes in Geomorphology, W.H. Freeman and Company

Rittenour, T. M., 1999, "Drainage History of Glacial Lake Hitchcock, Northeastern USA," unpublished MS thesis, University of Massachusetts

Schumm, S., 1977, Fluvial Processes in Geomorphology, John Wiley & Sons

Simons & Associates, 1992, "Analysis of Bank Erosion at the Skitchewaug Site in the Bellows Falls Pool of the Connecticut River"

Simons & Associates, 1996, "Discussion of Erosion at Vernon Station"

Simons & Associates, 1998, "Erosion Control Plan for the Turners Falls Pool of the Connecticut River"

Simons & Associates, 2008, "Full River Reconnaissance – 2008 Turners Falls Pool, Connecticut River"

Simons, Li & Associates, 1983, "Erosion Study to Determine Boundaries for Adjacent Development – Calabacillas Arroyo, Bernalillo County, New Mexico," prepared for the Albuquerque Metropolitan Arroyo and Flood Control Authority

Simons, D.B. and F. Senturk, 1991, Sediment Transport Technology – Water and Sediment Dynamics, Water Resources Publications

United States Army Corps of Engineers, 1979, "Connecticut River Streambank Erosion Study Massachusetts, New Hampshire and Vermont"

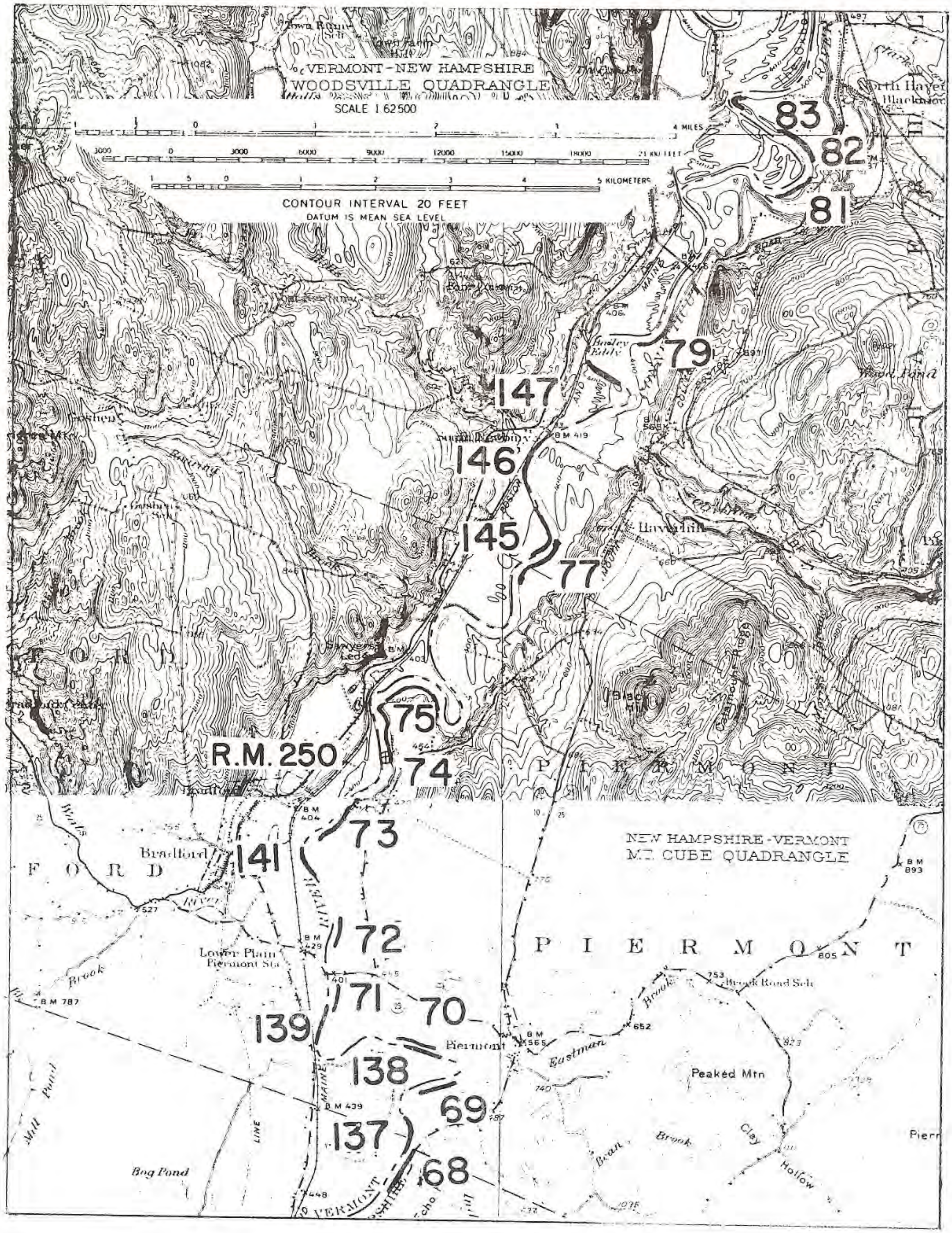
Vermont Agency of Natural Resources (Mike Kline and Kari Dolan, River Management Program), 2008, "Fluvial Geomorphic-Based Methodology to Reduce Flood Hazards and Protect Water Quality"

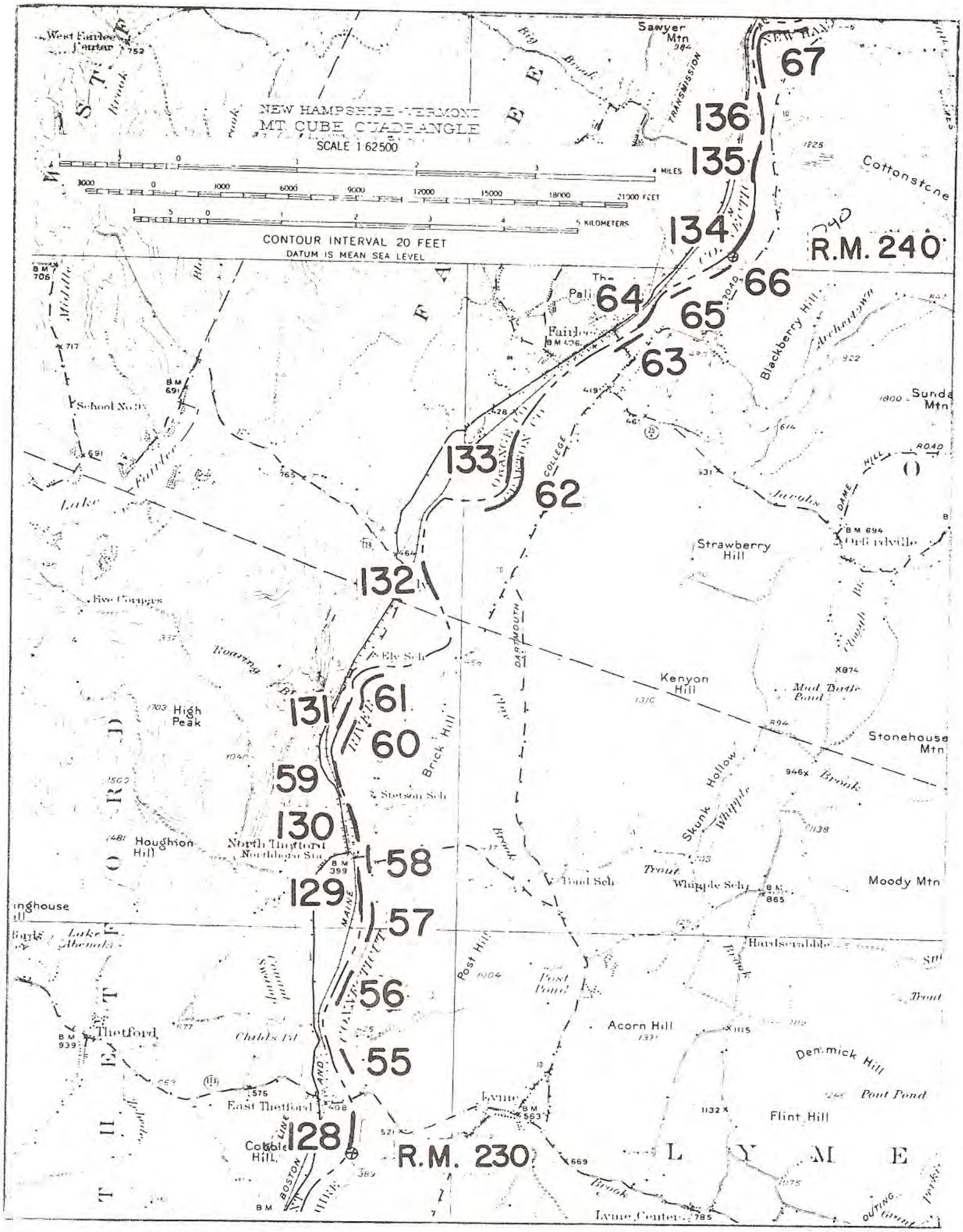
Vermont Agency of Natural Resources, “Mitigating Flood-Related Fluvial Erosion Hazards (FEH) Using River Corridor Protection, Fact Sheet”

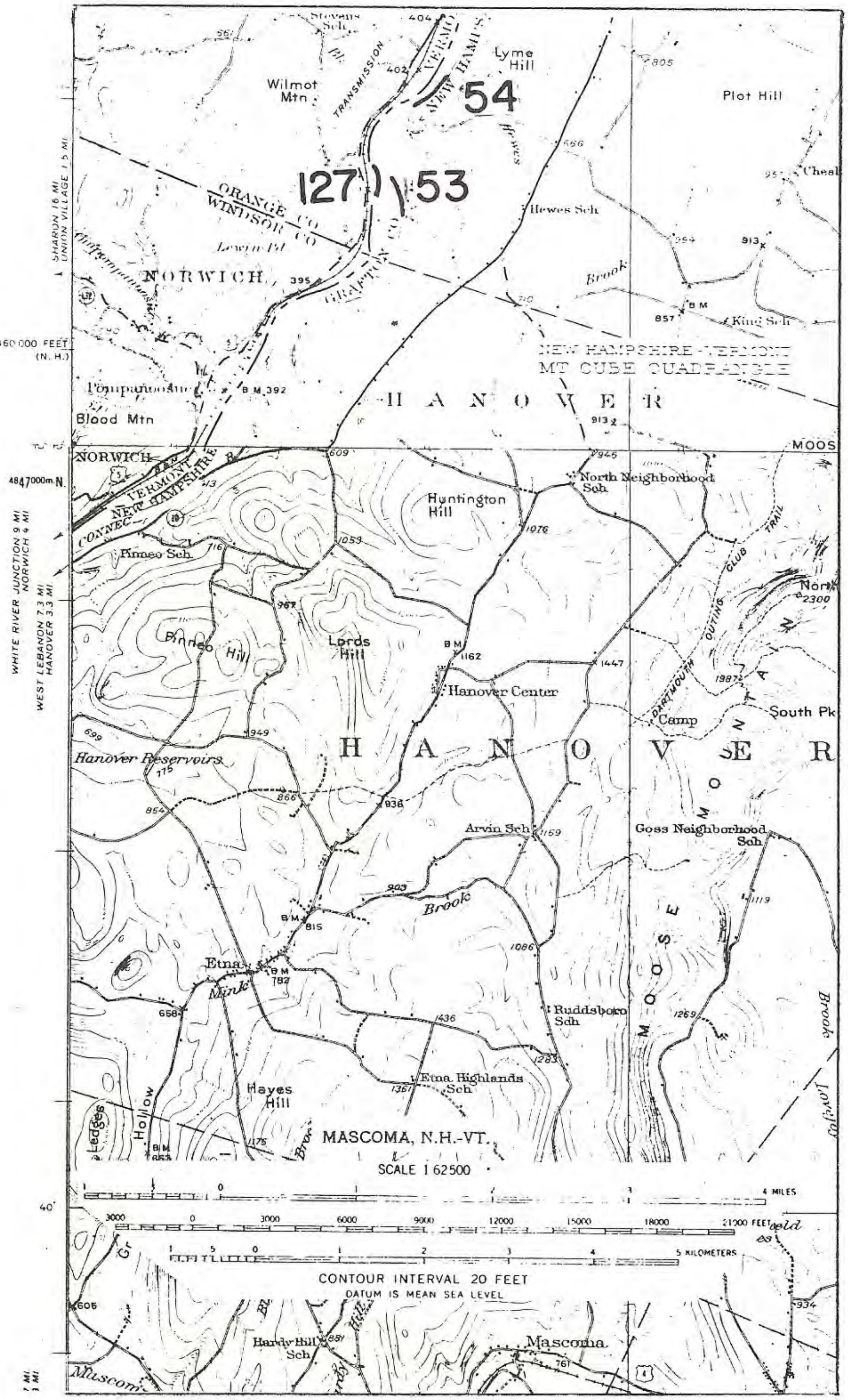
APPENDIX A

LOCATIONS OF EROSION SITES IN THE STUDY REACH

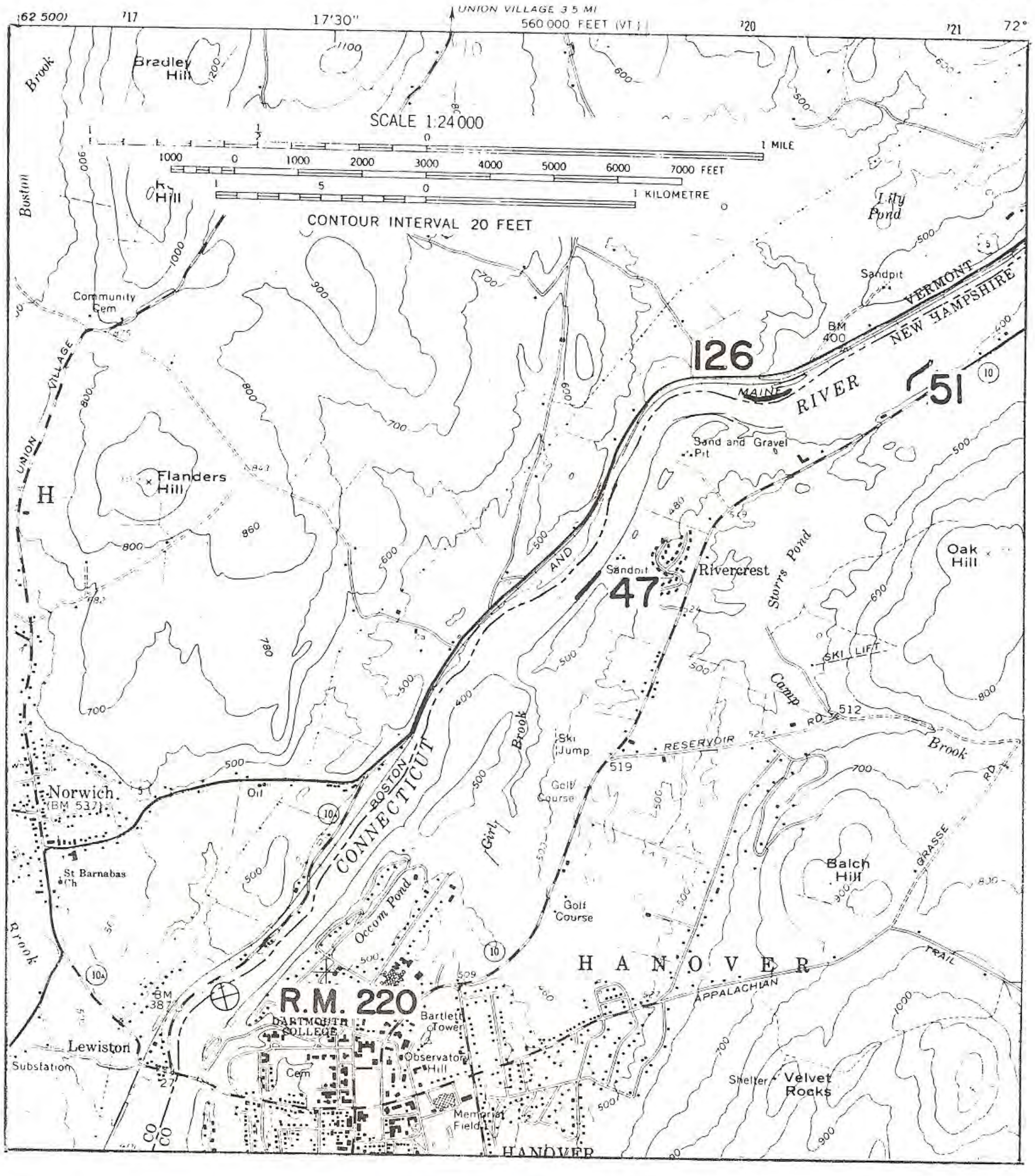

R Y E G A T E
N E W B U R Y
South Ryegate
Boltonville
Wells River
Jefferson Hill
Woodsville
Horse Meadow
VERMONT-NEW HAMPSHIRE
WOODSVILLE QUADRANGLE
SCALE 1 62500
4 MILES
21000 FEET
5 KILOMETERS
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
R.M. 260

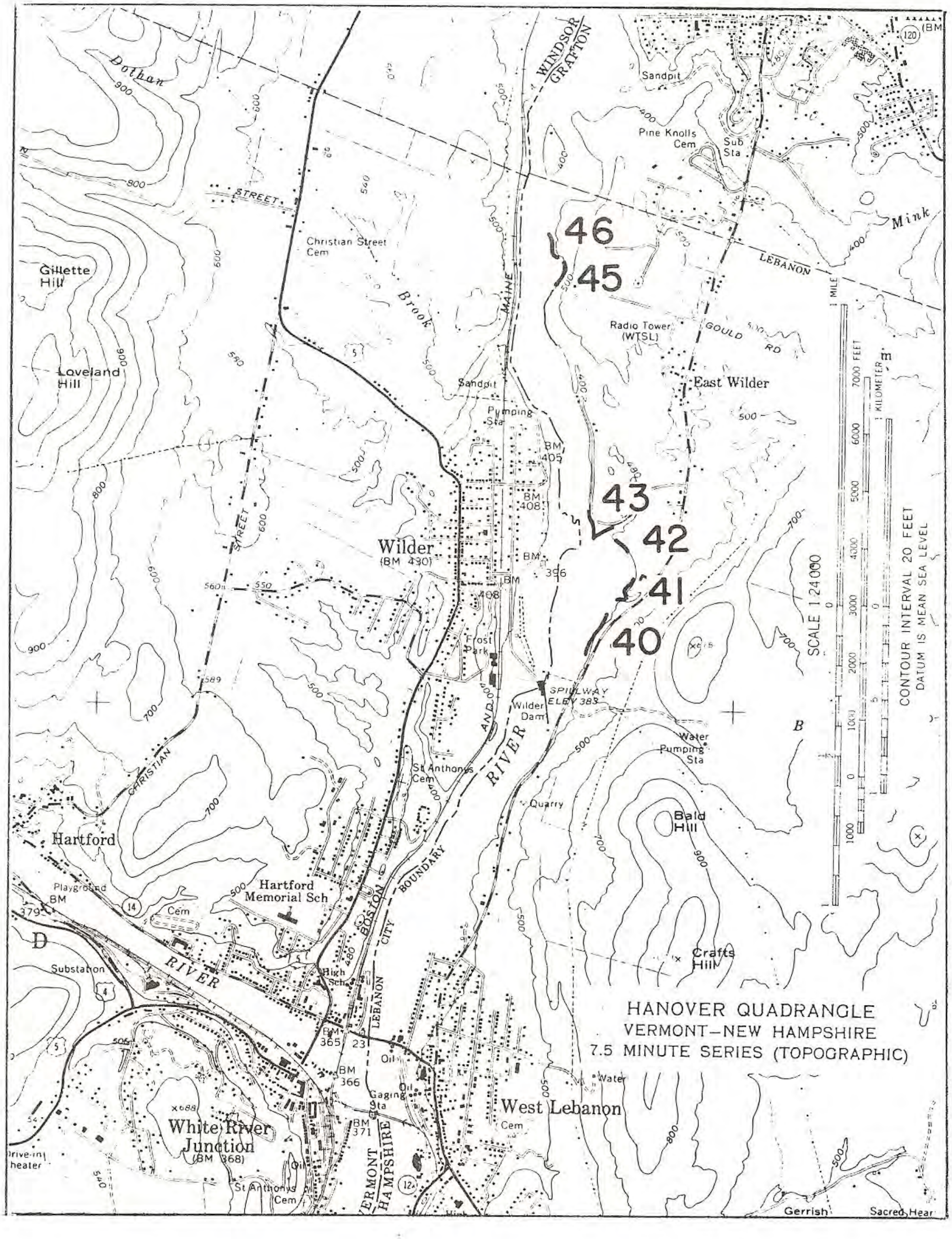

VERMONT-NEW HAMPSHIRE
WOODSVILLE QUADRANGLE
SCALE 1:62500
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
NEW HAMPSHIRE-VERMONT
MT. CUBE QUADRANGLE
R.M. 250
83
82
81
79
147
146
145
77
75
74
73
141
72
71
70
139
138
69
137
68
Haverhill
Bradford
Lower Plain
Piermont Sta
Piermont
P I E R M O N T
F O R D
Peaked Mtn
Bog Pond
Goshen
Eastman
Brook
Clay
Hollow
BM 419
BM 439
BM 787
BM 893

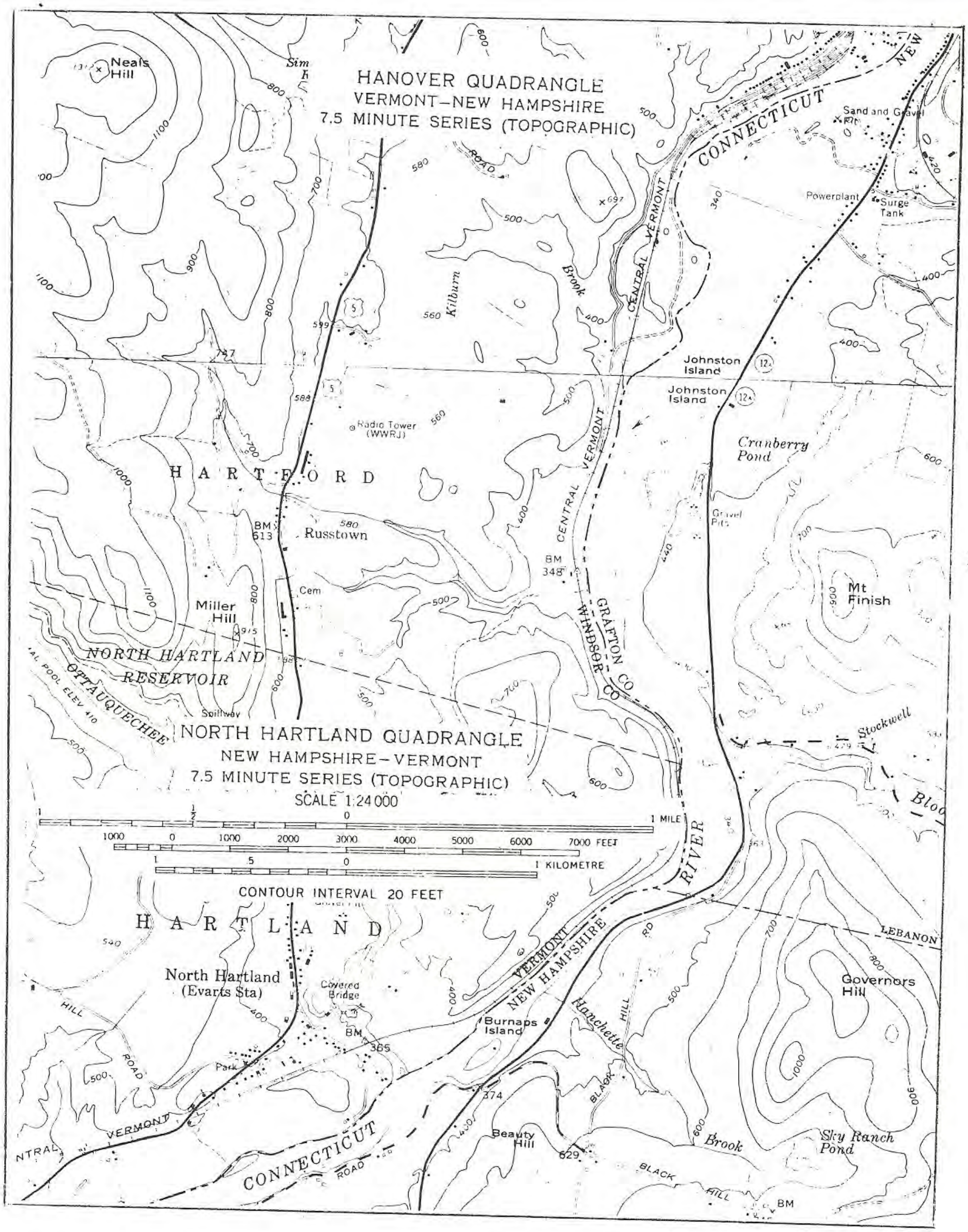

NEW HAMPSHIRE - VERMONT
MT. CUBE QUADRANGLE
SCALE 1:62500
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
R.M. 240
R.M. 230
67
136
135
134
66
64
65
63
133
62
132
61
131
60
59
130
58
129
57
56
55
128
Sawyer Mtn
Cottonstone
Blackberry Hill
Sunday Mtn
Strawberry Hill
Kenyon Hill
High Peak
Stonehouse Mtn
Houghton Hill
North Thetford
Moody Mtn
Acorn Hill
Den mick Hill
Flint Hill
East Thetford
Cobble Hill
Thetford
Brick Hill
Post Hill
Lyme
Lyme Center

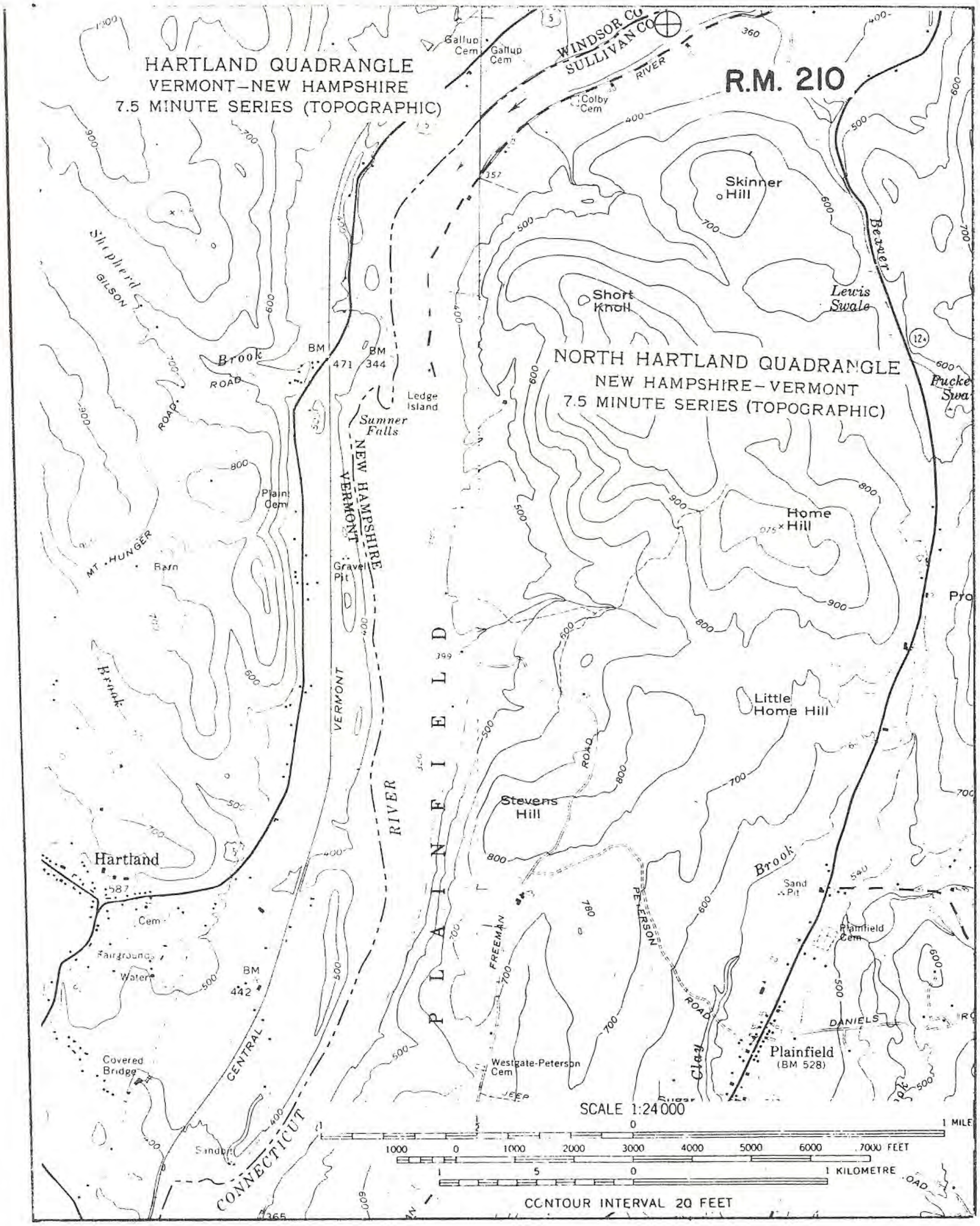

54
127
53
Wilmot Mtn
Lyme Hill
Plot Hill
NORWICH
HANOVER
Blood Mtn
Huntington Hill
Lords Hill
Pinneo Hill
Hanover Center
Hanover Reservoirs
Arvin Sch
Goss Neighborhood Sch
Etna
Ruddsboro Sch
Etna Highlands Sch
Hayes Hill
MASCOMA, N.H.-VT.
SCALE 1 62500
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
Mascoma
NEW HAMPSHIRE-VERMONT
MT CUBE QUADRANGLE

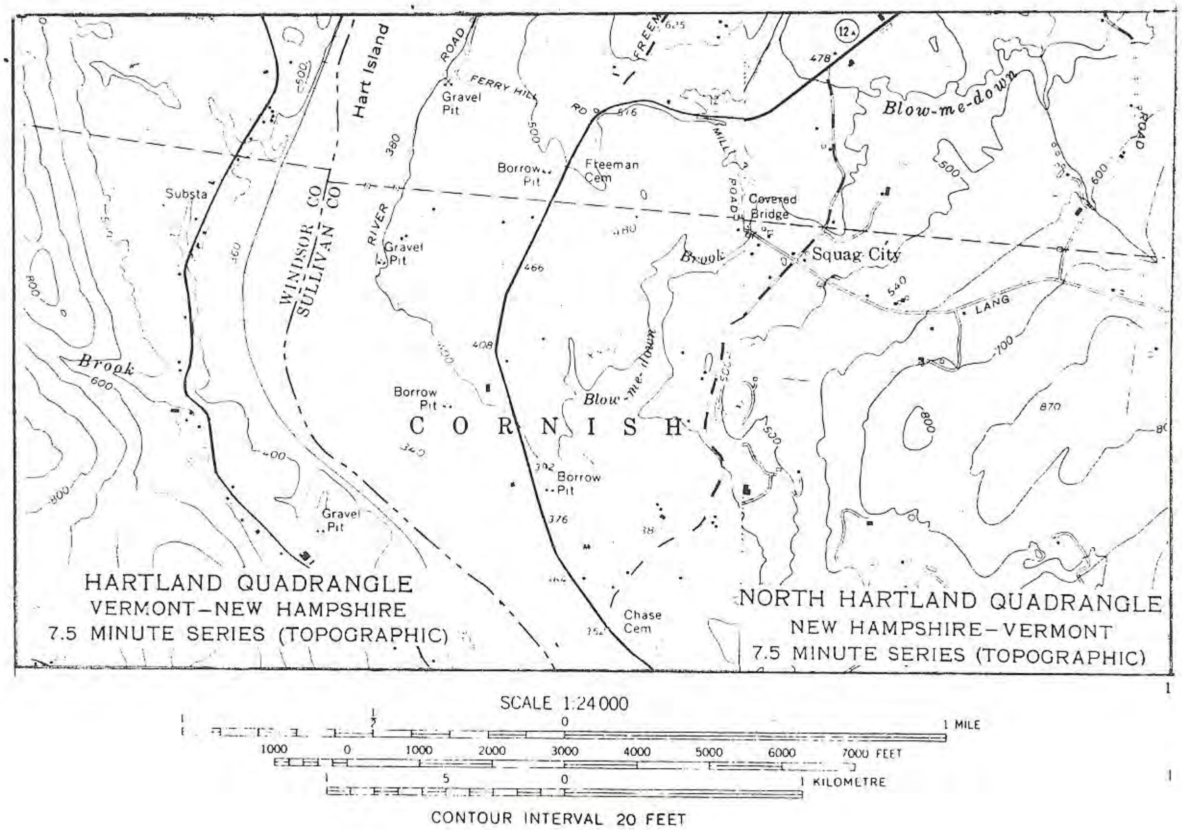
HANOVER QUADRANGLE
VERMONT–NEW HAMPSHIRE
7.5 MINUTE SERIES (TOPOGRAPHIC)



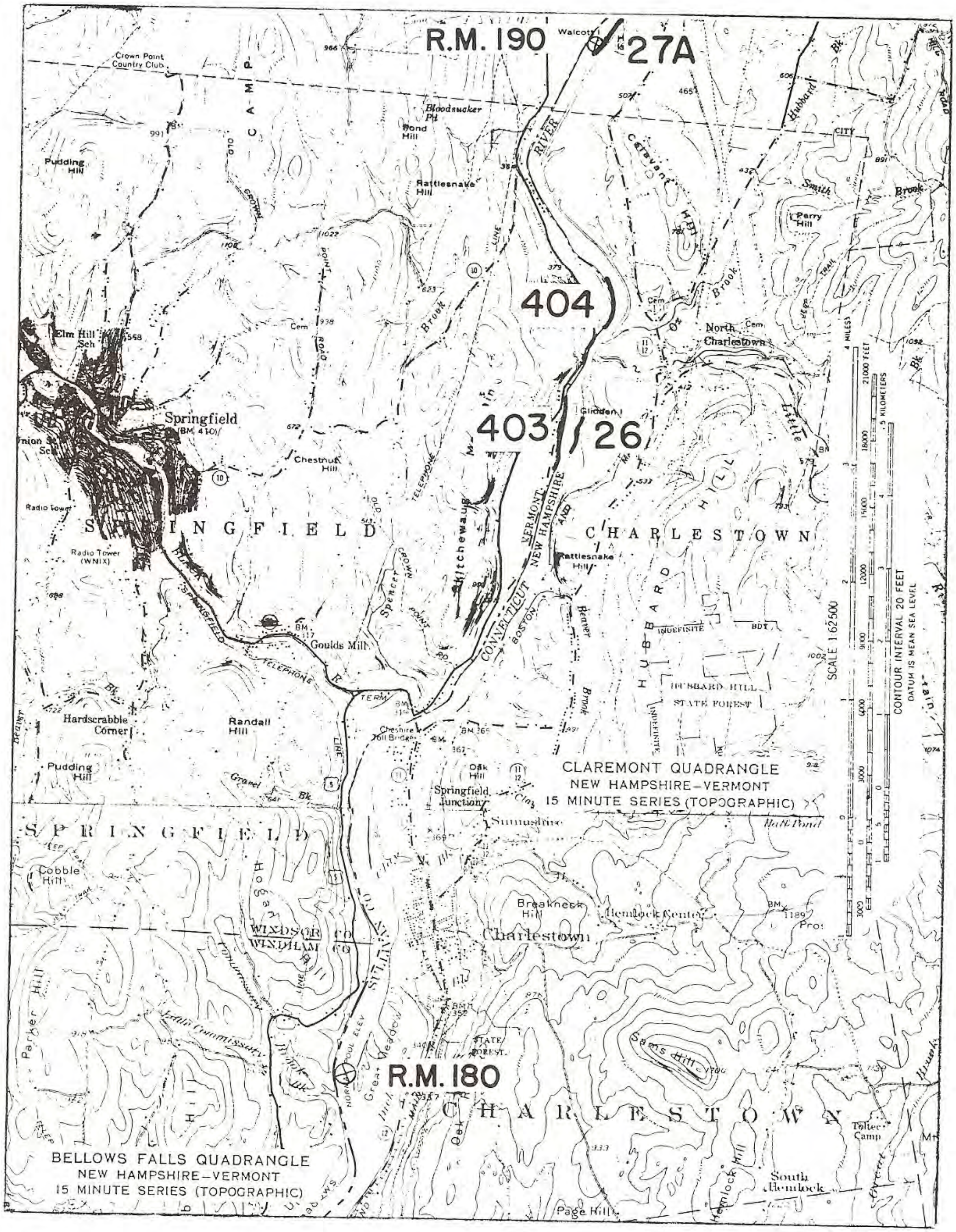

HANOVER QUADRANGLE
VERMONT–NEW HAMPSHIRE
7.5 MINUTE SERIES (TOPOGRAPHIC)
46
45
43
42
41
40
Wilder
(BM 430)
East Wilder
Radio Tower
(WTSL)
Pine Knolls
Cem
Sandpit
Christian Street
Cem
Gillette
Hill
Loveland
Hill
Hartford
Hartford
Memorial Sch
White River
Junction
(BM 368)
West Lebanon
Bald
Hill
Crafts
Hill
Wilder
Dam
SPILLWAY
ELEV 383
Water
Pumping
Sta
Quarry
St Anthonys
Cem
Frost
Park
Pumping
Sta
Substation
High
Sch
Gaging
Sta
Gerrish
WINDSOR
GRAFTON
BOSTON AND MAINE
RIVER
LEBANON
GOULD RD
Mink
SCALE 1:24000
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
VERMONT
HAMPSHIRE

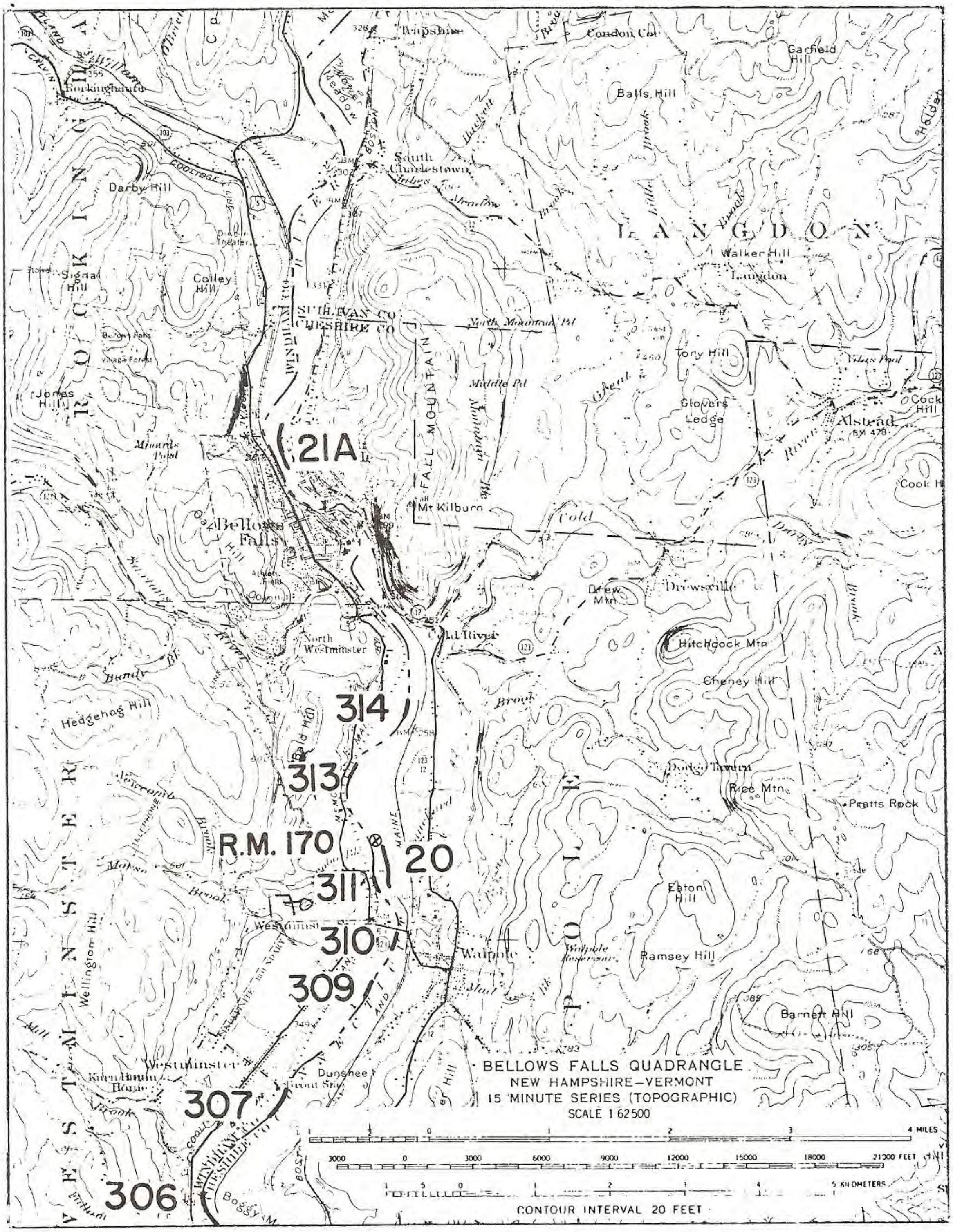

HANOVER QUADRANGLE
VERMONT–NEW HAMPSHIRE
7.5 MINUTE SERIES (TOPOGRAPHIC)
Neals Hill
CONNECTICUT
Sand and Gravel Pit
Powerplant
Surge Tank
CENTRAL VERMONT
Kilburn
Brook
Johnston Island
Radio Tower (WWRJ)
Cranberry Pond
H A R T F O R D
Russtown
Gravel Pits
Mt Finish
Cem
Miller Hill
NORTH HARTLAND RESERVOIR
OTTAUQUECHEE
Spillway
GRAFTON CO
WINDSOR CO
Stockwell
NORTH HARTLAND QUADRANGLE
NEW HAMPSHIRE–VERMONT
7.5 MINUTE SERIES (TOPOGRAPHIC)
SCALE 1:24 000
1 MILE
7000 FEET
1 KILOMETRE
CONTOUR INTERVAL 20 FEET
RIVER
LEBANON
H A R T L A N D
North Hartland (Evarts Sta)
Covered Bridge
VERMONT
NEW HAMPSHIRE
Hanchette
Governors Hill
Burnaps Island
Park
BLACK HILL
Beauty Hill
Brook
Sky Ranch Pond
CONNECTICUT
ROAD
BM

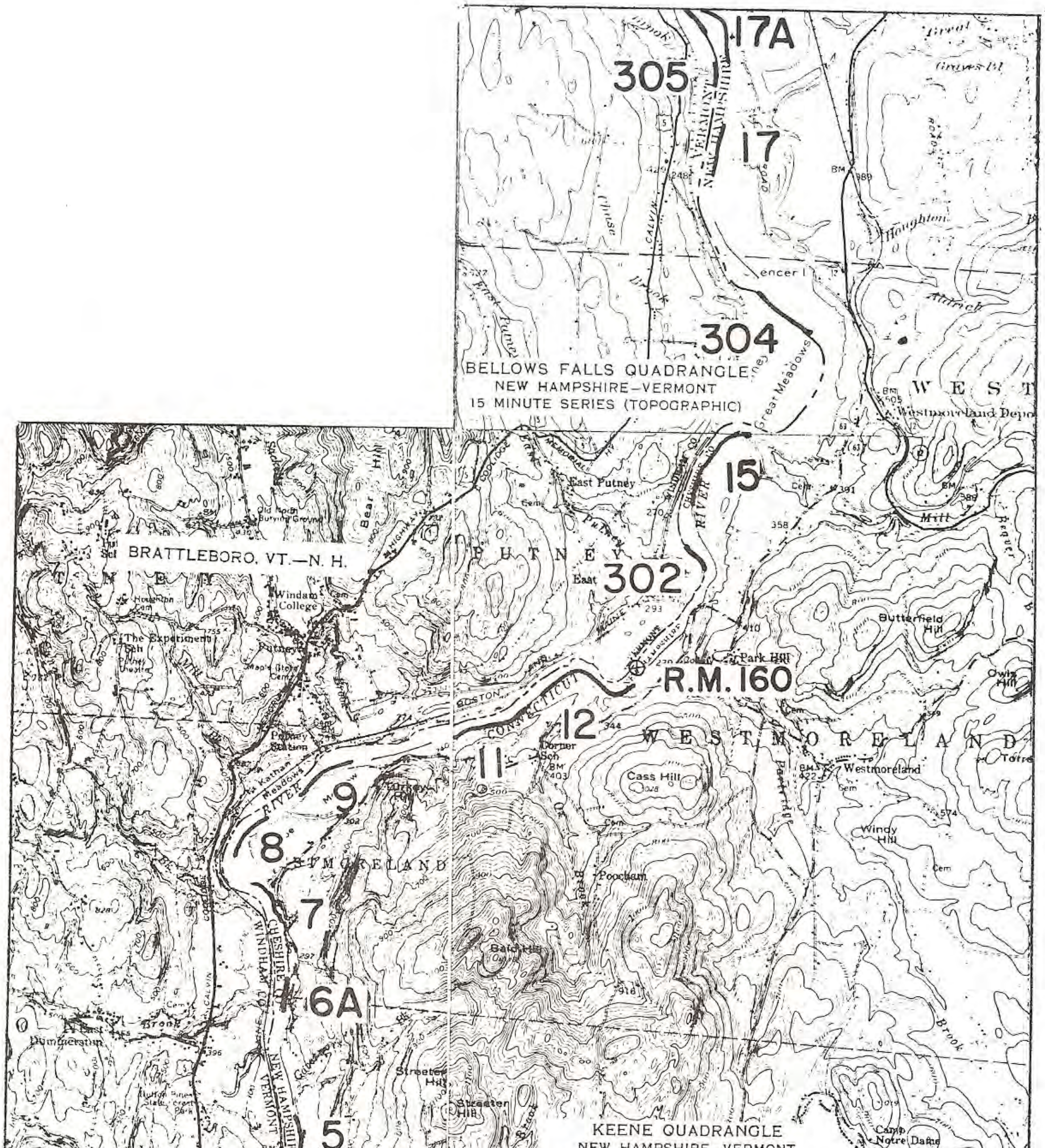

HARTLAND QUADRANGLE
VERMONT-NEW HAMPSHIRE
7.5 MINUTE SERIES (TOPOGRAPHIC)
R.M. 210
NORTH HARTLAND QUADRANGLE
NEW HAMPSHIRE-VERMONT
7.5 MINUTE SERIES (TOPOGRAPHIC)
WINDSOR CO
SULLIVAN CO
Skinner Hill
Short Knoll
Home Hill
Little Home Hill
Stevens Hill
Lewis Swale
Ledge Island
Sumner Falls
NEW HAMPSHIRE
VERMONT
PLAINFIELD
CONNECTICUT
RIVER
Hartland
Plainfield
(BM 528)
Covered Bridge
Westgate-Peterson Cem
SCALE 1:24 000
1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETRE
CONTOUR INTERVAL 20 FEET

