Suncook River

Fluvial Geomorphology Assessment

Explanation Guide

Allenstown, Pembroke, and Epsom, NH

New Hampshire Geological Survey
New Hampshire Department of Environmental Services
Spring 2015

Introduction

This narrative provides a written description (with picture supplements) of the data collected as part of the geomorphic assessment of the Suncook River in Allenstown, Pembroke and Epsom, New Hampshire. This document will not delve into great detail about the geologic setting of the Suncook River, or the events surrounding the avulsion in May 2006. Numerous other documents and maps exist that discuss this, and the reader can consult these for further background. This narrative reviews river conditions on the assessed reaches.

The focus of this assessment is the Suncook River mainstem, which faced the effects from the avulsion, in Epsom, in 2006. Fluvial geomorphology data was collected using the New Hampshire implementation of the Vermont Agency of Natural Resources protocols for river assessments (Phase I, a pre-field GIS analysis) and in-field rapid stream assessments (Phase II). For in-field data collection, the protocols are designed to assess multiple features of the river, including, but not limited to: condition of the streambanks and terraces directly adjacent to the river being assessed; condition of the stream channel bed, including material type; presence of large wood in the channel; constrictions from undersized culverts, bridges, old abutments or bedrock outcrops; and, sensitivity of river reaches to future change during high flow events.

In the Phase I GIS analysis, the length of the Suncook River within Allenstown, Pembroke and Epsom was divided into 11 separate reaches for assessment based upon natural features such as slope, changes in bed and river form, channel confinement and local geology, followed by an in-field Phase II geomorphic assessment. The Phase II geomorphic assessment was conducted by Field Geology Services (Farmington, Maine), under contract to the New Hampshire Department of Environmental Services (NHDES), New Hampshire Geological Survey. Based on in-field survey, some reaches are split into further segments. When this occurs, each segment of the original reach is completely assessed using the protocols.

The Phase II protocol field forms are divided into the following sections:

Valley and River Corridor
Stream Channel
Riparian banks, buffers and corridors
Channel Bed and Planform Changes

Also, there is a rapid geomorphic assessment form which collates the data from the reach to assist in assigning a condition for each reach, and when combined with the stream type, a sensitivity rating for the reach. These sensitivities are used in the fluvial erosion hazard meander belt delineation process. The condition score results from the scores of four principal components assessed for each reach after the data is collected and are reported in the *Stream Sensitivity* section for each reach below. A more detailed description of the condition and sensitivities for each reach are provided in Appendix A.

For the Suncook River assessment, at the request of community officials prior to the assessment, an enhanced large wood survey was conducted. This survey is more detailed than the typical Phase II large wood tallies. A description of the methods and results is provided in Appendix B.

For the convenience of the reader, a glossary of technical terms is provided in Appendix C.

Individual reach data descriptions

Maps of the data for each reach may be found at the end of each reach narrative.

Reach 1

Reach 1 extends for a length of 2,452 feet from the mouth of the Suncook River, at the confluence with the Merrimack River upstream to the hydroelectric dam adjoining Keystone Lane, which was assessed by Field Geology Services staff on September 29, 2013.

Valley and River Corridor
The estimated valley width (of the Suncook River) within this reach is 1124 feet, which classifies it as a river flowing through a very broad valley. There are two grade controls in the reach. First, at the upstream end of the reach is a 21 foot tall hydroelectric dam, with ledge present on the channel bed downstream of the dam that is 3.6 feet in height.

Stream Channel
Based on a representative cross-section surveyed in the reach, the channel is approximately 94 feet wide, with a depth of about 3.6 feet (measured from the deepest part of a cross-section to the cross-section survey line, set to the bankfull indicators on either side of the channel). The width of the floodplain at the cross-section is approximately 178 feet. The bed material is primarily cobble.

Riparian banks, buffers and corridors
Roads parallel the river on both sides, and the land adjacent to the channel is well developed, particularly the upstream end of the reach. The adjacent hillside has slopes of 4 to 8%, is never continuous with, or near the streambank, given the very broad floodplain. Streambanks are comprised of bedrock or a boulder/cobble mix at the base overlain by sand, and are steep. No bank erosion was mapped in the reach, though sections of the bank have been rip-rapped in the past, including 633 on the south bank and 658 feet on the north bank. Channel canopy is open, meaning that the river width is not greatly shaded by canopy cover from the trees adjoining the banks.

Flow Modifiers
There are no springs, seeps or tributaries draining to the river in this reach, and there are no adjacent wetlands. Presence of the hydroelectric dam at the upstream end of the reach, combined with the old mill complex on the south side of the river and its related water works, create sizeable changes in river flow in this area. Three stormwater inputs, two from road ditches, and one from the mill complex on the south bank, are present. The lower portion of the reach experiences backwater from the Merrimack River (Figure 1). One constriction is present in the reach – a 90-foot wide (across the channel) bridge that functions to constrict both the channel and adjacent floodplain.

Figure 1. Confluence of the Suncook and Merrimack Rivers, looking from the mouth of the Suncook to the opposite west bank of the Merrimack.

Channel Bed and Planform Changes

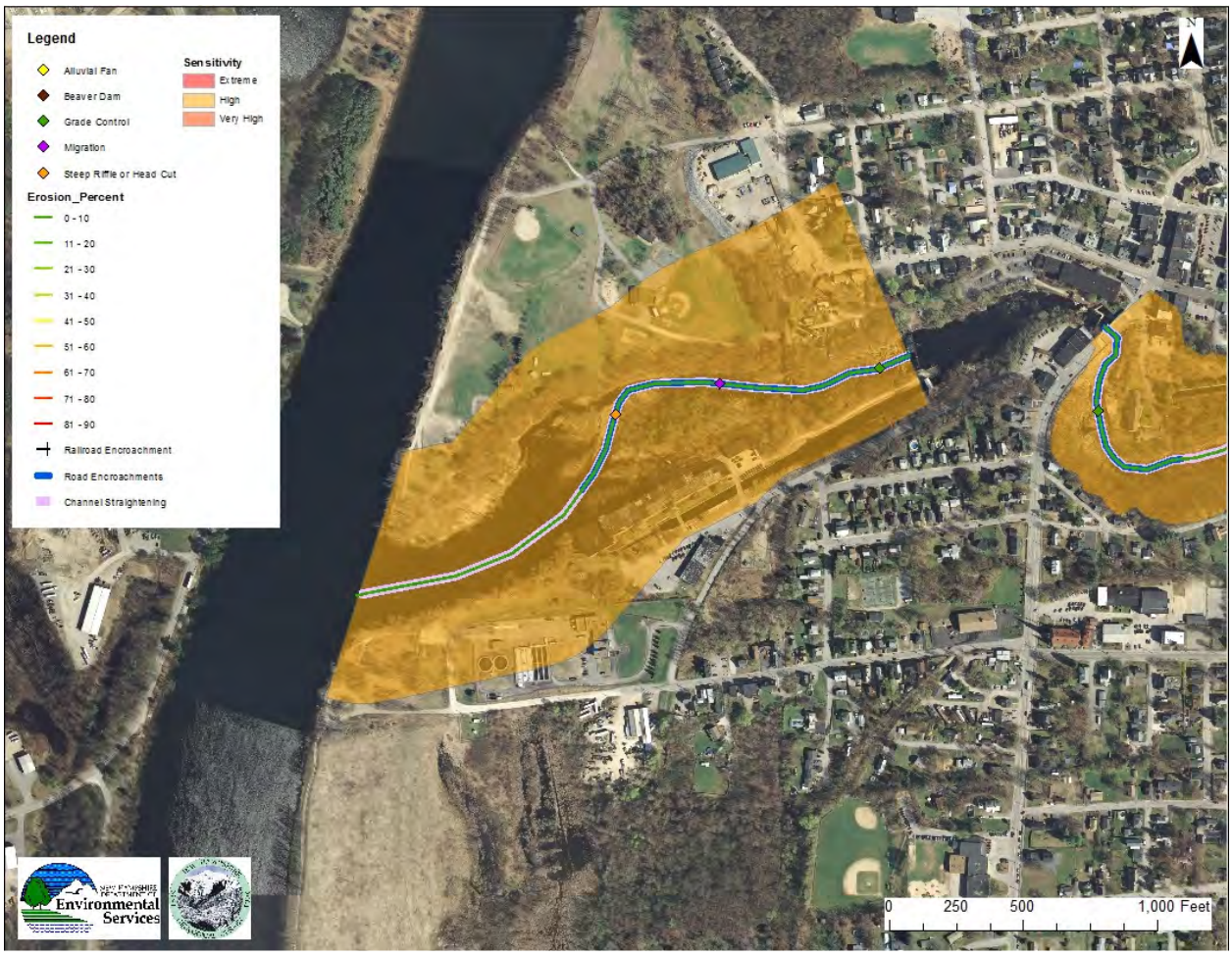
Three bars (one each of mid-channel, point and diagonal) were assessed, with three islands present, in addition to one flood chute and one steep riffle. The entire length of the channel has been straightened and modified in the past, as evidenced by the presence of the mill and related works (Figure 2).