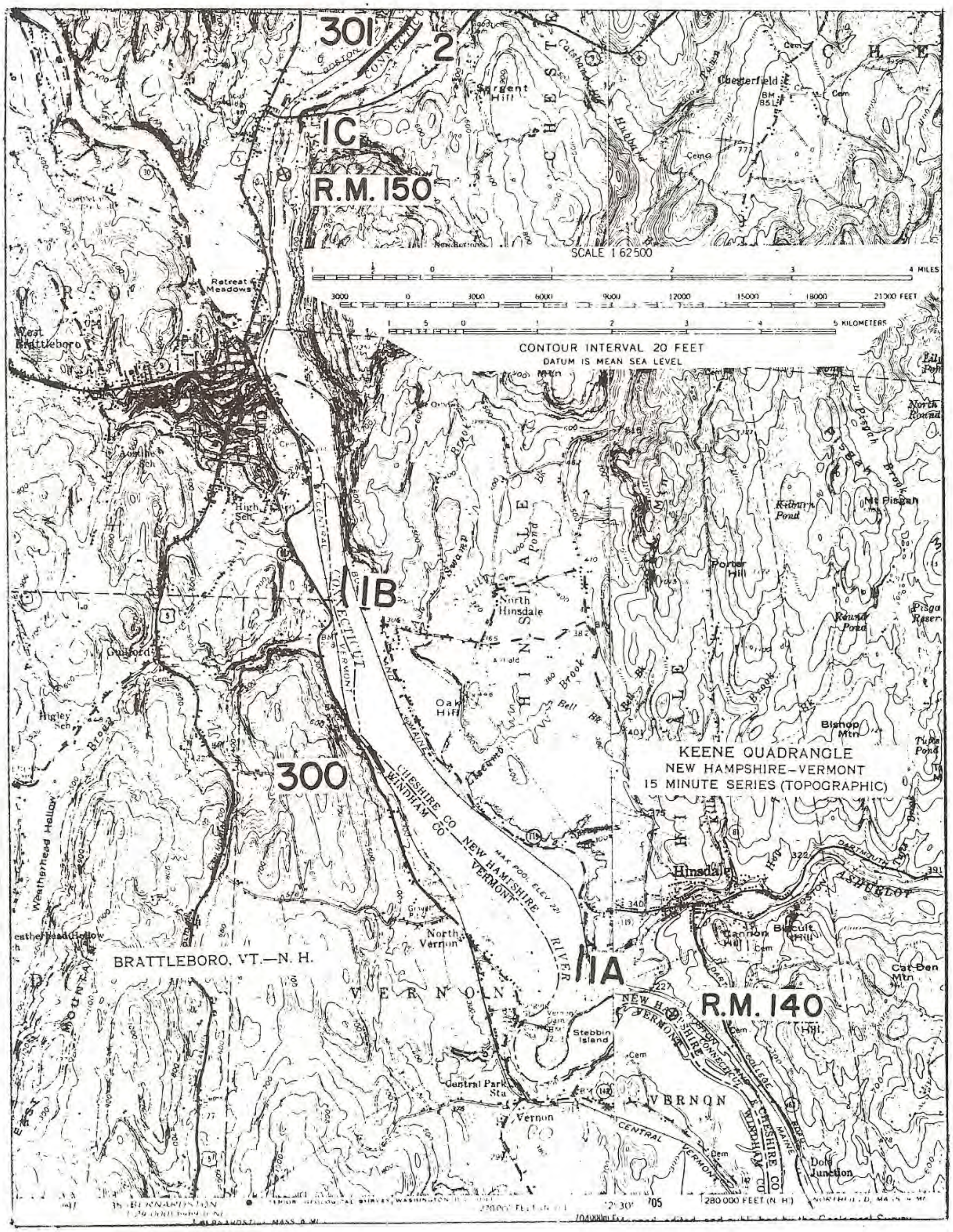

HARTLAND QUADRANGLE
VERMONT-NEW HAMPSHIRE
7.5 MINUTE SERIES (TOPOGRAPHIC)
NORTH HARTLAND QUADRANGLE
NEW HAMPSHIRE-VERMONT
7.5 MINUTE SERIES (TOPOGRAPHIC)
CORNISH
Hart Island
WINDSOR CO
SULLIVAN CO
RIVER
Squag City
Covered Bridge
Freeman Cem
Chase Cem
Blow-me-down
Brook
Gravel Pit
Borrow Pit
Substa
FERRY HILL RD
MILL ROAD
LANG
ROAD
SCALE 1:24 000
1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETRE
CONTOUR INTERVAL 20 FEET

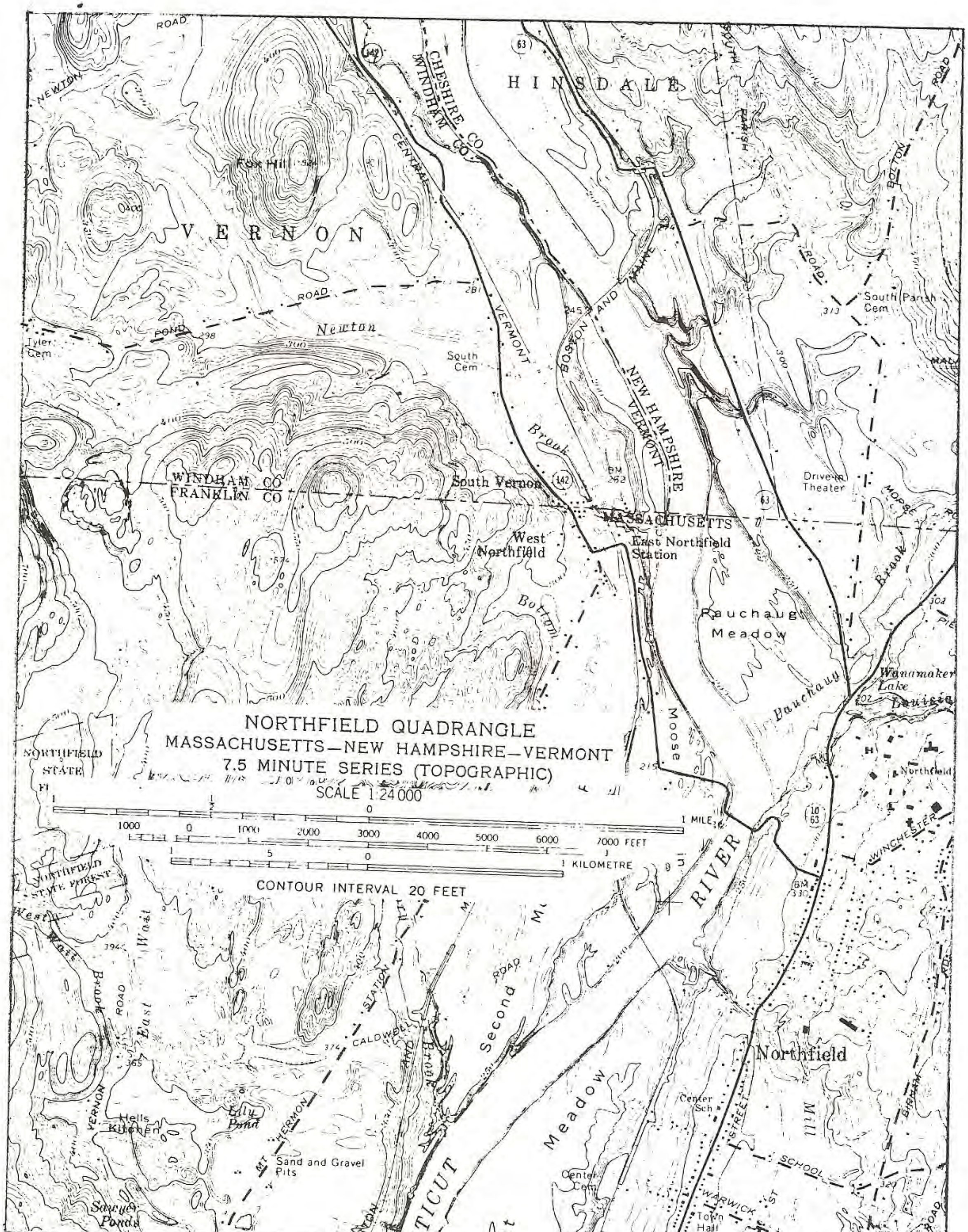

R.M. 200
31
406
405
Windsor
Ascutney
West Claremont
Claremont Junc.
WEATHERSFIELD
Weathersfield Center
Weathersfield Bow
CONNECTICUT
VERMONT
NEW HAMPSHIRE
WINDSOR CO
SULLIVAN CO
SUGAR
RIVER
SCALE 1:62500
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
CLAREMONT QUADRANGLE
NEW HAMPSHIRE–VERMONT
MINUTE SERIES (TOPOGRAPHIC)

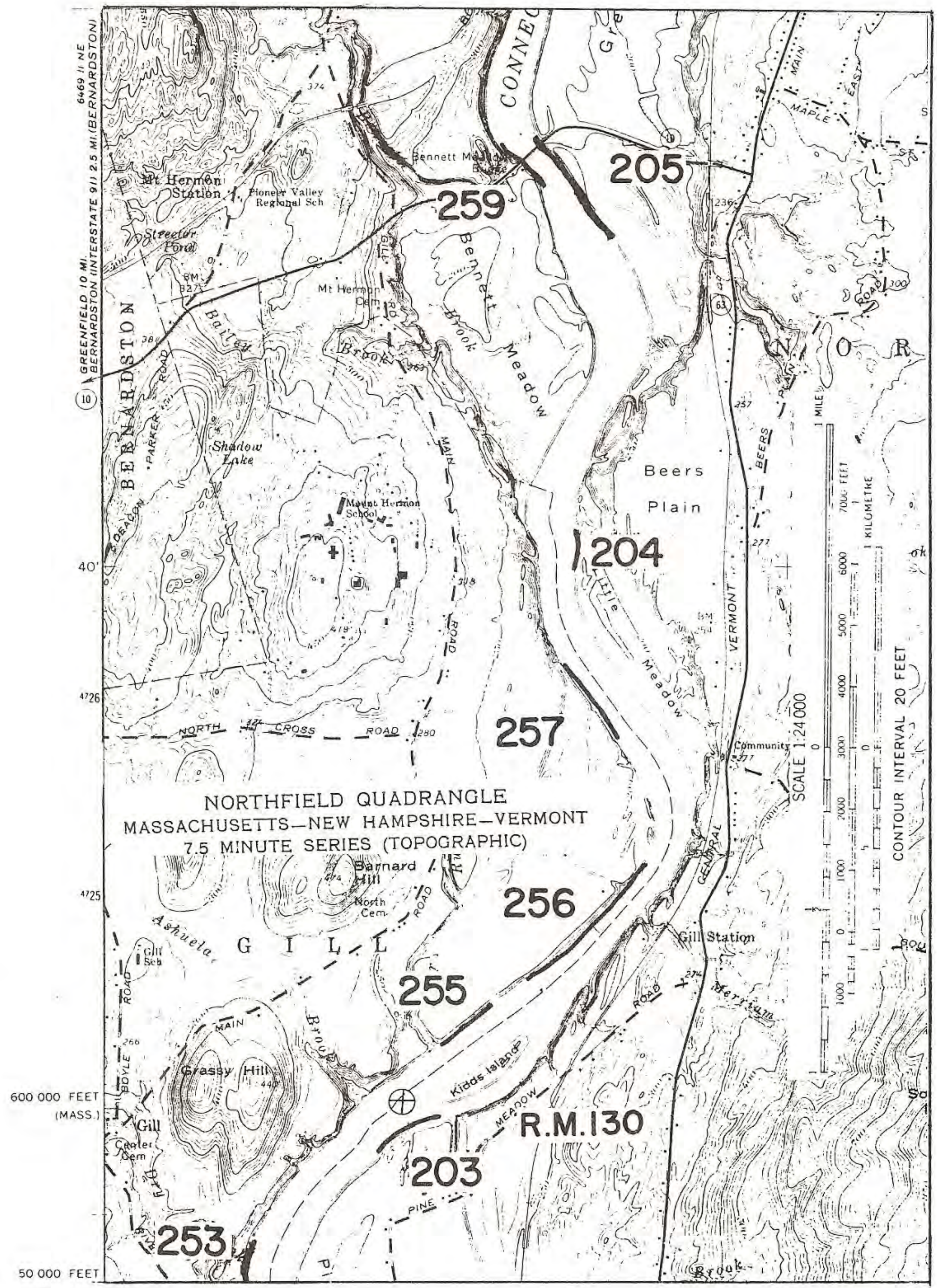

R.M. 190
27A
404
403
26
R.M. 180
Springfield
CHARLESTOWN
SPRINGFIELD
Charlestown
North Charlestown
Goulds Mill
Springfield Junction
CLAREMONT QUADRANGLE
NEW HAMPSHIRE-VERMONT
15 MINUTE SERIES (TOPOGRAPHIC)
BELLOWS FALLS QUADRANGLE
NEW HAMPSHIRE-VERMONT
15 MINUTE SERIES (TOPOGRAPHIC)
SCALE 1:62500
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

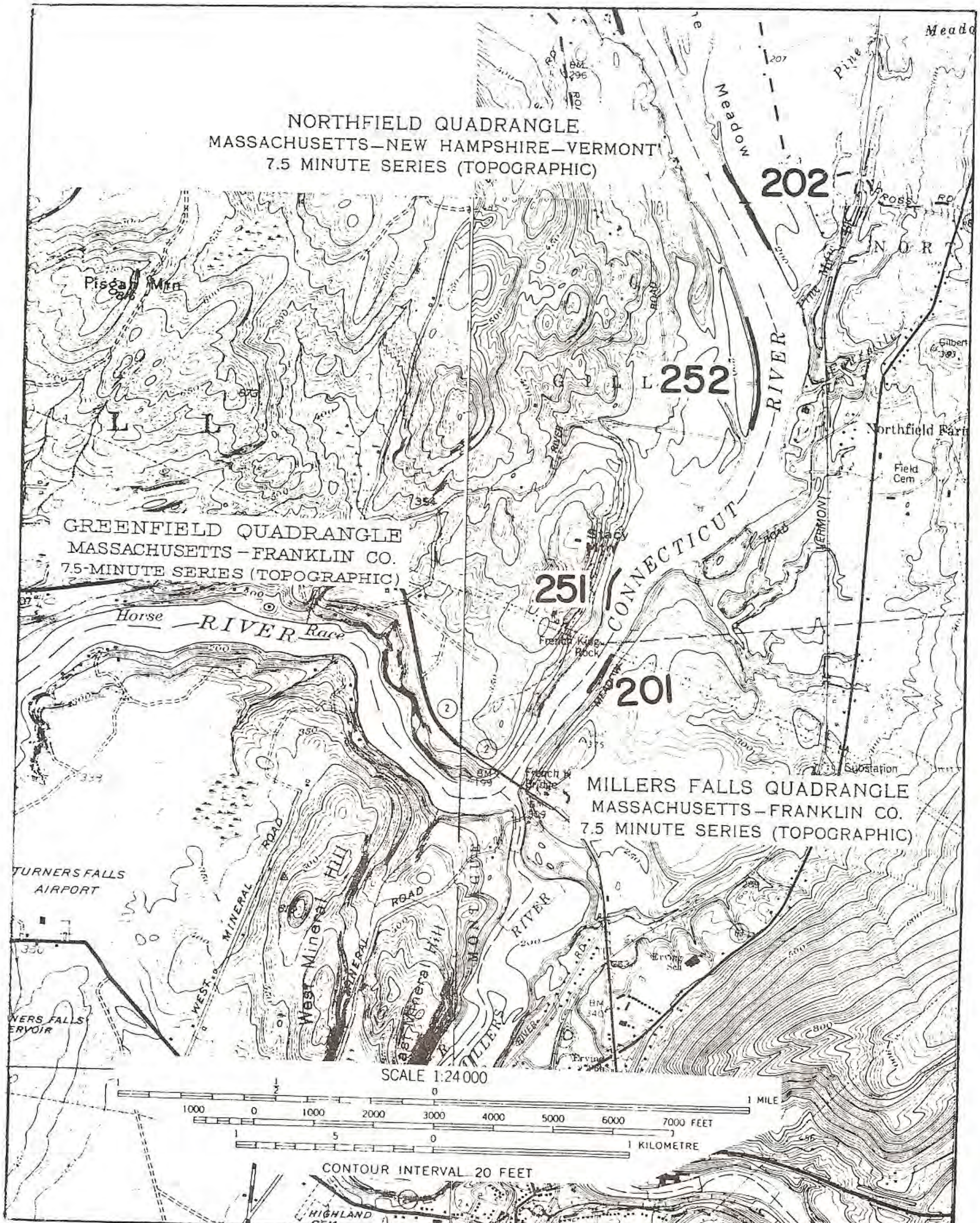

BELLOWS FALLS QUADRANGLE
NEW HAMPSHIRE–VERMONT
15 MINUTE SERIES (TOPOGRAPHIC)
SCALE 1:62500
CONTOUR INTERVAL 20 FEET
21A
314
313
R.M. 170
20
311
310
309
307
306
Bellows Falls
North Westminster
Westminster
Walpole
Drewsville
Alstead
Langdon
South Charlestown
Mt Kilburn
Hitchcock Mtn
Cheney Hill
Eaton Hill
Ramsey Hill
Barnett Hill
Pratts Rock
Rice Mtn
Tory Hill
Glovers Ledge
Walker Hill
Balls Hill
Garfield Hill
Darby Hill
Colley Hill
Signal Hill
Jones Hill
Hedgehog Hill
Wellington Hill
Cook Hill
Cock Hill
Drew Mtn
SULLIVAN CO
CHESHIRE CO
WINDHAM CO
FALL MOUNTAIN
L A N G D O N
R O C K I N G H A M
W E S T M I N S T E R

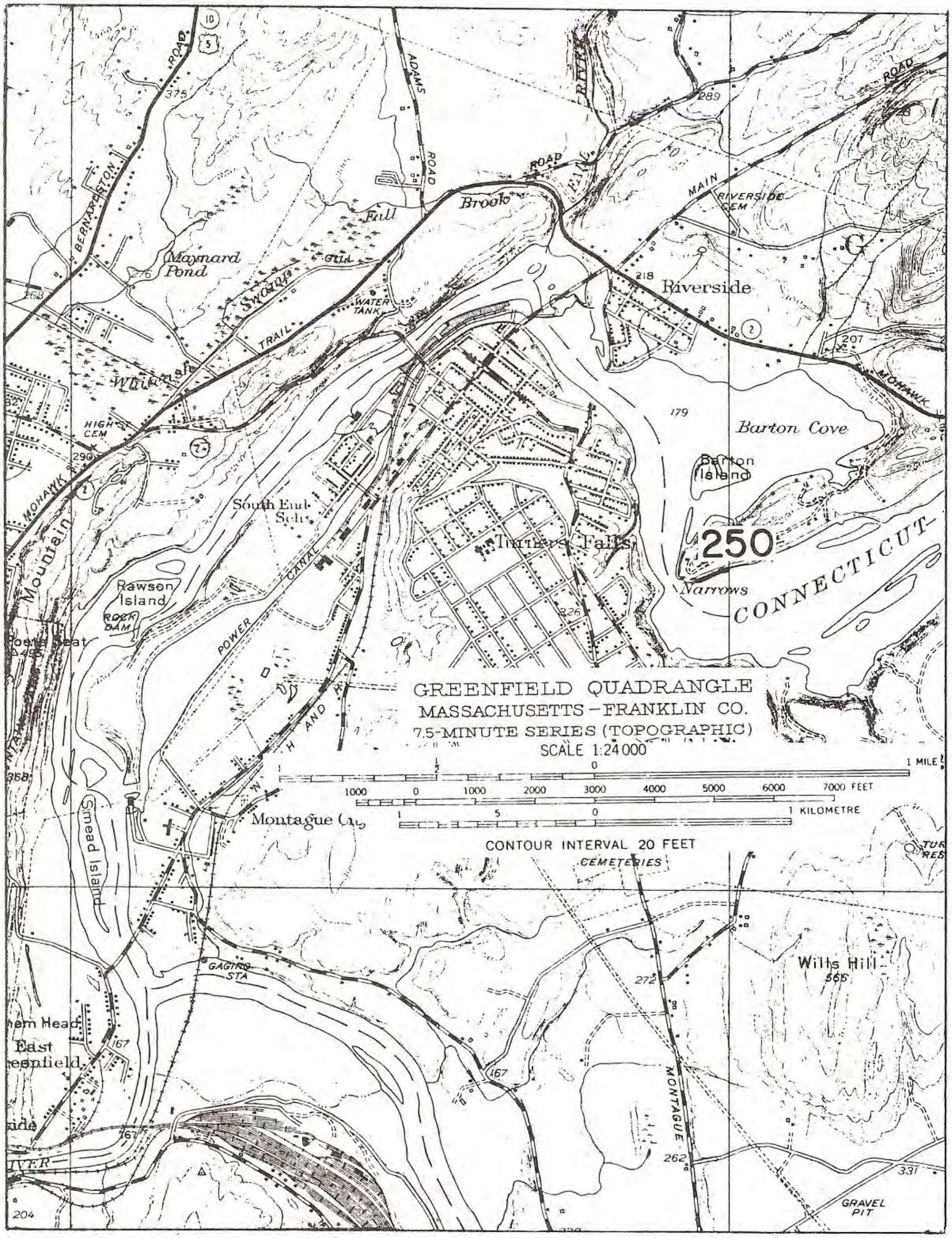

BELLOWS FALLS QUADRANGLE
NEW HAMPSHIRE-VERMONT
15 MINUTE SERIES (TOPOGRAPHIC)
BRATTLEBORO, VT.—N. H.
KEENE QUADRANGLE
NEW HAMPSHIRE-VERMONT
15 MINUTE SERIES (TOPOGRAPHIC)
SCALE 1:62500
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
17A
305
17
304
15
302
R.M. 160
12
11
9
8
7
6A
5
4
East Putney
PUTNEY
WESTMORELAND
Westmoreland
Cass Hill
Windy Hill
Butterfield Hill
Park Hill
Bald Hill
Streeter Hill
Poocham
Windham College
Putney
Putney Station
CONNECTICUT
RIVER
Great Meadows
Camp Notre Dame
Catsbane Island


301
2
1C
R.M. 150
SCALE 1 62500
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
Retreat Meadows
West Brattleboro
Chesterfield
Sargent Hill
1B
North Hinsdale
Oak Hill
Porter Hill
Mt Pisgah
Bishop Mtn
KEENE QUADRANGLE
NEW HAMPSHIRE-VERMONT
15 MINUTE SERIES (TOPOGRAPHIC)
300
CHESHIRE CO
WINDHAM CO
NEW HAMPSHIRE
VERMONT
MAX POOL ELEV 221
RIVER
Hinsdale
North Vernon
Guilford
1A
R.M. 140
BRATTLEBORO, VT.—N. H.
Stebbin Island
Central Park Sta
Vernon
VERNON
Cat Den Mtn
Dole Junction

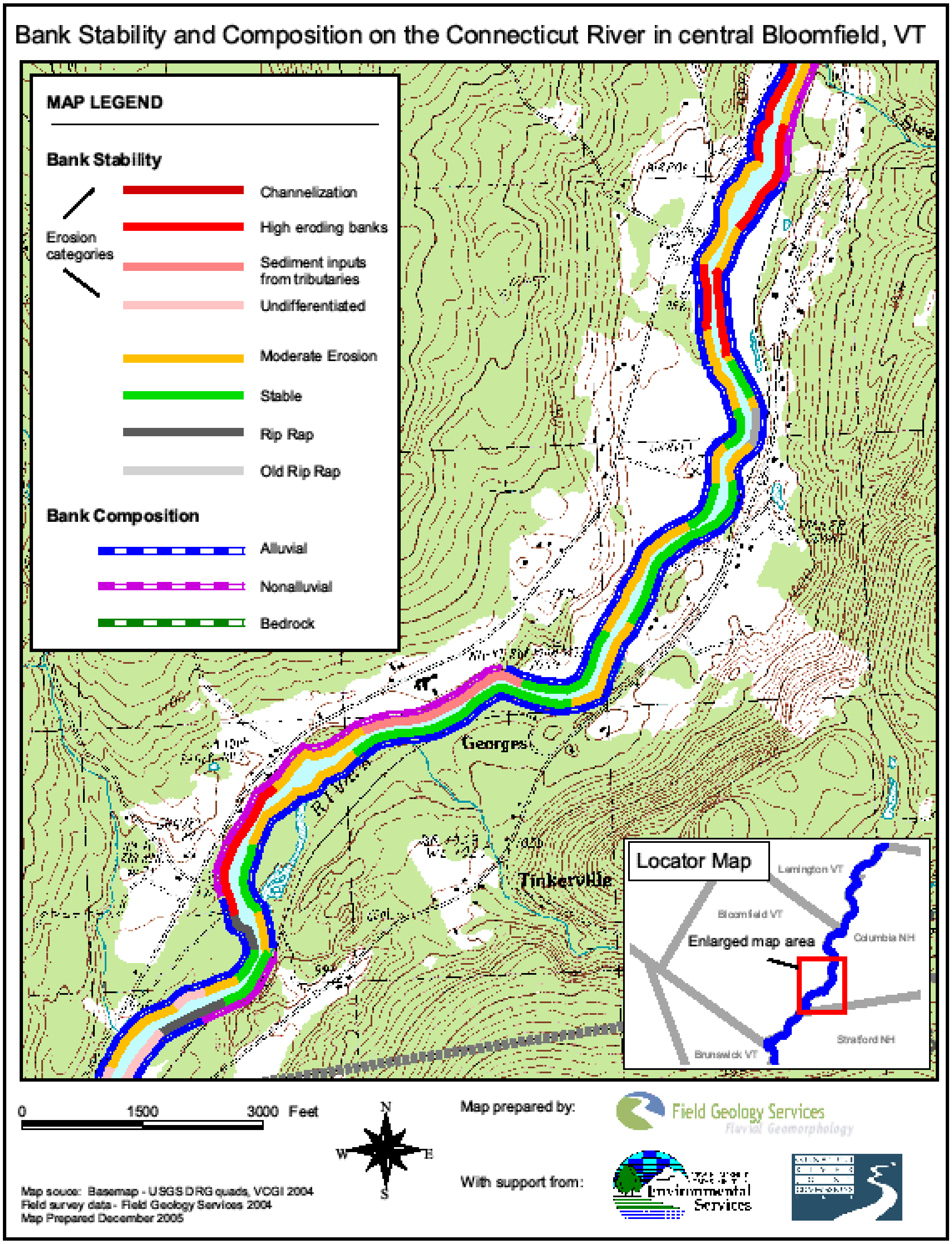

NORTHFIELD QUADRANGLE
MASSACHUSETTS—NEW HAMPSHIRE—VERMONT
7.5 MINUTE SERIES (TOPOGRAPHIC)
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
VERNON
HINSDALE
South Vernon
West Northfield
East Northfield Station
Pauchaug Meadow
Northfield
MASSACHUSETTS
NEW HAMPSHIRE
VERMONT
WINDHAM CO
FRANKLIN CO
CHESHIRE CO
Fox Hill
Hells Kitchen
Lily Pond
Sand and Gravel Pits
Wanamaker Lake
Drive-in Theater
South Parish Cem
South Cem
Tyler Cem
Center Sch
Center Cem
Town Hall
RIVER


NORTHFIELD QUADRANGLE
MASSACHUSETTS–NEW HAMPSHIRE–VERMONT
7.5 MINUTE SERIES (TOPOGRAPHIC)
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
1 MILE
1 KILOMETRE
7000 FEET
6469 II NE
GREENFIELD 10 MI.
BERNARDSTON (INTERSTATE 91) 2.5 MI.(BERNARDSTON)
40'
4726
4725
600 000 FEET (MASS.)
50 000 FEET
205
259
204
257
256
255
203
253
R.M.130
Bennett Meadow Bridge
Mt Hermon Station
Pioneer Valley Regional Sch
Streeter Pond
Mt Hermon Cem
Bennett Brook
Bennett Meadow
Bailey Brook
BERNARDSTON
Shadow Lake
Mount Hermon School
Beers Plain
Little Meadow
NORTH CROSS ROAD
MAIN ROAD
PARKER ROAD
DEACON
Barnard Hill
North Cem
GILL
Gill Sch
Gill Station
Kidds Island
MEADOW ROAD
Grassy Hill
Gill Center Cem
PINE
Community
VERMONT
CENTRAL
BEERS PLAIN
MAIN
MAPLE
EAST
ROAD
CONNEC
Merriam
Brook

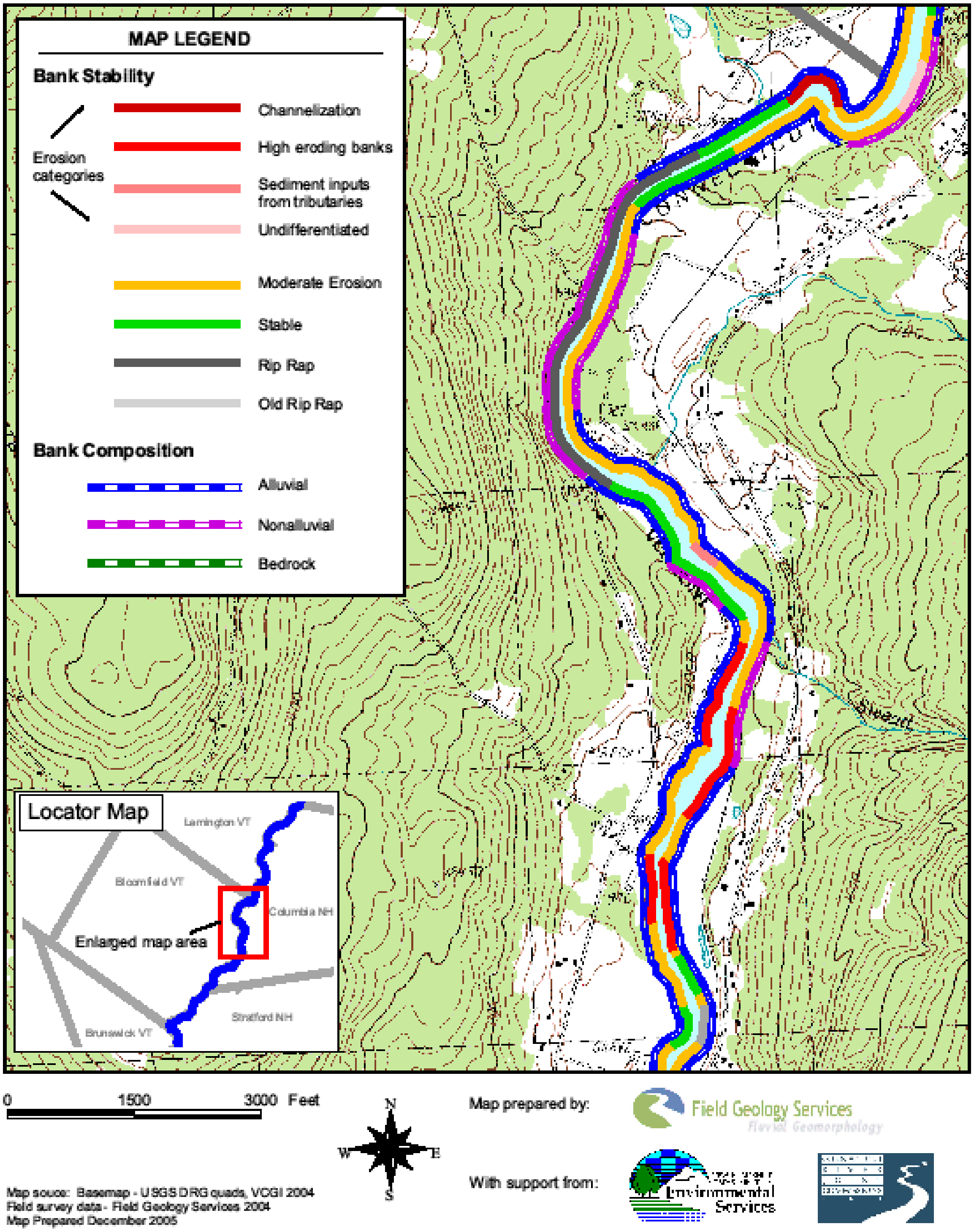

NORTHFIELD QUADRANGLE
MASSACHUSETTS–NEW HAMPSHIRE–VERMONT
7.5 MINUTE SERIES (TOPOGRAPHIC)
GREENFIELD QUADRANGLE
MASSACHUSETTS – FRANKLIN CO.
7.5-MINUTE SERIES (TOPOGRAPHIC)
MILLERS FALLS QUADRANGLE
MASSACHUSETTS – FRANKLIN CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
202
252
251
201
Meadow
CONNECTICUT
RIVER
Horse
RIVER
Race
Pisgah Mtn
French King Rock
French King Bridge
Northfield Farm
Field Cem
Substation
TURNERS FALLS AIRPORT
WEST MINERAL ROAD
West Mineral Hill
East Mineral Hill
MONTAGUE
MILLERS
RIVER
HIGHLAND CEM
SCALE 1:24 000
1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETRE
CONTOUR INTERVAL 20 FEET


GREENFIELD QUADRANGLE
MASSACHUSETTS – FRANKLIN CO.
7.5-MINUTE SERIES (TOPOGRAPHIC)
SCALE 1:24 000
1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETRE
CONTOUR INTERVAL 20 FEET
Turners Falls
Riverside
Barton Cove
Barton Island
Narrows
CONNECTICUT
Rawson Island
Smead Island
Montague City
Maynard Pond
Fall
Brook
South End Sch
POWER CANAL
Mountain
MOHAWK
TRAIL
MAIN
ROAD
ADAMS ROAD
BERNARDSTON ROAD
RIVERSIDE CEM
HIGH CEM
WATER TANK
ROCK DAM
CEMETERIES
GAGING STA
GRAVEL PIT
MONTAGUE
Wills Hill
East Greenfield
250

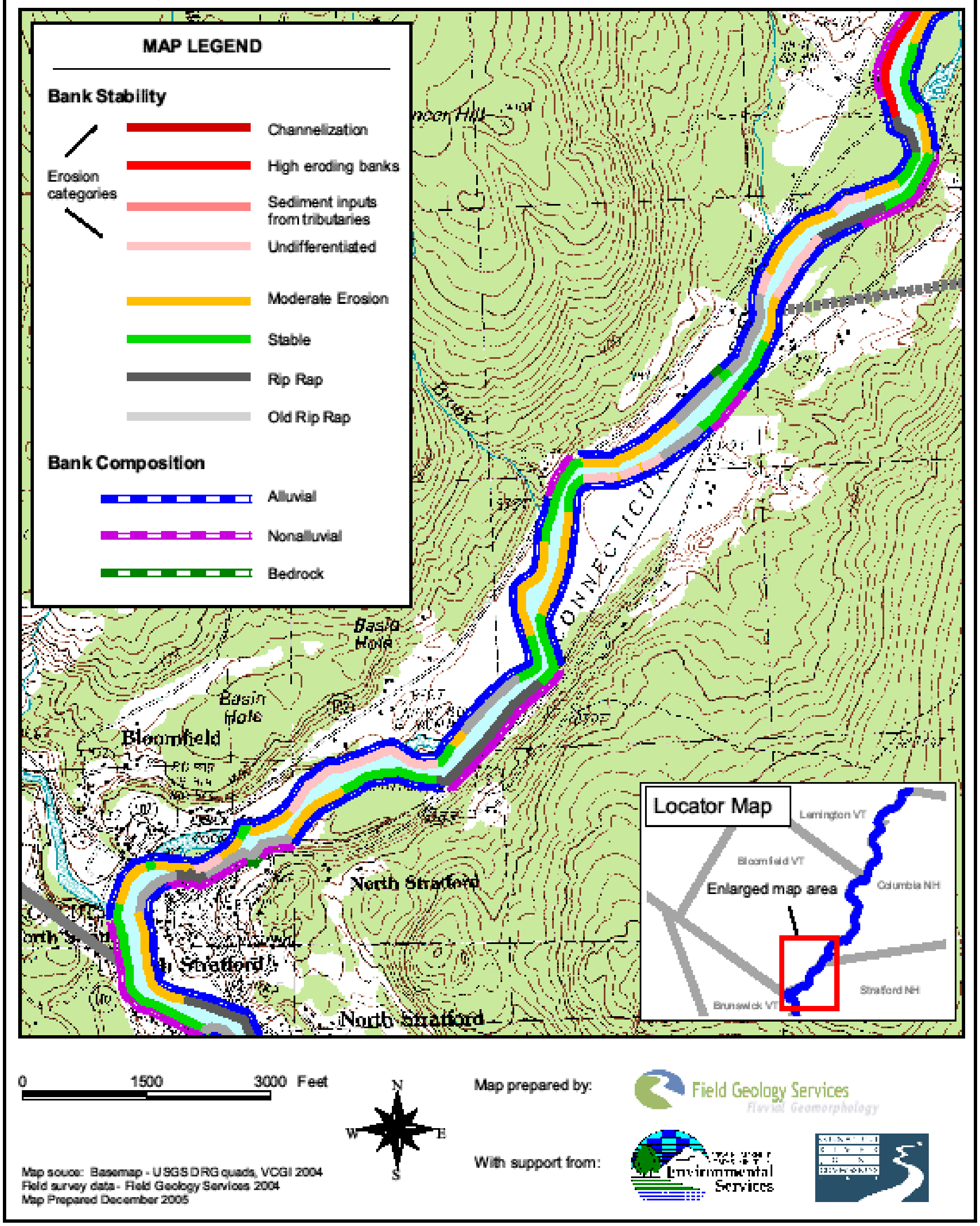
Appendix B – Erosion and Bank Composition Maps – Northern Connecticut River
(after, Field Geology Services (2005)



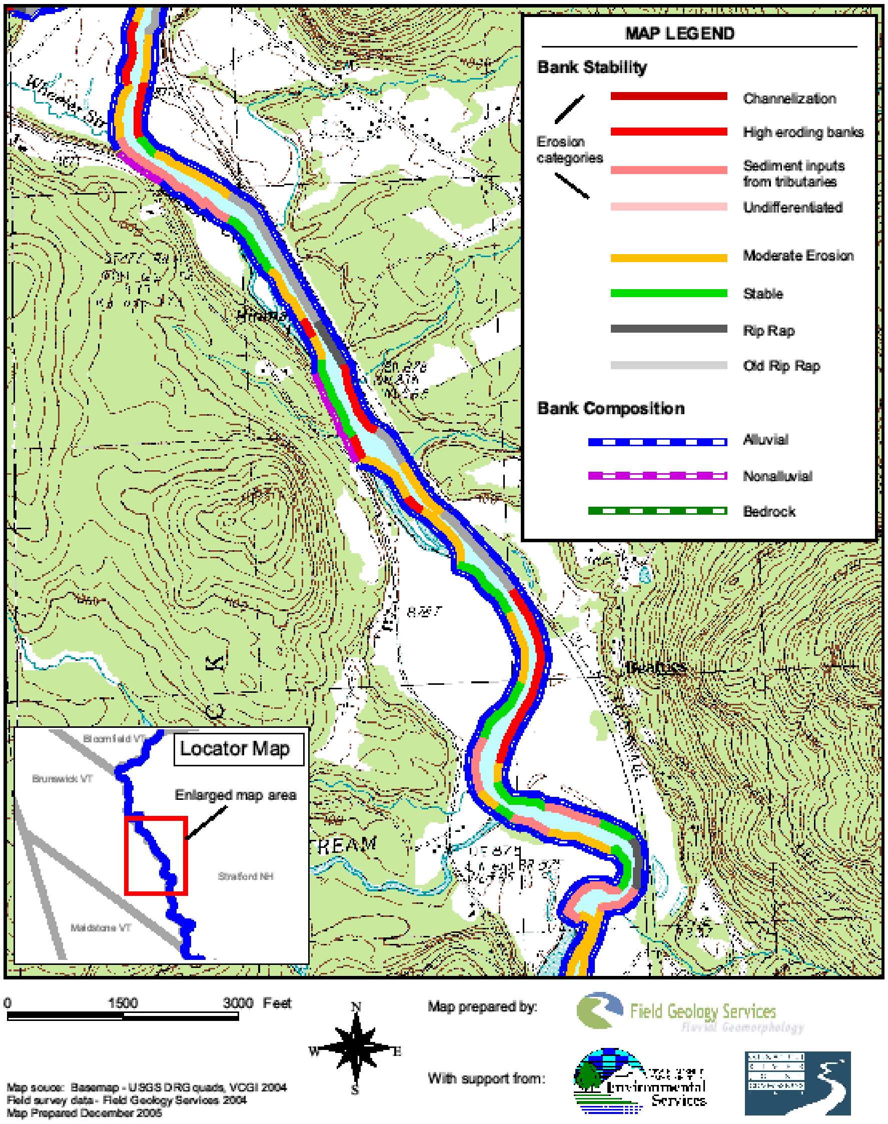
Bank Stability and Composition on the Connecticut River in northern Bloomfield, VT

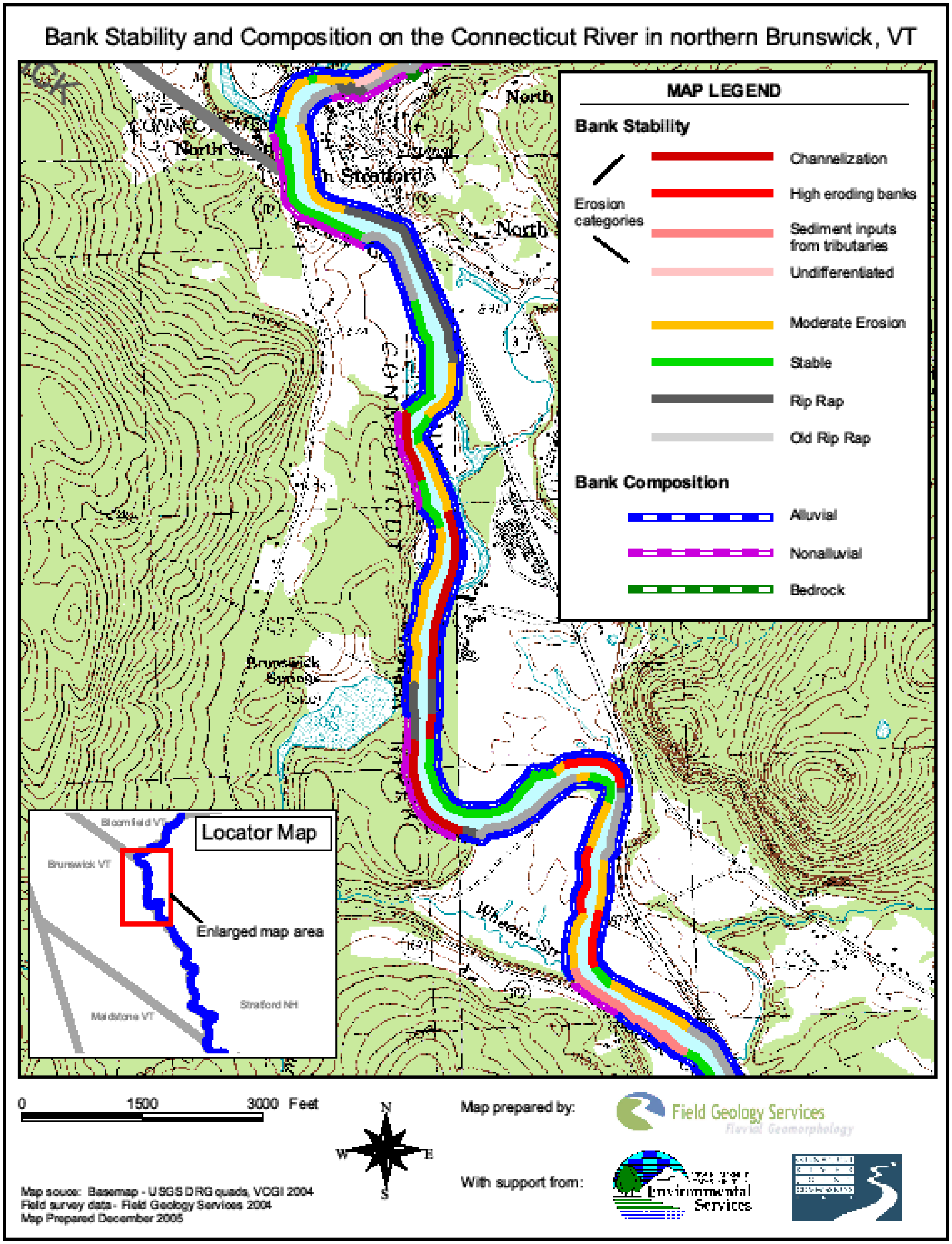


Bank Stability and Composition on the Connecticut River in southern Bloomfield, VT



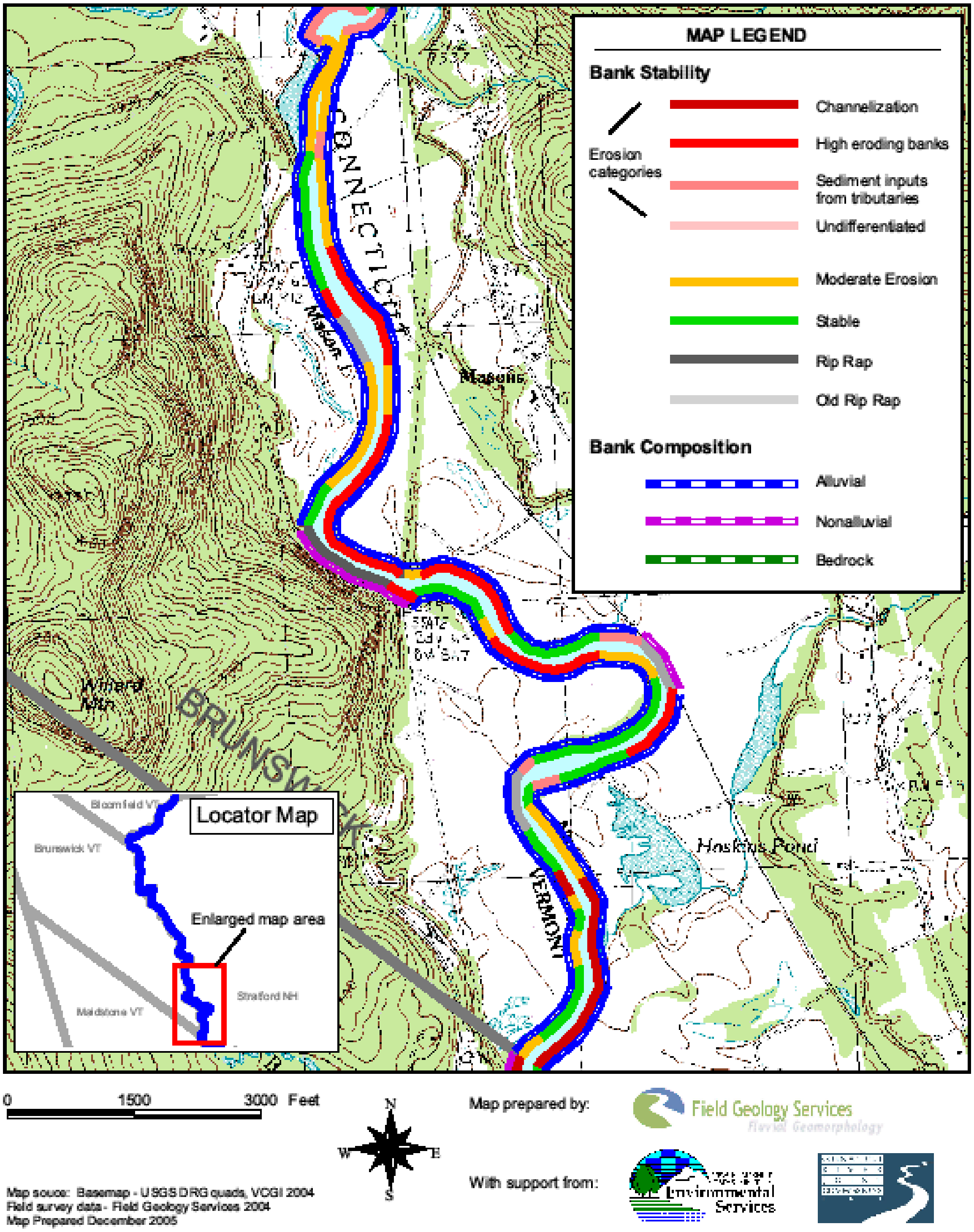
Bank Stability and Composition on the Connecticut River in central Brunswick, VT



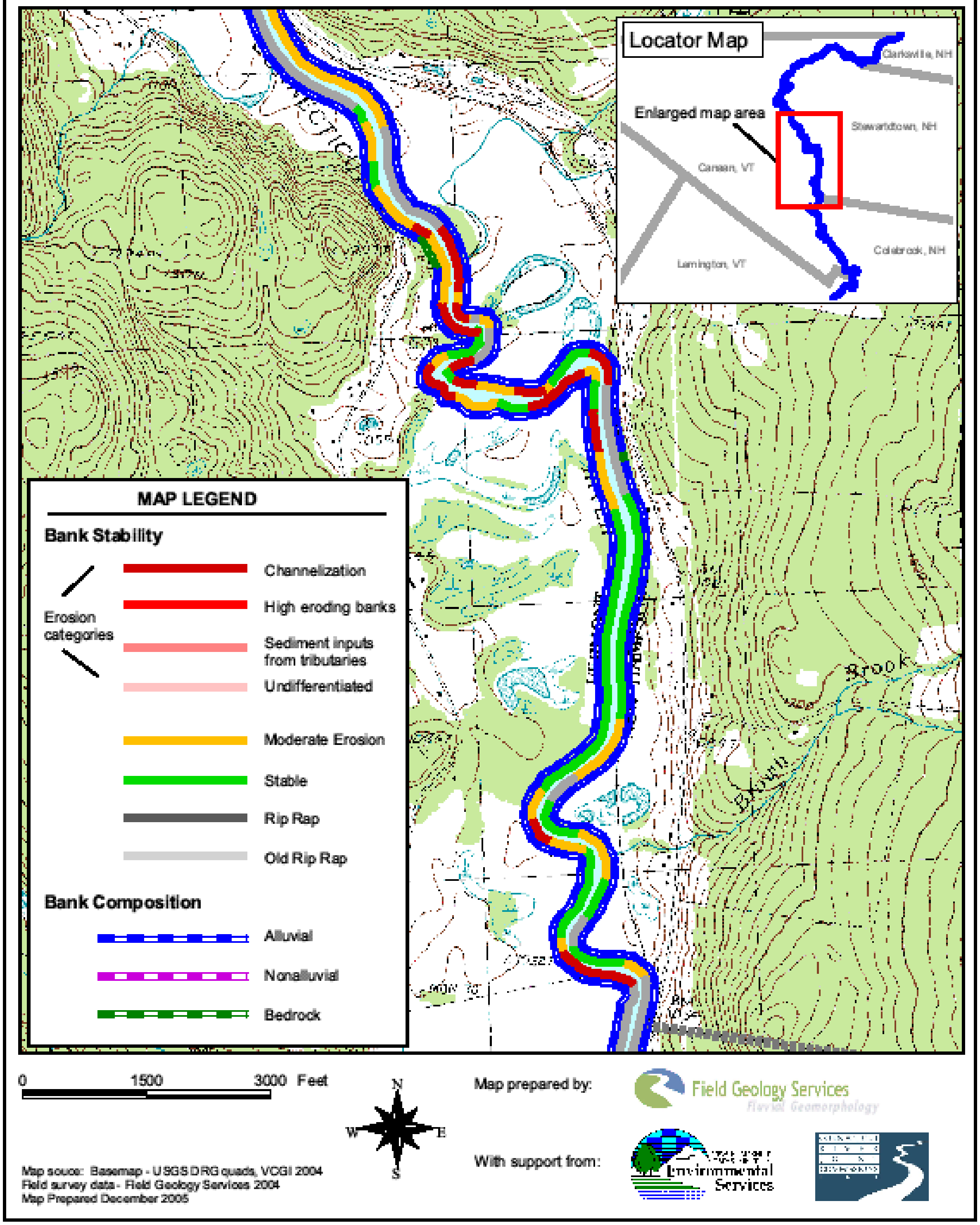


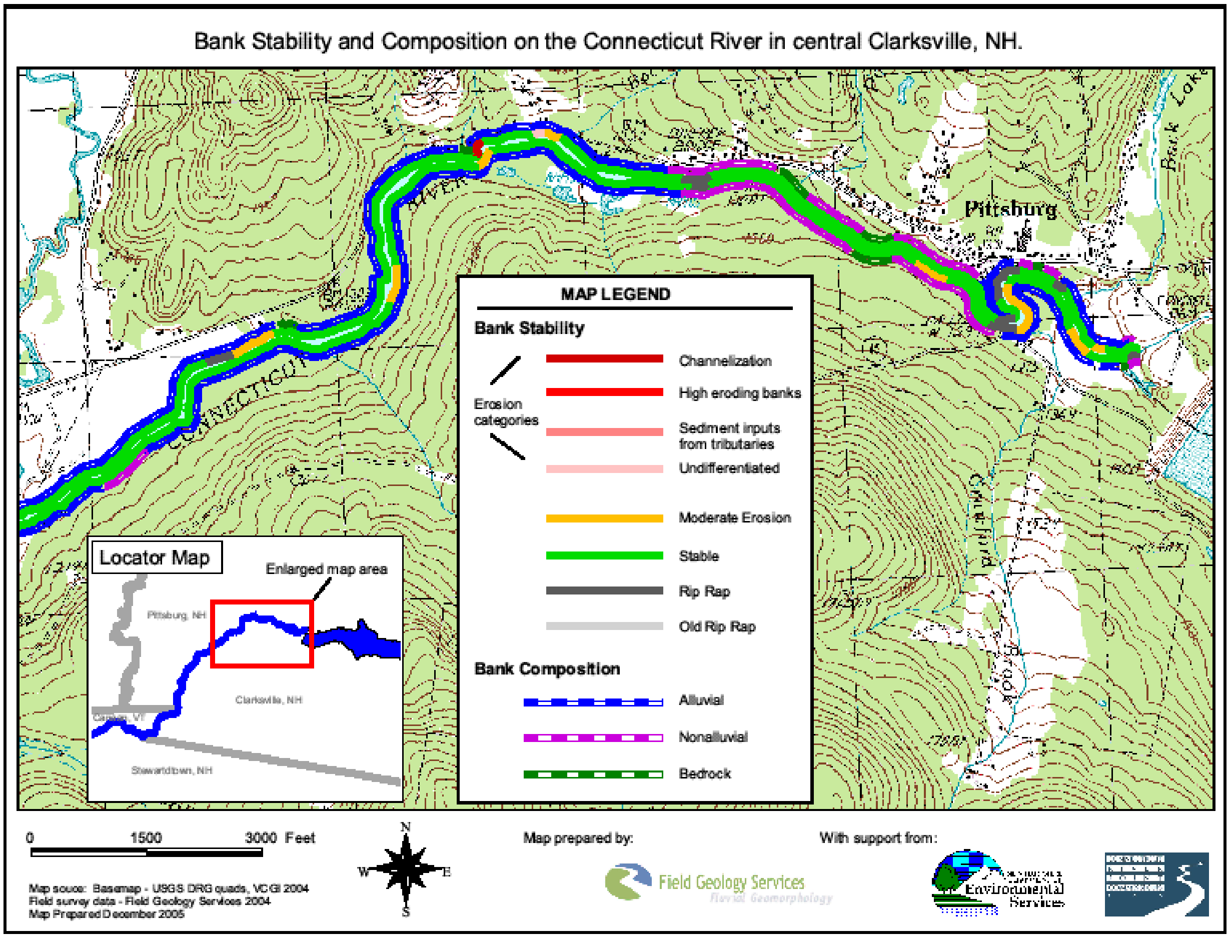
Bank Stability and Composition on the Connecticut River in northern Brunswick, VT
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
Locator Map
Bloomfield VT
Brunswick VT
Enlarged map area
Stratford NH
Maidstone VT
0
1500
3000 Feet
N
S
E
W
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

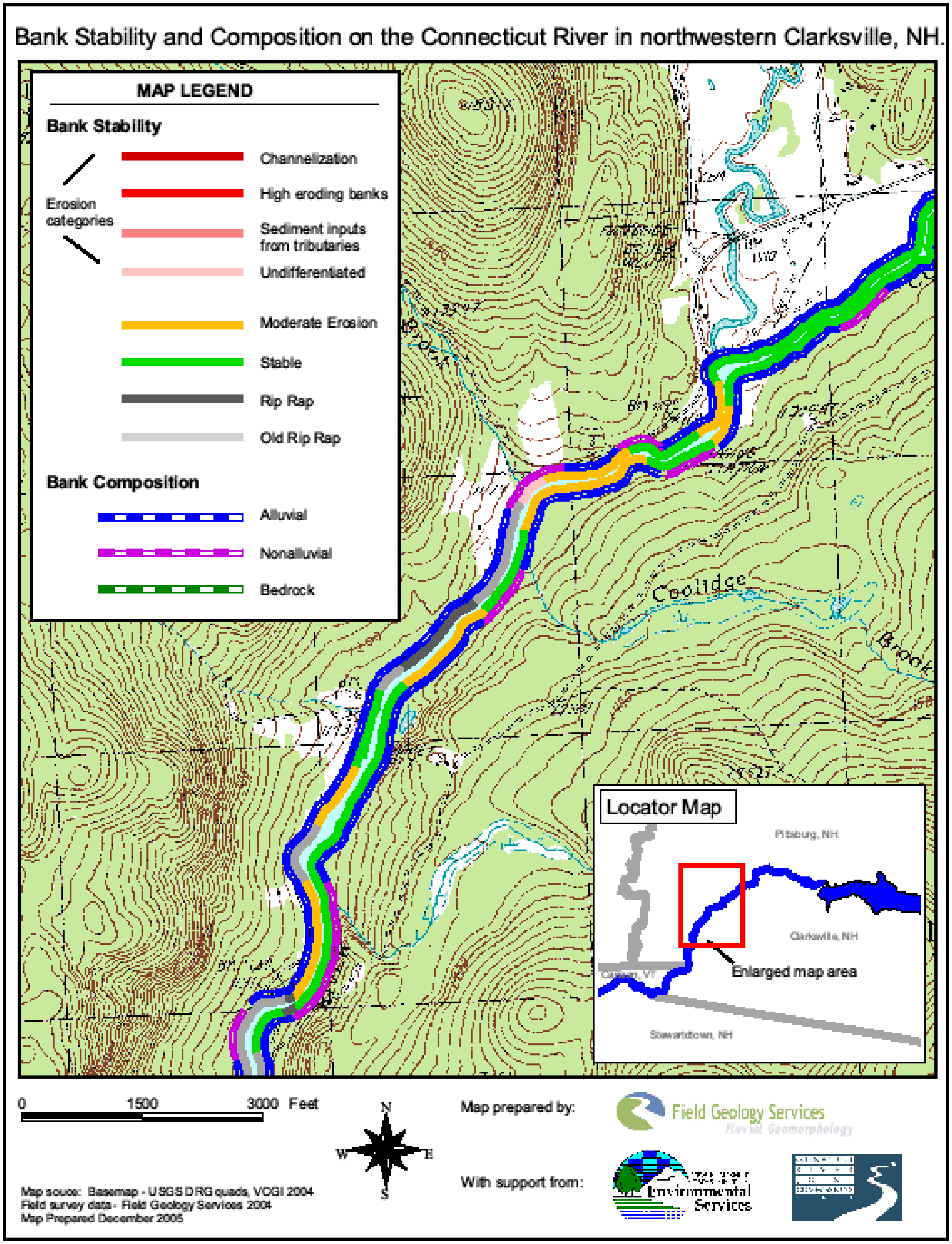
Bank Stability and Composition on the Connecticut River in southern Brunswick, VT



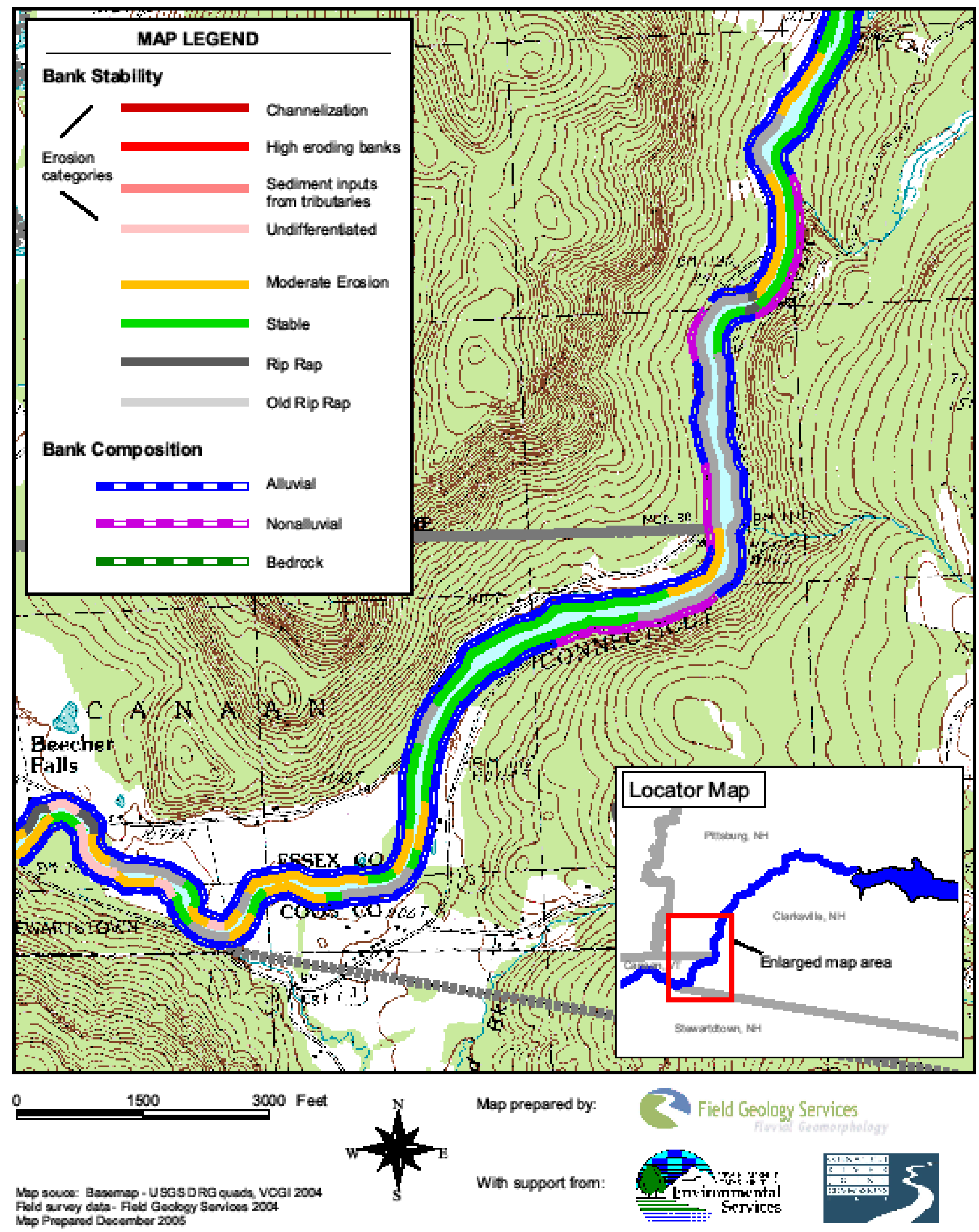
Bank Stability and Composition on the Connecticut River in central Canaan, VT

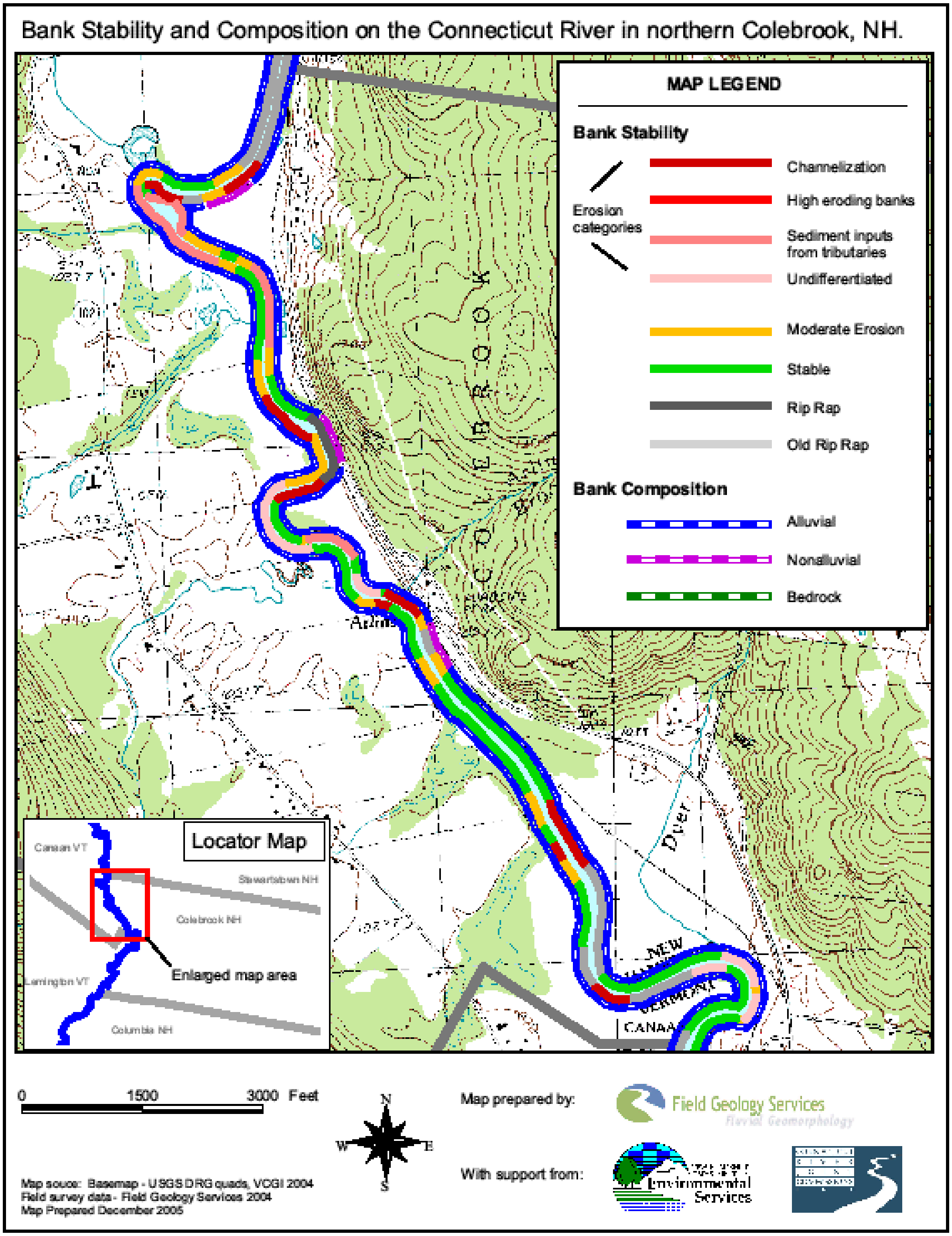



Bank Stability and Composition on the Connecticut River in central Clarksville, NH.
Pittsburg
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
Locator Map
Enlarged map area
Pittsburg, NH
Clarksville, NH
Stewartstown, NH
0
1500
3000 Feet
N
S
E
W
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services

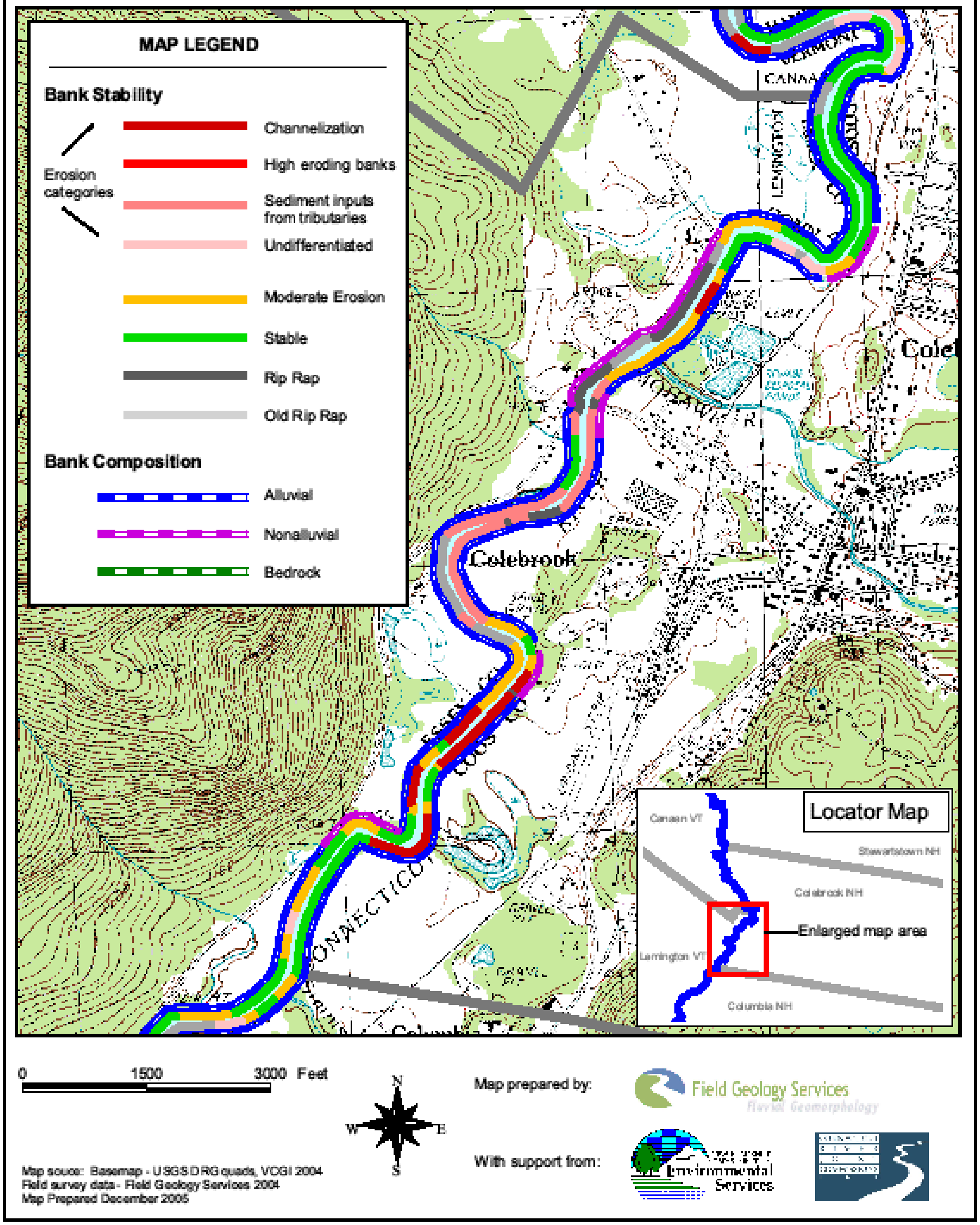

Bank Stability and Composition on the Connecticut River in northwestern Clarksville, NH.
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
Coolidge
Brook
Locator Map
Pittsburg, NH
Clarksville, NH
Canaan, VT
Enlarged map area
Stewartstown, NH
0
1500
3000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

Bank Stability and Composition on the Connecticut River in southwestern Clarksville, NH.

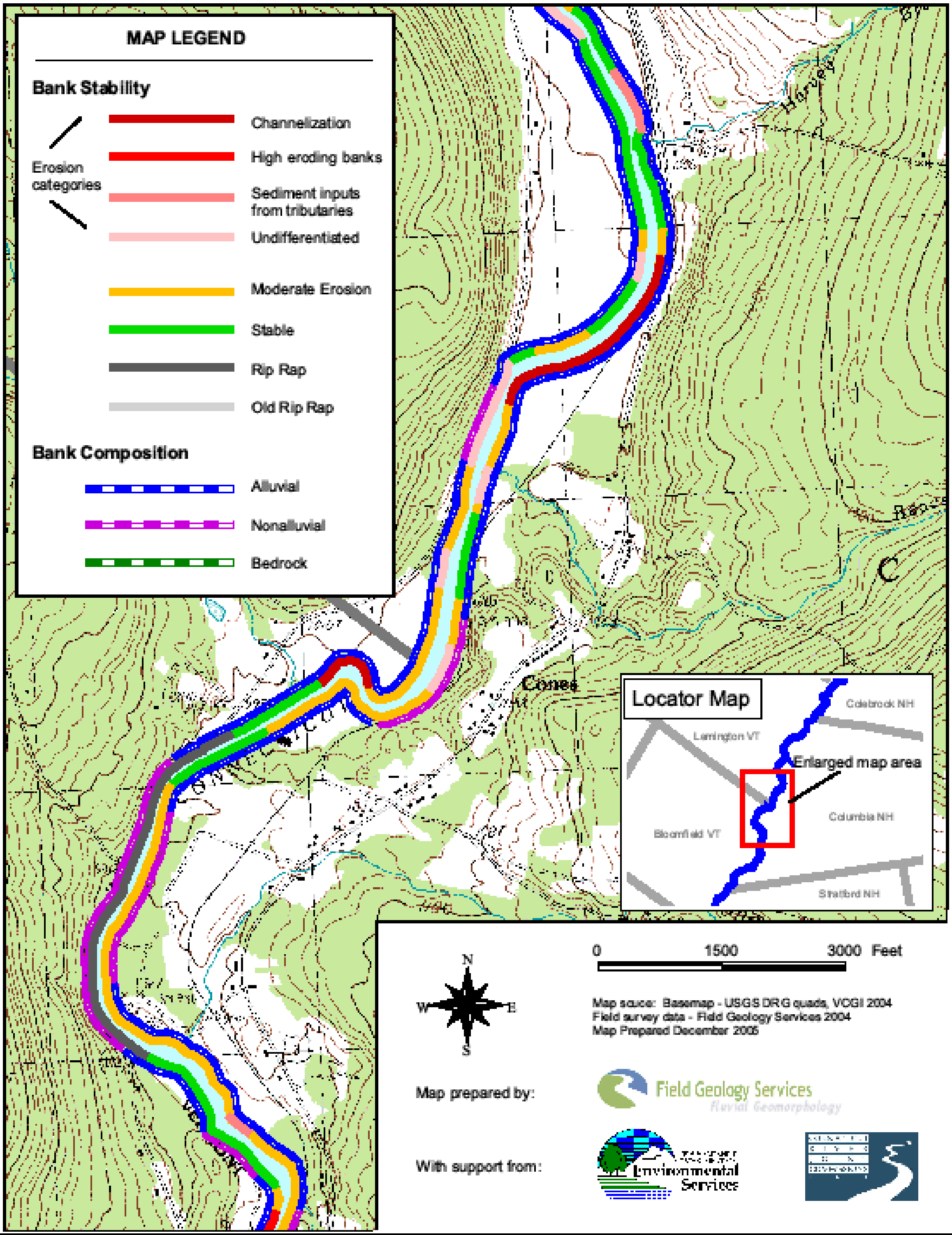


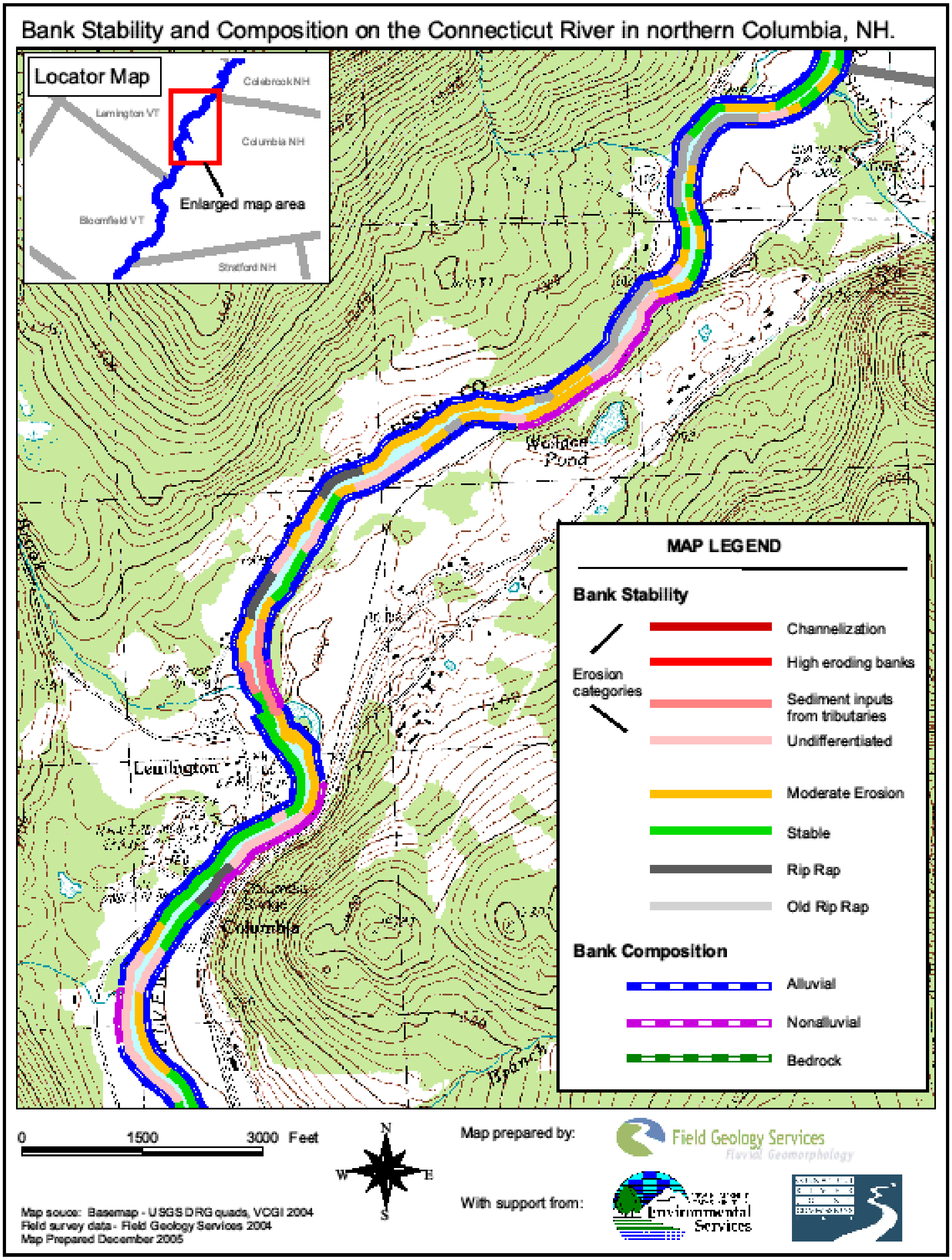

Bank Stability and Composition on the Connecticut River in northern Colebrook, NH.
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
Locator Map
Canaan VT
Stewartstown NH
Colebrook NH
Lemington VT
Columbia NH
Enlarged map area
0 1500 3000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

Bank Stability and Composition on the Connecticut River in southern Colebrook, NH.

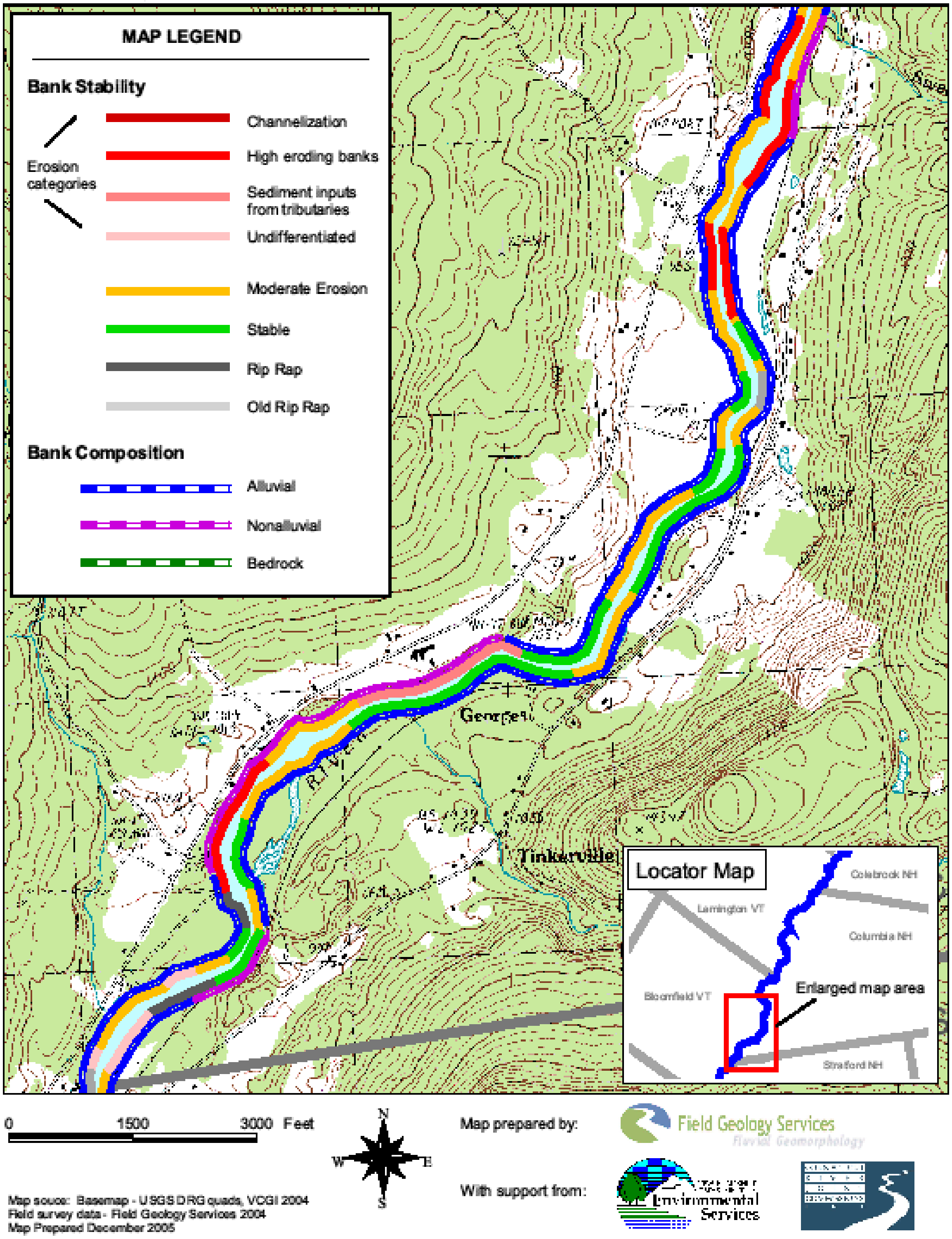


Bank Stability and Composition on the Connecticut River in central Columbia, NH.

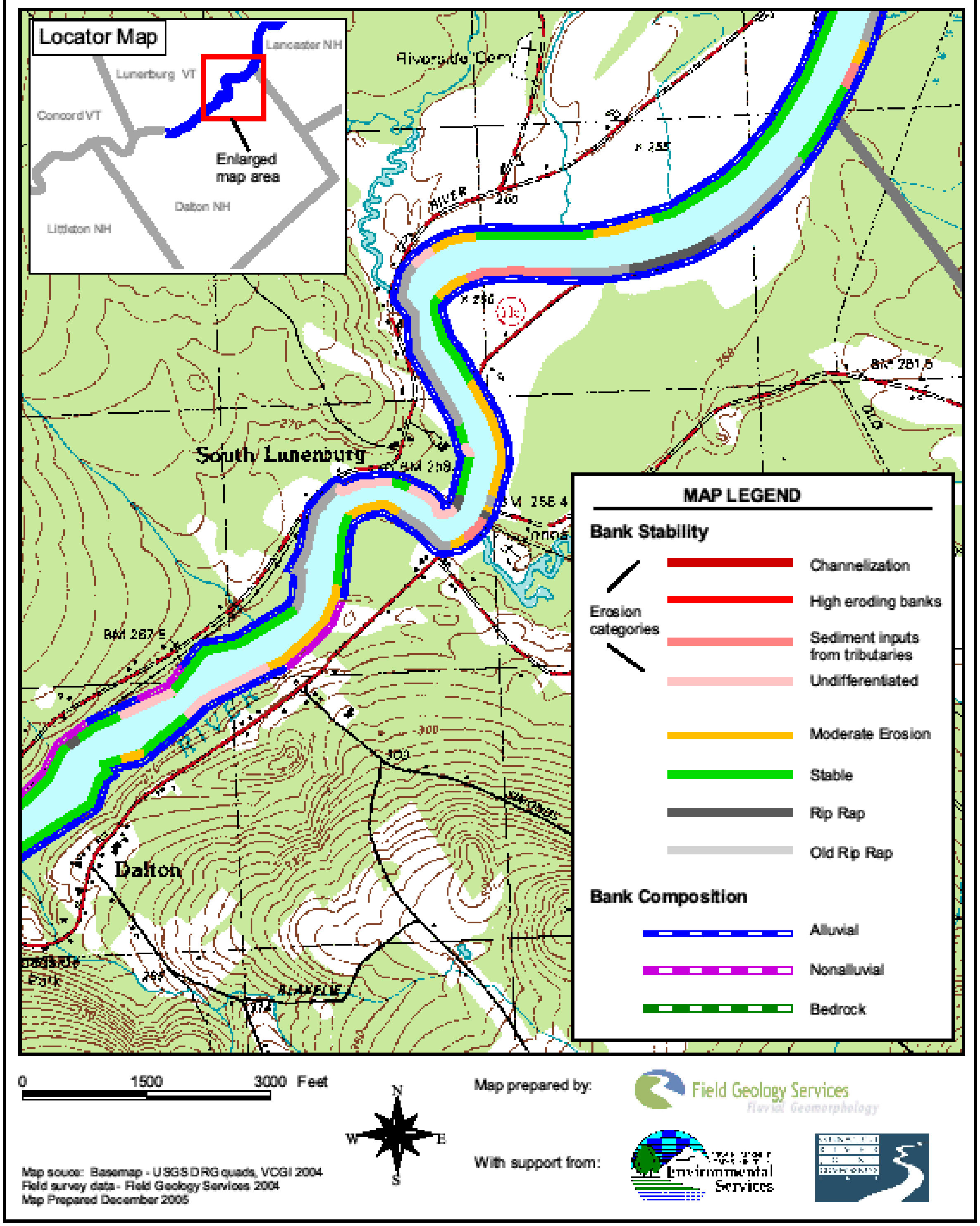


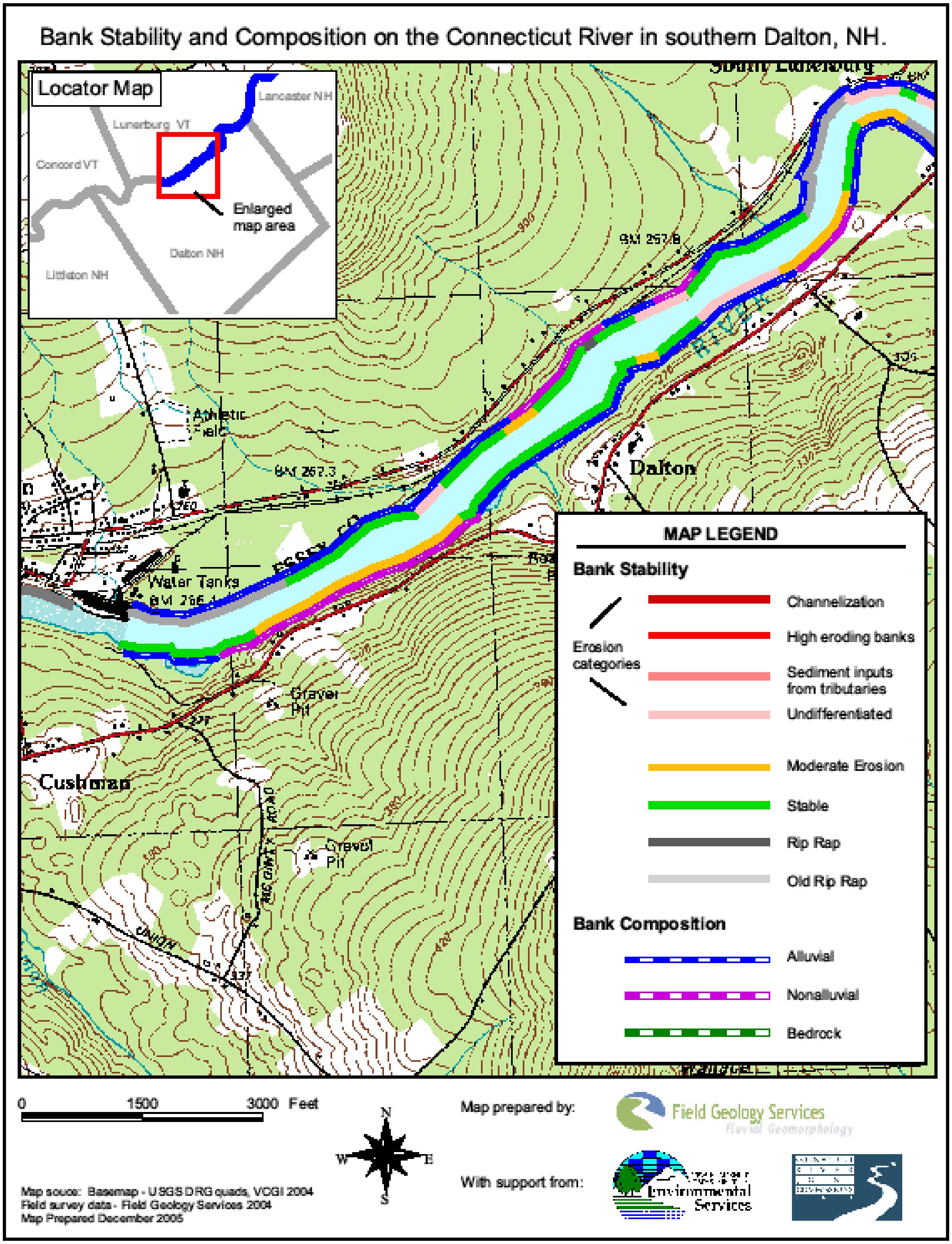

Bank Stability and Composition on the Connecticut River in northern Columbia, NH.
Locator Map
Colebrook NH
Lemington VT
Columbia NH
Enlarged map area
Bloomfield VT
Stratford NH
Lemington
Columbia
Walden Pond
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
0
1500
3000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

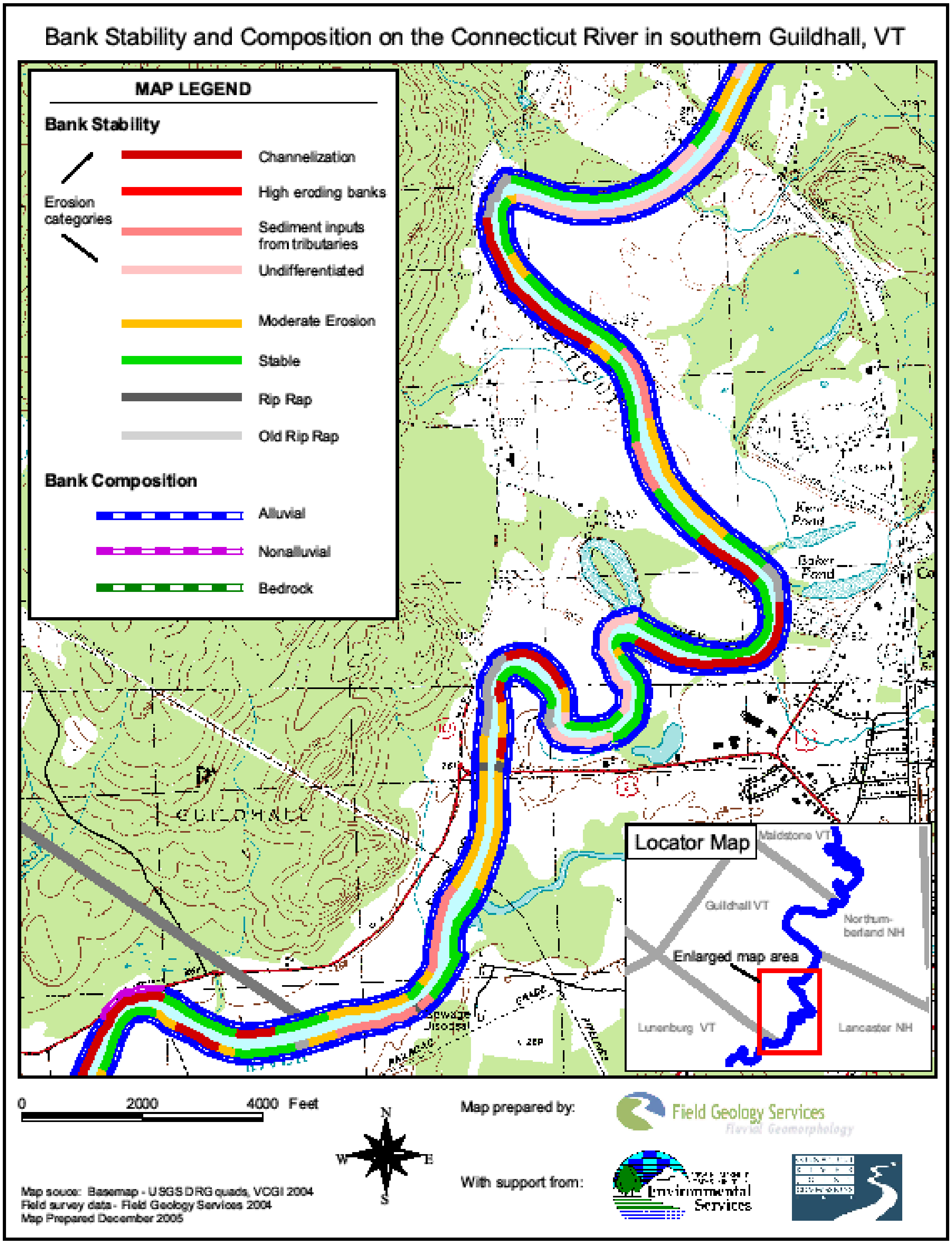
Bank Stability and Composition on the Connecticut River in southern Columbia, NH.