Figure 2. Example photo looking upstream. Note the pipe crossing the channel, with the dam at the head of the reach in the distance. Also note the coarse nature of the bed material through much of this reach.

Stream Sensitivity

Reach 1 typed as a B3 stream in the Rosgen classification system (described in Appendix A), and the geomorphic condition of the reach caused it to be assigned a condition rating of Fair, which translates to a reach with High sensitivity. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	5
Channel Aggradation	13
Widening Channel	8
Change in Planform	13
Condition Rating	0.49



Map 1. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 1.

Reach 2

Reach 2 extends from the dam at the head of Reach 1 upstream to the dam/spillway at the Main Street crossing. The river in this reach is impounded by the presence of the downstream dam, and the stream assessment protocols are not designed for impoundments (they are designed for flowing segments of river). Thus, this reach was not assessed.

Reach 3

Reach 3 extends for a distance of 1408 feet from the spillway at the Main Street crossing upstream to the Suncook River Reservoir dam, and was assessed by Field Geology Services on September 26, 2013.

Valley and River Corridor
The estimated valley width in this reach is 552 feet. Five grade controls are present in the reach. The largest grade control is the dam at the upstream end of the reach (Suncook River Reservoir) which is 34.5 feet high. Four other grade controls are present, all of which consist of bedrock

ledge, and range from 1.5 to 7.8 feet in height. Roads and development, including water works structures, are present just to the north of the channel. The adjacent hillsides are extra steep (>25% slope) to the south of the channel and run directly to the streambank, and are largely bedrock. To the north, the adjacent hillside is very steep and not continuous with the streambank, though sometimes within about 100 feet of it.

Stream Channel
At a representative cross-section, the channel width is about 102 feet, with a maximum depth of 2.7 feet, and a floodplain width of 134 feet. Riffles are present, and are spaced an average of 45 feet apart. Bed material is cobble, with boulders and bedrock outcrops also present.

Riparian banks, buffers and corridors
Channel bank slopes are typically steep, and are comprised of boulders at the bases and overlain by sand, though bank erosion is not present in the reach. However, much of the reach length on both banks have had bank revetment placed, extending for a total of 1105 feet on the south bank (boulder armoring) and 718 feet on the north bank (stone wall) (Figure 3). The channel canopy is open. The adjacent vegetation primarily consists of deciduous trees, both on the banks and in the adjacent floodplain, with the water works and buildings directly adjacent to the channel on the north.

Figure 3. Example of the stone wall armoring on the north bank in Reach 3.

Flow Modifiers

There are minimal springs, seeps and tributaries in this reach, with no adjacent wetlands. Flow through the reach is highly regulated by the presence of the large hydroelectric dam (Suncook River Reservoir) at the upstream end (Figure 4). At the downstream end of the reach, the presence of the spillway just downstream of Main Street also acts to produce a large and deep pool just upstream of it (Figure 5). There is one stormwater input, possibly a hydro engineering structure input.

Figure 4. Looking upstream at the Suncook River Reservoir dam within Reach 3. The bedrock nature of the bed can be seen here.

Figure 5. View of the large and deep pool just upstream of the spillway at the lower end of Reach 3 (seen in distance) at the Main Street crossing.

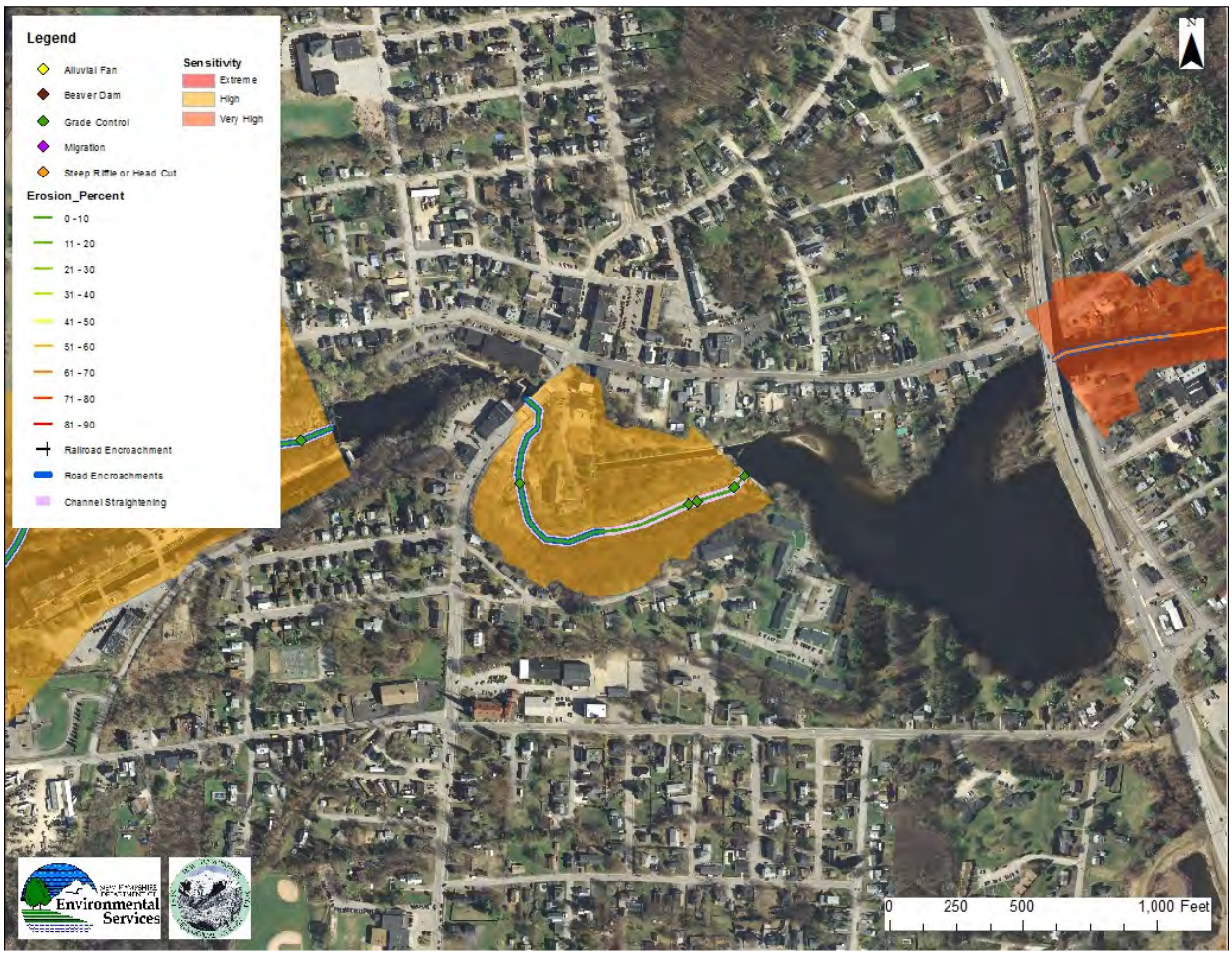
Channel Bed and Planform Changes

Overall, channel bed features are lacking in this reach, though one point bar is present. The entire length of the reach demonstrates evidence of past historical channel straightening, as evidenced by the boulder armoring along the length of the south bank and the stone wall along a portion of the north bank.

Stream Sensitivity

The stream was classified as a B3, and with a Poor condition, produced a sensitivity of High. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	2
Channel Aggradation	5
Widening Channel	3
Change in Planform	13
Condition Rating	0.29



Map 3. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 3.

Reach 4

Reach 4 extends from the Suncook River Reservoir dam upstream to the Route 3 crossing. The river in this reach is impounded by the presence of the downstream dam, and the stream assessment protocols are not designed for impoundments (they are designed for flowing segments of river). Consequently, this reach was not assessed.

Reach 5A

Reach 5A extends for a length of 2.65 miles, extending upstream from the Route 3 crossing in Suncook. This reach was surveyed by Field Geology Services on October 2, 2013.