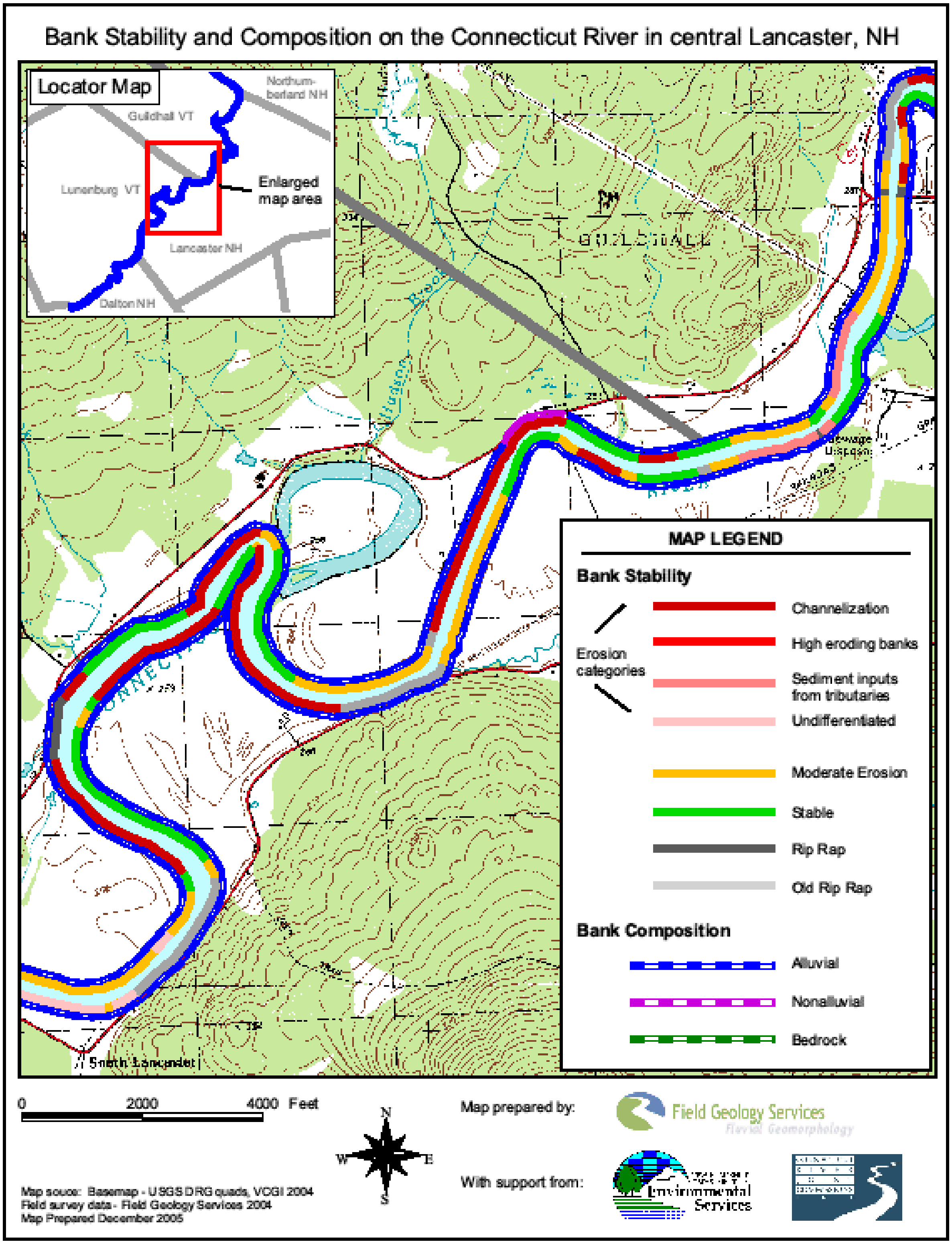


Bank Stability and Composition on the Connecticut River in northern Dalton, NH.

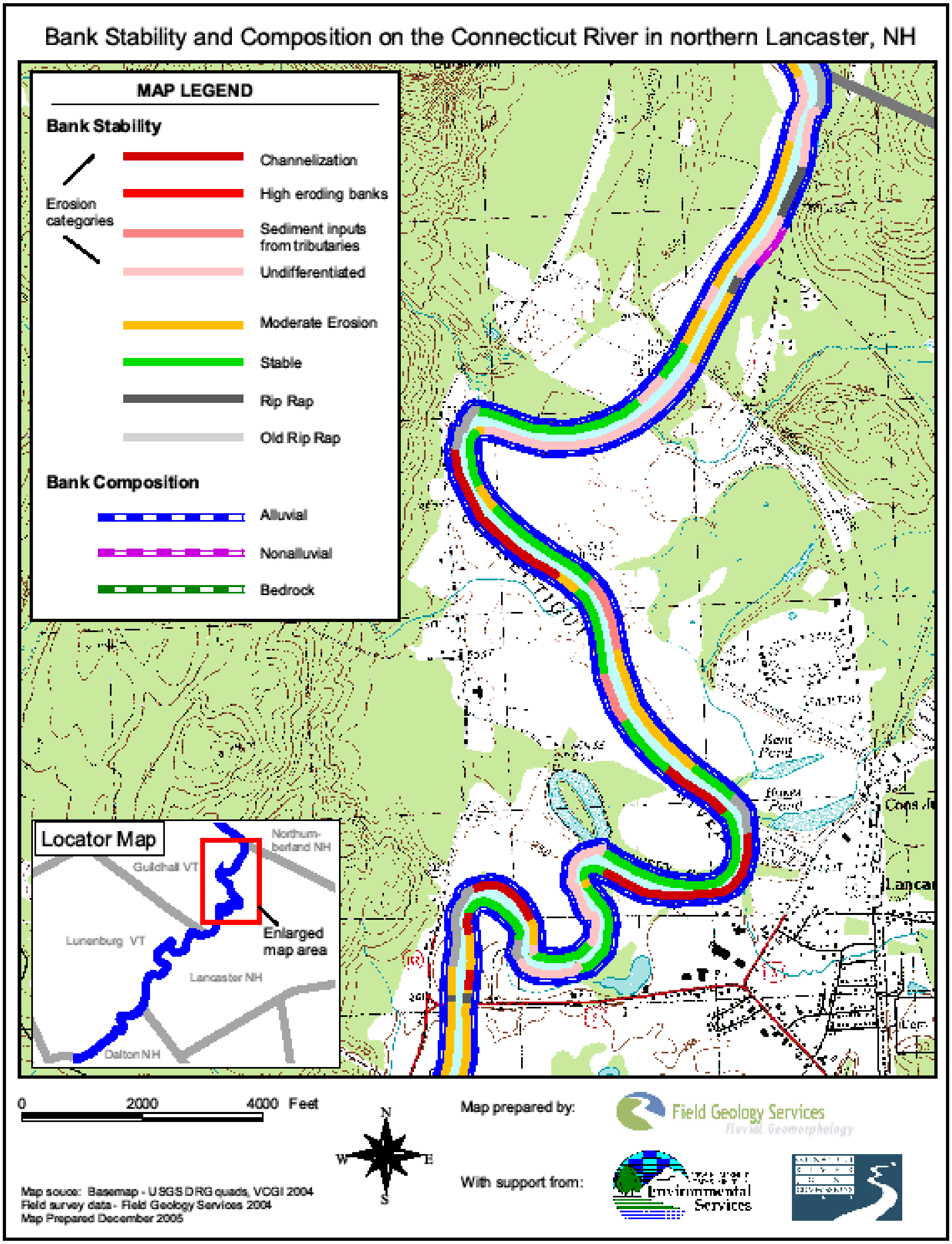


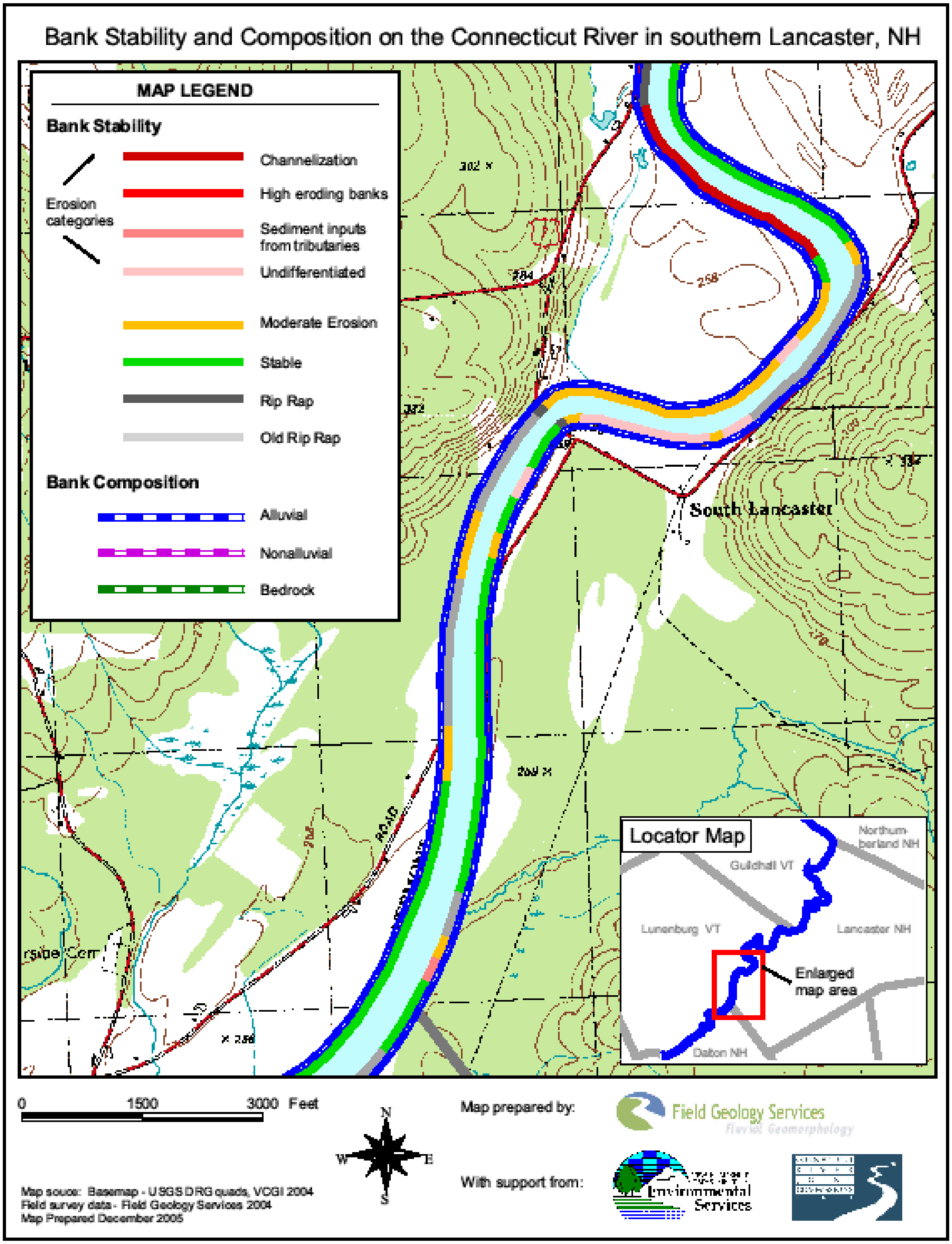

Bank Stability and Composition on the Connecticut River in southern Dalton, NH.
Locator Map
Lancaster NH
Lunenburg VT
Concord VT
Enlarged map area
Dalton NH
Littleton NH
Athletic Field
Water Tanks
Dalton
Gravel Pit
Cushman
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
0 1500 3000 Feet
N
W E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005


Bank Stability and Composition on the Connecticut River in southern Guildhall, VT
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
Locator Map
Maidstone VT
Guildhall VT
Northumberland NH
Enlarged map area
Lunenburg VT
Lancaster NH
0
2000
4000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

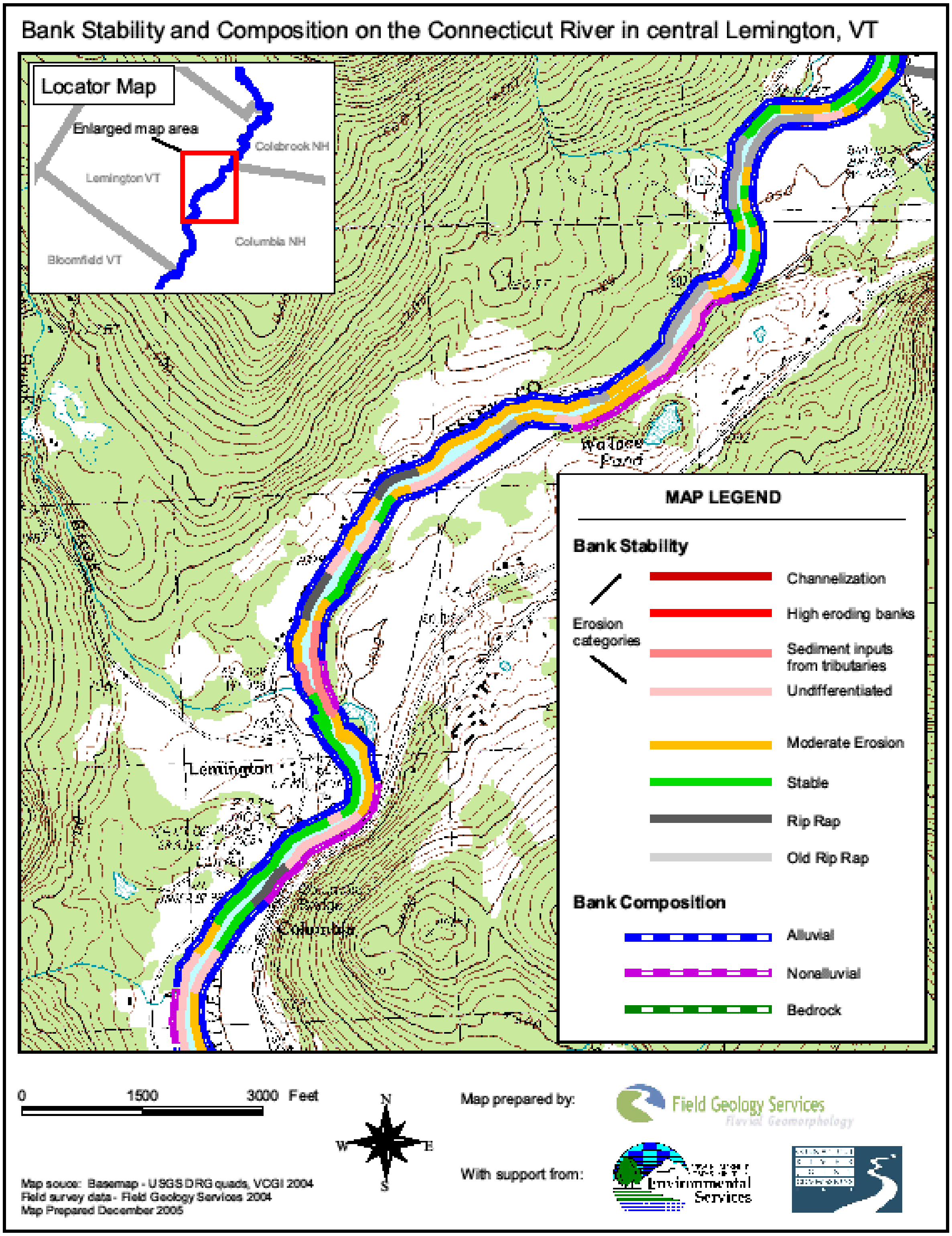

Bank Stability and Composition on the Connecticut River in central Lancaster, NH
Locator Map
Northum-
berland NH
Guildhall VT
Lunenburg VT
Enlarged
map area
Lancaster NH
Dalton NH
GUILDHALL
South Lancaster
MAP LEGEND
Bank Stability
Erosion
categories
Channelization
High eroding banks
Sediment inputs
from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
0
2000
4000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental
Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

Bank Stability and Composition on the Connecticut River in northern Lancaster, NH

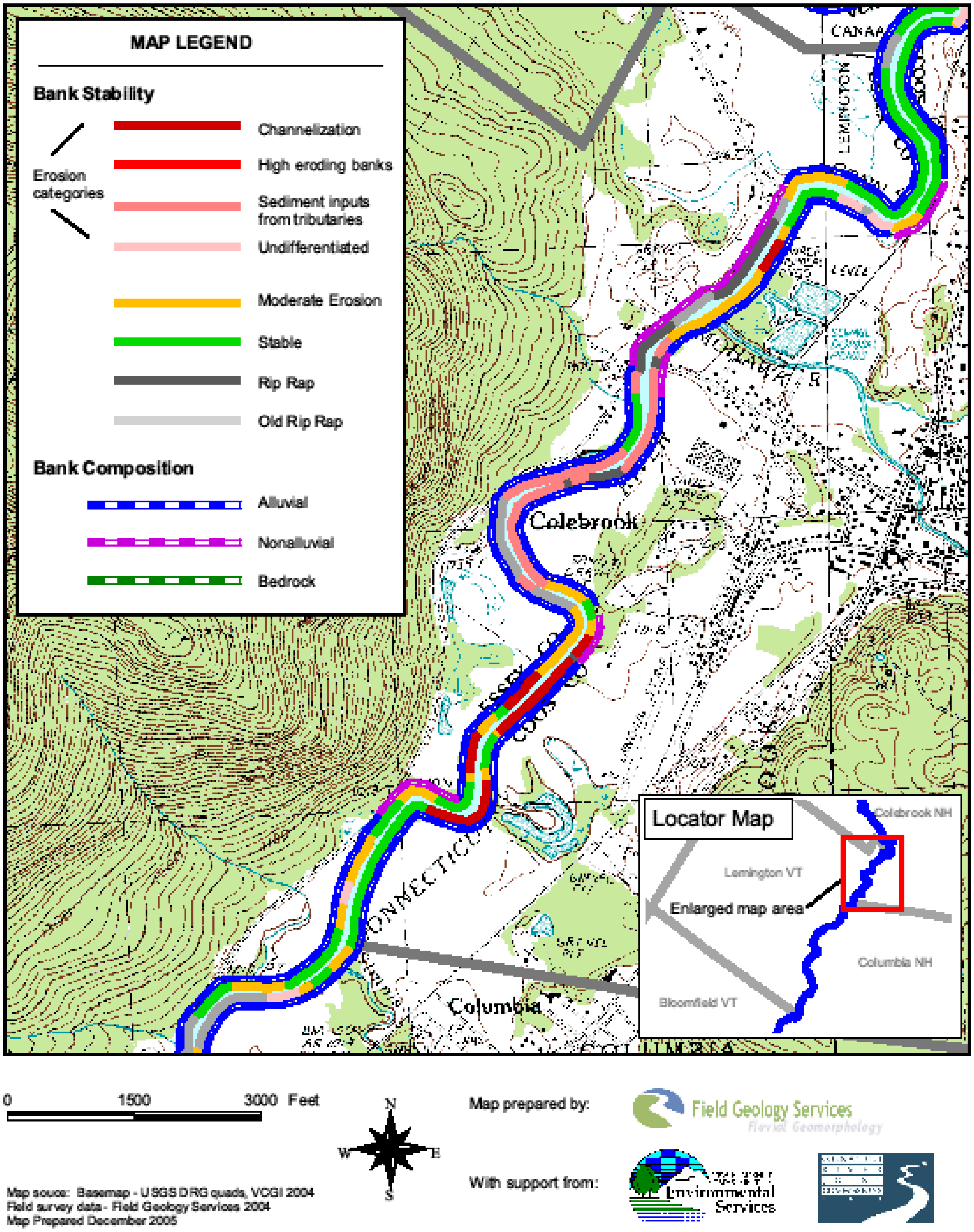


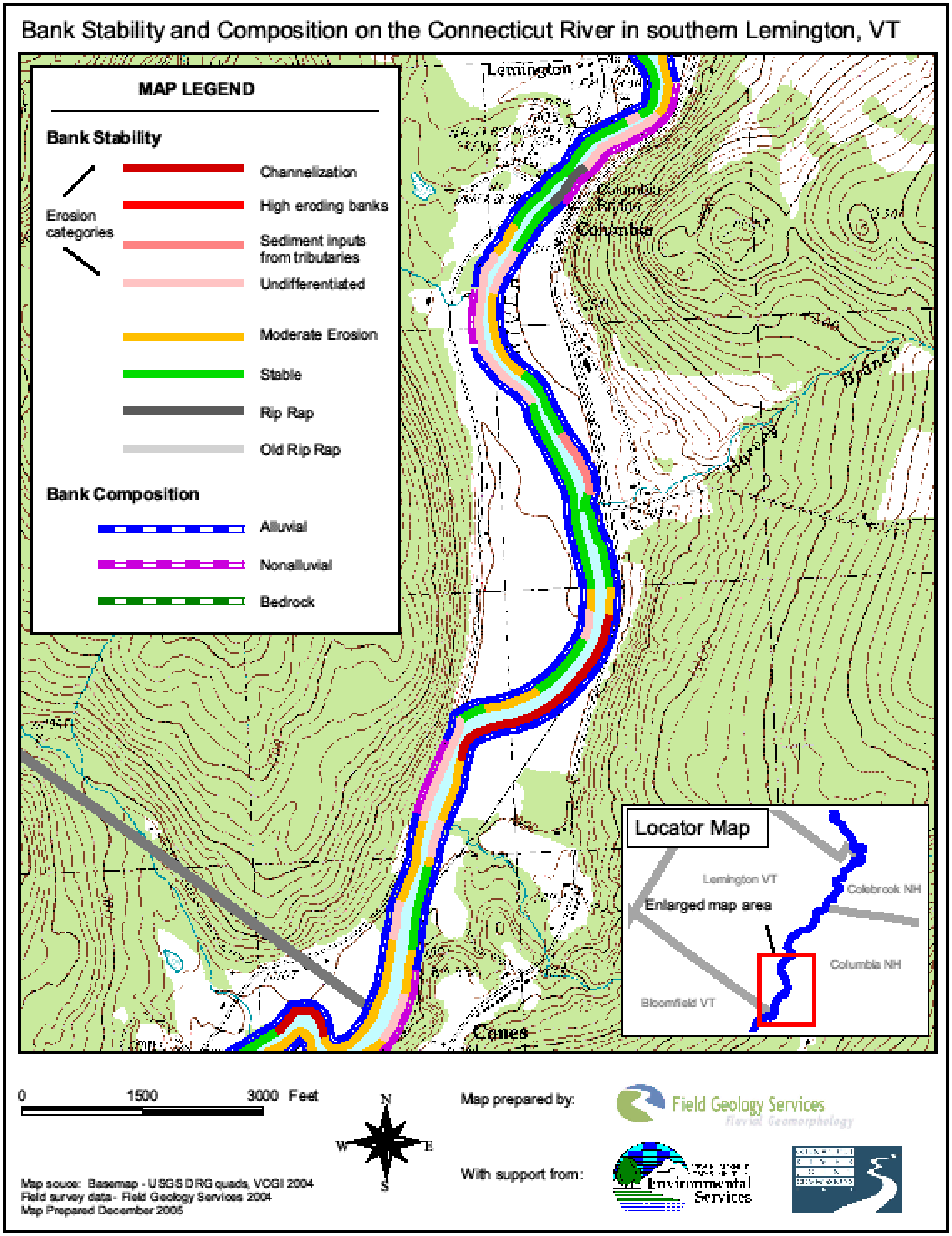


Bank Stability and Composition on the Connecticut River in southern Lancaster, NH
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
South Lancaster
Locator Map
Northumberland NH
Guildhall VT
Lunenburg VT
Lancaster NH
Enlarged map area
Dalton NH
0
1500
3000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

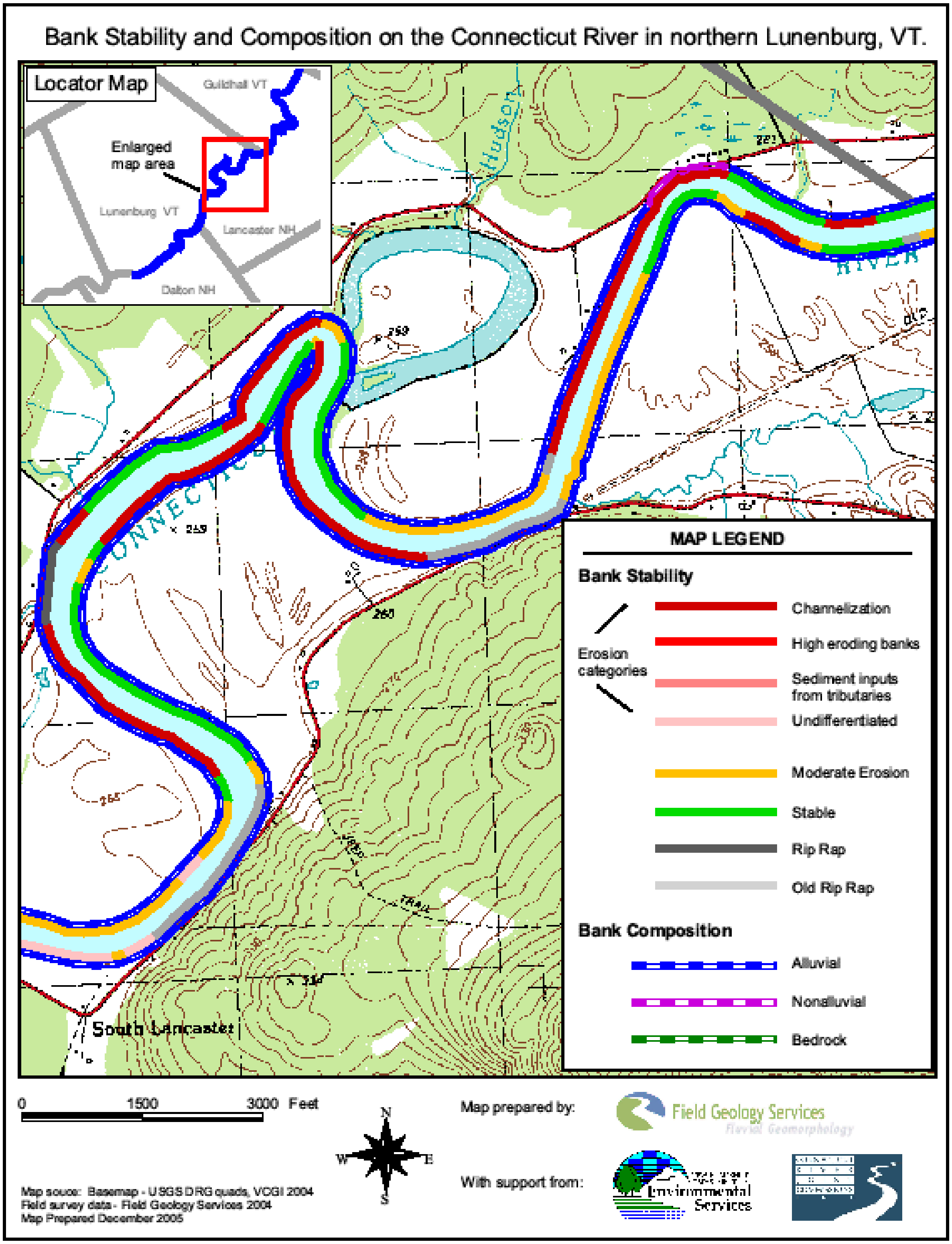

Bank Stability and Composition on the Connecticut River in central Lemington, VT
Locator Map
Enlarged map area
Colebrook NH
Lemington VT
Columbia NH
Bloomfield VT
Lemington
Columbia
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
0
1500
3000 Feet
N
S
E
W
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

Bank Stability and Composition on the Connecticut River in northern Lemington, VT

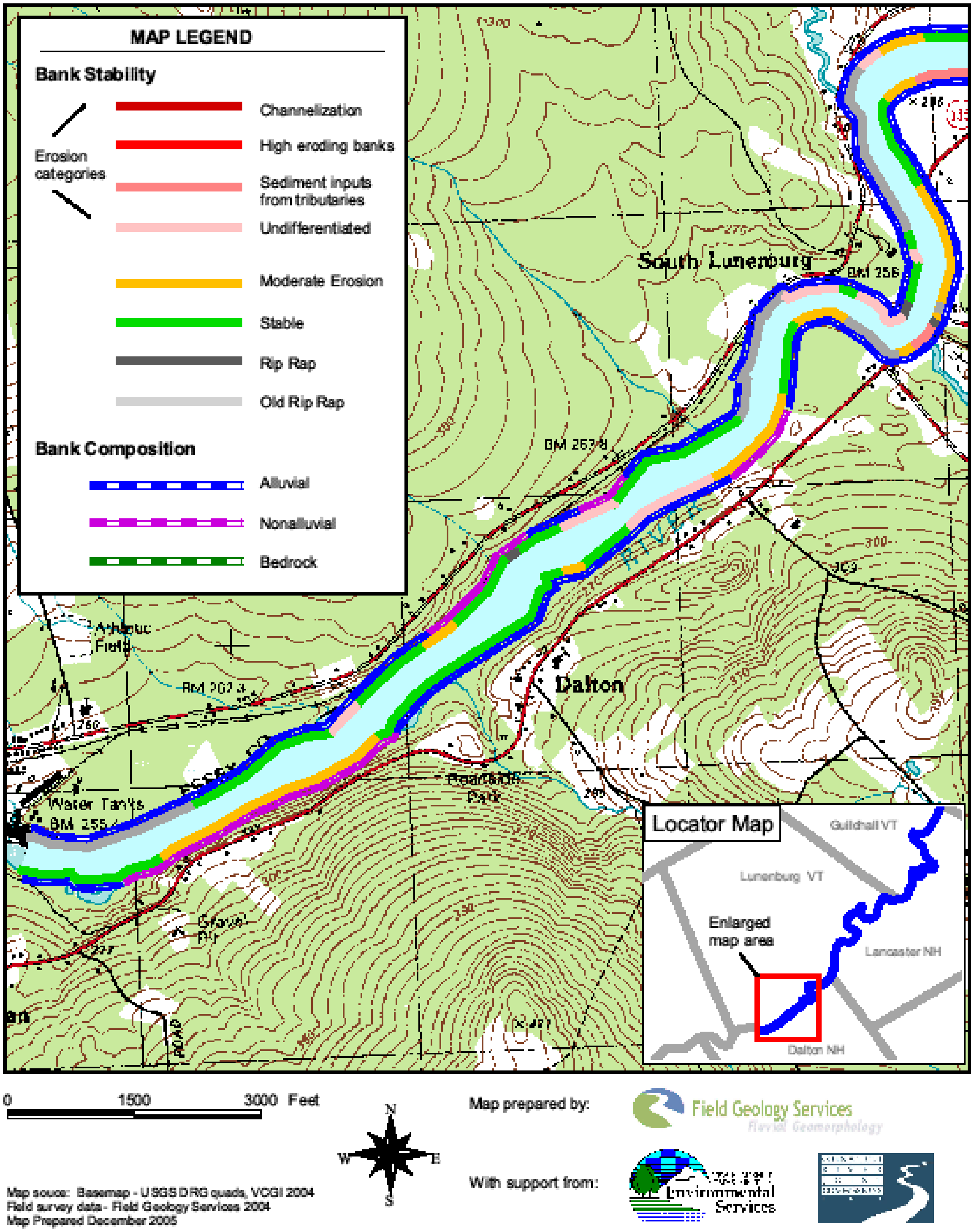


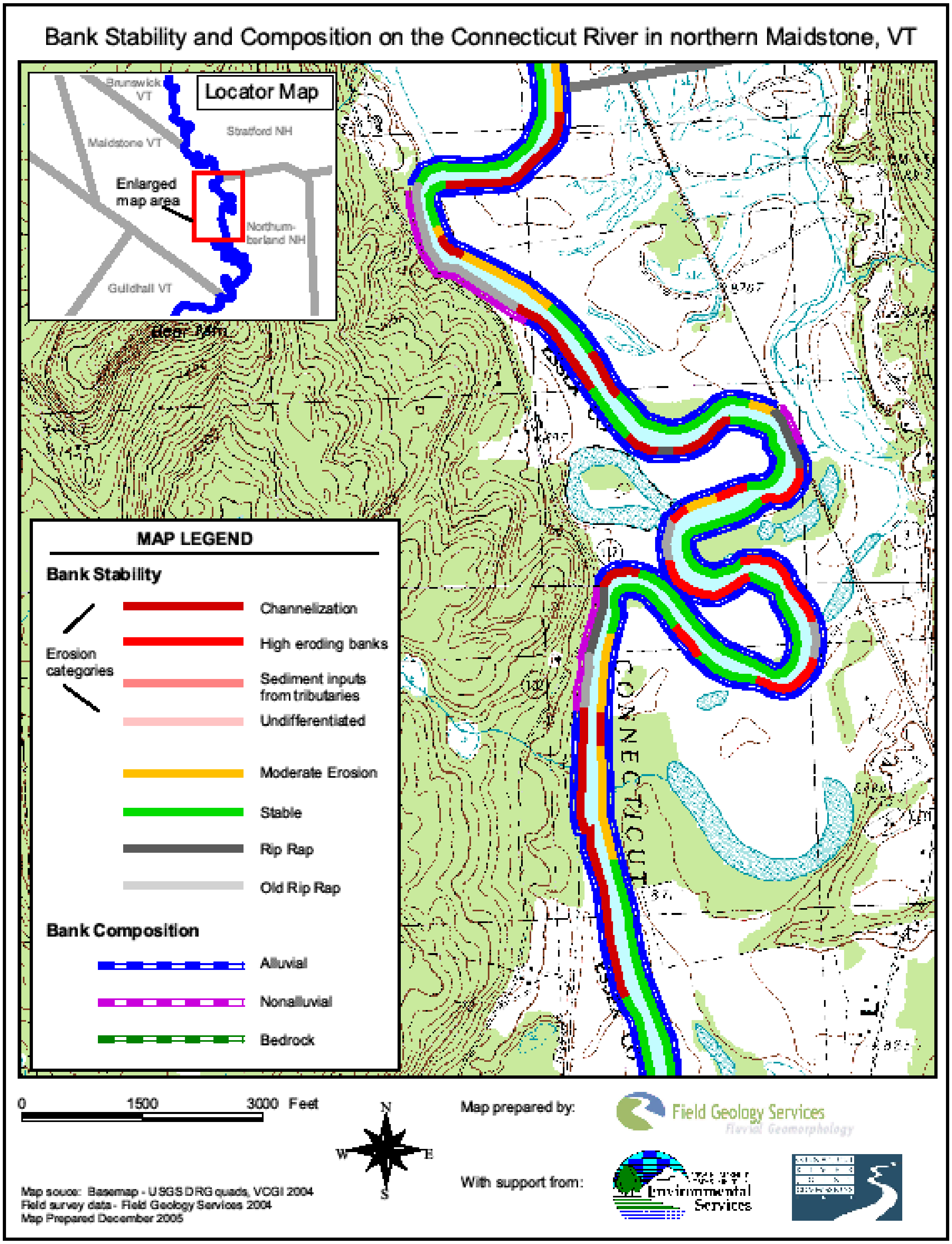


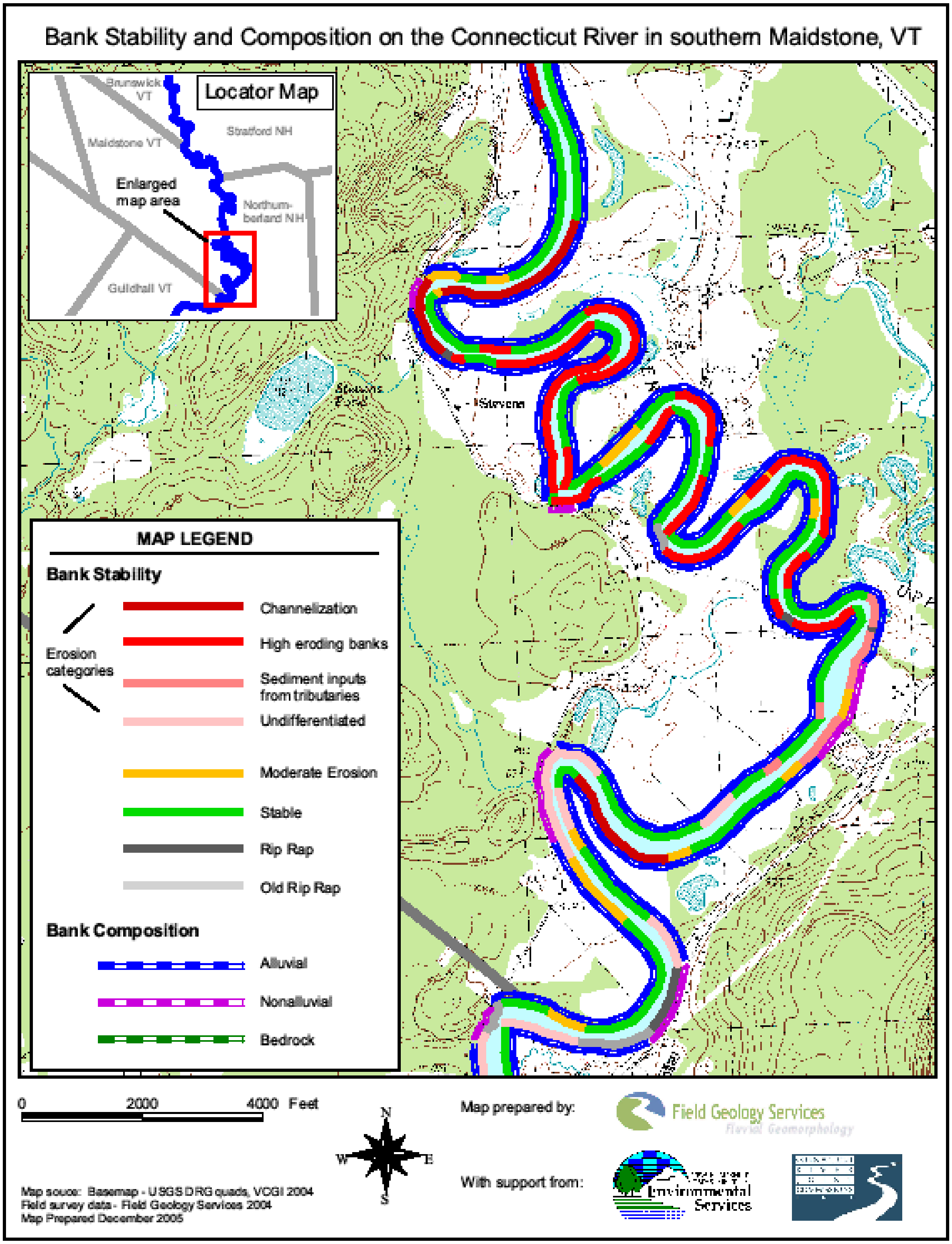
Bank Stability and Composition on the Connecticut River in southern Lemington, VT
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
Lemington
Columbia Bridge
Columbia
Branch
Canaan
Locator Map
Lemington VT
Colebrook NH
Enlarged map area
Columbia NH
Bloomfield VT
0
1500
3000 Feet
N
S
E
W
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

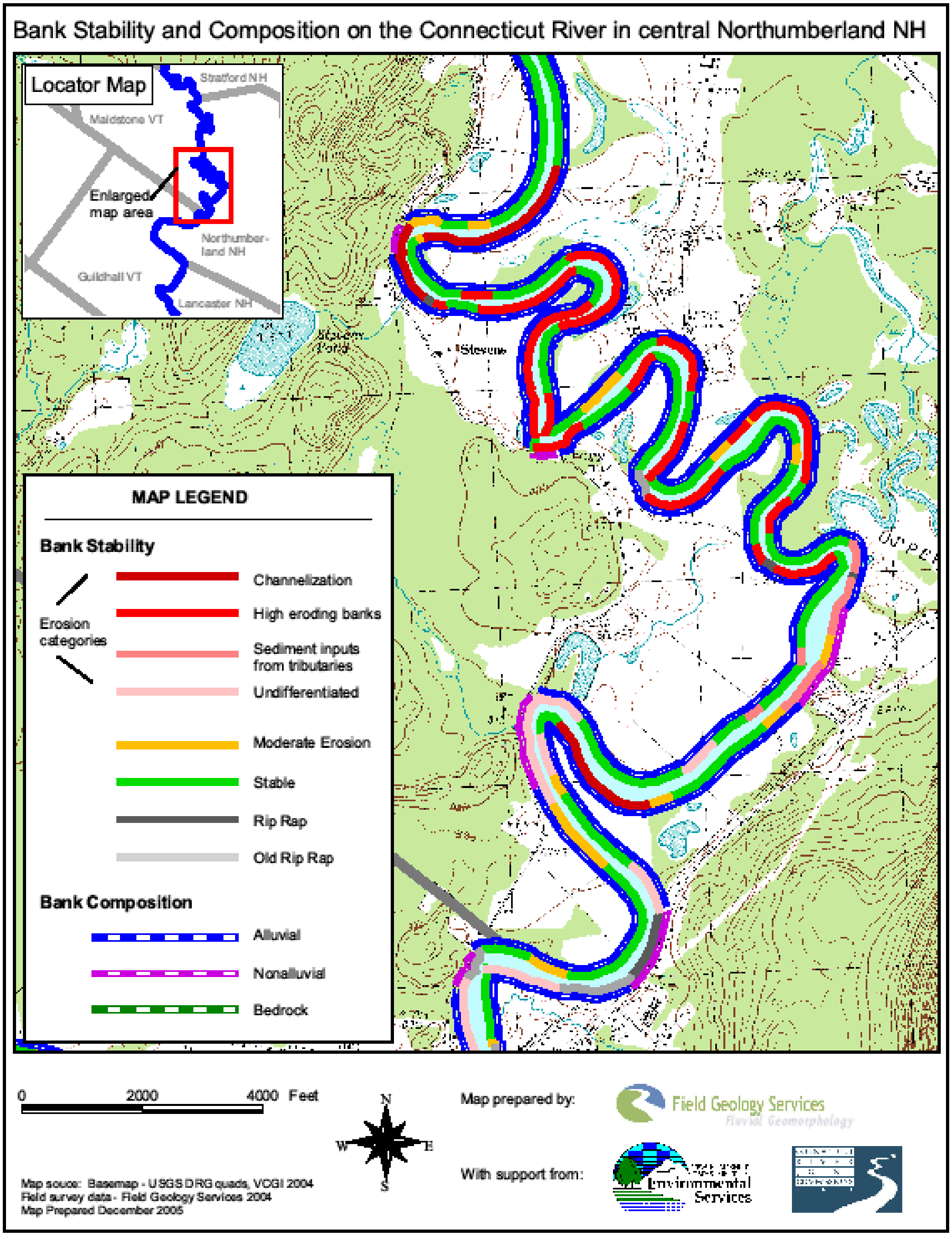

Bank Stability and Composition on the Connecticut River in northern Lunenburg, VT.
Locator Map
Guildhall VT
Enlarged map area
Lunenburg VT
Lancaster NH
Dalton NH
South Lancaster
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
0
1500
3000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

Bank Stability and Composition on the Connecticut River in southern Lunenburg, VT.



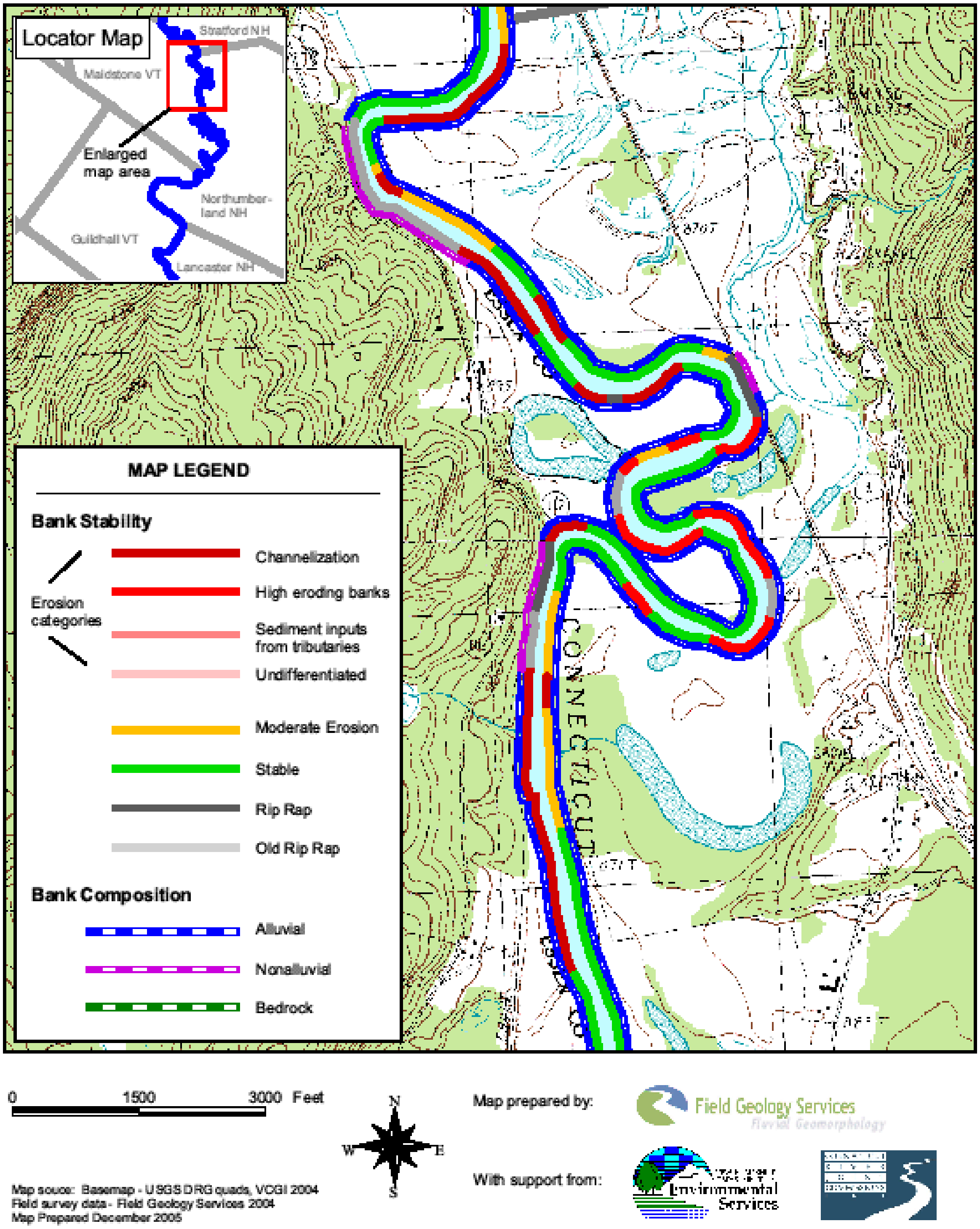

Bank Stability and Composition on the Connecticut River in northern Maidstone, VT
Locator Map
Brunswick VT
Stratford NH
Maidstone VT
Enlarged map area
Northumberland NH
Guildhall VT
Bear Mtn
CONNECTICUT
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
0
1500
3000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

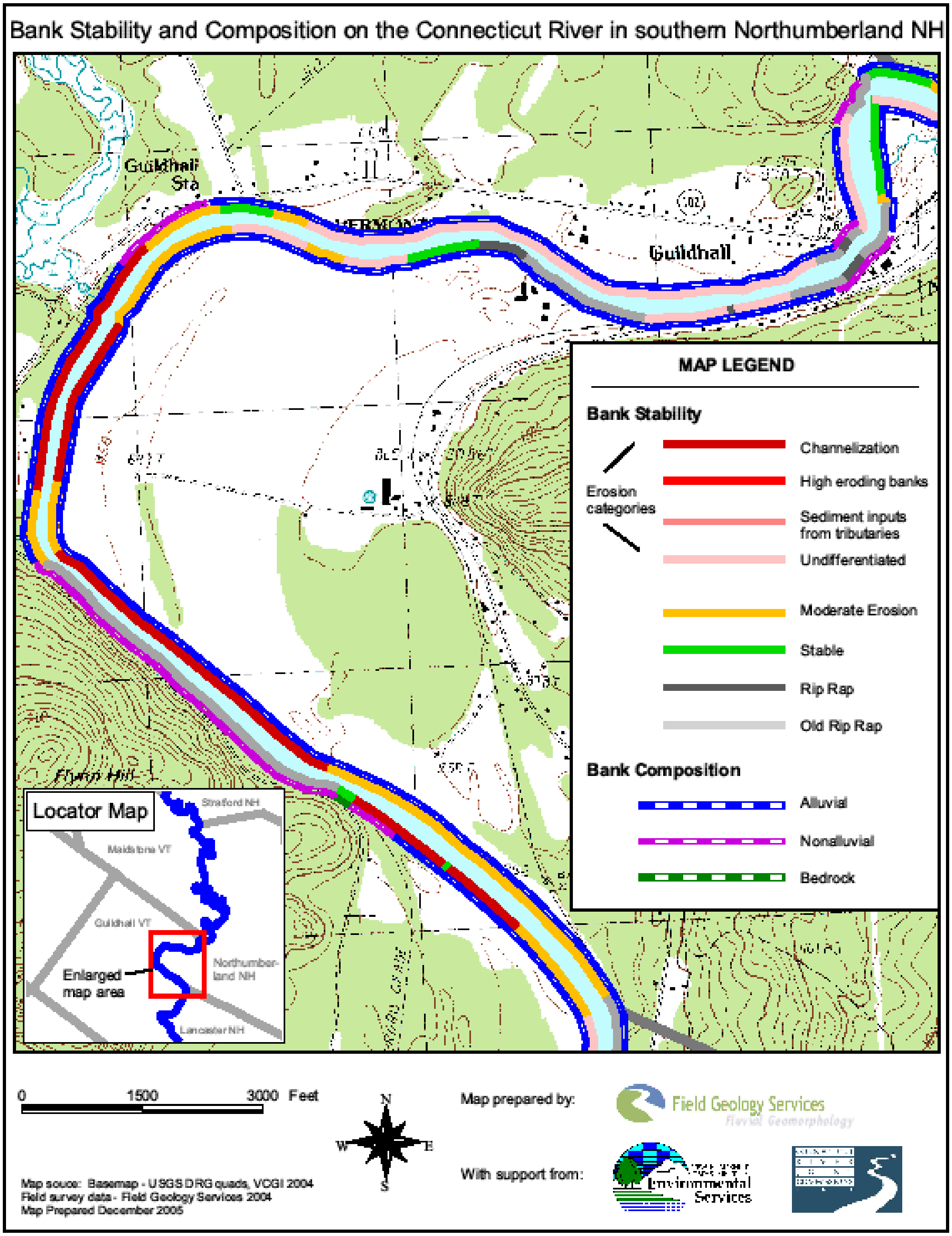

Bank Stability and Composition on the Connecticut River in southern Maidstone, VT
Locator Map
Brunswick VT
Maidstone VT
Stratford NH
Enlarged map area
Northumberland NH
Guildhall VT
Stevens
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
0 2000 4000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

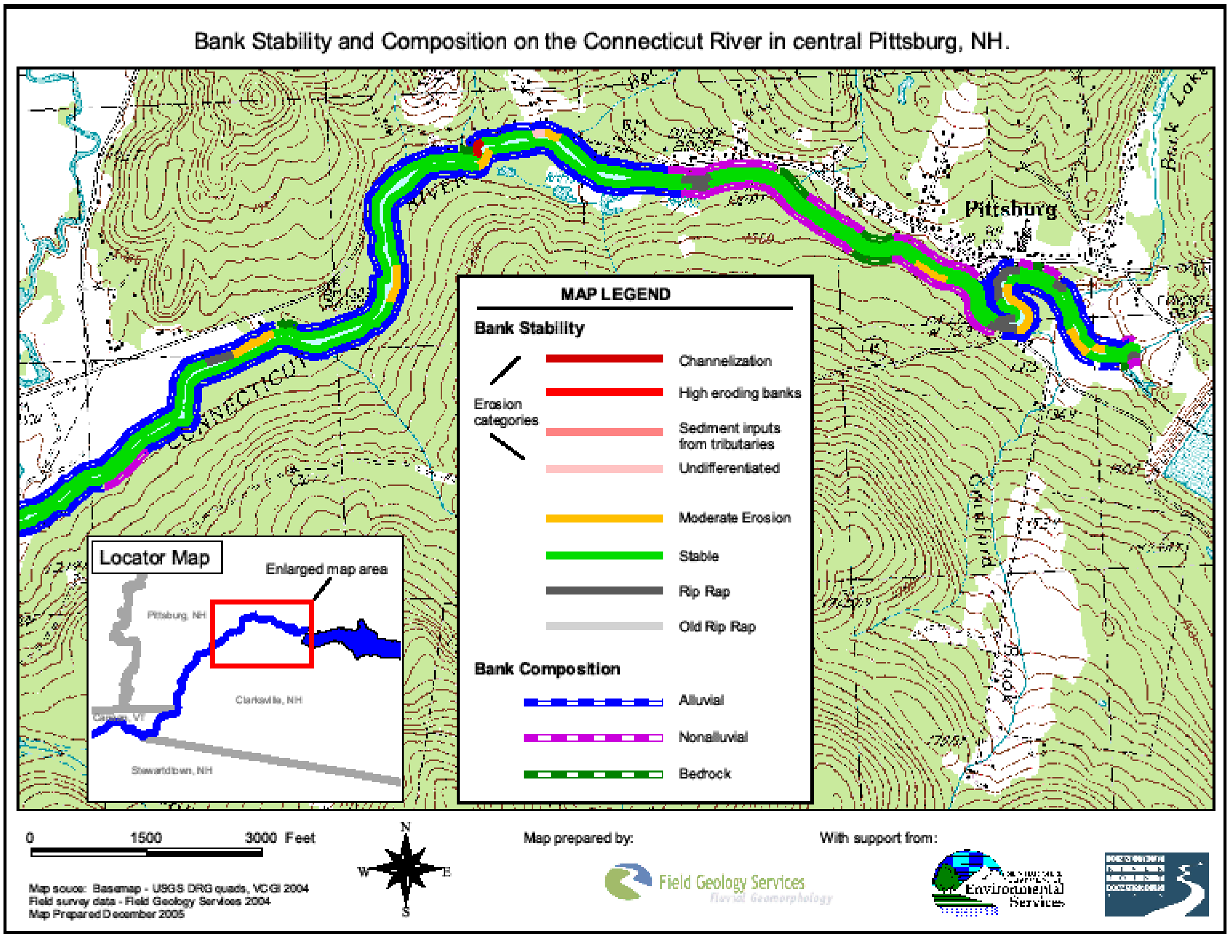


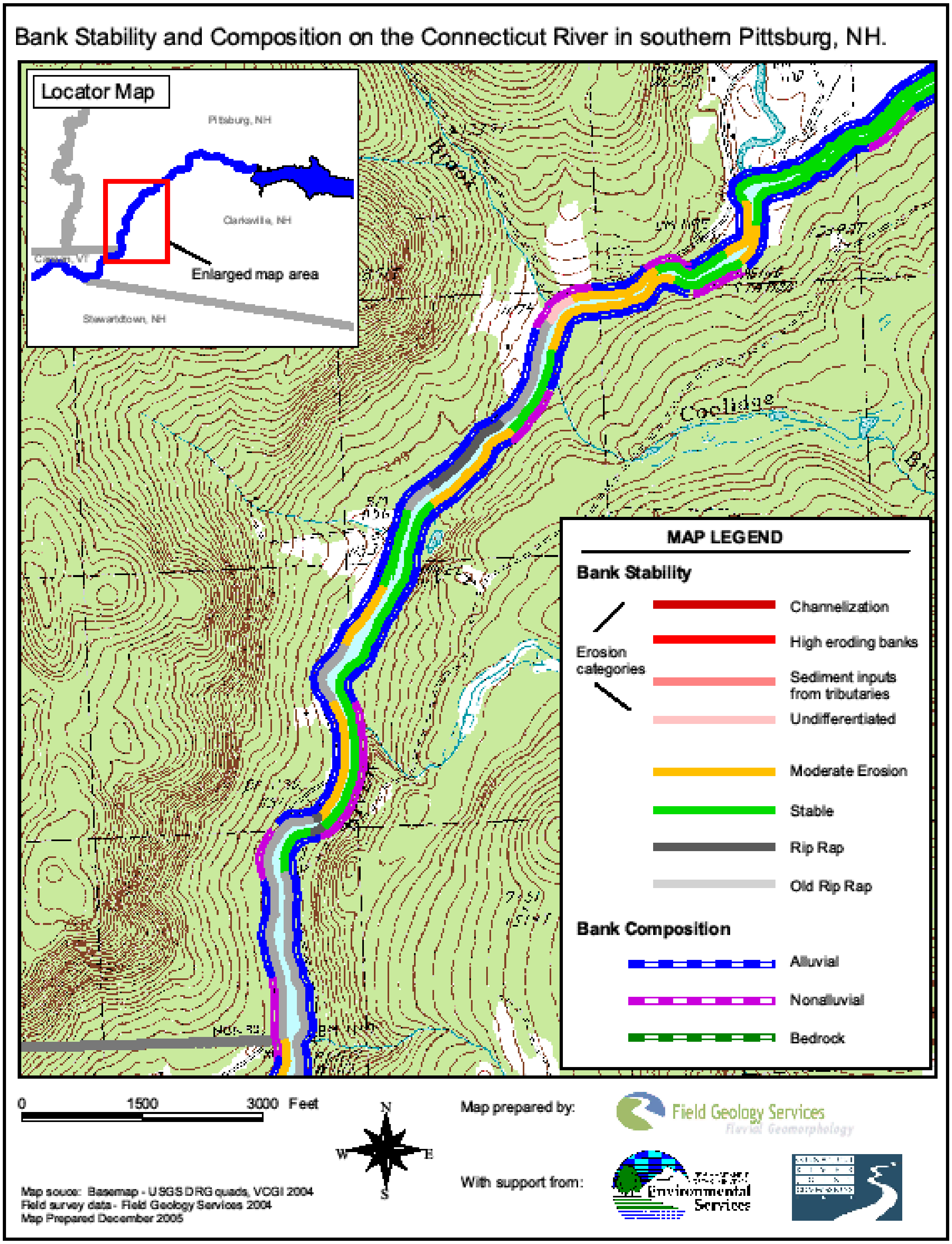
Bank Stability and Composition on the Connecticut River in central Northumberland NH
Locator Map
Stratford NH
Maidstone VT
Enlarged map area
Northumberland NH
Guildhall VT
Lancaster NH
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
0
2000
4000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

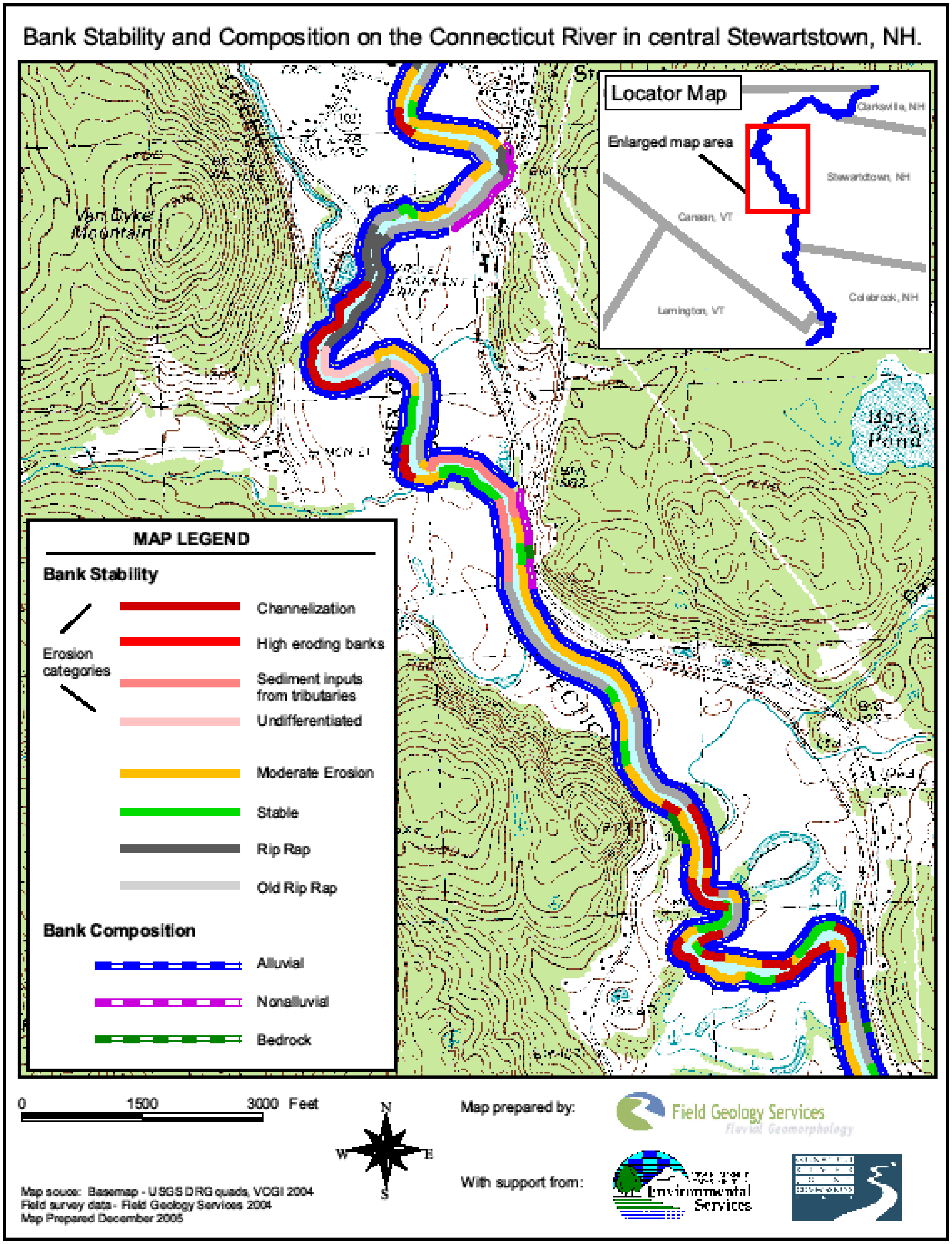
Bank Stability and Composition on the Connecticut River in northern Northumberland NH



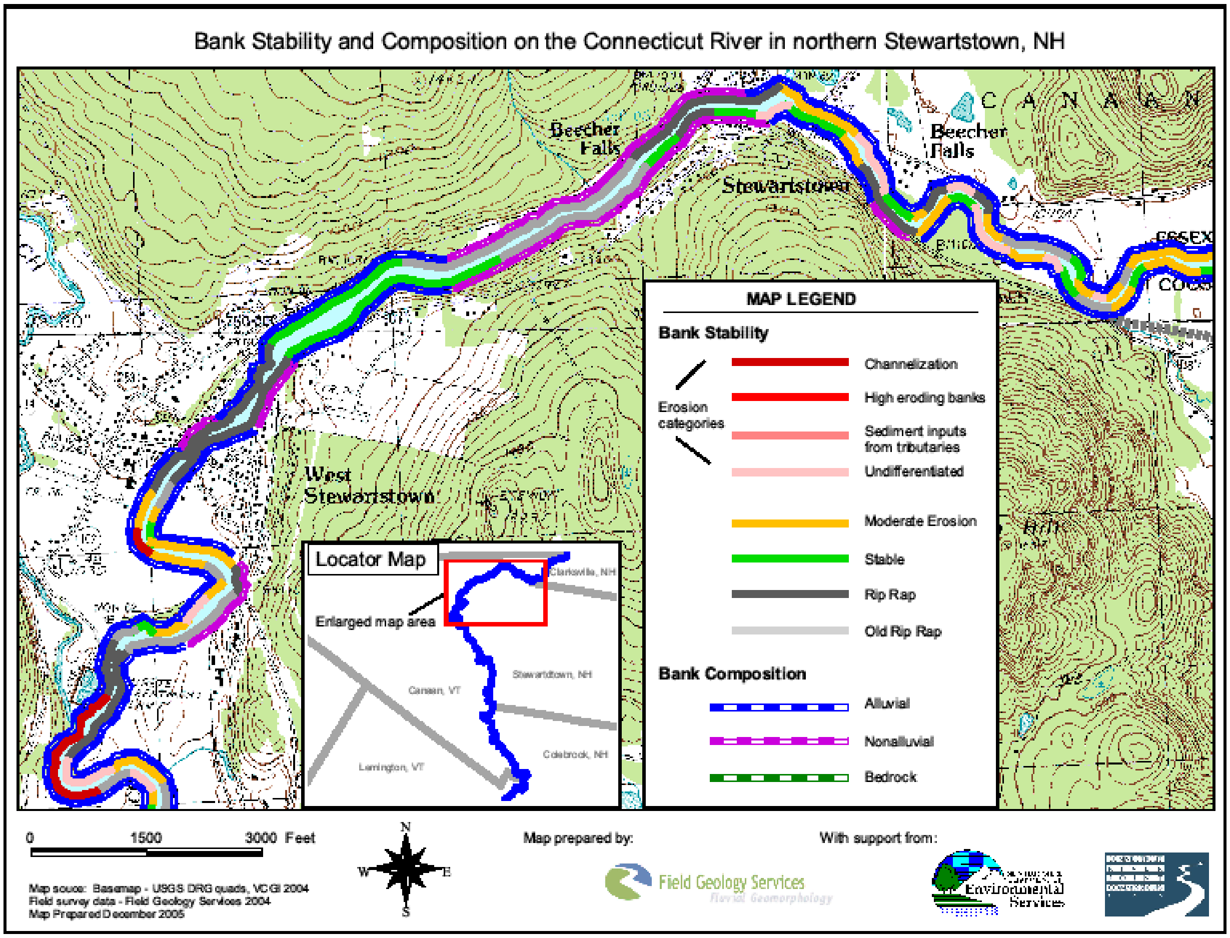

Bank Stability and Composition on the Connecticut River in southern Northumberland NH
Guildhall Sta
Guildhall
VERMONT
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
Locator Map
Stratford NH
Maidstone VT
Guildhall VT
Northumber-land NH
Enlarged map area
Lancaster NH
0
1500
3000 Feet
N
S
E
W
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005


Bank Stability and Composition on the Connecticut River in central Pittsburg, NH.
Pittsburg
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
Locator Map
Enlarged map area
Pittsburg, NH
Clarksville, NH
Stewartstown, NH
0
1500
3000 Feet
N
S
W
E
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005
Map prepared by:
Field Geology Services
With support from:
Environmental Services

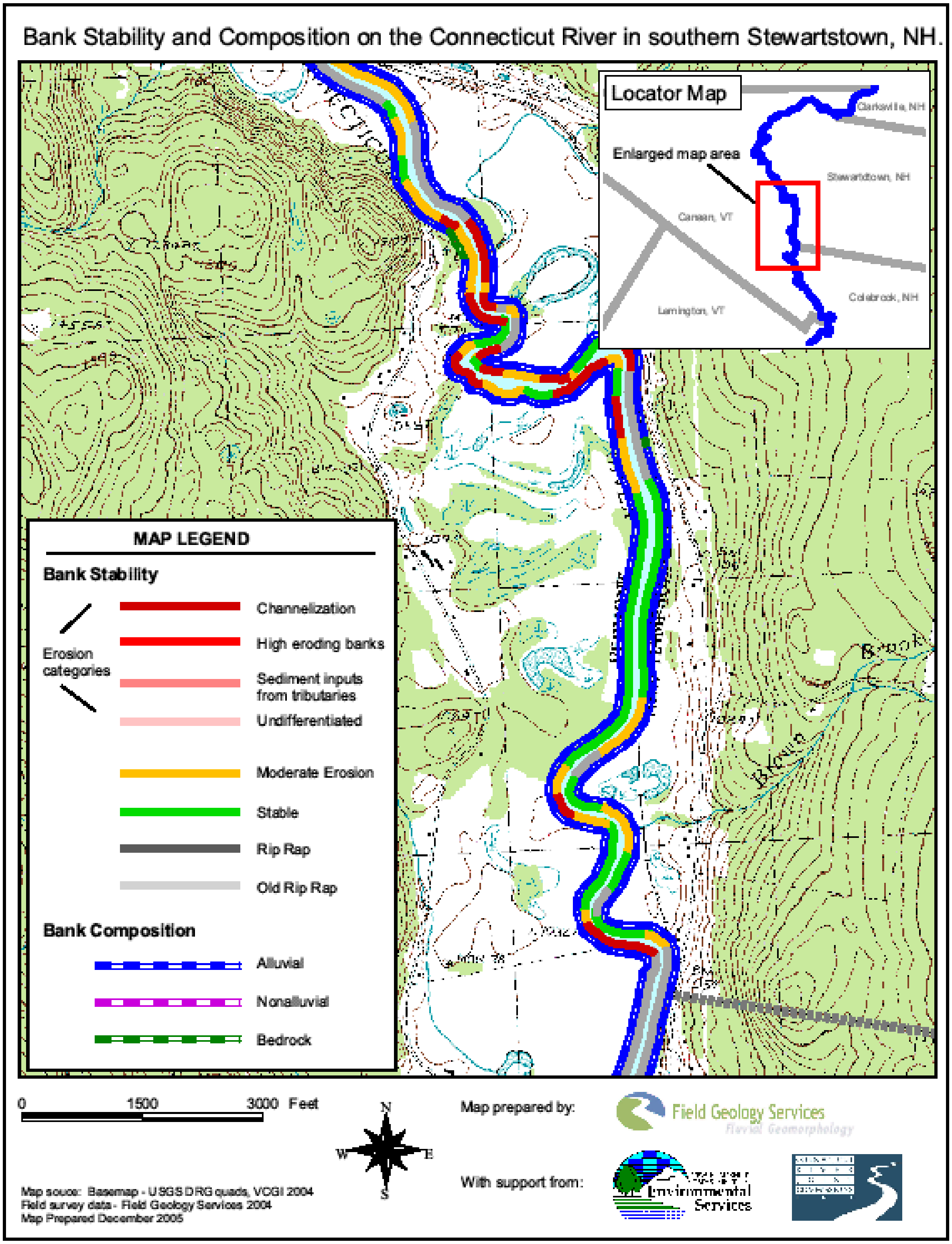

Bank Stability and Composition on the Connecticut River in southern Pittsburg, NH.
Locator Map
Pittsburg, NH
Clarksville, NH
Canaan, VT
Enlarged map area
Stewartstown, NH
Brook
Coolidge
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
0
1500
3000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005



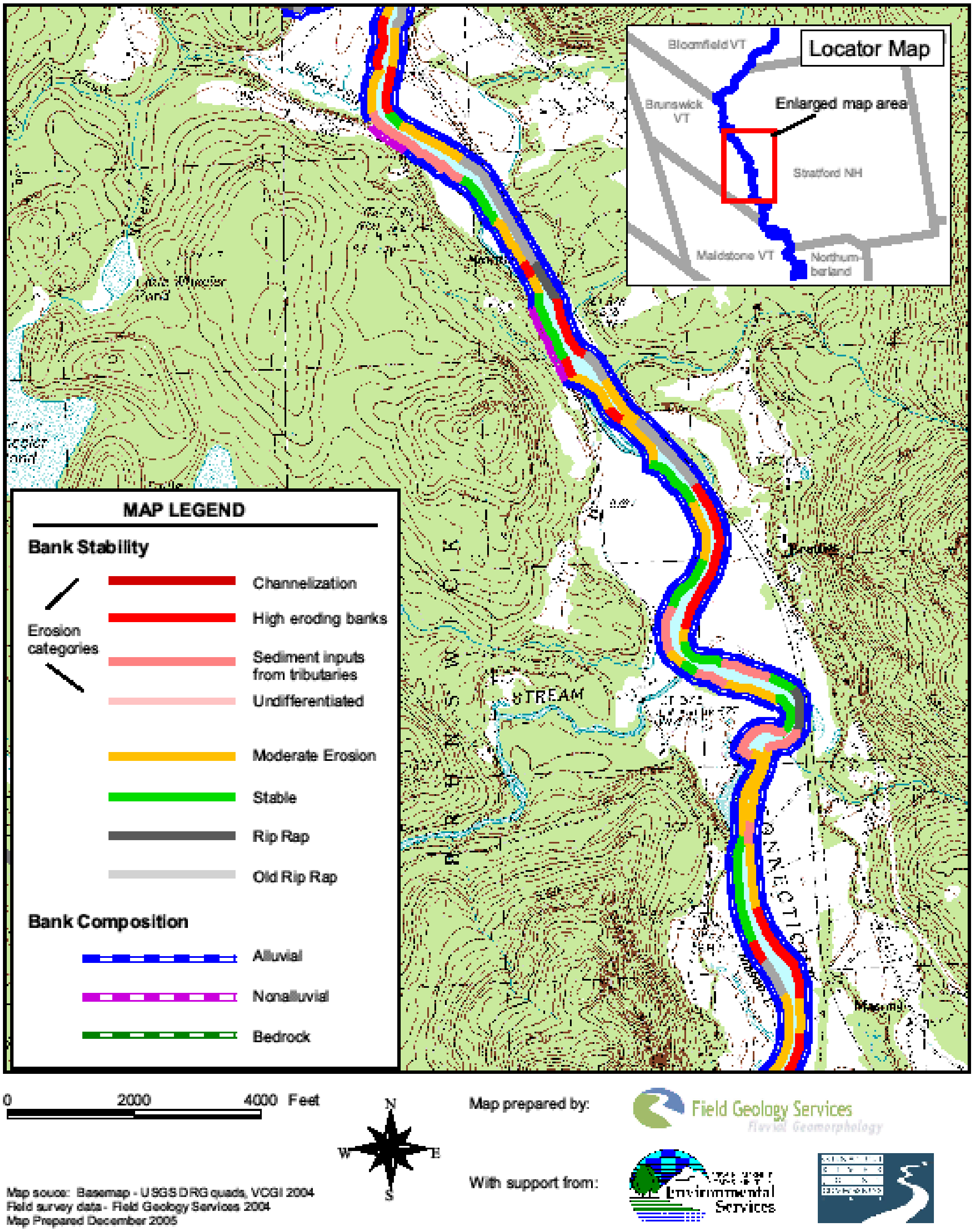
Bank Stability and Composition on the Connecticut River in central Stewartstown, NH.
Locator Map
Enlarged map area
Clarksville, NH
Stewartstown, NH
Canaan, VT
Colebrook, NH
Lemington, VT
Van Dyke Mountain
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
0
1500
3000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005



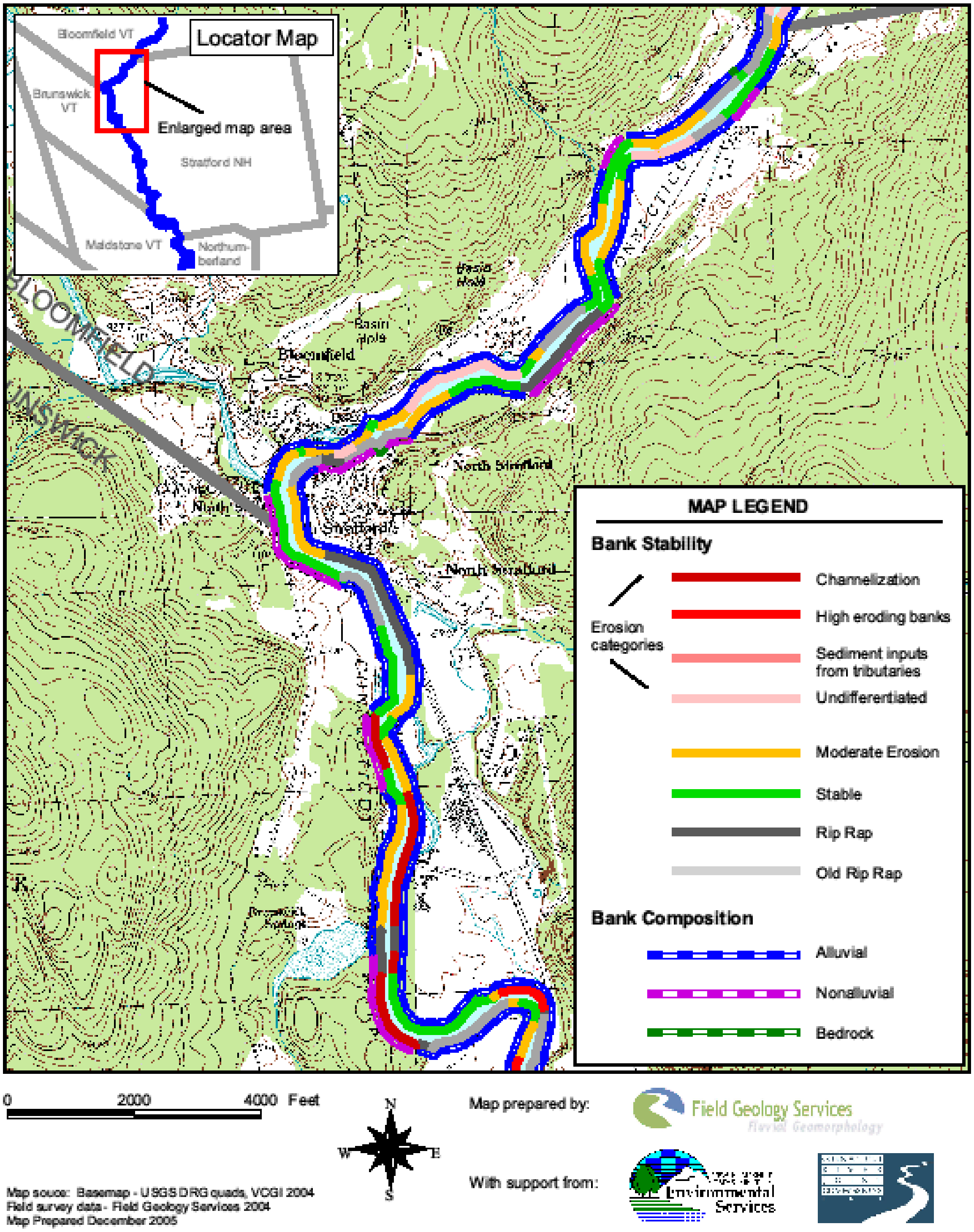
Bank Stability and Composition on the Connecticut River in northern Stewartstown, NH
Beecher Falls
Stewartstown
West Stewartstown
Locator Map
Enlarged map area
Clarksville, NH
Stewartstown, NH
Canaan, VT
Colebrook, NH
Lemington, VT
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
0 1500 3000 Feet
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005
N
W E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services


Bank Stability and Composition on the Connecticut River in southern Stewartstown, NH.
Locator Map
Enlarged map area
Clarksville, NH
Stewartstown, NH
Canaan, VT
Lemington, VT
Colebrook, NH
MAP LEGEND
Bank Stability
Erosion categories
Channelization
High eroding banks
Sediment inputs from tributaries
Undifferentiated
Moderate Erosion
Stable
Rip Rap
Old Rip Rap
Bank Composition
Alluvial
Nonalluvial
Bedrock
0
1500
3000 Feet
N
W
E
S
Map prepared by:
Field Geology Services
Fluvial Geomorphology
With support from:
Environmental Services
Map souce: Basemap - USGS DRG quads, VCGI 2004
Field survey data - Field Geology Services 2004
Map Prepared December 2005

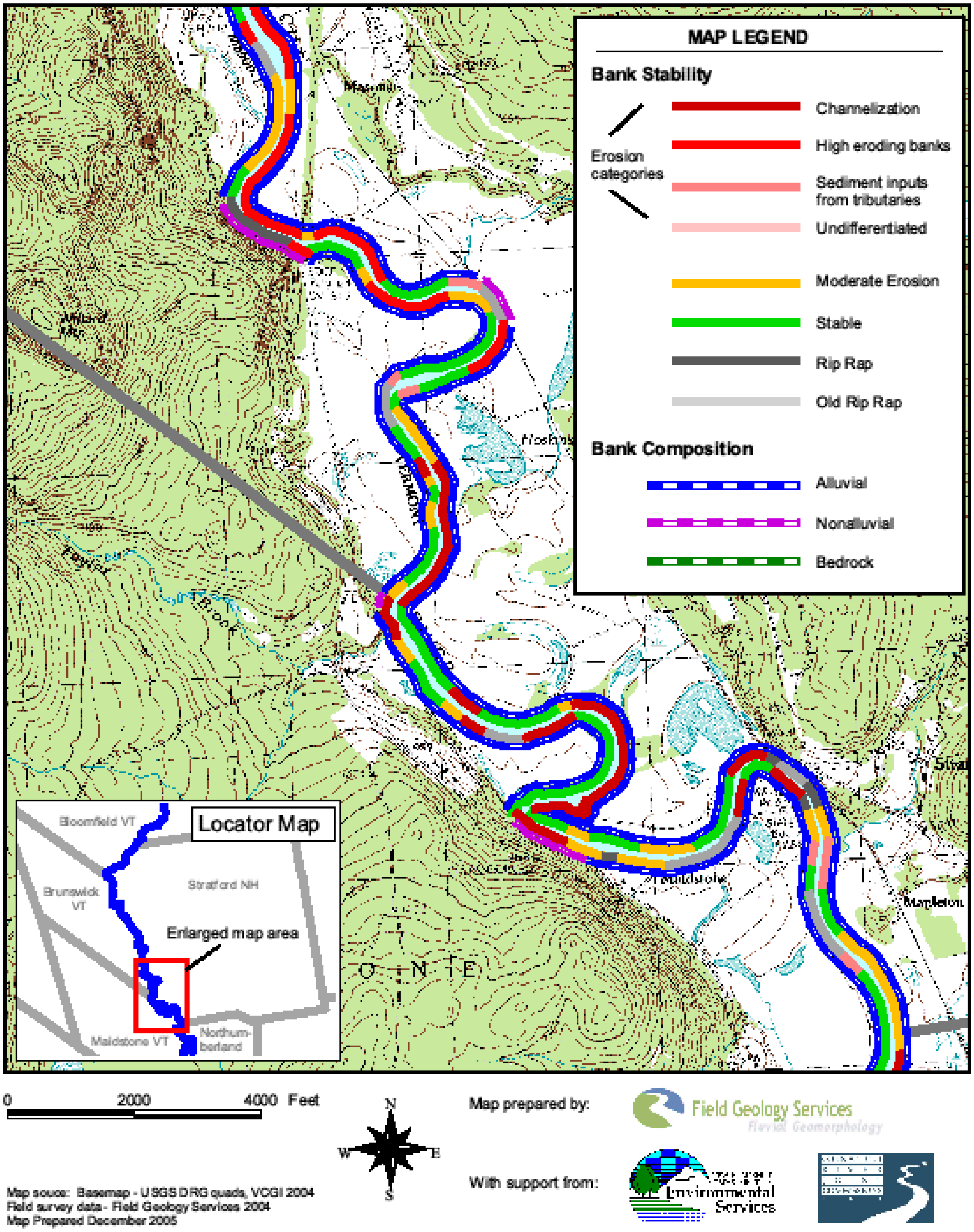
Bank Stability and Composition on the Connecticut River in central Stratford, NH.



Bank Stability and Composition on the Connecticut River in northern Stratford, NH.



Bank Stability and Composition on the Connecticut River in southern Stratford, NH.



Appendix C – Bellows Falls Pond Bank Inspection, 1991

BELLOWS FALLS POND BANK INSPECTION
30 May 1991

GENERAL

The Bellows Falls Pond banks were inspected by boat on 30 May 1991. The inspection party consisted of Bernard Hinds - Bellows Falls, John Huysentruyt - Lebanon, and Christopher Kane and Armand Millette - Westborough, Civil Engineering.

The boat was launched from the ramp on the New Hampshire side of the river, 0.3 miles above Windsor Bridge. The bridge gage reading was Elevation 116.45 and the boat became moored on shoals just downstream of the bridge. **Note**: The gage **must** read Elevation 116.5 or higher to negotiate this section of the river. The deepest channel hugs the Vermont shore. The river flow at Bellows Falls dam averaged 6,400 CFS.

Generally, the pond banks have continued to be active since the 1977 inspection. The following properties continue to cut back and be active as previously noted:

	River Mile	Original Owner	File No.	Riverbank
1.	24.3 - 23.7	L. M. Baker	BF-303	New Hampshire
2.	21.0	W. J. Wilgus	BF-147	Vermont
3.	13.8	Whitmore	BF-225	New Hampshire
4.	12.6 - 12.0	V. W. Tallman	BF-229	New Hampshire
5.	11.5 - 11.0	Vital Blais	BF-86	Vermont
6.	5.8 - 5.7	Kenyon	BF-73	Vermont
7.	5.7 - 5.3	New England Power Co.	BF-68	Vermont
8.	4.9 - 4.5	Stearns-Piper	BF-184,185	New Hampshire
9.	4.5 - 4.2	New England Power Co.	BF-182,183	New Hampshire
10.	2.2 - 1.9	Rutland Railroad	BF-56	Vermont
11.	1.3 - 1.2	New England Power Co.	BF-173b	New Hampshire
12.	1.2 - 0.8	Cray Oil Company	BF-172b	New Hampshire

At River Miles 22.4 and 22.1, a large outwash was observed in 1976 at each location on the Vermont side with steep sided gullies back from the river several hundred feet. The 20 May 1976 inspection of both locations between Route 5 and the river indicates each area is the result of uncontrolled drainage from an intermittent sand and gravel operation (Mile 22.4) and a 10-acre cornfield (Mile 22.1). This erosion problem is on the following properties:

	River Mile	Original Owner	File No.	Riverbank
1.	22.4	A. G. Westney	BF-250	Vermont
2.	22.1	F. D. Whitcomb	BF-149	Vermont

New England Power Company has flowage rights on both properties. The Whitcomb property shows evidence to control the erosion because numerous trees are cut and laid onto the gully slopes along with stones dumped at the start of the gully. There is no apparent effort on the Westney property to stop the erosion. Both areas should be checked periodically from Route 5 for the record. These areas appear stabilized in 1984 and 1991.

Photographs were taken where conditions appeared to have changed and were spotted at many locations of previous inspections for comparison purposes.

INSPECTION NOTES

Mile 26.4 to 25.8
NH

Railroad Bridge to Foot of Chace Island, New Hampshire
The Weld property slides are inactive along this 1,500' long bank with some healing evident. Gravel shoals are building up in the river upstream of Chace Island. **[See Picture A-1]** Shoals also building on upstream bank of Chace Island. **[See Picture A-2]**

Mile 25.7 to 25.5
VT

"Kennedy Farm", Vermont
This 800' long section of bank is inactive, weed covered, and shows signs of healing. A 50' long by 20' high slide at the upstream property line, noted in 1977, is still healing.

Mile 25.5 to 24.2
VT

BF-253, A. B. McClary, Vermont
This section is slightly active with gravel build-up along banking, with 8 dead elms down at Mile 24.2.

Mile 25.0
NH

G. B. Mood, New Hampshire
This section appears inactive. There is a dead elm standing at the top of slope and another down on the slope.

Mile 24.6
NH

BF-301, U. A. & M. A. Stimpson, New Hampshire
This 75' long slide continues to be active and raw since 1964. Trees are sliding on the slope and in the water. Outwash and gravel build-up is occurring from the stream at the downstream property line.

Mile 24.3 to 23.7
NH

BF-303, 304, & 305, Baker, Chadbourne, & Ballock New Hampshire
This 2,000' long by 30' high bank is still active along the Baker property and moderately active in the downstream half. This section shows the active conditions with trees down on the bank and slope sods. [See Pictures A-3 & A-4] The undercutting continues active on the Chadbourne property with poplars undercut and trees down at the river's edge. At the Chadbourne-Ballock property line, the lower bank continues to be active for 500'. Clumps of brush and undercut trees continue to slide on the slope and shoals are evident near shore.

Mile 23.9 to 23.6
VT

BF-252, Austin's Greenhouses, Inc., Vermont
A 100' long by 40' high section is now active with trees down on slope. [See Picture A-5] At the Windsor-Weathersfield town line, there are two 50' long by 30' high slides which remain stabilized by dumped gravel and rip-rap. [See Picture A-6] Rock placed on the slope in 1984 is keeping bank stabilized. [See Pictures A-7 & A-8]

Mile 23.6
NH

Philip Pederson, New Hampshire
Previously noted trees remain on the slope for protection.

Mile 23.5
NH

BF-277, Leonard R. Haubrich, New Hampshire
A 100' long by 20' high section with trees leaning and down is stabilizing with moderate grass and brush growth. [See Picture A-9]

Mile 23.3 to 22.8
VT

BF-252, Vinton H. Parker, Vermont
At Mile 23.0 the 1984 report noted 2 shoals connected with the downstream shoal approximately 1,000' long. It appears that the shoals have been separated. [See Picture A-10] A 300' long by 20' high slide is now active at Mile 22.9 with 6 birch trees down. [See Picture A-12]

Mile 23.0
NH

BF-274, Sadie & Fletcher Donoghue, New Hampshire
A high slide active in 1984 has since had trees, stumps, and brush cover dumped on the slope stabilizing activity and allowing healing. [See Picture A-11]

Mile 22.8
NH

BF-275, Stephen R. Breck, New Hampshire
This slide continues to be active with trees leaning and sods on the bank.