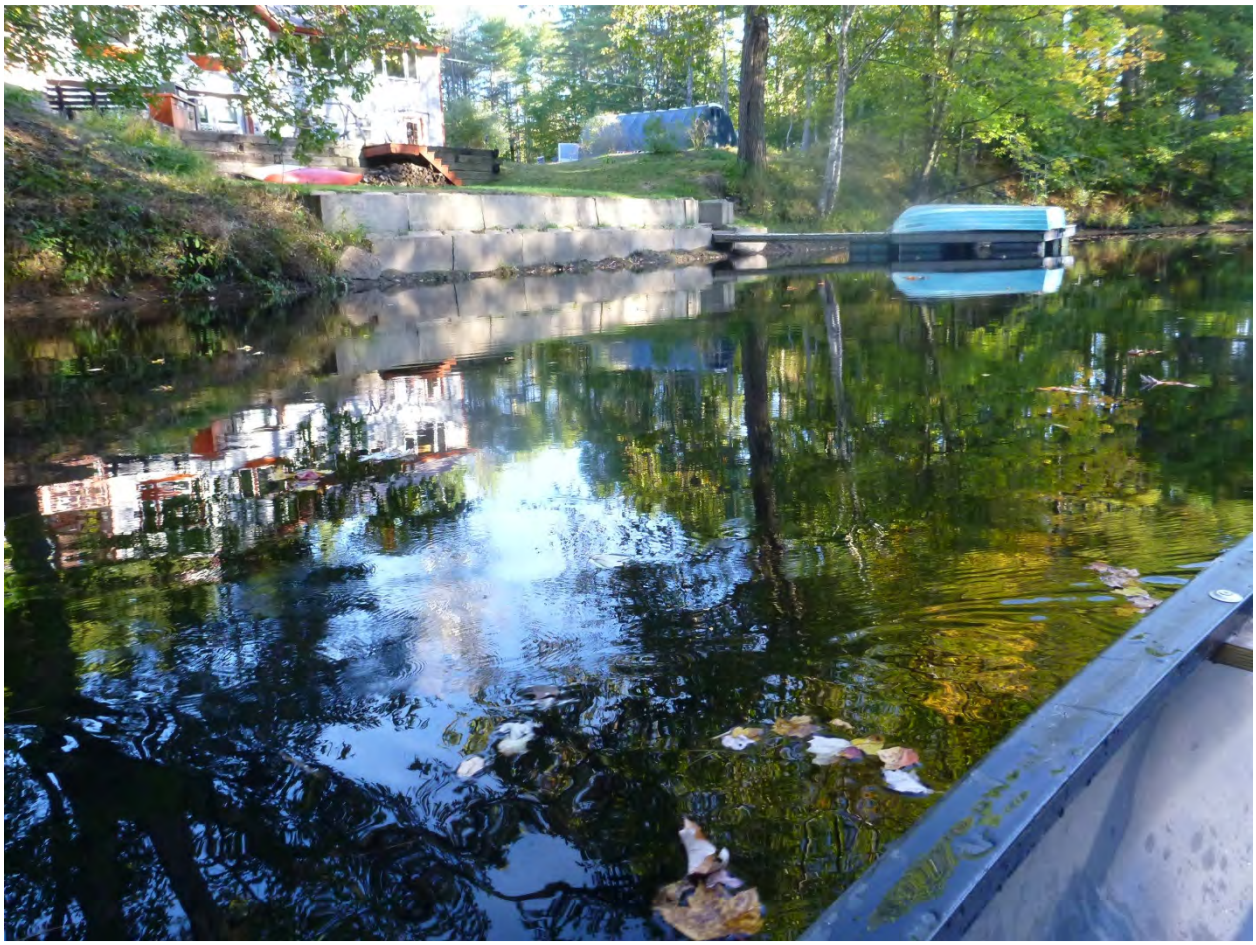


Figure 6. Example typical view of Reach 5A.

Valley and River Corridor

Reach 5 was split into three segments (A, B, C) based on field conditions. A segment break (dividing Reach 5 into Segments A and B) was placed in the reach, marking the upstream extent of Reach 5A by a change in channel dimensions and flow conditions. Upstream of Reach 5A, the Suncook River becomes narrower and slightly shallower, such that the river upstream is of a different form and condition.

Within Reach 5A, the estimated valley width is 532 feet. There are no grade controls present in this reach. Roads are present adjacent to the channel on both sides of the river, though the features are more prevalent to the east (Route 28). A berm lies adjacent to the river on the west, which has a length of 166 feet. The adjacent hillsides are very steep to the east of the channel, and are sometimes located at the streambank, and are composed of sand. To the west, the adjacent hillside is steep, never runs to the bank, and is also composed of sand.

Stream Channel

Based on a representative cross-section in the segment, the channel is approximately 122 feet wide, and about 14 feet deep. Riffles and pools are not present in the reach. Sand is the dominant bed material in the reach, with silt/clay also present.

Riparian banks, buffers, and corridors
Slopes of the streambanks are typically steep throughout the reach, and are comprised of non-cohesive sand. Bank erosion occurs throughout the reach, with a total length of 7410 feet on the west bank and 7668 feet on the east bank, with average heights of erosion averaging 8 feet on the west bank and 7.1 feet on the east (Figure 7). Bank revetment has been installed on both banks, with a total length of 1851 and 1284 feet on the west and east banks. The channel canopy is open. Directly to the west of the river, the land consists of residences, while the land to the east is comprised of farm fields, with some residences.

Figure 7. Example of high bank scour/erosion present in Reach 5A.

Flow Modifiers
Minimal springs, seeps and tributaries are present in the reach, though adjacent wetlands are abundant. A total of four stormwater inputs were noted, including three road ditches and one urban stormwater input. Two constrictions are present in the reach. One is an old abutment that constricts the channel, while the second is a bridge (Route 3) that constricts both the channel and the floodprone area. This reach is upstream of the Suncook River Reservoir Dam, which creates a backwater pool and consequent low velocity condition, throughout the reach (Figure 6).

Channel Bed and Planform Changes

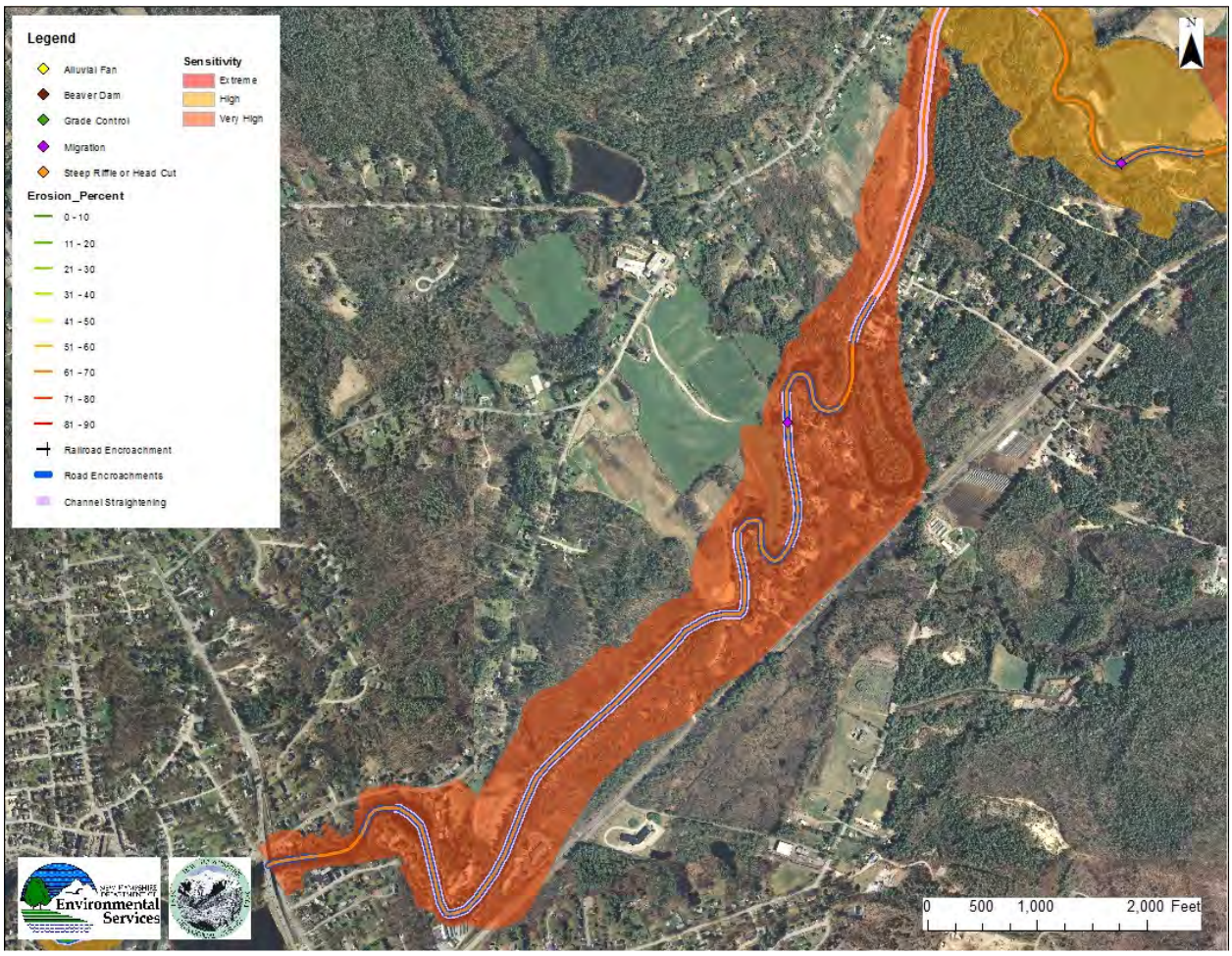
One flood chute is present in the reach, with 1.96 miles of the reach length (74%) identified as having been straightened (Figure 8).