Mile 22.7
VT

BF-251, Clarence H. Martin, Vermont
The campsite erosion remains inactive with small stones on bank. [See Picture A-13]

<u>Mile 22.4</u> VT	<u>BF-250, Albert G. Westney, Vermont</u> A large 40' deep gully, previously noted, created a 200' long outwash along the shoreline. A land inspection on 20 May 1976 revealed this gully resulted from an uncontrolled drainage pattern through an intermittent sand and gravel operation on this property and a trash landfill operation beyond the gravel excavation. This area has stabilized since 1977.
<u>Mile 22.1</u> VT	<u>BF-149, Frank D. Whitcomb, Vermont</u> The large gully noted in 1974 has stabilized. This gully extends about 500 feet back from the river and is a result of drainage from a large cornfield between the tree line and Route 5. [Picture A-14] shows the gully area.
<u>Mile 22.1 to 21.8</u> NH	<u>BF-270, Hugh and Mary E. Deming, New Hampshire</u> The downstream area active in 1984 is now inactive and healing with moderate brush cover and tree growth. [See Picture B-1]
<u>Mile 21.7</u> VT	<u>BF-252, Harlan L. Whipple, Vermont</u> This low silt bank just upstream of the new Ascutney Bridge is still healing since 1977.
<u>Mile 21.6</u> NH	<u>BF-269, Roy D. Hunter, New Hampshire</u> There are 3 trees down and in water at the Sugar River Confluence. [See Picture B-2]
<u>Mile 21.5</u>	<u>Connecticut River</u> Upstream shot of Ascutney Bridge. [See Picture B-3]
<u>Mile 21.5</u> VT	<u>BF-147, Leonard M. Wilgus, Vermont</u> A scoured area with outwash noted in 1977 is now inactive and healing except where a dead tree is down in the river. [See Picture B-4]
<u>Mile 21.5 to 20.9</u> NH	<u>BF-269, Roy D. Hunter, New Hampshire</u> This long low meadow bank, rated in 1977 as active for 500 feet of the upstream end, is now healing and the remaining downstream portion is weed covered and inactive.
<u>Mile 21.0</u> VT	<u>BF-147, W. J. Wilgus, Vermont</u> This 200' long by 40' high section abutting Wilgus State Park is now active with slides at top of slope approximately 15' from high voltage tower. [See Pictures B-5 & B-7] The banking upstream is inactive where rip-rap has been placed. [See Picture B-6]

Mile 20.6 to 20.5 NH	BF-268, James Duncan Urham, New Hampshire This area is now inactive with 3 trees laying on upstream bank and 2 large pines uprooted on downstream bank.
Mile 20.8 to 20.4 VT	BF-147, N. J. Milgus, Vermont 200' long by 10' high section has had rip-rap placed on bank with a new boat ramp. [See Picture B-8] Downstream bank is slightly active with areas of scouring. [See Pictures B-9 & B-10]
Mile 20.7 to 19.7 VT	BF-146, Horace C. Mayhew, Vermont The upstream end of this 15' high bank is active with trees leaning and sliding. There is weed cover on the downstream end. [See Picture B-11]
Mile 19.7 to 19.5 VT	BF-145, Fred H. Fullam, Vermont This 12' high bank continues to be active with sods on the slope. There are several clumps of small trees down on the slope. A 30' high slide on the downstream end was rip-rapped in 1976 and appears stable.
Mile 19.5 to 19.2 NH	BF-267, Russell Jarvis, New Hampshire This 10' high bank is inactive and healing.
Mile 19.5 to 19.0 VT	BF-144, Clarence R. Randall, Vermont This section is active with raw, undercut banks and many trees either undercut and down on the slope. At Mile 19.2 there is a house 20 feet from the top of slope. Trees on the slope have been cut since 1977 and the bark shows signs of healing. A yellow house, approximately 30 feet from the top of slope, and a white house is approximately 10 feet from the top of slope with a picket fence at the top of slope.
Mile 18.6 NH	BF-267, Russell Jarvis, New Hampshire This slide area continues active for 150' by 70' high with sliding trees on the slope and at the river's edge. [See Picture B-12]
Mile 18.3 VT	BF-141, W. Eugene Moore, Vermont This bank remains active with trees down on the slope. [See Picture B-13] Brush has been cut on the slope and fence posts are lying at the top of slope.
Mile 18.2 to 17.7 NH	BF-266 and BF-265, Laura L. & J. Laban Ainsworth, New Hampshire The upstream end of this section is active with trees leaning. [See Picture B-14] River silt fill has been dumped over the bank on the downstream section and is inactive.

<u>Mile 18.2 to 17.7</u> VT	<u>BF-141, M. Eugene Moore, Vermont</u> The old 15' high slide remains active with sods and trees down on the slope.
<u>Mile 17.8</u>	<u>Connecticut River</u> Upstream shot of Island. [See Picture B-15]
<u>Mile 17.5 to 17.4</u> NH	<u>BF-269, Martin Hougsrud, New Hampshire</u> New asphalt boat ramp with rip-rapped banks on each side. [See Picture B-16] Drain 20' from river with dirt road 50' downstream. [See Picture B-17]
<u>Mile 17.3 to 17.2</u> VT	<u>BF-139, Ben Johnson, Vermont</u> Active bend in river with trees leaning in water. [See Picture B-18] Downstream more trees leaning in water. [See Picture B-19]
<u>Mile 16.6 to 16.5</u> NH	<u>BF-260, Drusilla Farwell, New Hampshire</u> The wooded banks on each side of the channel are inactive and grassed over. At the upstream end of the channel, there are numerous leaning trees and heavy ice scars on tree trunks. The main stream side of Hubbard Island is raw with many trees down for much of its length.
<u>Mile 16.3</u> VT	<u>BF-137, Lewis C. Stevens, Vermont</u> The two old slides on this property remain active with the upstream slide 200' long by 30' high containing two leaning trees and the downstream slide 250' long by 30' high raw at the top with weed growth at the toe. There is a birch tree sliding and leaning on the slope with cow paths leading to edge of water.
<u>Mile 16.1 to 15.8</u> NH	<u>BF-260, E. J. Farwell, Est., New Hampshire</u> The 10' high silt bank is active with trees down and ice scars on the slope.
<u>Mile 16.05</u> VT	<u>BF-136, Floyd C. Eastman, Vermont</u> This 45' high bank is active again with trees leaning and sliding down in the water. The 1962 break is active again. [See Picture B-20]
<u>Mile 15.75 to 15.55</u> VT	<u>BF-132 and BF-131, Margaret C. Haskett and Arthur F. Putnam, Vermont</u> This section remains stable. [See Picture B-22] A braced fence post at the top of the slope in 1984 is now gone.

Mile 15.65 to 15.2 NH	BF-238, J. H. Farwell, New Hampshire The 20' high slide is stabilizing. There is a house approximately 15 feet from the top of slope. [See Picture B-21] There is an old slide at Mile 15.5 with large trees down on the slope and in the water. [See Picture B-23] The remaining 700' long by 30' high bank is active with dead trees on the slope and in the water. [See Picture B-24]
Mile 15.3 to 14.9 NH	BF-237, Roxie K. Dunmore, New Hampshire This 30' high by 2,000' long bank is now very active with many trees undercut, leaning, sliding, and down in the water. [See Picture C-1]
Mile 14.3 to 14.1 NH	BF-235, Mattie J. Loveland, New Hampshire This 1,000' long low wooded bank is slightly active. As noted in 1974, the island opposite this property is gone.
Mile 14.15 VT	BF-127, Paul Gilioli, Vermont This 500' long by 10' high bank is now inactive.
Mile 13.95 VT	BF-126, Arthur Putnam, Vermont The raw area, about 300' long by 15' high with sliding trees on the slope, is still healing. A 30" maple tree is sliding and leaning halfway on the slope.
Mile 13.8 NH	BF-225, Harry N. Whitmore, New Hampshire The 40' long by 30' high break, first noted in 1962, is now 300' long and very active with trees leaning and down in the water.
Mile 13.8 to 13.55 VT	BF-125, Adin T. Putnam, Vermont This steep silty bank 20' high remains slightly active with sods on the slope. Beaver slides were noted in the riverbank silt from the cornfield to the river. [See Picture C-2]
Mile 13.6 NH	BF-226, Alex Raymo, New Hampshire A new 40'long by 40' high slide is still active.
Mile 13.4 NH	BF-227, George L. Farron, New Hampshire A 5' high undercut bank with growth overhanging the top of slope is slightly active. [See Picture C-3]
Mile 13.2 to 13.0 NH	BF-228, Wellington Curtis, New Hampshire This 10' high silt bank is active again. [See Picture C-4]

<u>Mile 12.9 to 12.7</u> NH	<u>BF-228 and BF-229, Wellington Curtis and Ulysses S. Tallman, New Hampshire</u> The upstream end is stable and healing due to new rip-rap on bank. **[See Picture C-5]** This low bank remains slightly active with sods on the slope and a cluster of maple trees at top of slope. **[See Picture C-6]**
<u>Mile 12.6 to 12.2</u> NH	<u>BF-229, Ulysses S. Tallman, New Hampshire</u> This long silty 10' high bank continues to be active, raw, and undercut with numerous sods at the river's edge. The fence posts remain at the top of the bank with 3 posts over the bank. [See Picture C-8]
<u>Mile 12.5 to 12.1</u> VT	<u>New England Power Company, Vermont</u> This area is intermittently active with 10' high banks and sod on river edge. **[See Picture C-7]**
<u>Mile 12.4 to 12.3</u> VT	<u>BF-88, Frank M. Corliss, Vermont</u> This 300' long by 5' high silt bank remains active.
<u>Mile 12.2 to 12.0</u> NH	<u>BF-217, Boston and Maine Railroad, New Hampshire</u> This 1,000' long section is still active with numerous poplar trees down and leaning on bank.
<u>Mile 11.5 to 11.0</u> VT	<u>BF-86, Vital Blais, Vermont</u> A rip-rapped section on the upstream end remains stable. A 400' long by 15' high bank with many bank swallow holes is very active and raw with sods at the edge of the river. The road is approximately 20' from riverbank edge. [See Pictures C-10 thru C-18]
<u>Mile 11.5 to 11.2</u> NH	<u>BF-217, Boston and Maine Railroad, New Hampshire</u> This 50' high bank continues to be raw at the downstream end for 150 feet. There are trees sliding and down with undercut sods on the slope. [See Picture C-9]
<u>Mile 11.1 to 10.5</u> NH	<u>BF-218, G. D. Austin, New Hampshire</u> This bank is now inactive. Some poplars at the top of slope are undercut. Offset measurements show a 28-year erosion of 17.5 feet through 1982. Refer to the 1982 report for the erosion tabulation.
<u>Mile 10.6 to 10.2</u> VT	<u>BF-840, Ellen M. Butterfield, Vermont</u> This area is now inactive. Both rip-rap and ledge have kept bank stable.

<u>Mile 10.5 to 9.8</u> NH	<u>B&M Railroad, New Hampshire</u> This 30' high slide remains active with trees sliding and down in water. A 200' long by 40' high slide remains active with trees down in water. [See Picture C-19]
<u>Mile 9.2 to 9.1</u> NH	<u>BF-213, J. C. Fairbrother, New Hampshire</u> This 100' long area is now cleared out for boat moorings and recreation along shore. [See Picture C-20] Downstream is a 1,000' long by 10' high active section along the Town Park with sods on slope and trees undercut and leaning. Precast concrete bulkhead on bank is used for stairway to river. [See Picture C-21]
<u>Mile 9.2 to 9.1</u> NH	<u>BF-212, M. E. Corliss, New Hampshire</u> The upstream area 200' long by 10' high is active and now connected to the downstream area, 300 feet long in 1977. The total area affected is now 1,000' long with sods on the slope and trees undercut and leaning.
<u>Mile 8.7</u> VT	<u>BF-76, R. W. Dent, Vermont</u> This 40' high bank, with an old slide 75' long and dead trees in the water, is healing. [See Picture C-22] An existing dock remains on inactive bank. [See Picture C-23]
<u>Mile 8.15 to 7.7</u> VT	<u>BF-76, R. W. Dent, Vermont</u> The upstream end of this 30' high bank continues to be raw at the top with brush at the bottom, indicating moderate activity. The downstream end of this 10' to 15' high steep raw bank continues to be undercut with sods and some brush in the water. Banks are very active and nearly vertical. [See Picture C-24]
<u>Mile 7.6 to 7.5</u> NH	<u>BF-200, S. A. Richardson, New Hampshire</u> This high bank shows moderate activity with a 30" leaning pine sliding on the slope. [See Picture D-1] The downstream end is active with a 40" pine at the bottom of the slope.
<u>Mile 7.2 to 6.2</u> NH	<u>New England Power Company, New Hampshire</u> About 2,000' of this bank has been rip-rapped by the Army Corps of Engineers to arrest the bank erosion and protect the Town of Charlestown sewage treatment plant's lagoon. [See Picture D-2] The riverbank upstream of the treatment plant has rip-rap placed at an outwash area downstream along banking. [See Picture D-3]
<u>Mile 6.6</u> VT	<u>BF-75, L. R. Bigelow and BF-74, NEP, Vermont</u> This slide is healed and is inactive. [See Picture D-4]

Mile 3.5 to 3.3
VT

BF-61, New England Power Company, Vermont
The 300' long area downstream of the old boat landing is now inactive with weed cover on the upstream end and raw downstream. Utility poles are approximately 15 feet from the top of slope at the picnic grounds.

Mile 3.3 to 2.4
NH

BF-176, BF-175a, New England Power Company, New Hampshire
This 1500' low silty bank remains active with undercut sods.
[See Pictures D-12, D-13, and D-14]

Mile 2.2 to 1.9
VT

BF-57a, Rutland Railroad Company, Vermont
This 10' high sandy gravel bank is active and has sustained some loss since 1977. The "Steamtown Railroad" had a spur track parallel to the bank top about 15 feet back. This bank is very susceptible to wind and wave action.
See Picture D-15] At Mile 1.95, concrete slabs and rocks have been dumped over the slope at a gully. This area is stable, but a 200' long by 12' high area just downstream is active.

Mile 1.75 to 1.2
VT

BF-53a, BF-52, New England Power Company, Vermont
This low active bank has some rock protection still in good condition. A 24" beech tree remains undercut and leaning since 1977.

Mile 1.45 to 1.2
NH

BF-173b, New England Power Company, New Hampshire
The rip-rap placed in 1964 remains in good condition. [See Picture D-16] However, there is a slide 50' long by 12' high just downstream with trees sliding and in the water.

Mile 1.2
NH

BF-172b, Cray Oil Company, New Hampshire
This 35' high silt bank continues to be very active with the top of bank being undercut and trees and brush sliding down the face to the water. [See Picture D-17]

Mile 1.1 to 1.0
NH

BF-172b, Cray Oil Company, New Hampshire
A 50' long by 20' high bank is active with many raw areas. Some boulders and trees have been placed on the slope to help control slides. House is now approximately 50 feet away from the top of the slope. [See Picture D-18] A 200' long by 20' high raw section with leaning trees at top of slope remains active.
[See Picture D-19]

Mile 0.6
VT

BF-50, Rutland Railroad, Vermont
The large rock slabs dumped over the bank for erosion protection are stable and in excellent condition. [See Pictures D-20 & D-21/Crew]

Mile 0.5 NH — New Hampshire Bank
The intermittent activity between the log yard boat landing and the steel arch bridge is slight. Concrete slabs have been placed on the slope just downstream of the boat landing. [See Pictures D-22 & D-23]

Mile 0.2 — Connecticut River
Downstream picture of the new highway bridge, which replaced the steel arch bridge in 1983. [See Picture D-24]

Attachments

Attached herewith is a complete set of double letter size FERC Project Boundary Maps (24 sheets) with the bank slides and photograph locations shown thereon.


A-1


A-2


A-3


A-4


A-6


A-8


A-5


A-7


A-14


B-2


A-13


B-1


A-10


A-12


A-9


A-11


B-8


B-10

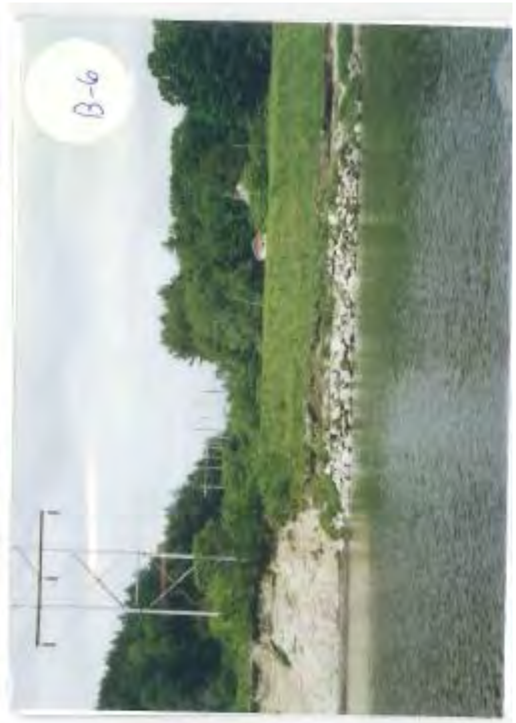

B-7


B-9


B-3


B-4


B-5


B-6

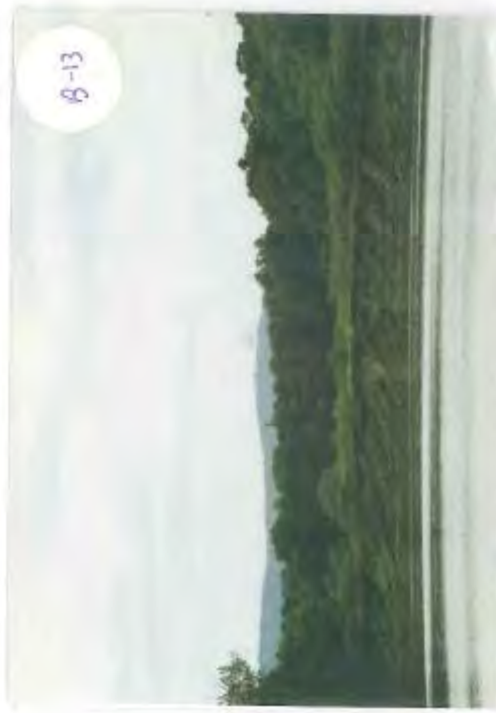

B-16

B-18

B-15

B-17


B-11

B-12

B-13

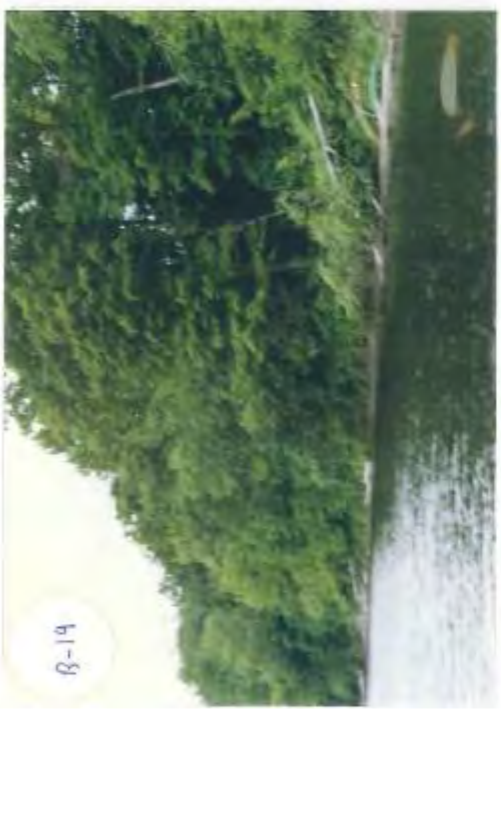
B-14


B-24

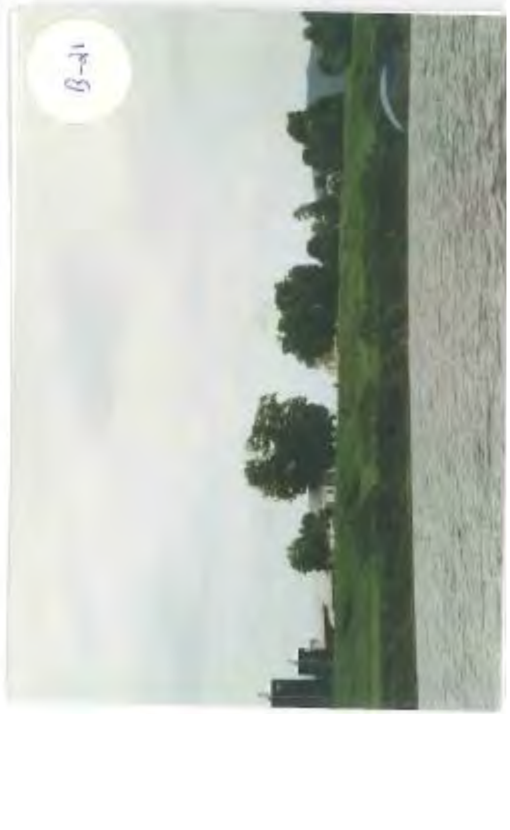

B-23


C-2


C-1


B-19

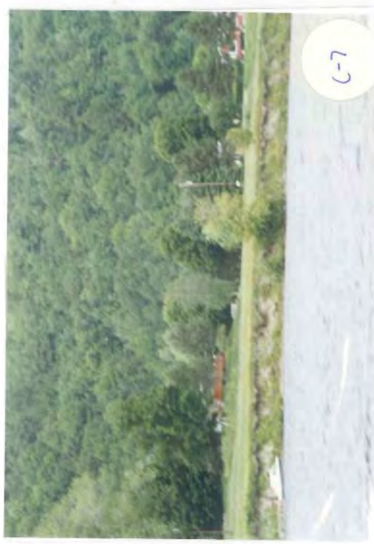

B-20

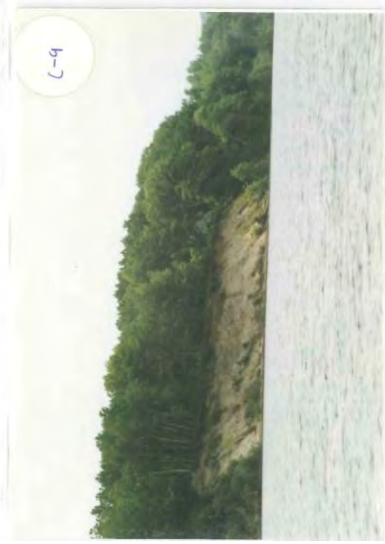

B-21


B-22

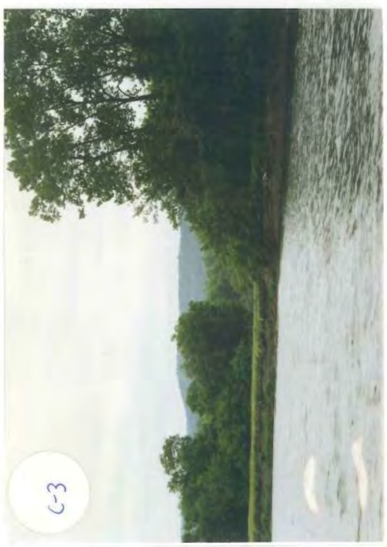

C-8


C-10


C-7


C-9

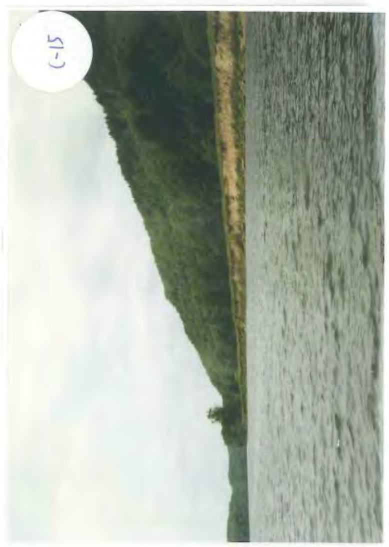

C-4

C-6

C-3

C-5


C-16


C-18


C-15


C-17


C-12

C-14

C-11

C-13


C-24


D-2


C-23


D-1


C-20


C-22


C-19

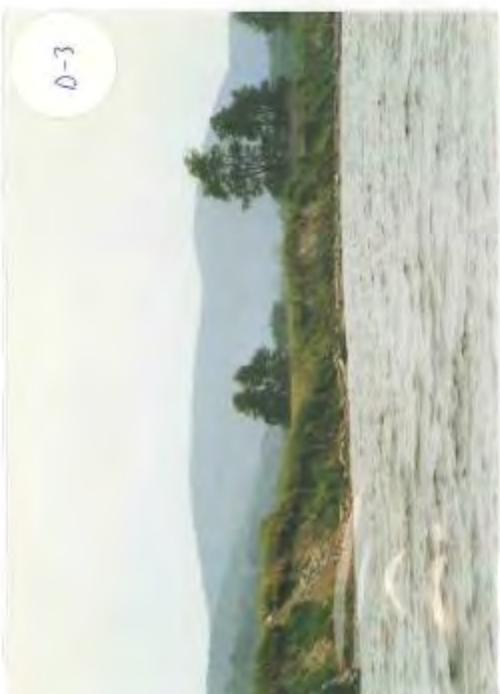

C-21


D-10


D-7


D-9







O-16


O-18


O-15


O-17

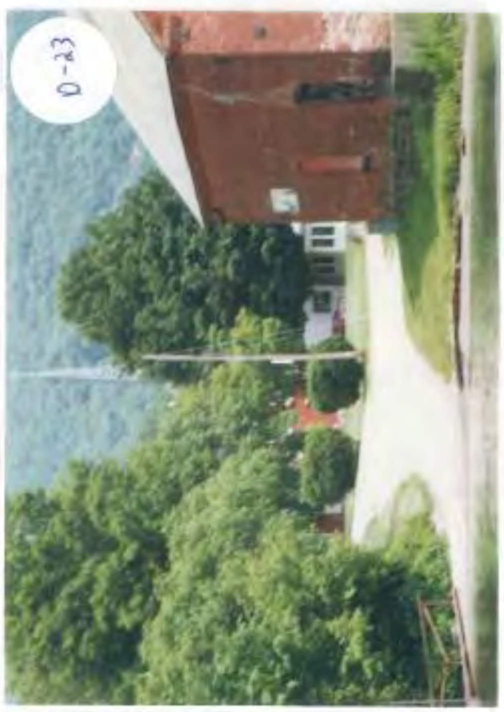

D-11

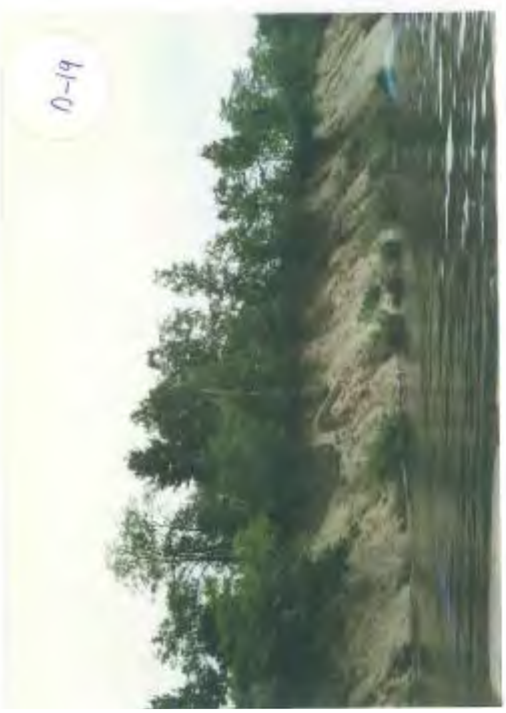

D-12


D-13

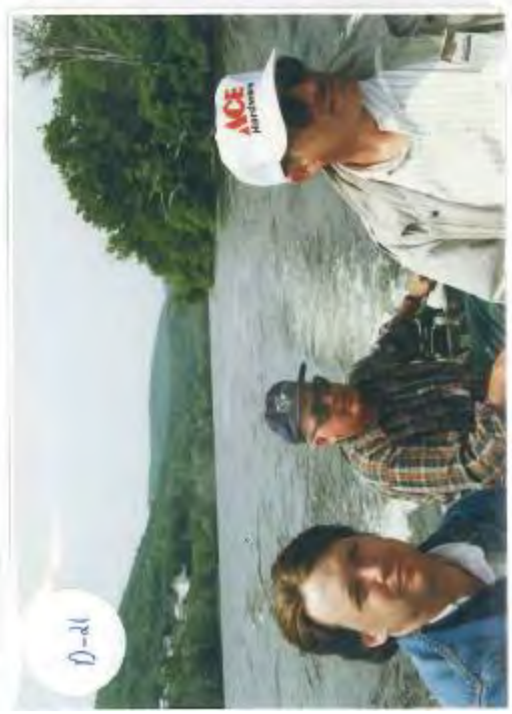

D-14


D-24

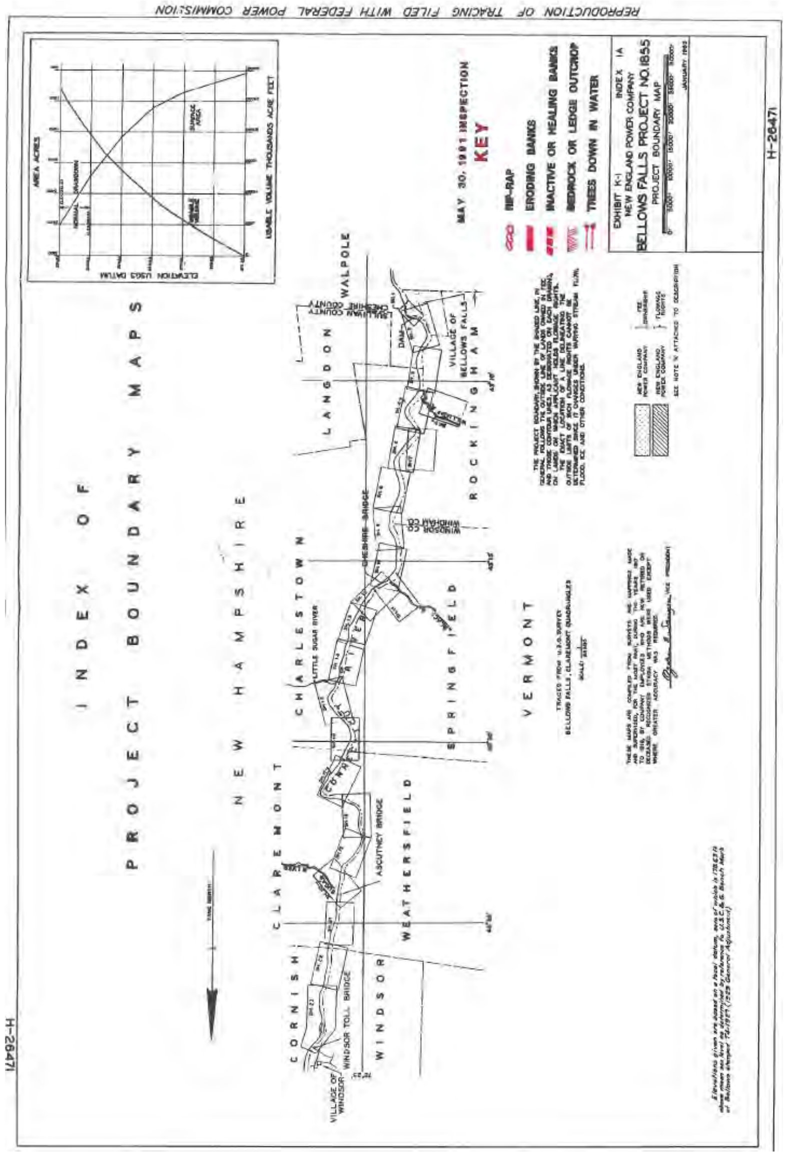

D-23

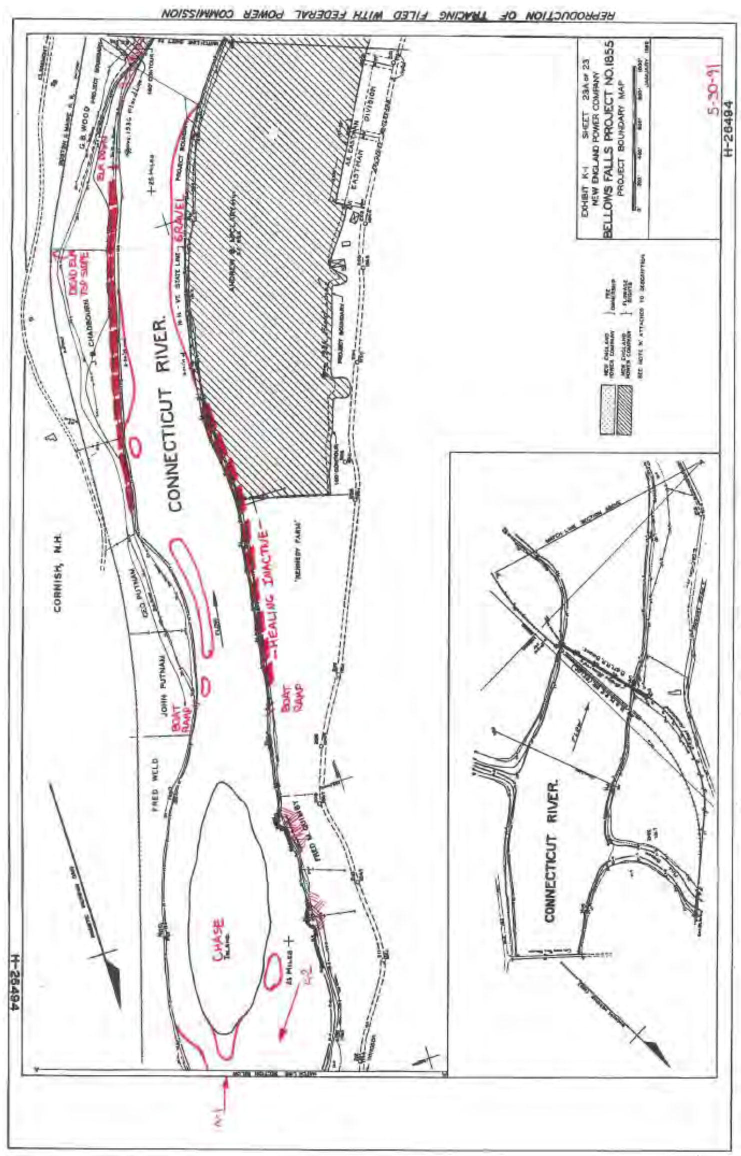

D-19

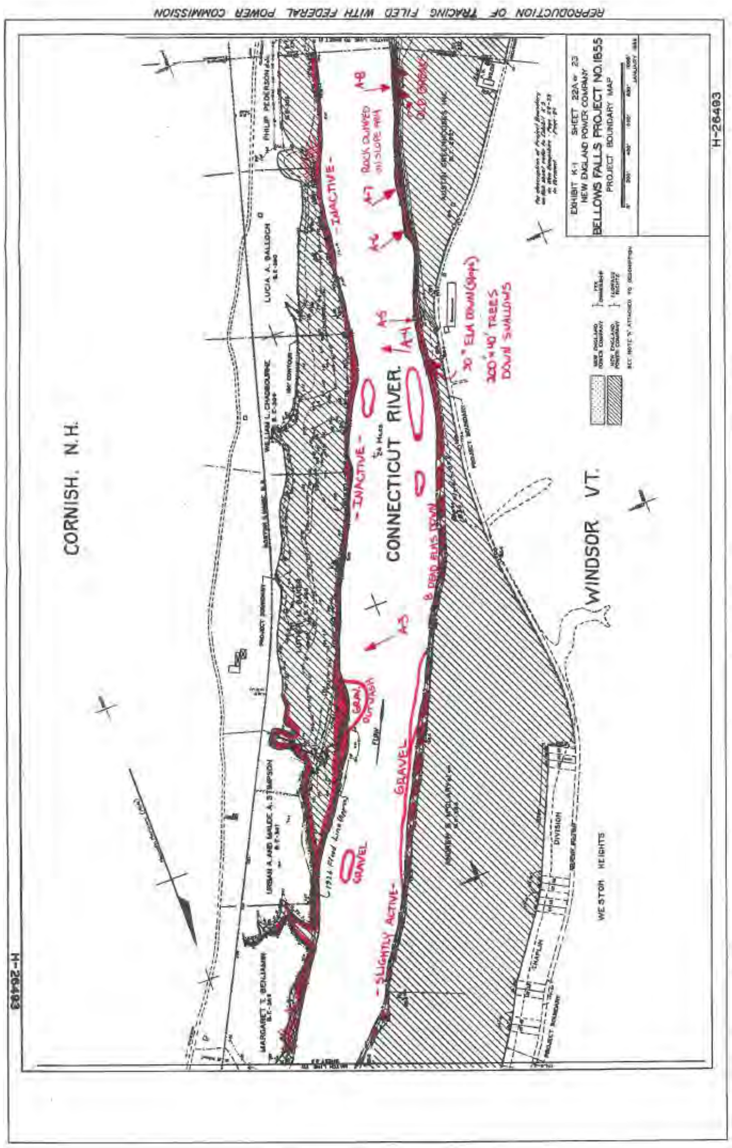

D-20


D-21
ACE

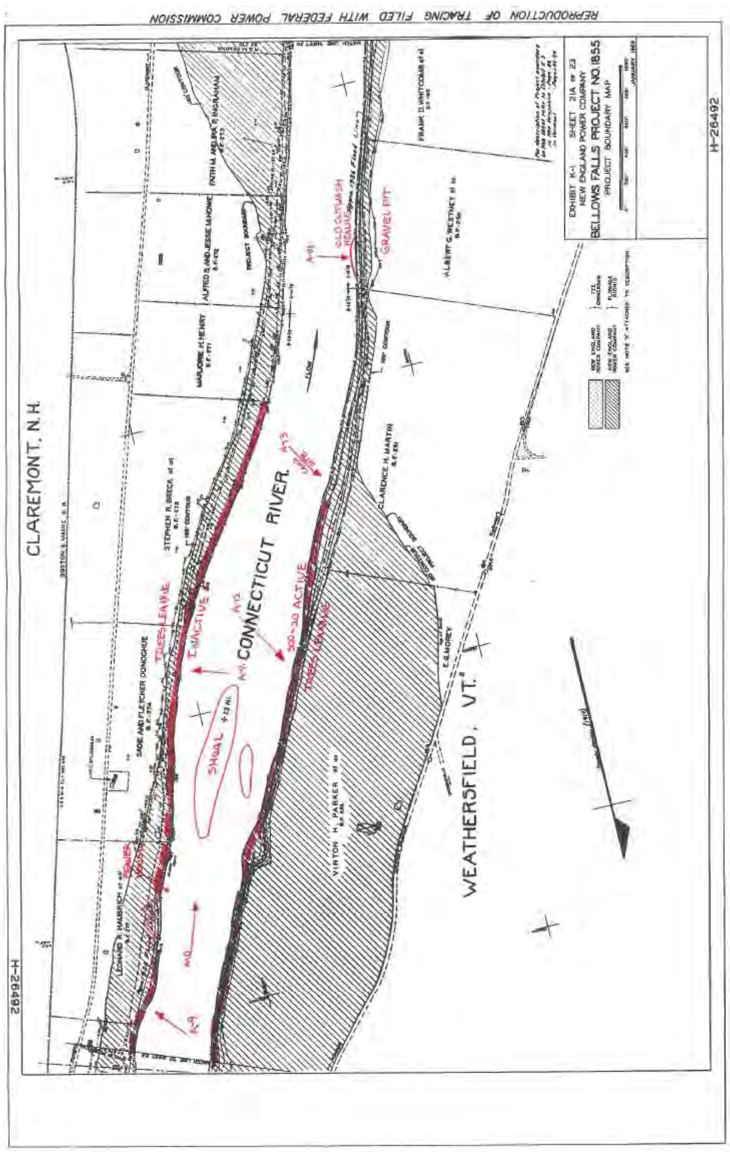

D-22

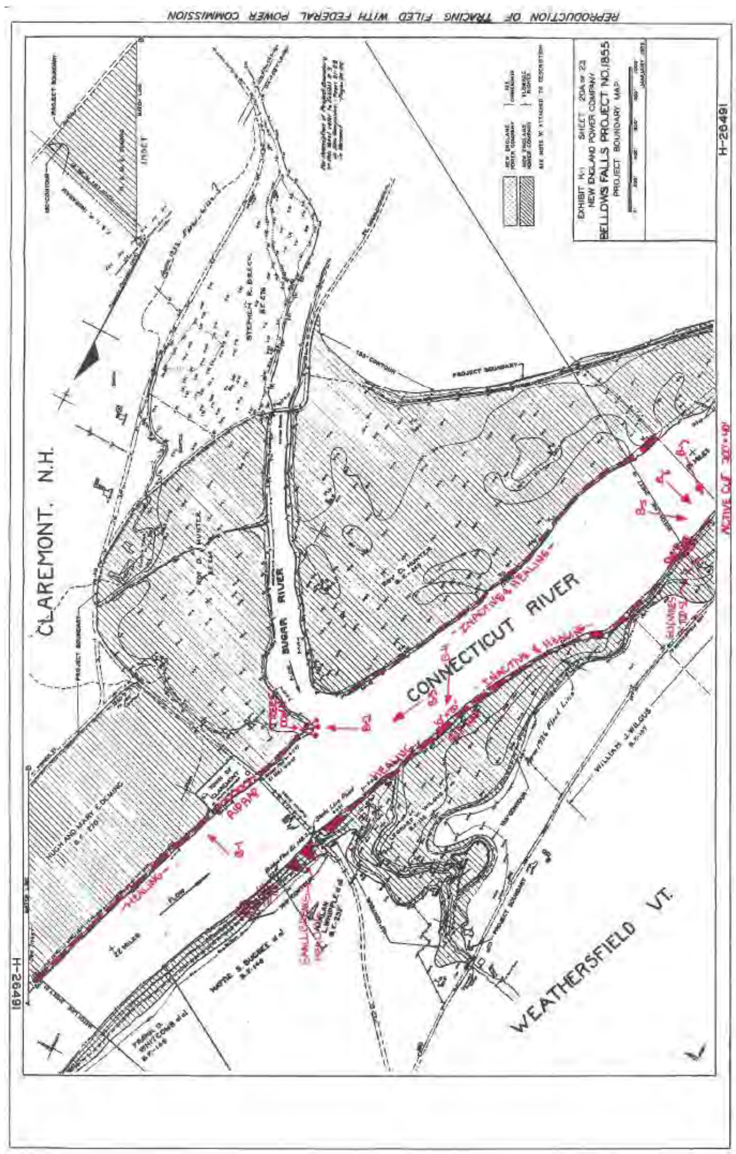

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
INDEX OF PROJECT BOUNDARY MAPS
NEW HAMPSHIRE
VERMONT
CORNISH
CLAREMONT
CHARLESTOWN
LANGDON
WALPOLE
WINDSOR
WEATHERSFIELD
SPRINGFIELD
ROCKINGHAM
VILLAGE OF WINDSOR
WINDSOR TOLL BRIDGE
ASCUTNEY BRIDGE
CHESHIRE BRIDGE
VILLAGE OF BELLOWS FALLS
DAM
MAY 30, 1991 INSPECTION
KEY
RIP-RAP
ERODING BANKS
INACTIVE OR HEALING BANKS
BEDROCK OR LEDGE OUTCROP
TREES DOWN IN WATER
EXHIBIT K-1
INDEX 1A
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
H-28471
H-28471


REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CONNECTICUT RIVER
CORNISH, N.H.
EXHIBIT K-1 SHEET 23A of 23
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
H-26494
5-30-91
GRAVEL
HEALING INACTIVE
BOAT RAMP
CHASE
JOHN PUTNAM
FRED WELD
CONNECTICUT RIVER

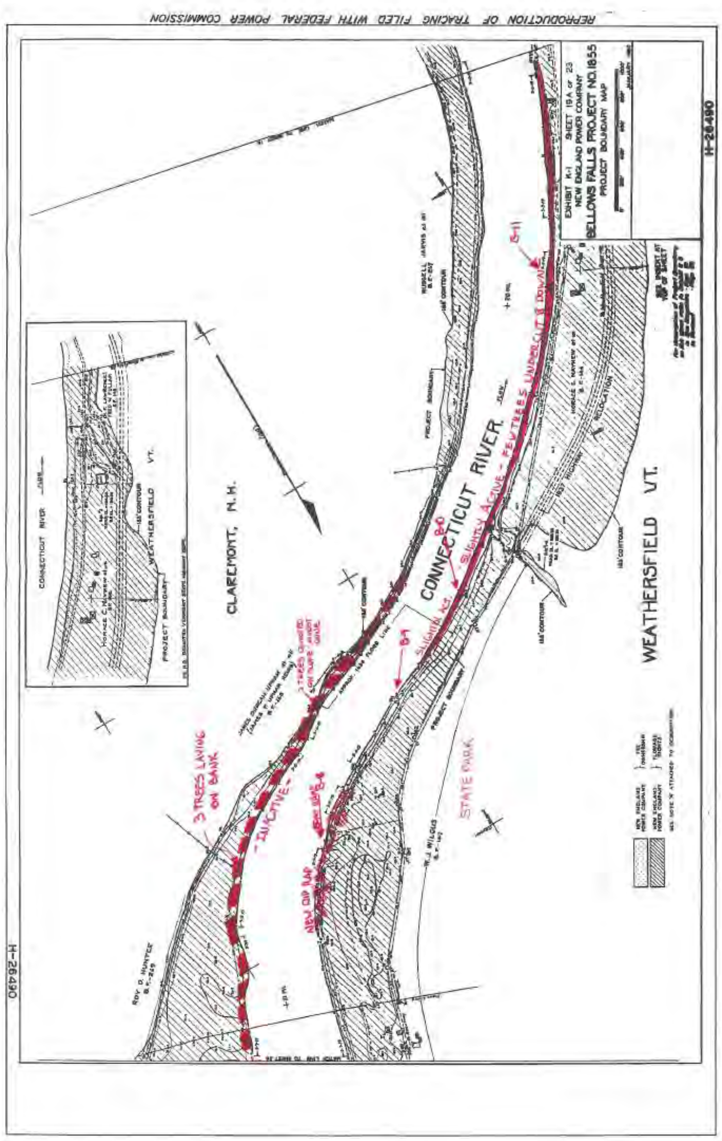


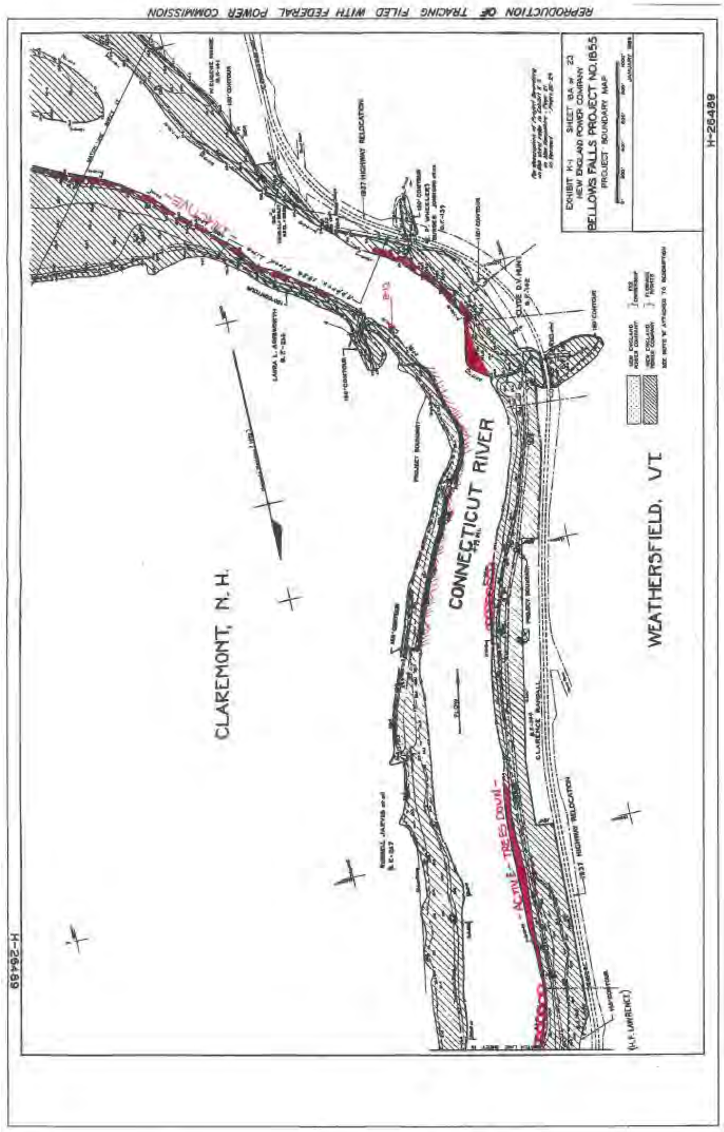
REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CORNISH, N.H.
CONNECTICUT RIVER
WINDSOR VT.
- INACTIVE -
- SLIGHTLY ACTIVE -
GRAVEL
BELLOWS FALLS PROJECT NO.1855
NEW ENGLAND POWER COMPANY
PROJECT BOUNDARY MAP
H-26483

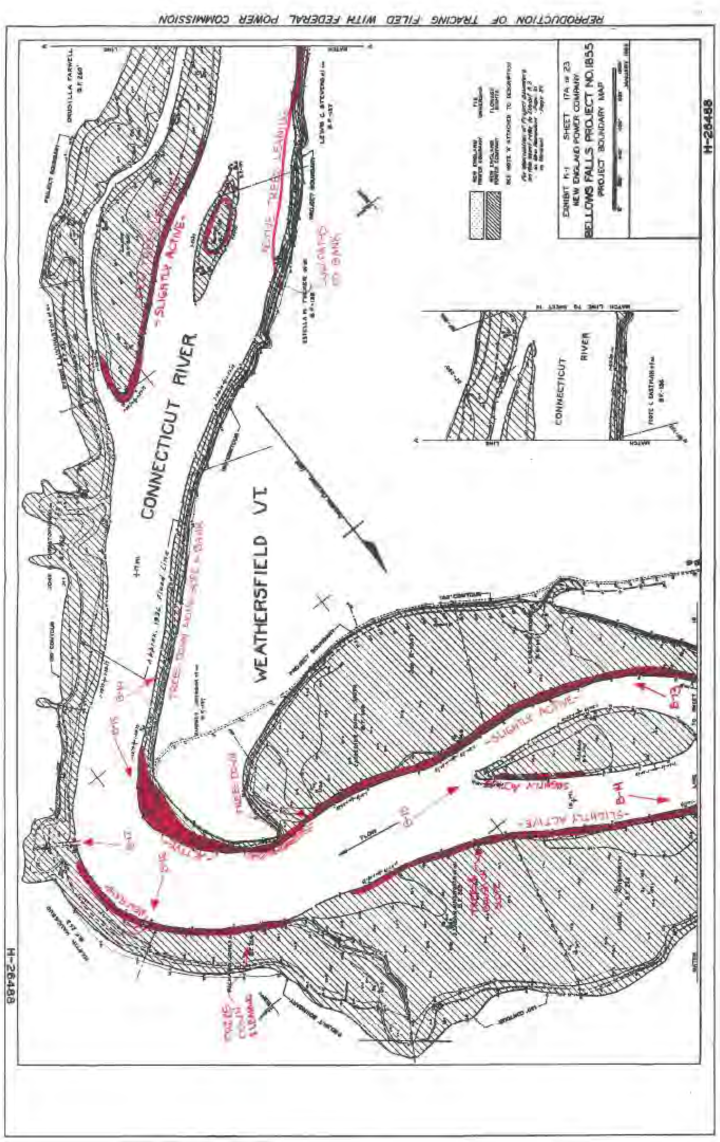

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CLAREMONT, N.H.
CONNECTICUT RIVER
WEATHERSFIELD, VT.
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO. 1855
PROJECT BOUNDARY MAP
H-26492

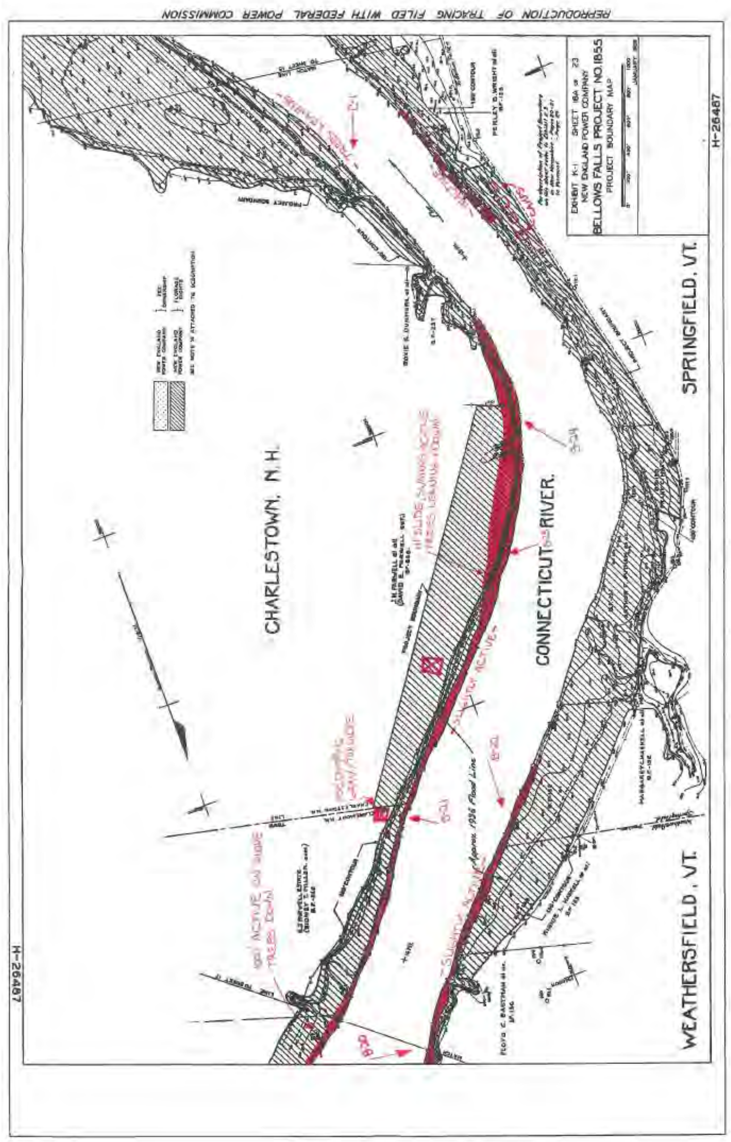


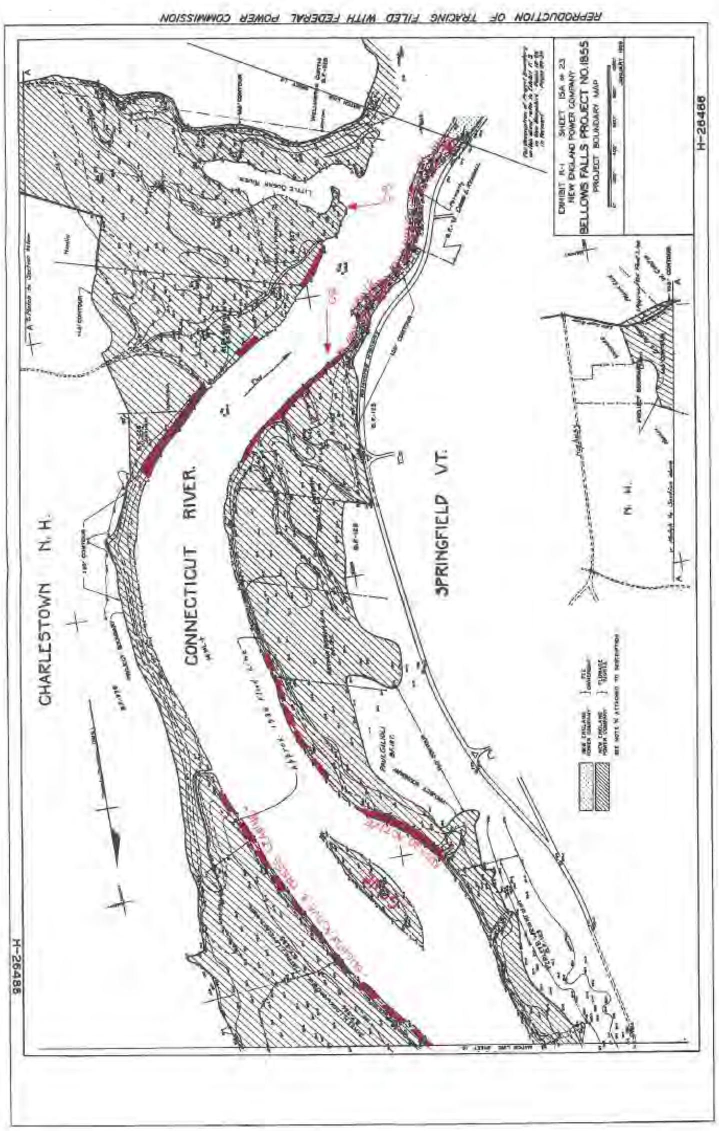
REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CLAREMONT. N.H.
SUGAR RIVER
CONNECTICUT RIVER
WEATHERSFIELD VT.
EXHIBIT K-1 SHEET 20A of 23
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
H-26491
H-26491

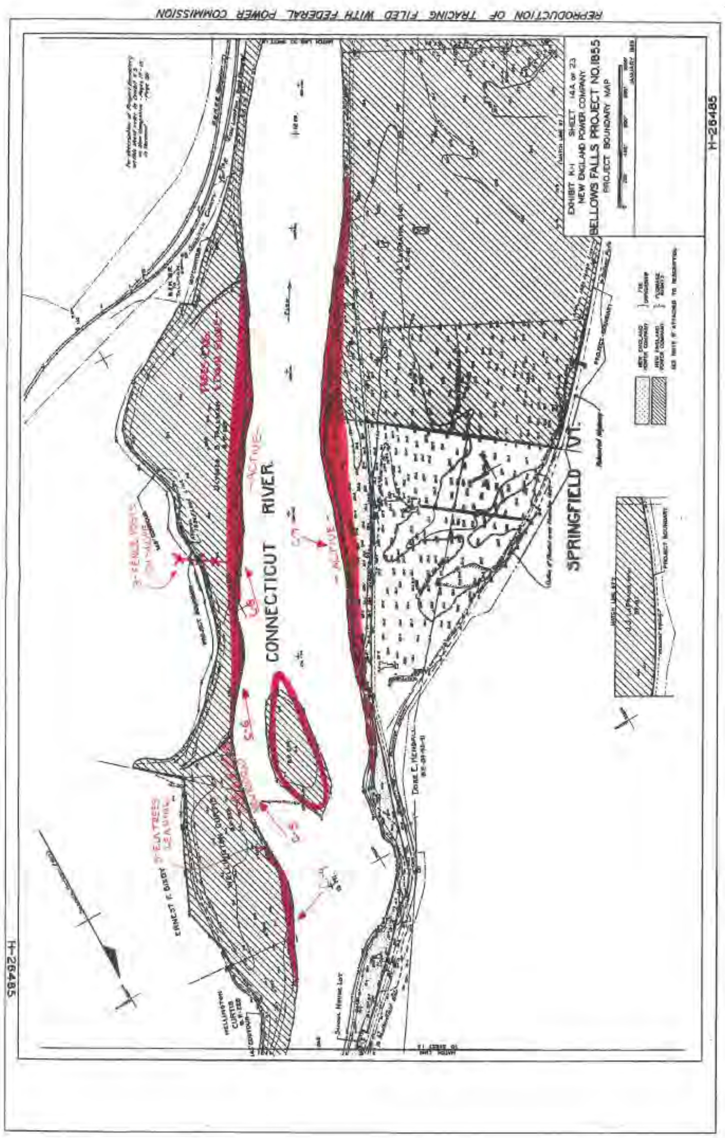

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
EXHIBIT K-1 SHEET 19A of 23
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
H-26490
CLAREMONT, N.H.
CONNECTICUT RIVER
WEATHERSFIELD VT.
STATE PARK
3 TREES LAYING ON BANK
INACTIVE
PROJECT BOUNDARY

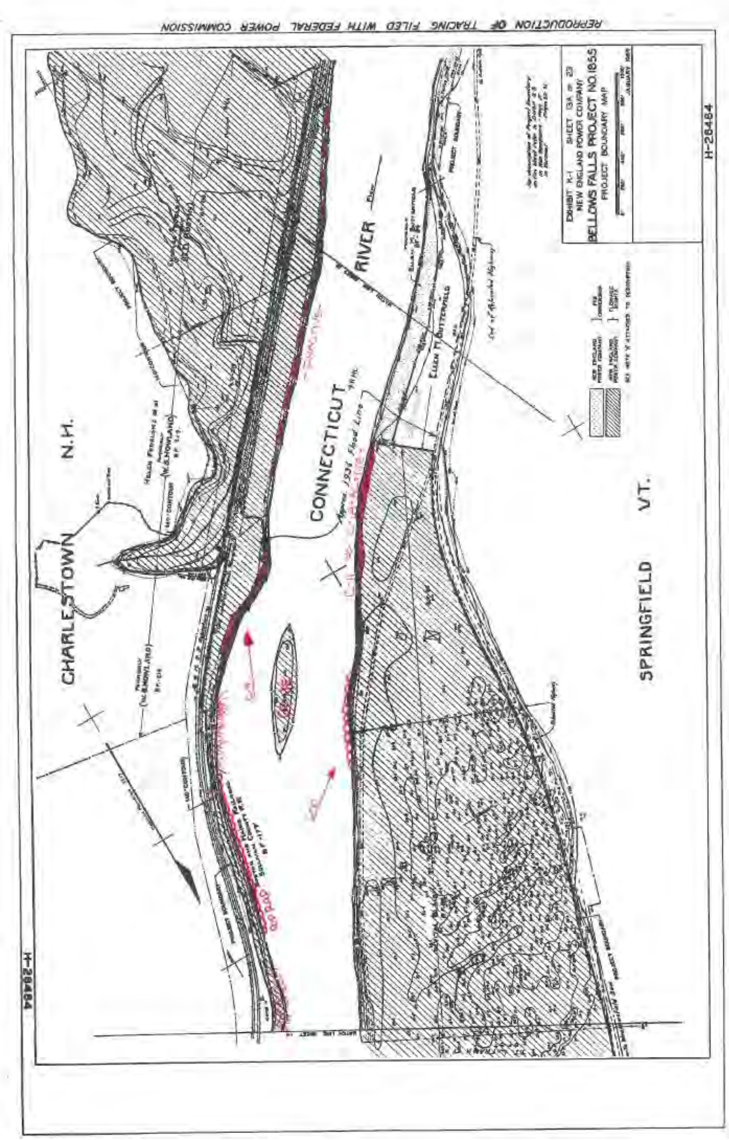

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CLAREMONT, N. H.
CONNECTICUT RIVER
WEATHERSFIELD, VT.
PROJECT BOUNDARY MAP
1937 HIGHWAY RELOCATION
H-26489

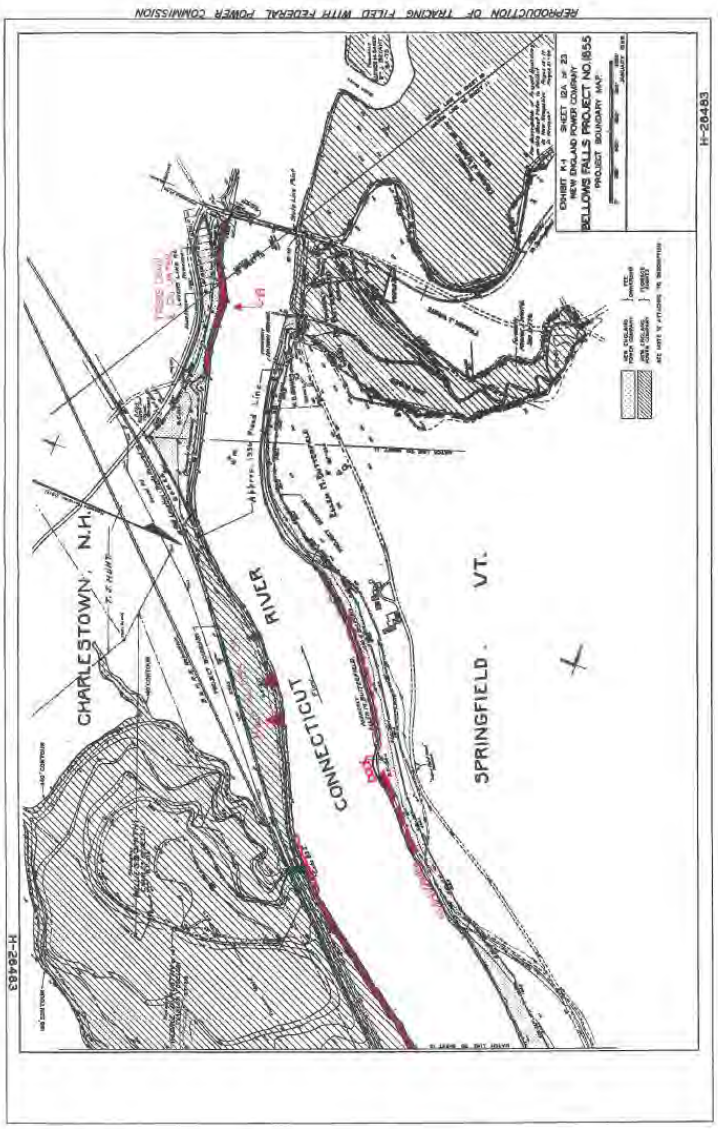

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CONNECTICUT RIVER
WEATHERSFIELD VT.
-SLIGHTLY ACTIVE-
BELLOWS FALLS PROJECT NO.1855
H-26488

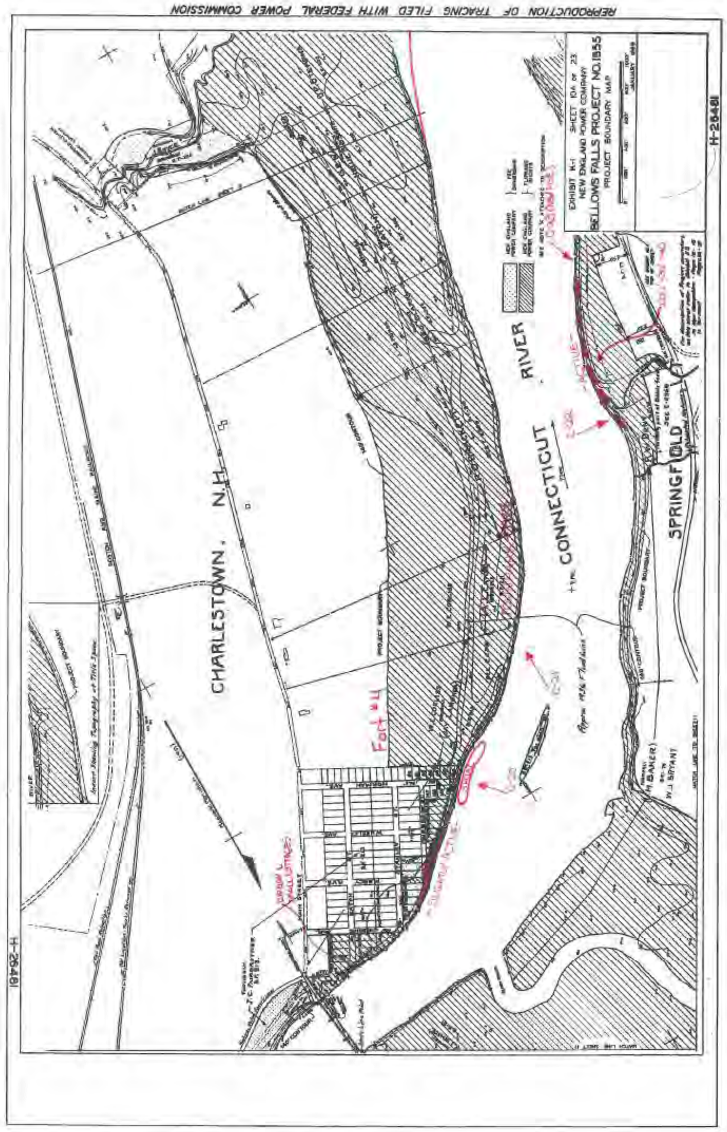

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CHARLESTOWN, N.H.
CONNECTICUT RIVER
SPRINGFIELD, VT.
WEATHERSFIELD, VT.
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
H-26487

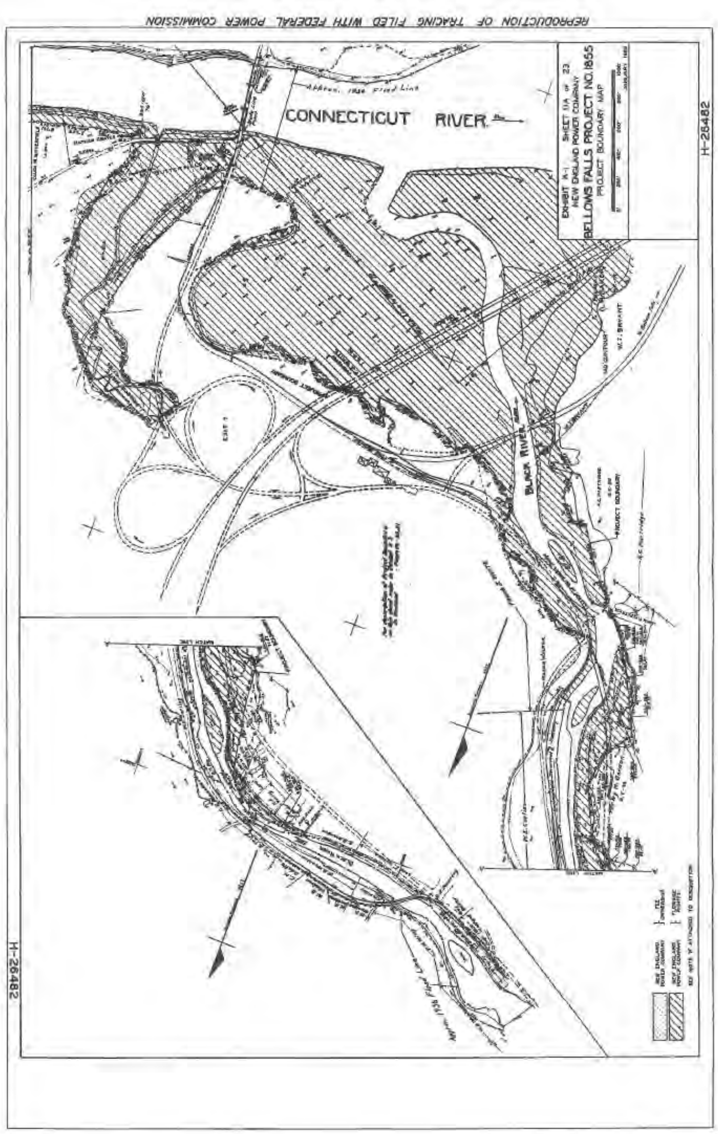

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CHARLESTOWN N. H.
CONNECTICUT RIVER
SPRINGFIELD VT.
BELLOWS FALLS PROJECT NO. 1855
H-26488

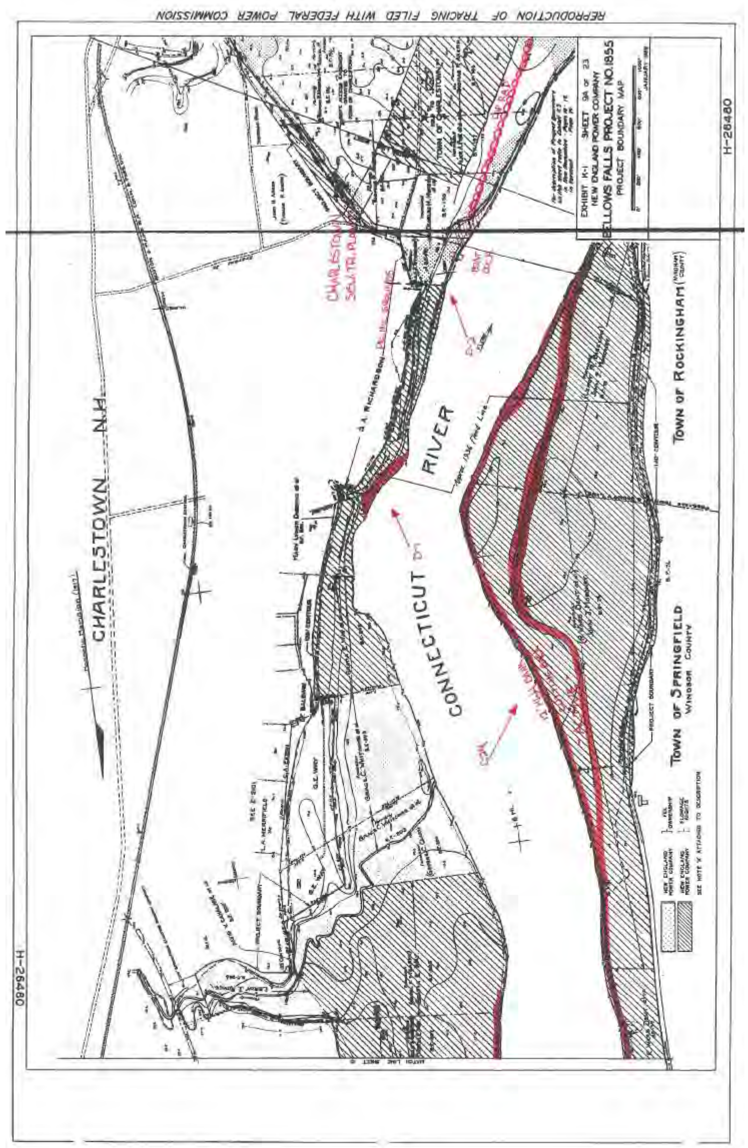

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CONNECTICUT RIVER
SPRINGFIELD VT.
EXHIBIT K-1 SHEET 14A of 23
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
H-26485
H-26485

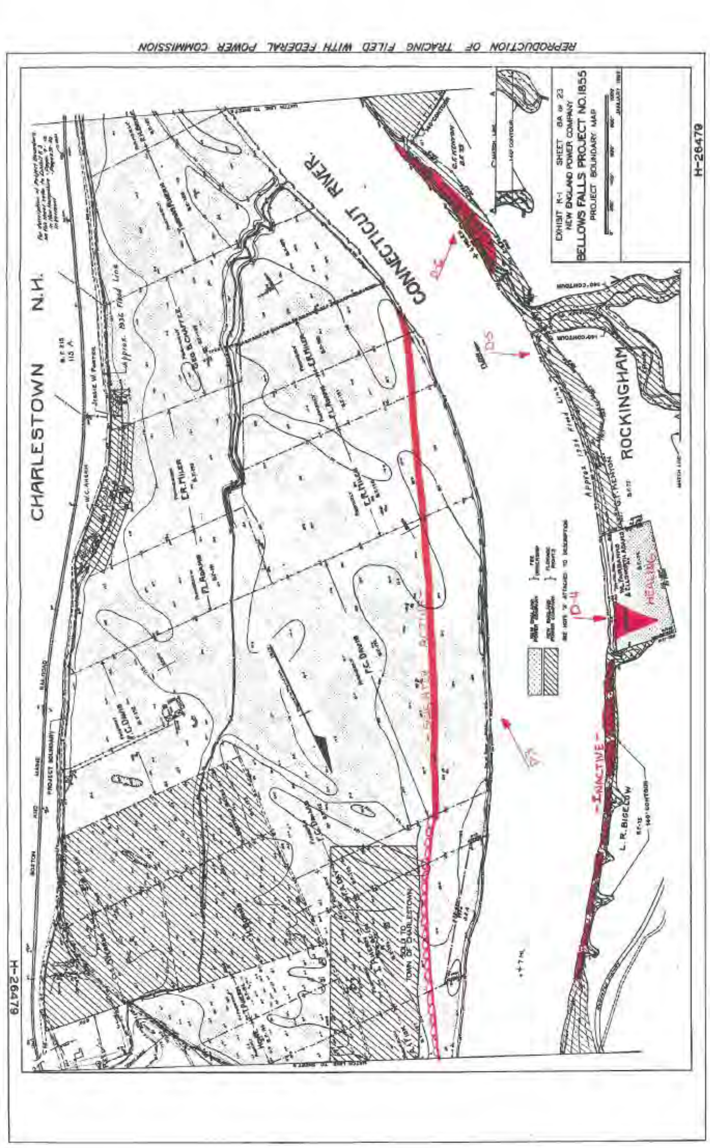

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CHARLESTOWN
N.H.
CONNECTICUT
RIVER
SPRINGFIELD
VT.
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
H-28484


REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CHARLESTOWN, N.H.
CONNECTICUT RIVER
SPRINGFIELD, VT.
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
H-26483
H-26483

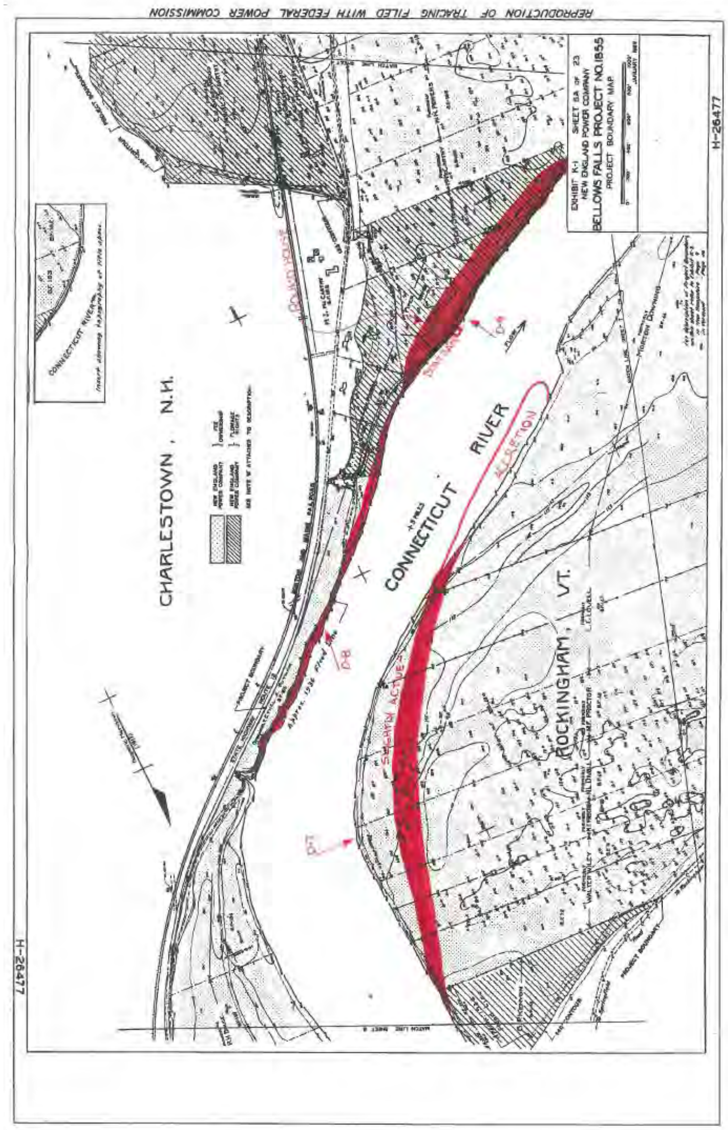

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CHARLESTOWN, N.H.
CONNECTICUT RIVER
SPRINGFIELD
Fort #4
EXHIBIT K-1 SHEET 10A OF 23
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
H-26481

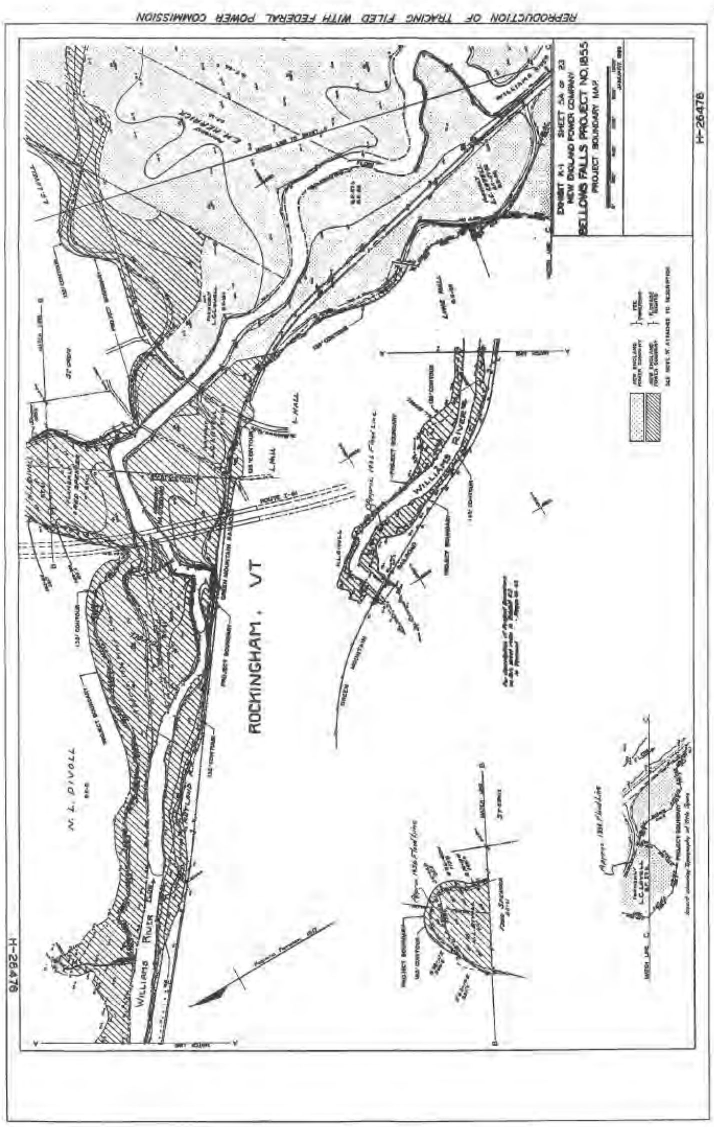

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CONNECTICUT RIVER
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO. 1855
PROJECT BOUNDARY MAP
BLACK RIVER
H-28482
H-28482

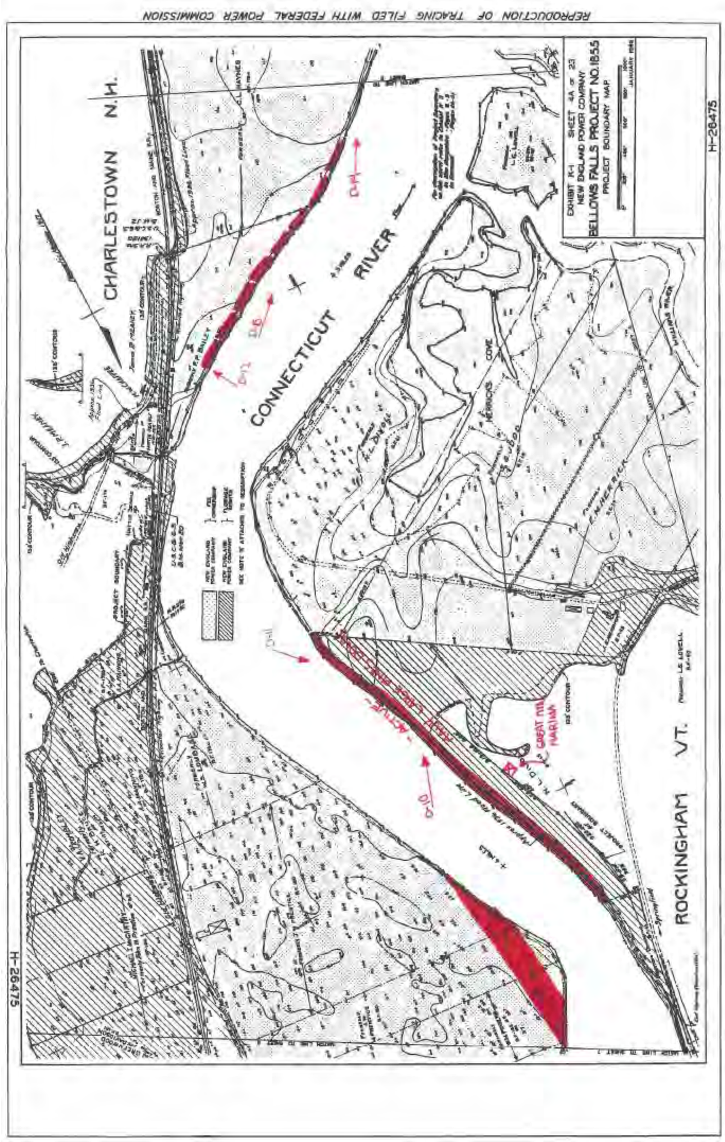

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CHARLESTOWN N.H.
CONNECTICUT RIVER
TOWN OF SPRINGFIELD
WINDSOR COUNTY
TOWN OF ROCKINGHAM
EXHIBIT K-1
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
H-26480


REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CHARLESTOWN N.H.
CONNECTICUT RIVER
ROCKINGHAM
BELLOWS FALLS PROJECT NO. 1855
NEW ENGLAND POWER COMPANY
PROJECT BOUNDARY MAP
H-26479
H-26479
INACTIVE
HEALING

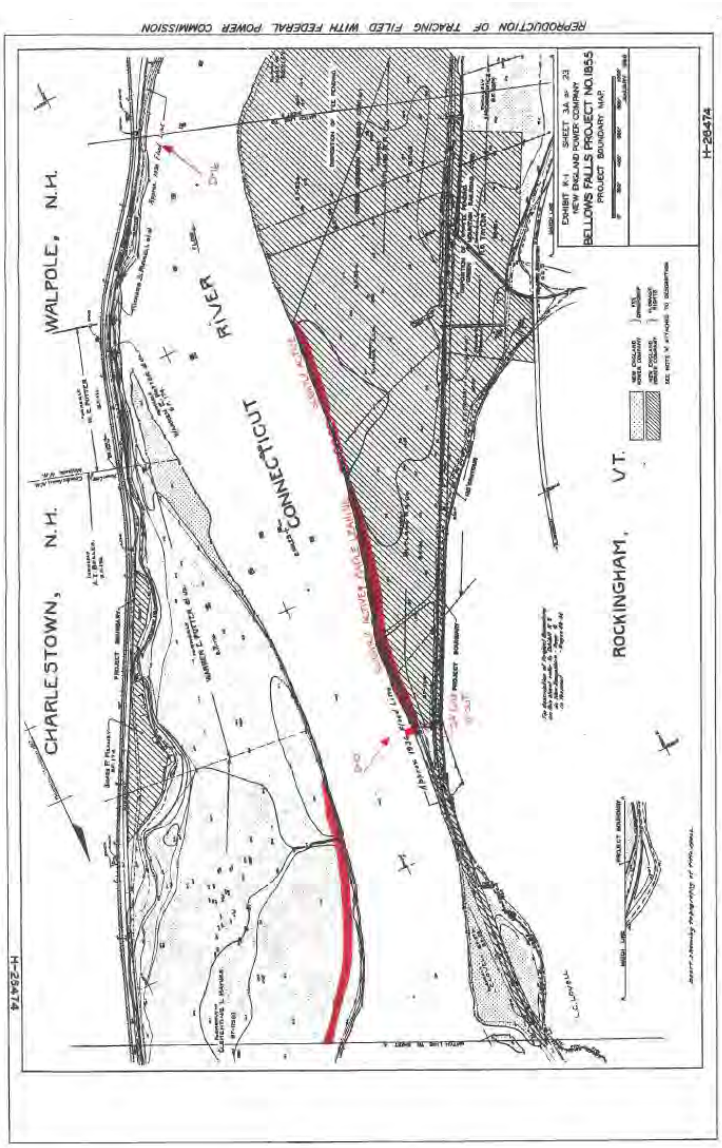

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
EXHIBIT K-1 SHEET 7A OF 23
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO. 1855
PROJECT BOUNDARY MAP
H-28478
CONNECTICUT RIVER
ROCKINGHAM VT.
Approx. 1936 Flood Line
H-28478

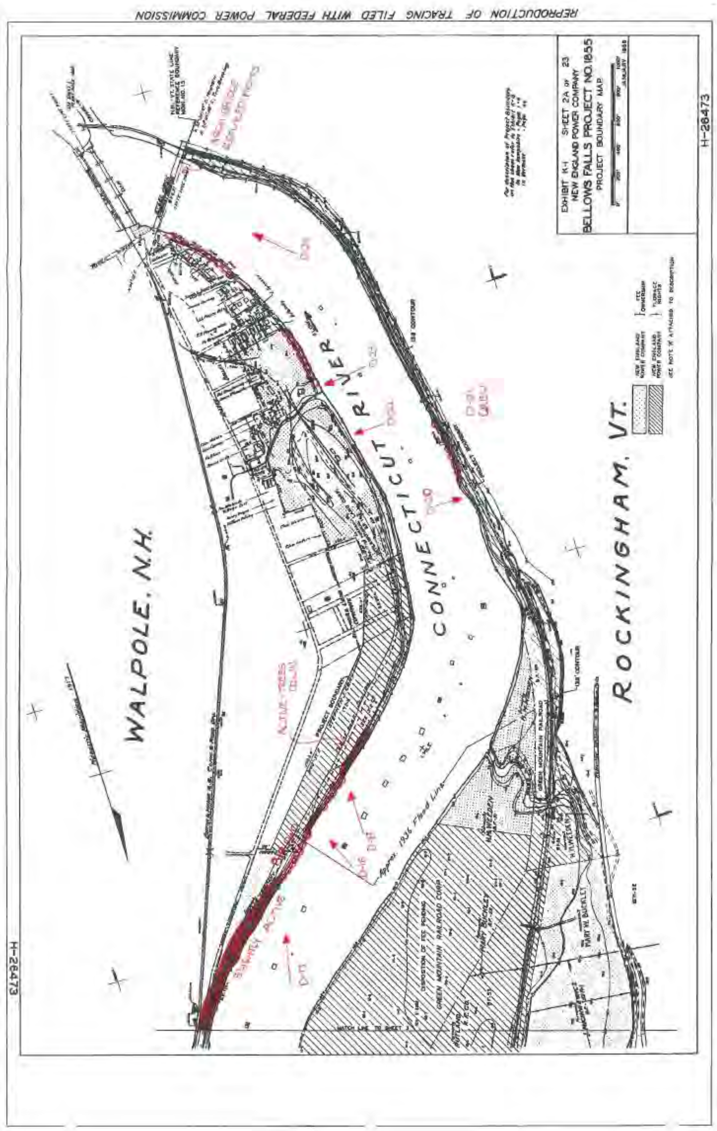

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CHARLESTOWN, N.H.
CONNECTICUT RIVER
ROCKINGHAM VT.
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
ACCRETION
H-26477

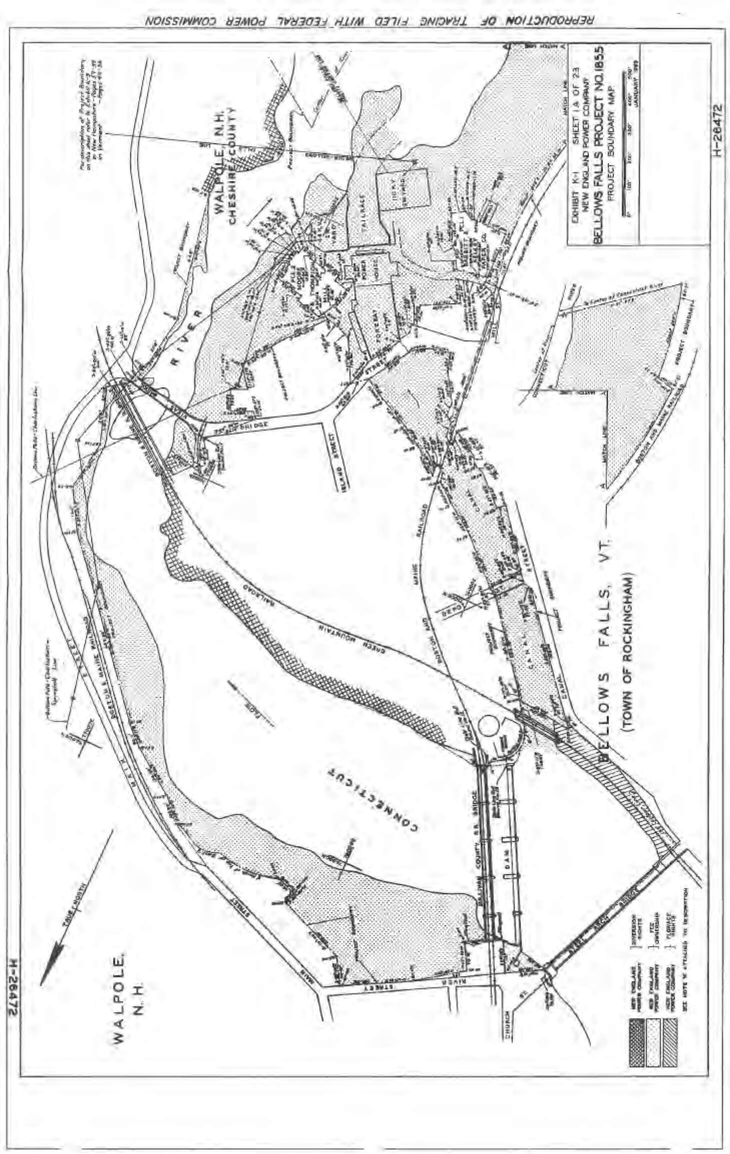

REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO. 1855
PROJECT BOUNDARY MAP
H-26476
ROCKINGHAM, VT
N. L. DIVOLL
WILLIAMS RIVER
H-26476



REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CHARLESTOWN N.H.
CONNECTICUT RIVER
ROCKINGHAM VT.
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
H-28475


REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
CHARLESTOWN, N.H.
WALPOLE, N.H.
CONNECTICUT
RIVER
ROCKINGHAM, VT.
EXHIBIT K-1 SHEET 3A of 23
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
H-28474
H-28474


REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
WALPOLE, N.H.
CONNECTICUT RIVER
ROCKINGHAM, VT.
EXHIBIT K-1 SHEET 2A of 23
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
H-26473


REPRODUCTION OF TRACING FILED WITH FEDERAL POWER COMMISSION
EXHIBIT K-1
SHEET 1A OF 23
NEW ENGLAND POWER COMPANY
BELLOWS FALLS PROJECT NO.1855
PROJECT BOUNDARY MAP
WALPOLE, N.H.
CHESHIRE COUNTY
RIVER
CONNECTICUT
BELLOWS FALLS, VT.
(TOWN OF ROCKINGHAM)
WALPOLE,
N.H.
H-26472
H-26472

Appendix D – Bellows Falls Impoundment Erosion Site Comparison: 1997-2008

Bellows Falls Impoundment Location 1

1997

2008

Bellows Falls Pool – Location 2

1997

2008

Bellows Falls Pool – Location 3

1997

2008

Bellows Falls Pool – Location 4

1997

2008

Bellows Falls Pool – Location 5

1997

2008

Bellows Falls Pool – Location 6

1997

2008

Bellows Falls Pool – Location 7

1997

2008

Bellows Falls Pool – Location 8

1997

2008

Bellows Falls Pool – Location 9

1997

2008

Bellows Falls Pool – Location 10

1997

2008

Appendix E – Vernon Impoundment Erosion Site Comparison: 1997-2008

Vernon Pool – Location I

1997

2008

Vernon Pool – Location J

1997

2008

Vernon Pool – Location K

1997

No photo in 2008

Vernon Pool – Location L

1997

2008

Vernon Pool – Location M

1997

2008

Appendix F – Examples of Vernon Impoundment Erosion in 1954

File Copy/km

Armand J. Millette
Senior Engineer

New England Power Service
25 Research Drive
~~20 Turnpike Road~~
Westboro, Massachusetts 01581
Telephone (617) 366-8811 366-9011

CONNECTICUT RIVER POWER COMPANY

OBSERVATIONS OF EROSION

ON BANKS OF CONNECTICUT RIVER

BELLOWS FALLS TO VERNON

SEPTEMBER 2-3, 1954

R. F. CASCADDEN 11/15/54

Copies to:	Attachments
1 - A. S. Walker	1 set of maps
2 - H. A. Suprenant	" " " "
3 - L. H. Mann	" " " "
4 - E. P. Moseley (File Copy)	" " " "

VERNON POND BANKS INSPECTION
SEPTEMBER 2 AND 3, 1954

General

The inspection of the erosion of the banks between Bellows Falls and Vernon Dam was made on September 2 and 3, 1954. Members of the party included H. E. Stockwell from the Shelburne Falls office, F. D. Meader from the Littleton office, and R. F. Cascadden from the Boston office.