Figure 8. Typical view of a straightened section of the Suncook River in Reach 5A (view upstream).

Stream Sensitivity

The stream was classified as a C5, and with a Fair condition, produced a sensitivity of Very High. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	11
Channel Aggradation	12
Widening Channel	10
Change in Planform	8
Condition Rating	0.51



Map 5A. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 5A.

Reach 5B

Reach 5B extends for a length of 4433 feet and contains a section of the Suncook River that has multiple meanders (at least relative to the river segments directly upstream and downstream of it), with numerous old oxbows (old river paths) adjacent to the channel (Figures 9 and 11). The flow path in this segment of river is largely aligned southeast to northwest, as opposed to the north to south path upstream and downstream of it. This segment was assessed by Field Geology Services on October 20, 2013.

Figure 9. Typical view of Reach 5B. Note the backwater pool condition. (Upstream view.)

Valley and River Corridor

Reach 5B was segmented out from the larger Reach 5 because of differences in bed material size, slope and channel widths and depths as compared to the other sections of the reach. Valley width is estimated as being about 900 feet wide overall for the reach. There are no grade controls present in the reach. Route 28 parallels the river to the east, with some development near the river, for total lengths of 234 and 141 feet, to the east and west. To the west, the adjacent hillside is steep and is not continuous with or near the bank; while to the east, the adjacent hillside is hilly (4-8% slope), is not continuous with the bank, though sometimes coming to within about 95 feet of the river. Textures of the adjacent hillsides are sand.

Stream Channel

Based on a representative cross-section surveyed in this reach, the river width is 97 feet, with a depth of 13 feet. Bed material is largely sand, with silt/clay also present. Riffles and pools are not present in the reach.

Riparian banks, buffers and corridors

The slopes of the banks are typically steep and are comprised of sand (Figure 10). Bank erosion is mapped throughout the reach, with 1725 feet on the west bank (average 7 feet in height) and 2084 feet on the east bank (average height 6.2 feet). Rip-rap has been installed on the east bank,

for a length of 969 feet. Adjacent land to the east of the river is dominated by deciduous forest, with homes also present, while to the west, farm fields, with some deciduous forest also present. The channel canopy is open.

Figure 10. Example view of the banks (east bank in photo) in Reach 5B. Note the sandy, unconsolidated and erosive nature of the banks.

Flow Modifiers

Minimal springs, seeps or tributaries are present in the reach, though adjacent wetlands are abundant. Although the channel is more sinuous in the reach, it is still governed by the backwater pool created by the presence of the Suncook River Reservoir Dam (Figure 9).

Channel Bed and Planform Changes

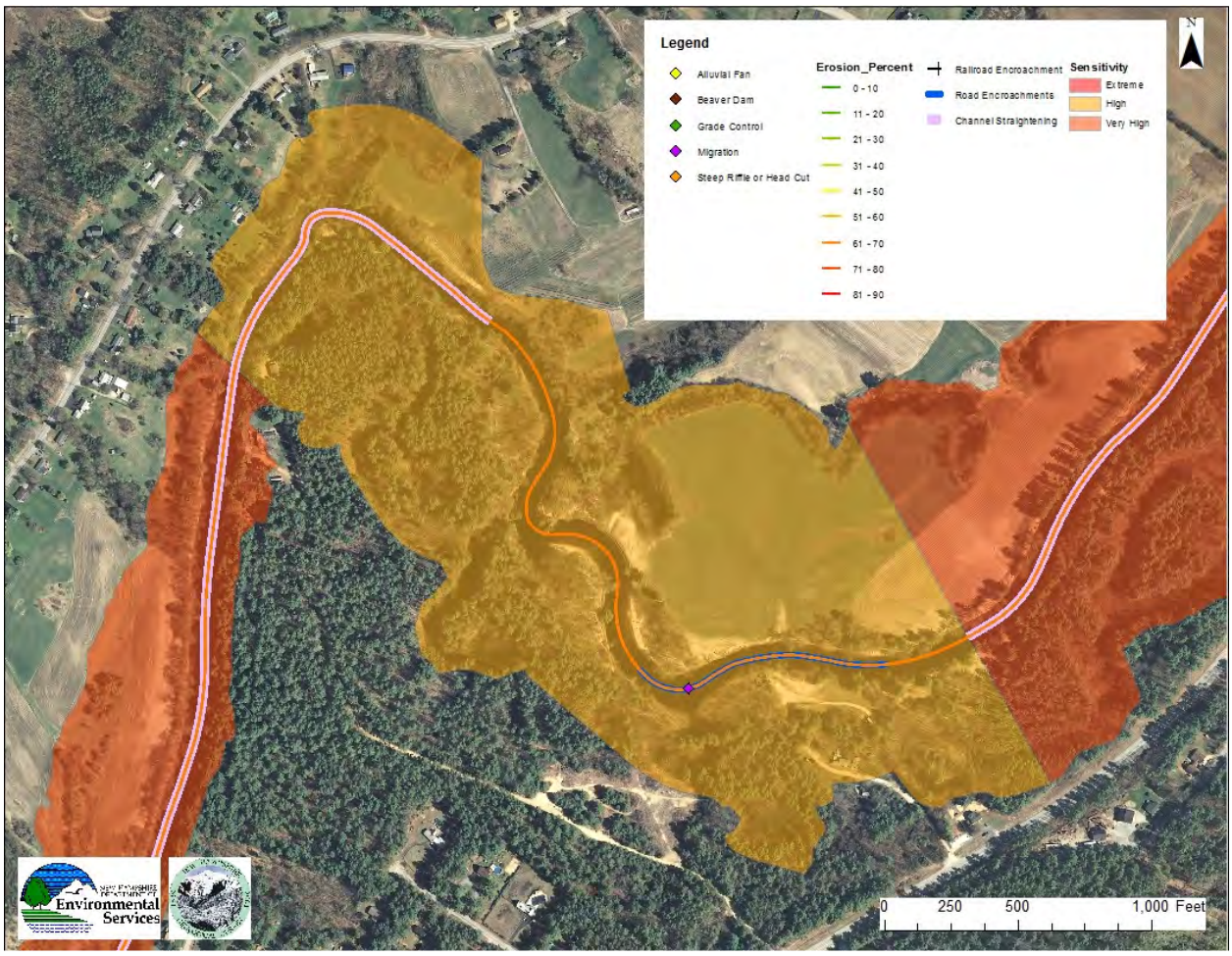
A total of 6 bars were counted in the reach, including 4 side and 2 diagonal bars. One flood chute is also present in the reach. A total of 1448 feet (or 33%) of the reach length is identified as being straightened in the past.

Stream Sensitivity

The stream was classified as a C5, and with a Good condition, produced a sensitivity of High. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	14
Channel Aggradation	12
Widening Channel	16
Change in Planform	10
Condition Rating	0.64

Figure 11. Aerial view of the Suncook River segment classified as Reach 5B. Note the increased incidence of meanders present in the reach, and the presence of oxbows (old river paths) adjacent to it in the floodplain. Note the greater amount of meandering (sinuosity) as compared to the straighter sections of river both directly upstream and downstream.



Map 5B. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 5B.

Reach 5C

Reach 5C is 4568 feet long, and is bounded by the location of the former Buck Street Dam at its upstream end, and was surveyed by Field Geology Services on October 20, 2013.

Valley and River Corridor

Reach 5C was segmented out from the original Reach 5 because of several features that separate it from other segments of the river (within Reach 5). These include channel slope, the condition of the streambanks and adjacent floodplain, and a lack of adjacent wetlands as compared to segments of river downstream. In Reach 5C, the width of the adjacent valley is estimated at about 578 feet. No grade controls are present in the reach. Some development is located near the river to the east of the channel. To the west, the adjacent hillside is very steep, which runs to the channel bank in some locations; while to the east, the adjacent hillside is steep, is not continuous with the bank, though sometimes coming to within about 120 feet of the river. Textures of the adjacent hillsides are as sand.

Stream Channel

Based on a representative cross-section surveyed in the reach, channel width is 124 feet, with depth of 11 feet. Bed material is chiefly sand, with silt/clay also present. Riffles and pools are not present in the reach.