The discharge from Bellows Falls was about 15,000 c.f.s. at 8:00 a.m. September 2nd due to heavy rains during "Hurricane Carol." At this flow observation of banks below water line was impossible.

In most all cases the banks had not changed a great deal since the observations made in 1953. Erosion occurred at the same places and new breaks were only confined to small local bank slides.

Due to the abundance of rain this summer, woods and brush covered many slopes that show raw faces in the late spring.

Since the eroding banks occur at the same mileages as last year no attempt to give descriptive details of the banks composition etc. is made in this report. It is suggested that the 1953 report be kept at hand in order to get these descriptions and for comparison of photographs which in a great many cases speak for themselves.

The boat was transferred from the Bellows Falls Log yard to a point below the tailrace on the Walpole side of the river the first thing Thursday morning, September 2, 1954.

Kodacolor photos were also taken of the banks in Vernon Pond for experimental purposes as in Bellows Falls Pond and are contained in a separate folder for comparison with black and white prints made from the same negatives. This will be circulated for observation and comments by interested parties.

The following notes, pictures etc. were made traveling downstream and are so recorded to facilitate future observations made by boat.

Inspection Notes

Thursday, September 2, 1954

Mile 30.7 to 30.35 Vt. bank. W. S. Powers property. V-409

This bank has not changed in appearance and still presents a raw, silty face with some weeds. The large elms at upstream portion of bank still stand though badly buffeted by "Hurricane Carol."

See picture No. 43952, page 2-A, looking upstream along this bank.

Mile 29.0 N. H. bank. C. Emery. V-439 (Opposite Cobb Brook).

No change has occurred in this 100 foot silt bank.

Mile 28.95 to 28.65 N. H. bank. C. Emery V-439 and C. Angier V-438.

This 25 foot high bank has become well weed covered this season, although it is composed mostly of silt. Very little eroding has been noted along this bank in recent years.

Mile 28.5 Vt. bank. Abenaque Machine Co. V-395.

This 400 foot section of wooded bank shows little change. Some trees as shown in picture No. 43953 are undercut and leaning over water, page 2-A, looking upstream.

Mile 28.0 Vt. bank. Anders Nelson. V-394 (Below Walpole Bridge).

This 400 foot section of bank remains about the same with more weeds in evidence this year than last. The top of the bank has not cut back a great deal as noted in relation to the fence which parallels the top of this bank.

Picture Nos. 43954 and 43955 are views looking directly at this bank, pages 2-A and 2-B.

Mile 25.55 Vt. bank. W. H. Bent. V-383 (Mouth of Mill Brook).

These banks are pretty well brush and tree covered with no change in the raw banks at the mouth of Mill Brook.

Mile 25.4 N. H. bank. Fanny Mason property. V-431.

No change has occurred along this wood covered 400 foot silt bank.

Mile 25.15 to 24.5 Vt. bank. John Trybulski property. V-381.

This bank along its entire length continues to be active. The slopes are steep, raw and undercut.

The large trees shown in picture No. 43956 are also leaning over the water this year due to further undercutting. No. 43957 shows the bank, looking upstream. Page 2-B. Picture Nos. 44151 and 44152 also show these banks above and below Fullam Brook on page 2-C.

Mile 24.55 to 24.4 N. H. bank. Fanny Mason. V-431 and E. B. Knapp. V-430.

The upper section remains steep and practically devoid of vegetation while the lower has a good growth of weeds.

See picture No. 43958, looking directly at this bank, and No. 43959 looking upstream from vicinity of the mouth of Great Brook. Page 2-D.

Mile 24.3 to 24.0 Vt. bank. E. E. Putnam. V-379.

No change was noted in this section of 20 foot high silt bank. The old slides are only slightly active at lower part of banks.

Mile 24.2 to 24.0 N. H. bank. E. B. Knapp. V-429.

This bank is moderately active and good cover of weeds blankets most of the raw silt face. The large elm shown in last years photo #42012

VERNON POND

Picture No. 43952

Vt. bank
Mile 30.5
W. S. Powers
V-409

Looking upstream

Picture No. 43953

Vt. bank
Mile 28.35
Abenaque Machine Co.
V-395

Looking upstream

Picture No. 43954

Vt. bank
Mile 28.0
Anders Nelson
V-394

(Just below Walpole Bridge)

VERNON POND

Picture No. 43955

Vt. bank
Mile 28.0
Anders Nelson
V-394

Picture No. 43956

Vt. bank
Mile 25.0
John Trybulski
V-381

Looking downstream
(upper end of property)

Picture No. 43957

Vt. bank
Mile 24.8
John Trybulski
V-381

Looking upstream
(mouth of Fullam Brook)

VERNON POND

Picture No. 44151

Vt. bank
Mile 25.0
John Trybulski
V-381

Looking at bank above Fullam Brook

Picture No. 44152

Vt. bank
Mile 24.6
J. Trybulski
V-381

Looking upstream (From point opposite Great Brook)

VERNON POND

Picture No. 43958

N. H. bank
Mile 24.5
Fanny Mason
V-431

Picture No. 43959

Same

Looking upstream
(From mouth of Great Brook)

Picture No. 43960

N. H. bank
Mile 24.0
E. B. Knapp
V-429

Looking upstream

Mile 24.2 to 24.0 (Cont'd.)

still stands though undercut. See picture No. 43960, page 2-D, looking upstream.

Mile 23.3 N. H. bank. S. J. Chickering V-425.

This 400 foot section of bank shows some activity since last season. There has been some cutting back of the bank and a few small trees are undermined, but the top of bank has not receded noticeably.

See picture No. 43961 page 3-A, looking at a section of this bank.

Mile 23.1 to 22.9 Same property (Mouth of Houghton Brook)

The willow sprouts that were set on bank above Houghton Brook seem to be growing very well and the bank has not changed in appearance above these sprouts. See picture No. 43962.

The bank below the brook also looks about the same. More weeds cover the slopes this season. See picture No. 43963 page 3-A, looking upstream along this bank.

The B. & M. R.R. were digging a trench with a shovel west of the tracks from a point in the vicinity of the town line, northerly to the vicinity of a gully 500 feet upstream. Sheet piling had been stacked along the bank and it looked like they were improving drainage along the slope which apperently contained blue clay.

Mile 22.45 to 21.8 Vt. bank. E. T. Hubbard V-338 ("Putney Meadows").

The banks below the mouth of Chase Brook had not changed and at this flow the large gully at the head of "The Meadows" contained water. This is the gully caused by the swirl pool in the 1936 flood.

See picture No. 44153 page 3-B, looking upstream along this bank.

The bank below the gully mouth shows some scouring. See picture No. 44154 page 3-B.

From this point downstream 1500+ feet the banks are made up of old silt slides, in some cases slightly active, and in others brush and small trees have taken hold.

See picture No. 44155 page 3-B looking upstream.

At the downstream end of this bank near bend, the wooded bank is steep and raw and the remains of some large trees can be seen at the river edge.

See picture No. 44156 page 3-B looking upstream.

Mile 21.35 to 21.0 N. H. bank. S. J. Chickering V-242-243.

The banks along upper section of property remain unchanged and inactive with a good covering of weeds and grass.

VERNON POND

Picture No. 43961

N. H. bank
Mile 23.2
S. J. Chickering
V-425

Picture No. 43962

N. H. bank
Mile 23.0
Same

(above Houghton Brook)

Picture No. 43963

N. H. bank
Mile 22.9
Same

(below Houghton Brook)

VERNON POND

Picture No. 44153

Vt. bank Mile 22.5
E. T. Hubbard V-338
Looking upstream
(Just below mouth of Chase brook)

Picture No. 44154

Vt. bank Mile 22.4
Same
Looking at bank below mouth to gully caused by swirl pool

Picture No. 44155

Vt. bank Mile 22.0
H. H. Phelps V-338

Looking upstream

Picture No. 44156

Vt. bank Mile 21.9
Same

Looking upstream

At mile 20.9, the 300+ foot meadow bank remains steep and undercut at the upper section while the lower section is covered with grass and weeds. See picture No. 43964 page 4-A, looking downstream at this bank.

Mile 20.6 N. H. bank. P. P. Action V-240 (Mouth Mill Brook).

The banks along this section show some undercutting and a few trees are leaning and falling into river. The bank below the brook shows greatest activity with one dead tree in river and its face is steep and raw.

The two large elms with roots exposed still stand in vicinity of the top of the bank.

See picture No. 43965 page 4-A, looking downstream along this bank.

No change has occurred to banks at downstream end of property. See picture No. 43966 page 4-B, looking upstream.

Mile 20.7 to 20.4 Vt. bank. E. T. Hubbard. V-337 (D.S. end of "Putney Meadows").

This 15 foot high silt bank has not changed and is kept raw by cattle pastured on meadow above.

See picture No. 44157 page 4-A, looking downstream at this bank.

Noon: September 2, 1954.

Mile 19.7 to 19.15 Vt. bank. H. W. Frost. V-335.

This bank remains moderately active with some undercutting and sliding of small trees. See picture No. 43967 page 4-B, looking upstream at upper section and No. 44158 showing faulting meadow bank above East Putney Brook, page 4-B.

The meadow bank below the brook mouth is quite active with large sods having broken off recently. See picture No. 43968 page 4-D, looking upstream.

Mile 17.9 to 17.4 N. H. bank. Chesire County Farm. V-236 (Formerly R. L. Blood).

The two small slides at upper end of faulting bank have not changed a great deal. Some dead trees lie on the face of the d.s. slide.

The banks to Mile 17.7 have become brushed over somewhat this season. See picture No. 43969 page 4-D, looking downstream.

The bank from Mile 17.7 to 17.6 is moderately active with undercutting and sods breaking off. This raw silt bank seems to be more active than last year. See picture No. 43970 page 4-D, looking upstream along this bank.

Mile 17.4 N. H. bank. C. M. Moore. V-235.

The high slide reported at lower end of V-236, upon further inspection was found to be about on the property line and mostly below it.

VERNON POND

Picture No. 43964

N. H. bank
Mile 20.9
S. J. Chickering
V-243

Picture No. 43965

N. H. bank
Mile 20.7
Peter P. Action
V-241

(Formerly C. M. Moore)

Picture No. 44157

Vt. bank
Mile 20.6
E. T. Hubbard
V-337

Looking downstream at bank above brook at d.s. end of "Putney Meadows"

VERNON POND

Picture No. 43966

N. H. bank
Mile 20.2
P. P. Action
V-241

Looking upstream

Picture No. 43967

Vt. bank
Mile 19.6
H. W. Frost
V-335

Looking upstream

Picture No. 44158

Vt. bank
Mile 19.5
H. W. Frost
V-335

Looking upstream
(above East Putney Brook)

VERNON POND

Picture No. 43968

Vt. bank
Mile 19.2
H. W. Frost
V-333

Looking upstream
(below E. Putney Brook)

Picture No. 43969

N. H. bank
Mile 17.8
Chesire County Farm
V-236

(formerly Blood property
below Ox Brook)

Picture No. 43970

N. H. bank
Mile 17.7

Same

Mile 17.4 (Cont'd.)

Very little change has occurred in the appearance of the slide although its face remains perpendicular at top and devoid of vegetation, while the section that slipped down the bank still has fairly large trees still standing. Quite a few trees are still in the river as shown in picture No. 44159, page 5-A, looking directly at this high bank.

Mile 17.45 Vt. bank. R. W. Hallock. V-331.

This 200' long and 10' high bank remains slightly active. A 35-foot elm has fallen at upstream end of slide, and a wash hole appears in silt bank below.

Mile 17.0 N. H. bank. C. M. Moore. V-235.

The 100-foot slide at this location shows some action. Small pine that was undercut last season is now falling. Other small trees to follow. This bank is heavily wooded.

Mile 16.2 N. H. bank. S. B. Lund. V-232.

This 400-foot section of silt slides, 10 to 15 feet high remains about the same in appearance. Its face has a fair cover of low growing weeds. See picture No. 44160, page 5-A, looking upstream.

Mile 15.7 to 15.4 N. H. bank. L. W. Churchill. V-231 (Opposite Putney Station).

This bank remains active, but no large amount of bank has broken off since last year. The face of the bank, being devoid of vegetation, shows washlines of various flow elevations this year.

The top remains undercut and steep. See picture Nos. 44161, 44162, and 44163, pages 5-A and 5-B.

Mile 14.8 Same property. V-230.

The high 40' slide at this location has not changed much since 1953. The 25' pines that were mentioned as being undercut last year are now leaning over bank.

Mile 14.6 to 14.4 Vt. bank. Vt. Valley R. R. V-284 (Mile 68)

This section of track and the banks above appear to be unchanged since observations made in the spring.

Picture No. 44164 shows the cinder remedial work done on the 1952 slide.

Mile 14.2 to 14.0 N. H. bank. L. W. Churchill. V-226 (Opposite Canoe Brook).

This low silt bank has not changed, but does have more weeds on its surface this season. See picture No. 43971, page 5-B, looking upstream.

VERNON POND

Picture No. 44159

N. H. bank   Mile 17.4
C. M. Moore   V-235

Picture No. 44160

N. H. bank   Mile 16.2
S. B. Lund   V-232

Looking upstream

Picture No. 44161

N. H. bank   Mile 15.6
L. W. Churchill   V-231
Looking downstream
(opposite Putney Station)

Picture No. 44162

Same

VERNON POND

Picture No. 44163

N. H. bank Mile 15.6
L. W. Churchill V-231
(opposite Putney Station)

Picture No. 44164

Vt. bank Mile 14.2
Vt. Valley R.R. V-284
(above Canoe Brook)

Picture No. 43971

N. H. bank
Mile 14.0
L. W. Churchill
V-226

(opposite Canoe Brook)

Picture No. 43972

Vt. bank
Mile 13.2
A. M. Bennett
V-283

(above mouth of Salmon Brook)

Mile 13.75 Vt. bank. Vt. Valley R. R. V-284.

The small slide noted at this point in 1953 was completely vine andweed covered.

No change was observed in the small slides on the N. H. bank on the F. L. Carey property. V-227.

Mile 13.15 Vt. bank. A. M. Bennett. V-262 (U.S. of mouth of Salmon Brook).

The breaks along this bank have increased to about 200 feet in length and vary from 6 to 15 feet in height.

One leafed out elm lies in the river, while a sycamore is undercut, and three 40-foot pines are still only a few feet back from the top of the slope. See picture No. 43972, page 5-B, looking upstream. This land is between the railroad and the river and is unused.

Mile 12.95 to 12.9 N. H. bank. E. J. Willette. V-197.

This 300' section of 15-foot bank has not changed.

See picture No. 43973, page 6-A, looking downstream.

Mile 12.55 N. H. bank. C. E. Chickering. V-195.

The old slides remain inactive along this bank and are mostly wood covered, except for a short section behind a new house being constructed.

Mile 12.4 N. H. bank. Town Road.

The road has been straightened and raised across this low section making it now passable at higher flows. In the past this location was one of the first to become inundated.

Mile 11.9 to 11.7 N. H. bank. West Chesterfield River Road (Improved Section).

The rip-rapped section of bank appears in good condition. There has been some surface washing along the slope and the guide fence cable is still broken opposite turn to "Hill Road," but no damage of a serious nature was observed. Picture No. 44165, page 6-A.

Mile 11.7 Vt. bank. E. M. Simeon and Son. V-279.

The 200' slide at this location has not changed.

Mile 11.6 to 11.5 N. H. bank. C. T. Chase. V-191.

This bank continues to be moderately active with the banks remaining steep, raw and undercut. See picture No. 44166 showing the upper section. Page 6-A.

The river bank just upstream from mouth of Cats Bane Brook is also active. Picture No. 43974, page 6-B, shows a typical section of this bank. The land is unused.

VERNON POND

Picture No. 43973

N. H. bank
Mile 12.95
E. J. Willette
V-197

Looking downstream

Picture No. 44165

N. H. bank
Mile 11.8
West Chesterfield Road
Repairs
V-192

Looking upstream

Picture No. 44166

N. H. bank
Mile 11.6
C. T. Chase
V-191

Looking upstream

VERNON POND

Picture No. 43974

N. H. bank
Mile 11.5
C. T. Chase
V-191

Picture No. 44167

Vt. bank
Mile 10.7
R. M. Peltier
V-275

Looking downstream

Picture No. 44168

Vt. bank
Mile 10.4
H. M. Chatterton, Jr.
V-275

Looking upstream

Mile 11.0 to 10.3 Vt. bank. R. M. Peltier. V-275.

This long, active section of meadow bank continues to recede, but action is very slow. The surface remains raw, steep, and devoid of vegetation.

See picture No. 44167, page 6-B, looking downstream along the bank.

The banks below the Chatterton lot remain moderately active.

Mile 10.45 Vt. bank. H. M. Chatterton, Jr. V-275.

The banks along this property have now receded back to the small willow trees. Picture No. 44168 shows these trees. Page 6-B.

Mile 10.2 N. H. bank. H. L. Williams. V-184.

This 300 foot section of bank has not changed, except that three trees are now beginning to lean out over river.

Mile 9.3 Vt. bank. R. M. Peltier. V-87.

The 200' long and 10 to 25 foot high slide at this location remains inactive.

Mile 9.0 Vt. bank. American Optical Co. V-86 (Above "Gulf Bridge").

The upper portion of this high slide remains raw and steep with the same 3 small oak trees undercut at the top of the bank, as shown in picture No. 43975, page 7-A, looking directly at this bank.

Mile 8.55 Vt. bank. H. G. Thomas. V-83.

This 200' section of 10-foot silt bank remains moderately active. Small trees are leaning over the river and a few have fallen since 1953. A camp with a boat landing for speed boat is just downstream from this break.

Mile 8.45 N. H. bank. Chesterfield Town Road, Vicinity of V. P. Schmitt.

The gravel and stone rip-rap repairs made to this section in 1952 remain in good condition.

Mile 8.3 Vt. bank. L. H. Noyes. V-81.

This low 100-foot bank is active, and the silt face remains steep and raw.

Three small trees were in river, but apparently went in due to "Hurricane Carol."

Friday, September 3, 1954.

Mile 5.55 Vt. bank. Energine Co.

One willow tree is down in setback between R.R. fill and Energine plant. Probably due to hurricane, although roots were noted as being exposed in 1953.

VERNON POND

Picture No. 43975

Vt. bank
Mile 9.0
American Optical Co.
V-86

(above Gulf Bridge)

Picture No. 43976

Vt. bank
Mile 4.4
Woodward Lumber Co.
V-23

(above Broad Brook)

Picture No. 43977

Vt. bank
Mile 4.0
Harris-Dunham-Fitts Est.
V-22

Looking downstream

Mile 5.55 (Cont'd.)

This 100-foot long bank is about 10 feet high and has a steep, raw silt face.

Mile 4.4 Vt. bank. Woodward Lumber Co., Inc. V-23.

The 200' section of bank remains moderately active with sods having broken off this year. The face of slide remains steep and raw.

See picture No. 43976, page 7-A, looking upstream at this bank.

Mile 4.2 Vt. shore. Central Vt. R.R.

The C.V.R.R. was again improving the ballast of their track through this section between Vernon and Brattleboro. Tamping machines were working the gravel ballast.

Mile 4.0 Vt. bank. Harris-Dunham Fitts Estate. V-22.

This 300'+ bank remains active with some cutting of bank since 1953. Some small trees are lying in river and more are to follow due to undercutting.

See picture No. 43977, page 7-A, looking downstream.

Mile 3.97 to 3.8 N. H. bank. Conn. River Railroad. V-115.

This bank remains very active along its entire length. The 15 to 20 foot slope is raw, steep, and continuously undercutting due to sand and silt composition.

At downstream section of bank many small trees have fallen over bank and one 8-inch pine lies in the river.

A double 50-foot maple is undercut at downstream end of these breaks.

See picture No. 44169 and 44170, page 8-A, looking upstream.

Mile 3.35 Vt. bank. Central Vt. R.R. V-20.

This bank remains unchanged as evidenced by comparing 1953 photo No. 42049 in 1953 report with 1954 picture No. 44171, page 8-A.

Mile 3.15 Same.

This high bank is non-active and no change was observed from last year's observations.

See picture No. 44172, page 8-A, looking directly at this slide.

Mile 2.6 and 2.35 N. H. bank. Conn. River R.R. V-110 and 109.

The slides at these points are now well brushed over and are inactive. They are on unused land well away from the railroad itself.

VERNON POND

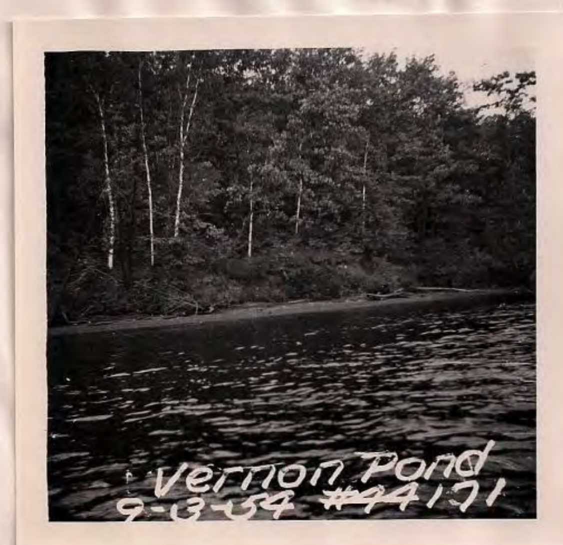
Picture No. 44169

N. H. bank Mile 3.9
Conn. River R.R. V-115

Looking upstream

Picture No. 44170

N. H. bank Mile 3.8
Same



Picture No. 44171

Vt. bank Mile 3.35
C.V.R.R. V-20

Picture No. 44172

Vt. bank Mile 3.2
Same

Mile 1.1 N. H. bank. Conn. River R.R. Culvert. V-104.

The culvert repairs made in 1952 by the railroad are in good condition.

See picture No. 44173 looking through the culvert, page 9-A.

Mile 0.75 N. H. bank (Same) V-101.

This high sand & silt slide shows some activity along the toe of slope which has washed back, thus making it more precipitous and vulnerable from slides up above.

See picture No. 43978, page 9-A, looking at this bank.

Mile 0.65 N. H. bank. C.R.P. Co. V-100.

Picture No. 44174 shows high sand and silt slide at this location. The beach is composed of silt and gravel and slopes off gradually from toe of slide.

Mile 0.35 "Vernon Neck"

Picture No. 44175 is a general view looking downstream at upstream side of "The Neck."

Trees and brush were cut to protect banks from erosion.

Mile 2.2 to Dam Vt. bank. C.R.P. Co.

The banks along this section are in good condition, and no changes were noted.

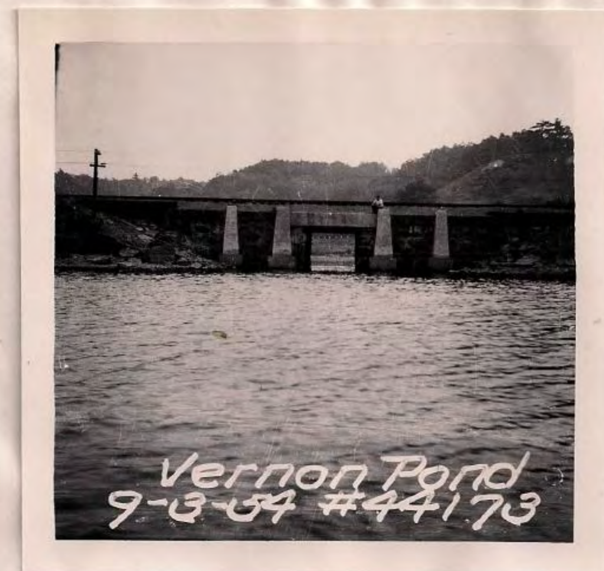
Conclusions

As noted herein, there have been no radical changes in the slides noted in 1953 as to location, enlargement, etc. Where the banks are steep, devoid of vegetation, and exposed to winds, a gradual recession continues and although this receding was difficult to observe in just one year's lapse of time, it is believed that photographs in time, when compared with those originally taken in 1953, will show this progressive action.

The banks have not undergone any heavy ice action, with abnormally high flows in the past few years so many banks that are vulnerable to this now appear to be non-active or healed over by brush grass and weed cover.

The next time the inspection is made it would be well to do it sometime in late May before foliage and weeds get started and when the silt from the spring's high water still shows on the banks. Photographs taken during previous inspections of interested properties at this time of year gave very good detail.

VERNON POND



Picture No. 44173

N. H. bank
Mile 1.1
Conn. River R.R.
V-104

Picture No. 43978

N. H. bank
Mile 0.8
Conn. River R.R.
V-101

VERNON POND

Picture No.44174

N. H. bank
Mile 0.6
C.R.P. Co.

Picture No. 44175

N. H. bank
"Vernon Neck"

Looking downstream

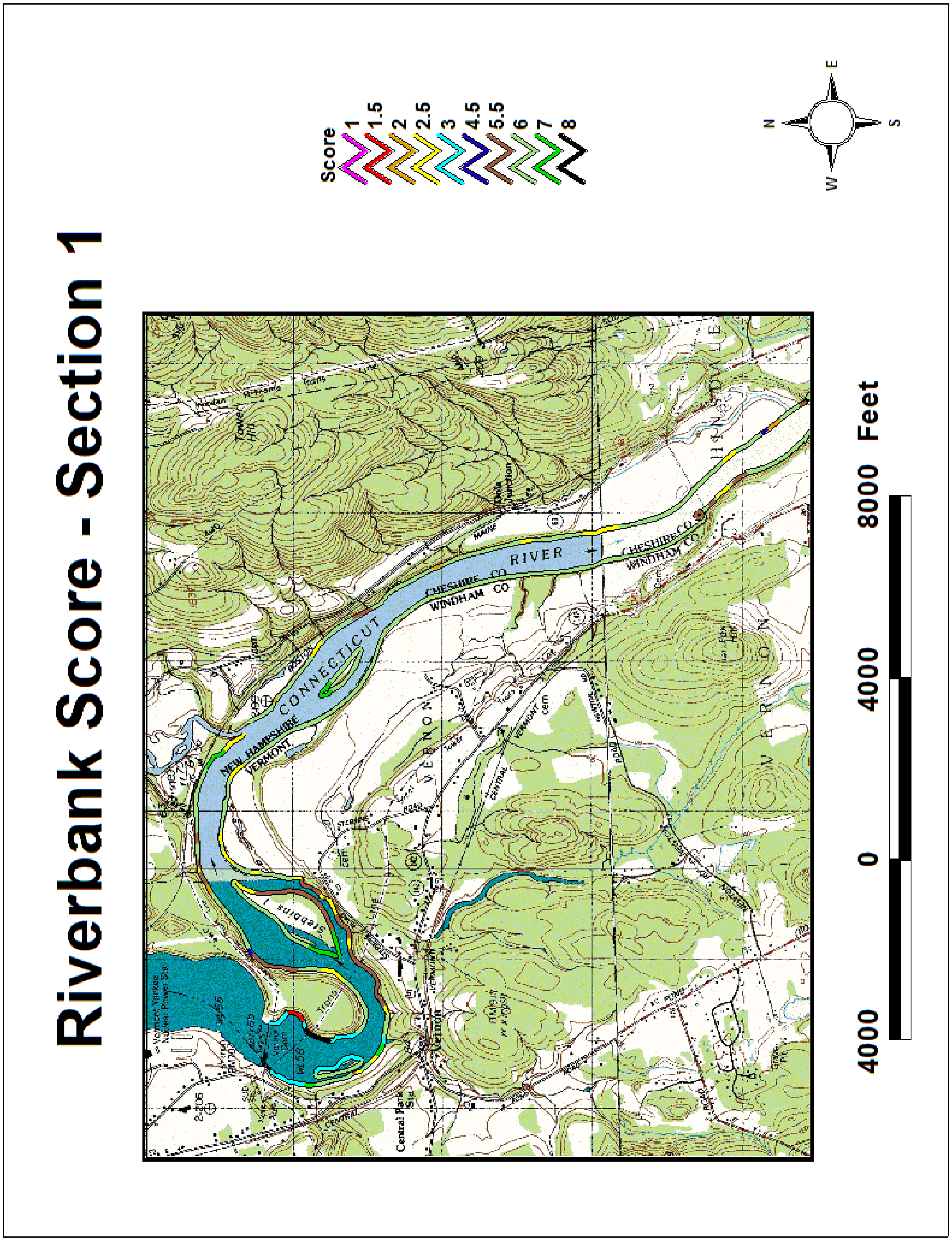
From a comparison of photos, on properties involved in the "Bellows Falls Flowage" cases, taken in 1945 through 1948 by H. M. Nelson, it appears that some of the banks involved have improved in appearance due to slope stabilization, and in some cases weeds and grass have covered the silted banks.

Other banks such as those on the Trybulski, L. W. Churchill, and R. M. Peltier properties remain active and are progressively receding at a rate that varies with the spring flows, ice conditions, etc.

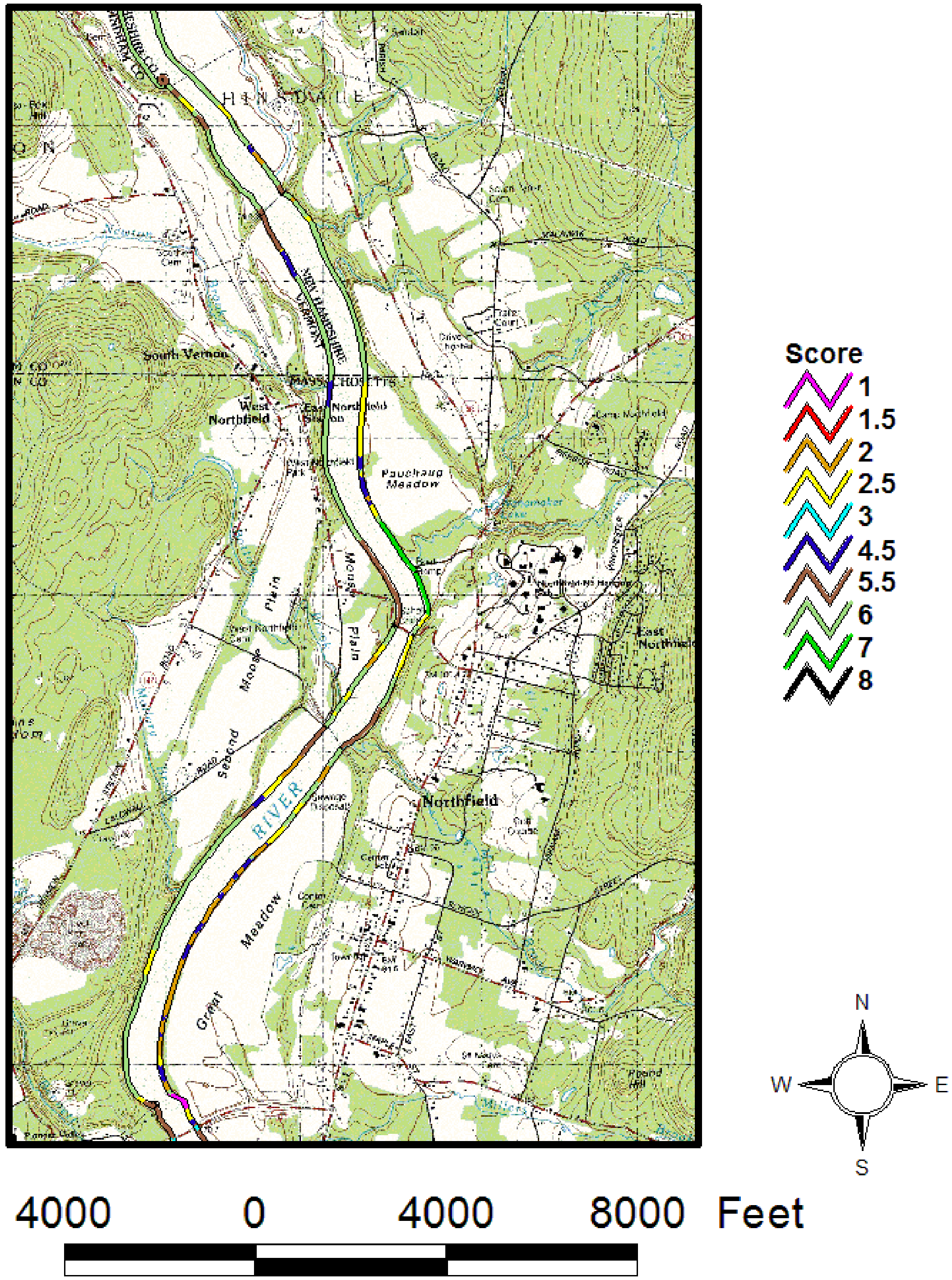
Attachments:

One set of double lettersize F.P.C. Project Boundary Maps, Exhibit K-2 (14 sheets) with eroding bank and picture locations colored thereon.

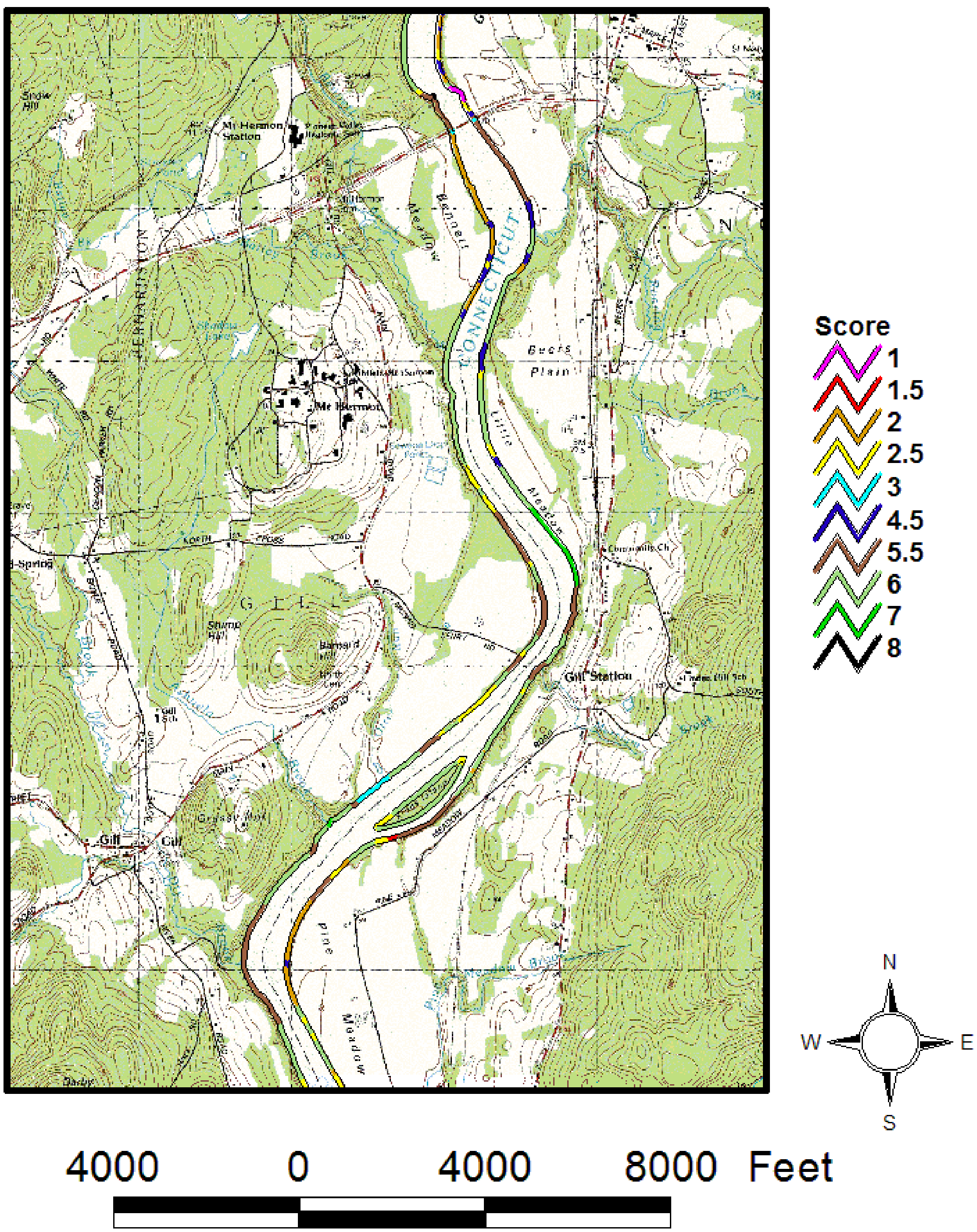
Appendix G – Turners Falls Impoundment FRR Summary Maps, 2008



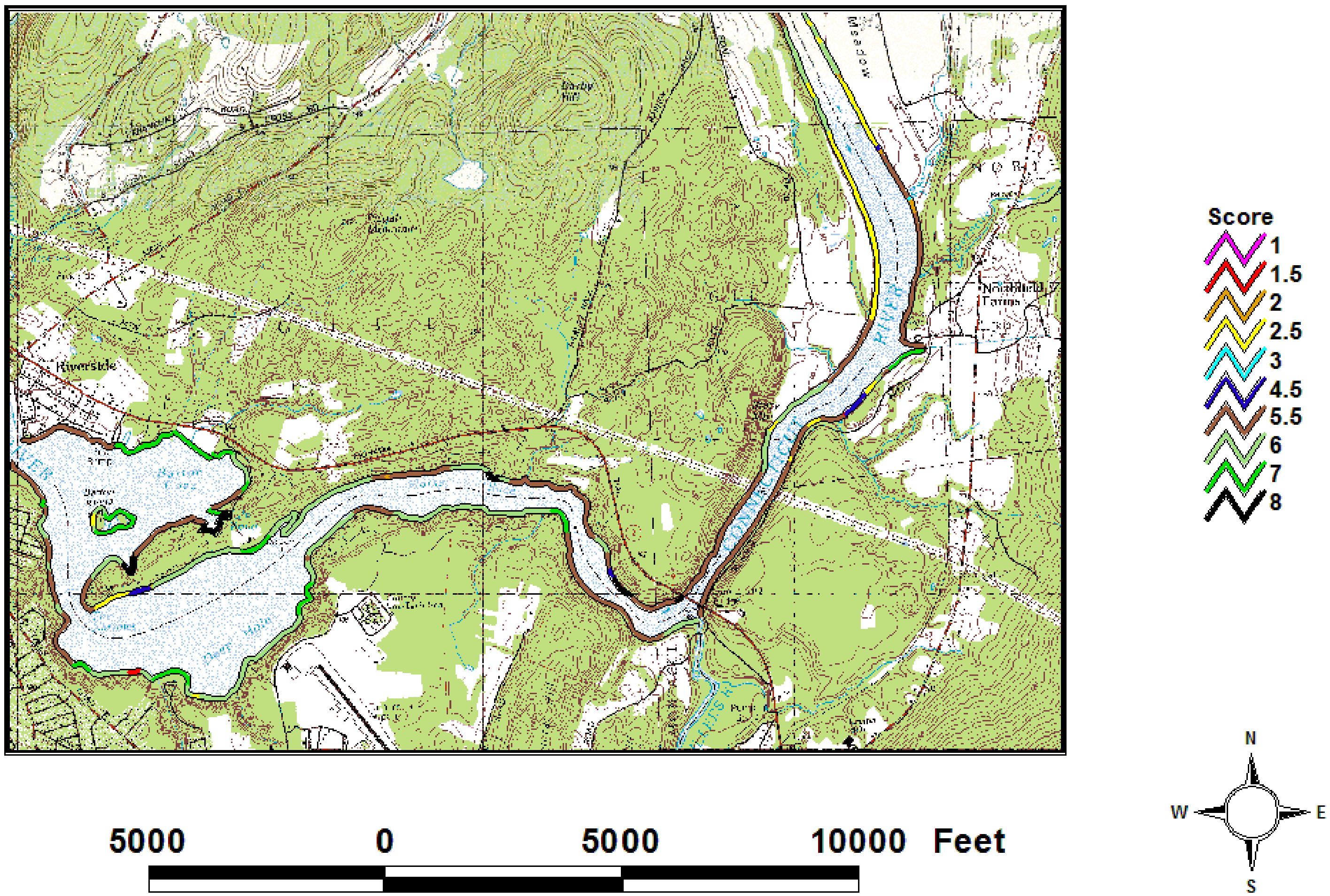
Riverbank Score - Section 2



Riverbank Score - Section 3



Riverbank Score - Section 4



Appendix H – Turners Falls Impoundment, Photos of Repaired Erosion Sites

Site 7 – Flagg, 1998

Site 7, Flagg (South), 2008 (from Maintenance Inspection Report)

Site 4 – Urgiel (upstream), before 2001

Site 4 – Urgiel (upstream), 2008 (from Maintenance Inspection Report)

Site 6 – Skalski, prior to 2004

Site 6 – Skalski, 2008 (from Maintenance Inspection Report)

Appendix I – Turners Falls Pool, Natural Stabilization Processes

1996 – Eddy-induced erosion downstream of Vernon Dam

2008 – Eddy-induced erosion downstream of Vernon Dam

Natural stabilization processes 1996-2008 downstream of Vernon Dam


Right Bank near downstream end of Stebbin's Island - 1998


Right Bank near downstream end of Stebbin's Island - 2008

Riverbank Segment with some low bank vegetation - 1998

Riverbank Segment with dense low bank vegetation - 2008

Close-up of low bank aquatic vegetation - 2008

Appendix J – Holyoke Impoundment Erosion Site Comparison: 1997-2008
Holyoke Pool - Location A

1997

2008

Holyoke Pool – Location B

1997

2008

Holyoke Pool – Location C

1997

2008

Holyoke Pool – Location D

1997

2008

Holyoke Pool – Location E

1997

2008

Holyoke Pool – Location F

1997

2008

Holyoke Pool – Location G

1997

2008

Holyoke Pool – Location H

1997

2008

Appendix K. Riverbank Erosion on other Rivers

Yellowstone River – Yellowstone National Park

Yellowstone River – Yellowstone National Park

Yellowstone River – Yellowstone National Park

Yellowstone River – Yellowstone National Park

Yellowstone River – Yellowstone National Park

Y
Yellowstone River – Yellowstone National Park


Yellowstone River – Downstream of Yellowstone National Park


Yellowstone River – Downstream of Yellowstone National Park

Middle Fork Flathead River – Glacier National Park

Middle Fork Flathead River – Glacier National Park


Avalanche Creek – Glacier National Park


Avalanche Creek – Glacier National Park

Avalanche Creek – Glacier National Park

Avalanche Creek – Glacier National Park

Middle Fork Flathead River – Glacier National Park

Middle Fork Flathead River – Glacier National Park

Middle Fork Flathead River – Glacier National Park

Middle Fork Flathead River – Glacier National Park

Middle Fork Flathead River – Glacier National Park

Flathead River - Montana

Bow River – Banff National Park, Canada

River in British Columbia

National Creek – Wrangell-St. Elias National Park, Alaska*

National Creek – Wrangell-St. Elias National Park, Alaska*

*After Hart-Crowser, 2005,“Geomorphic Assessment National Creek Kennecott, Alaska”

National Creek – Wrangell-St. Elias National Park, Alaska

National Creek – Wrangell-St. Elias National Park, Alaska

South Fork Skokomish River, Washington

South Fork Skokomish River, Washington

Lower Osage River, Missouri

Lower Osage River, Missouri


Rio Sao Francisco, Brazil

Rio Taquari, Brazil