Riparian banks, buffers and corridors
Slopes of the streambanks are typically steep, and are comprised of sand. Bank erosion is present on both banks, with a total of 1079 feet on the east bank (average 3 feet height) and 2480 feet on the west bank (average 5.5 feet height), which is producing overall channel widening (Figure 12). Bank revetment was mapped (length = 281 feet on east bank and 216 feet on west bank), which includes a wood armor bulkhead on the east bank. Adjacent land to the east of the channel is residential, while farm fields dominate to the west. Trees are also present adjacent to the channel on both sides, mainly near the banks, which are mostly deciduous, with a smaller quantity of coniferous. The channel canopy is open.

Figure 12. View of bank erosion and slumping in Reach 5C.

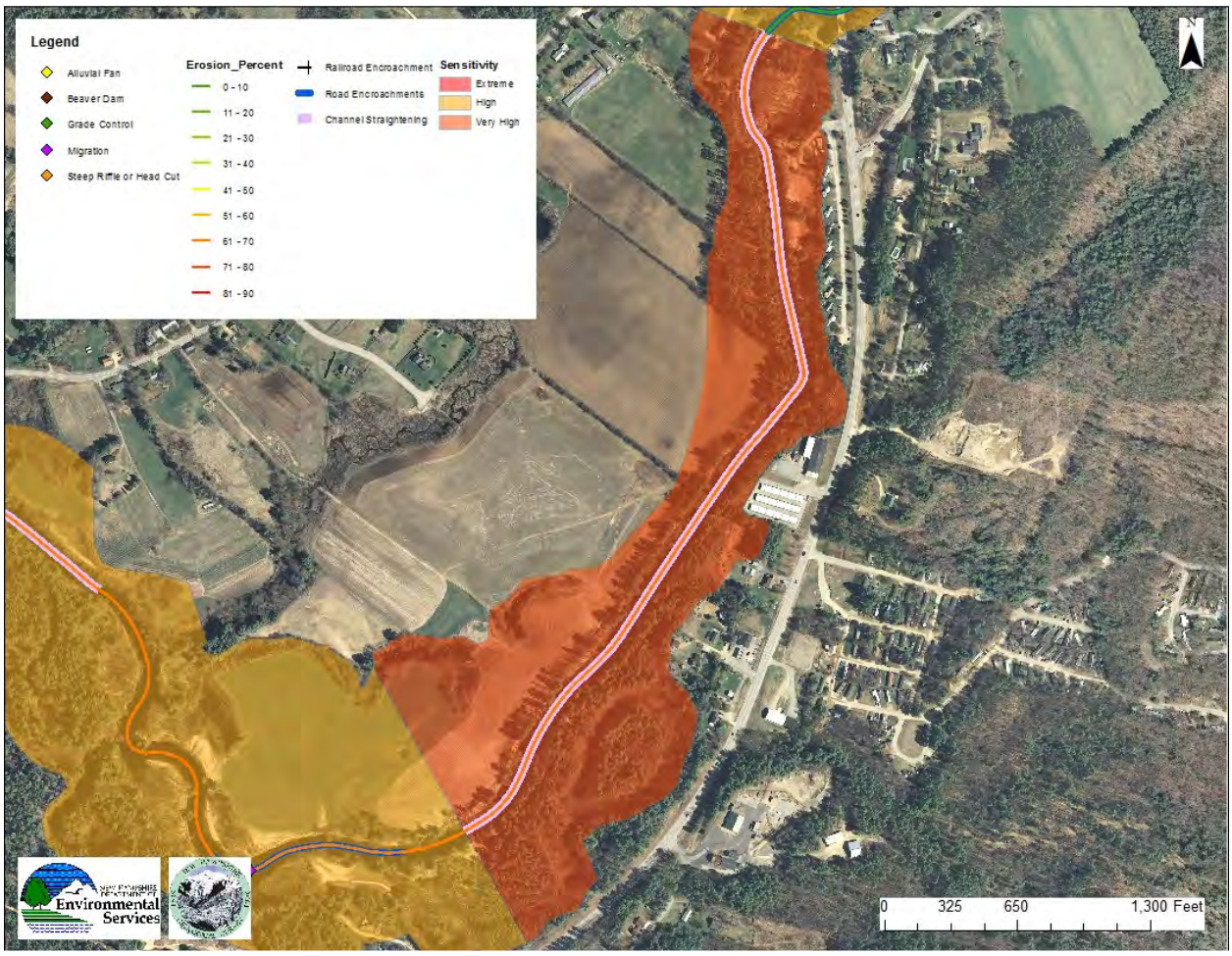
Flow Modifiers
Minimal springs, seeps or tributaries and no adjacent wetlands are present in this reach. As seen in Figures 12 and 13, a backwater condition remains in place as a result of the dam farther downstream.

Channel Bed and Planform Changes
A total of 2 side bars, in addition to 1 island, are present within the reach. The entire length of river has been straightened (Figure 13).

Figure 13. Typical view of Reach 5C, looking upstream. Note the straightened nature of the reach.

Stream Sensitivity
The stream was classified as a C5, and with a Fair condition, produced a sensitivity of Very High. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	4
Channel Aggradation	14
Widening Channel	5
Change in Planform	11
Condition Rating	0.425



Map 5C. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 5C.

Reach 6A

Reach 6A extends for 1.51 miles from the location of the former Buck Street Dam to the tributary confluence/junction with Fowler Brook. This reach was assessed by Field Geology Services on October 1, 2013.

Valley and River Corridor

Reach 6A was created by segmenting Reach 6. A segment break was placed at the tributary confluence with Fowler Brook. The valley width is estimated at 765 feet. No grade controls are present in the reach. The river is paralleled by roads and development (extending for a length of 2780 feet) to the east. Adjacent hillsides have very steep slopes, are not continuous with the bank to the west, but sometimes so to the east, and are comprised of till on both sides.

Stream Channel

Based on a representative cross-section surveyed in the reach, the channel width is about 135 feet, with a depth of approximately 6.3 feet. The floodprone, or floodplain width is about 204

feet. The bed material is sand, with a fairly uniform ripple-dune bedform and no riffle-pool features present in the reach (Figures 14 and 15).

Figure 14. View that is typical of most of Reach 6A.

Figure 15. Another typical view of Reach 6A, upstream of the former Buck Street Dam site.

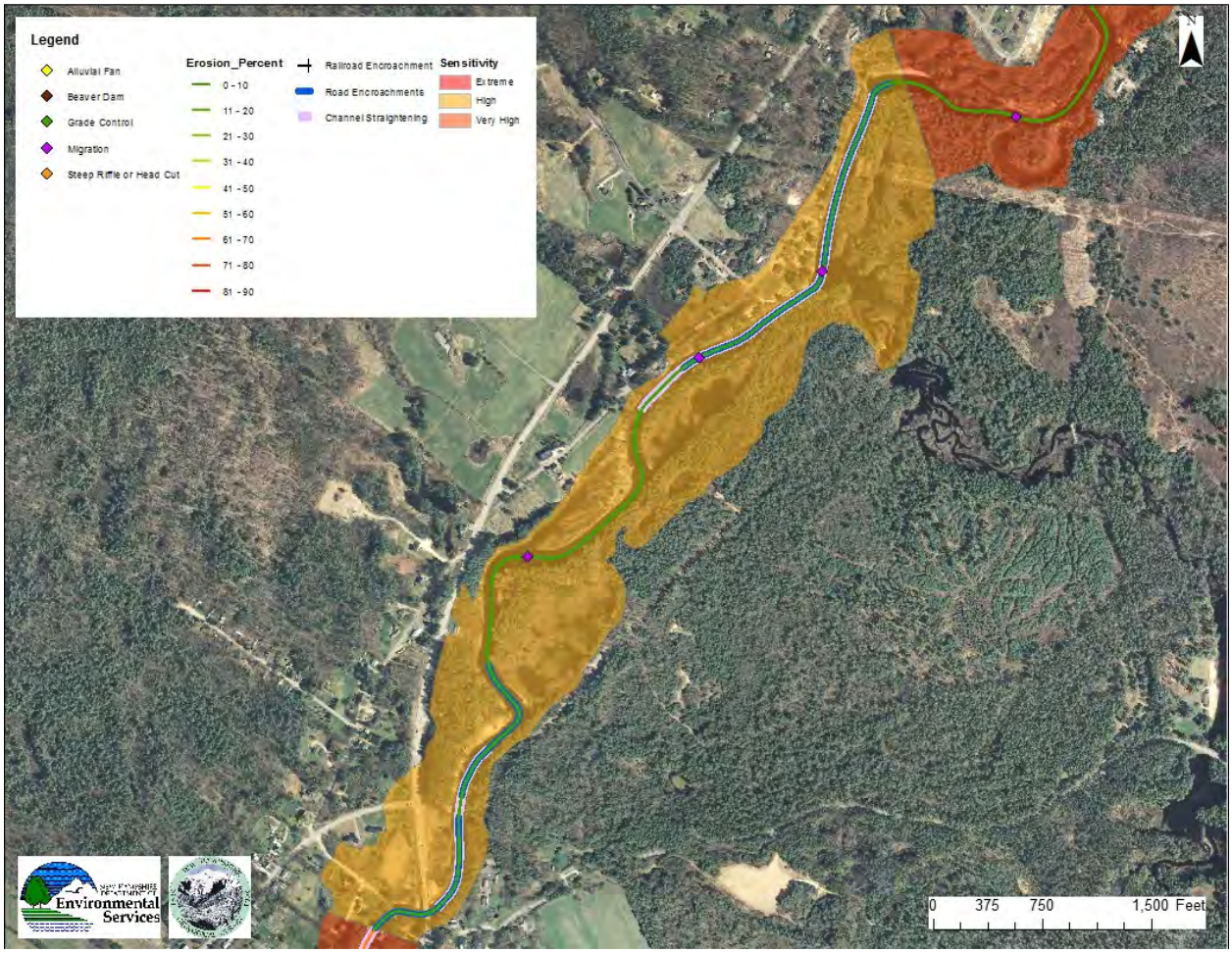
Riparian banks, buffers and corridors
Streambank slopes are typically steep, with the base of the banks comprised of cohesive clay, and overlain by sand. Eroding banks were mapped on the east bank, for a total length of 269 feet (average 4 feet height). Rip-rap revetment is present for 2181 feet, also on the east bank. To the east of the river, adjacent land is a deciduous-coniferous mixture, with some residences present, while adjacent land to the west consists of residences, with a subdominant forest. The channel canopy is open.

Flow Modifiers
Springs, seeps and tributaries are abundant throughout the reach, with a minimal amount of adjacent wetlands. Three bridges and one old abutment are present in the reach, all of which constrict both the river channel and floodprone area of the floodplain. The field assessors reported that the reach had slow velocities, and that the reach is governed by a backwater pool (Figures 14 and 15).

Channel Bed and Planform Changes
A total of one flood chute and two instances of river channel migration are present in this reach. In terms of channel straightening, a total of 0.77 miles (50%) of the reach has undergone this activity in the past.

Stream Sensitivity
The stream was classified as a B5, and with a Fair condition, produced a sensitivity of High. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	9
Channel Aggradation	11
Widening Channel	10
Change in Planform	14
Condition Rating	0.55



Map 6A. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 6A.

Reach 6B

Reach 6B extends for a length of 1.19 miles from the Fowler Brook tributary input, upstream to the Short Falls Road bridge crossing. This reach was assessed by Field Geology Services on September 30, 2013.

Valley and River Corridor

As with Reach 6A, Reach 6B was created by segmenting Reach 6 at the tributary confluence with Fowler Brook. The valley width in the reach is estimated at 673 feet. No grade controls are present. Roads are present adjacent to the river for a substantial portion of the reach length to the west (4760 feet total), while the presence of roads near the river is much less to the east (affecting only 354 of the reach length). Similar patterns are seen for land development adjacent to the river, with 78% of the reach length to the west with adjacent development, whereas this only occurs for 3% of the reach length to the east. The river is adjoined to the west by a berm for a length of 690 feet. The hillsides adjacent to the river and floodplain are steep to the east and very steep to the west, which approach the banks on both sides at some locations, and are comprised of till.

Stream Channel

Based on a representative cross-section, the channel width is 126 feet, with a maximum depth of 3.8 feet. Width of the floodprone area is 132 feet. Riffles and pools were not present on the bed in the reach, which is governed instead by a sandy, ripple-dune form (Figures 16 and 17). Sand accretion on the bed in this reach is extensive, and results from the avulsion upstream that occurred in 2006 (Figures 16 through 18).

Figure 16. View in Reach 6B, looking upstream at the Short Falls Road bridge. Note the extensive sand accumulations on the bed and the large sand bars.

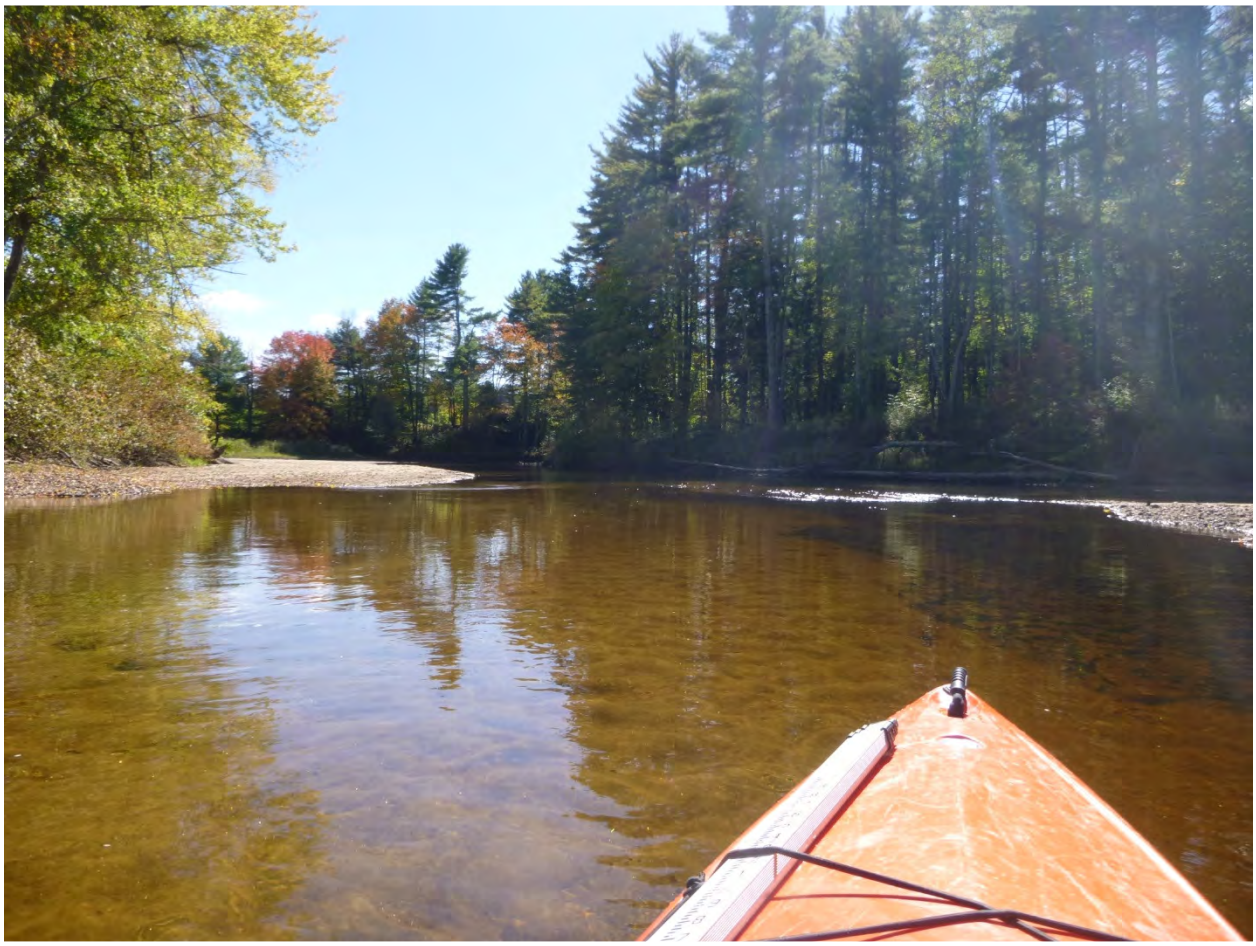


Figure 17. Downstream view from the vantage point in Figure 16. Note the extensively sandy, uniform bed, and side bar deposits in the distance.

Riparian banks, buffers and corridors

The slopes of the streambanks are typically steep, with bases comprised of cohesive clay, overlain by sand. Bank erosion and rip-rap occur at several locations on both banks in the reach. Total lengths of erosion include 616 feet on the east bank, and 513 feet on the west bank, with average heights of 5 and 3.3 feet; while a total of 314 feet of rip-rap is present on the east bank, with 229 feet for the west bank. The reach has an open channel canopy. Lands adjacent to the river are governed by a coniferous-deciduous forest. To the east of the river, some farm fields are also present, while residences are present to the west.

Flow Modifiers

Abundant springs, seeps and tributaries are present throughout the reach, while no wetlands adjacent to the channel occur. Four stormwater inputs were mapped in the reach. Three of these inputs were of the urban stormwater type, while one derived from a road ditch. No constrictions are present throughout the reach length.

Channel Bed and Planform Changes

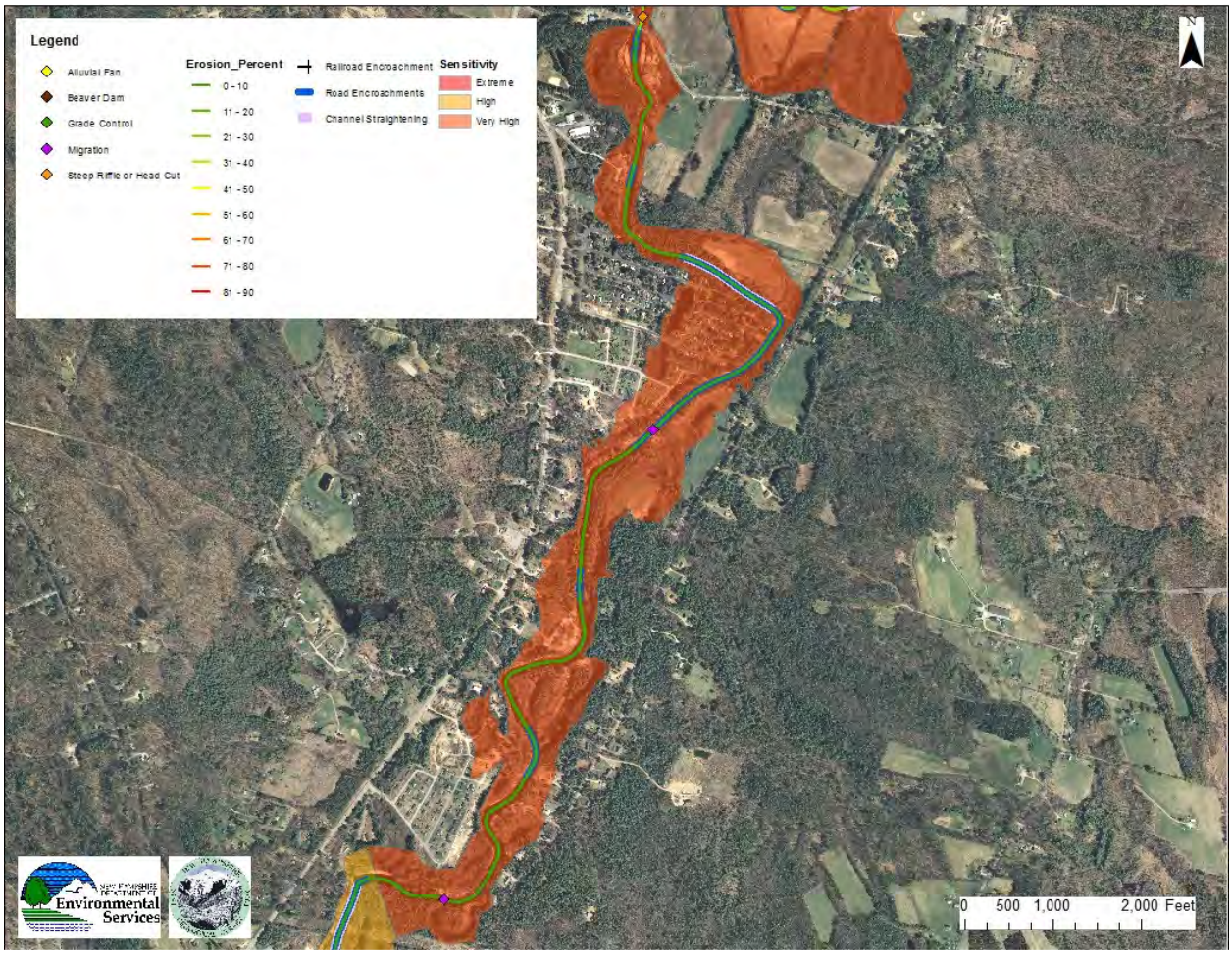
In this reach, 11 side bars, and 7 each of mid-channel and point bars (comprised of sand), a consequence of the 2006 avulsion upstream are present (Figure 18). One flood chute, and one instance of channel migration were also noted. A total of 18% of the reach length (1164 feet) is identified as having been straightened in the past, and this was found to have occurred with windrowing, meaning that evidence of material dredged from the river in the past being deposited adjacent to the river was found.

Figure 18. A view of the west bank in the vicinity of the trailer park downstream of Short Falls Road. Note the depositions of sand, both in the form of a bar (foreground) and adjacent to the base of the banks.

Stream Sensitivity

The stream was classified as a F5, and with a Fair condition, produced a sensitivity of Very High. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	5
Channel Aggradation	7
Widening Channel	9
Change in Planform	13



Map 6B. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 6B.

Reach 7A

This reach extends for a stream length of 1.23 miles from the Short Falls Road bridge, upstream to the northern extent of the closely spaced meander bends, where the channel transitions from these bends to the straighter reach beyond. Reach 7A was assessed by Field Geology Services on September 24, 2013.

Valley and River Corridor
Reach 7A was segmented out from the length of river upstream of it because of a change in the channel form and slope at this location (the break between Reaches 7A and 7B upstream), and in the condition of the channel banks. A series of two tightly spaced meander bends comprise the upper part of Reach 7A, while Reach 7B (upstream) is comprised of a straight section of channel, and thus, the channel form is different between the two reaches. Bank conditions vary between the two segments, as a greater extent of bank erosion is present in Reach 7A compared to Reach 7B upstream. The estimated valley width is 2000 feet. No grade controls are present in the reach.

Development adjacent to the river is much less compared to other reaches. There is no adjacent hillside or terrace near the river in this area, and the surrounding terrain is level.

Stream Channel

Based on a representative cross-section surveyed in the reach, the channel width is about 91 feet, with a maximum bankfull depth of 3.6 feet. Width of the floodprone area at the cross-section is 98 feet. The bed material is chiefly sand. Riffles/steps are present in the reach, with an average spacing of 400 feet. However, the overall bedform is classified as ripple-dune. Moving from upstream to downstream in the reach, the bank heights between the river bed and top of bank (where the level adjacent floodplain begins) decreases (Figures 19 through 21).

Figure 19. View looking downstream into the first meander bend from the upstream end of the reach.

Figure 20. View (looking downstream) toward the lower end of Reach 7A.

Riparian banks, buffers and corridors

Streambank slopes are typically steep, with the bank bases composed of cohesive silt/clay, which is overlain by non-cohesive sand. In terms of bank erosion, 1130 feet of erosion (with an average height of 4.2 feet) is present on the east bank, with 700 feet (average height of 3.4 feet) on the west bank. Presence of erosion is marked on the outsides of meander bends, and the potential exists for some channel migrations or cut-offs of the existing meanders. Bank revetment in the form of rip-rap for the reach totals 451 feet to the east, and 647 feet to the west. There is a 1-25% bank tree canopy on both sides of the channel. The adjacent floodplain consists mostly of fields, with shrubs and saplings also present. The river itself has an open channel canopy.

Figure 21. Closer view of the bank erosion on the outside of a meander bend in Reach 7A.

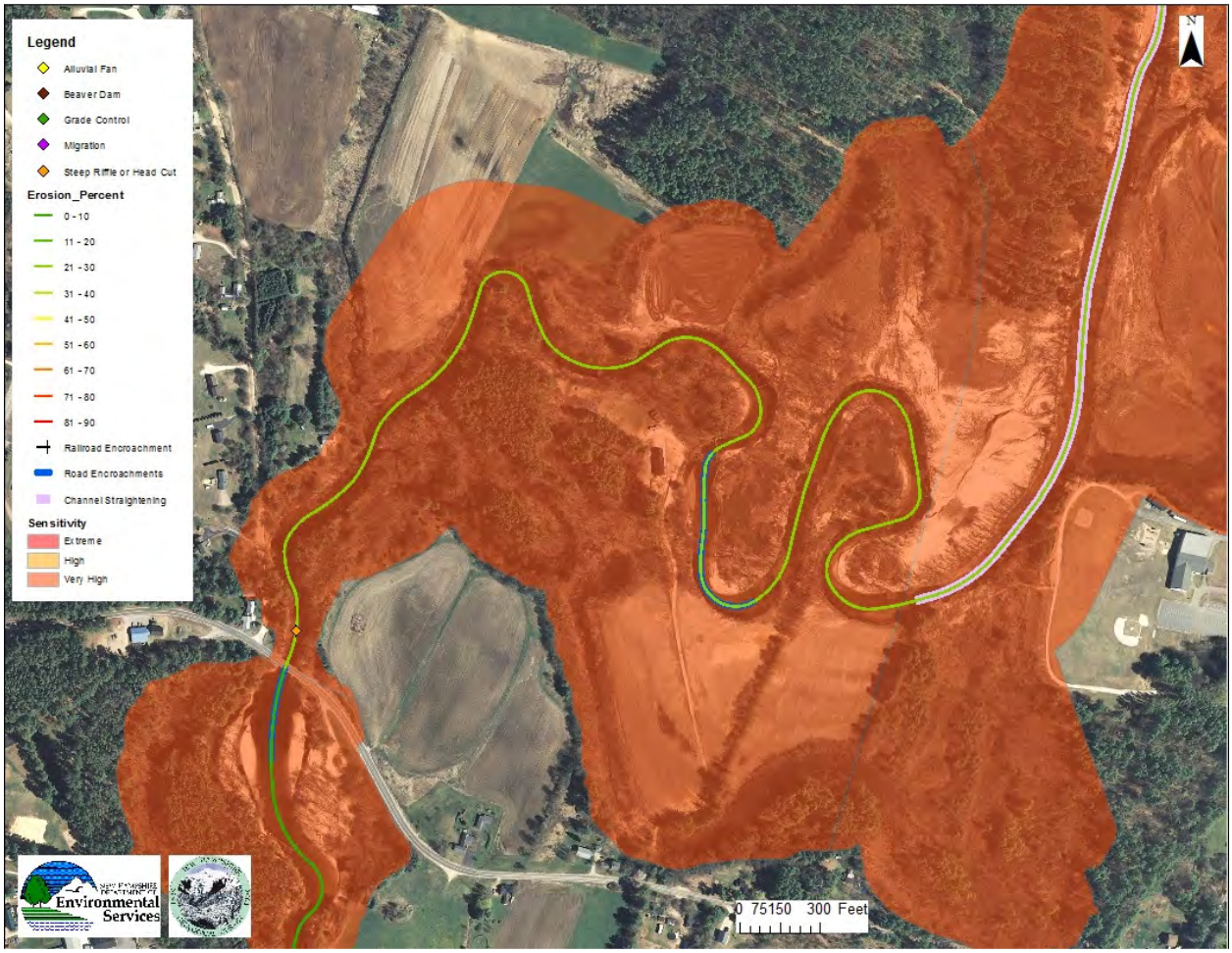
Flow Modifiers
Springs, seeps, tributaries and adjacent wetlands are all present in the reach, with no stormwater inputs. Old abutments are present in the reach that lead to a floodprone constriction, while one bridge (Short Falls Road), which spans the channel for a width of 51 feet, acts as both a constriction of the river channel and adjacent floodprone area. Also, scour is noted upstream of this bridge.

Channel Bed and Planform Changes
A total of 12 bars are present in the reach, including: 1 mid-channel bar, 9 point bars, and 2 side bars. As noted in the riparian banks, buffers and corridors section above, the potential exists for meander cutoffs or flood chute development, as a result of the existing erosion, within the area of the tightly looped meander bends.

Stream Sensitivity
The stream was classified as a F5, and with a Fair condition, produced a sensitivity of Very High. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	5

Channel Aggradation	16
Widening Channel	11
Change in Planform	17
Condition Rating	0.61



Map 7A. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 7A.

Reach 7B

This reach extends for a length of 3276 feet, and extends from above the tightly looped meanders to the confluence with the former west flow path of the Suncook River around Bear Island. Assessment of this reach was performed by Field Geology Services on September 25, 2013.

Valley and River Corridor
The rationale for the segmenting out of Reach 7B from the length of river downstream is discussed in this section under Reach 7A above. Reach 7B has an estimated valley width of about 1000 feet. No grade controls are present in the reach. Land adjacent to both sides of the river consists of level terrain.

Stream Channel

Based on a representative cross-section, the channel width is about 112 feet, with a maximum bankfull depth of 2.4 feet. Width of the floodprone area at the surveyed cross-section is 467 feet. Riffles are present, though sedimented, with an incomplete appearance, and are spaced about 1000 feet apart. The bed overall is dominated by runs. Bed material is dominated by gravel (53%), with sand constituting 47% of the remaining material sampled on the bed (Figure 22).

Figure 22. Typical view of the Suncook River in Reach 7B, looking upstream. Note the uniform gravel nature of the bed.

Riparian banks, buffers and corridors

Streambank slopes are typically steep, and are comprised of a cohesive silt base, overlain by non-cohesive sand. On the east bank, 34% of the total reach length has erosion, with average heights of 3.6 feet. A total of 530 feet of rip-rap is present, also on the east bank. No bank revetment of any type is present on the west bank. Adjacent land to the east consists of shrubs and saplings, with fields also present. To the west, the land is comprised of mixed forests, though fields are present here as well, toward the downstream end of the reach. The channel canopy is open.

Flow Modifiers

Springs, seeps, tributaries, and adjacent wetlands are abundant in this reach. In fact, the river is directly connected to the adjacent wetlands for some portions of the east bank through the reach (Figure 23). There is one stormwater input, a field ditch, mapped in the reach. No channel or floodprone constrictions are present.

Figure 23. Downstream view in Reach 7B, with east bank at left. Note how the river flow is connected with the adjacent wetland here.

Channel Bed and Planform Changes

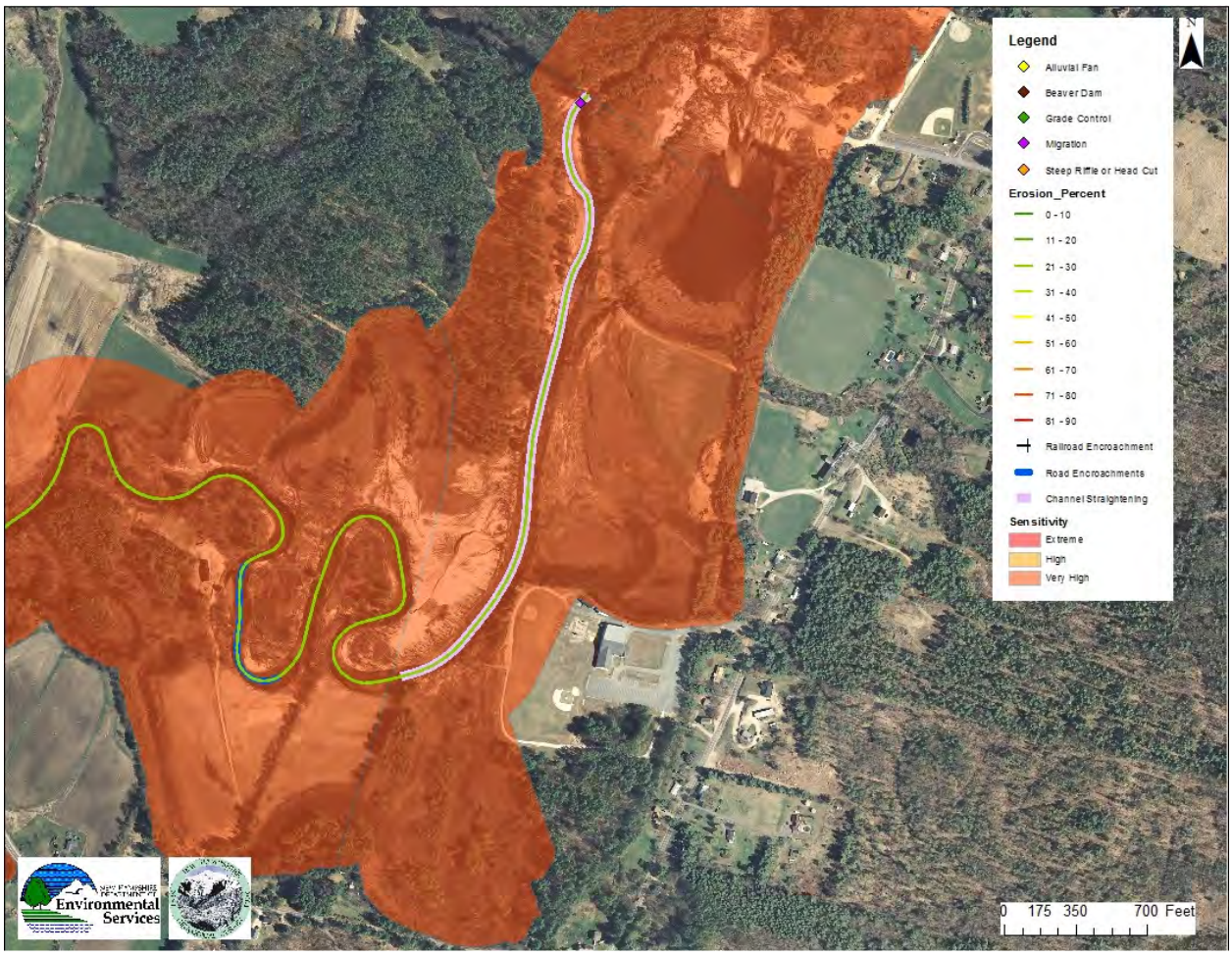
A total of 12 bars were mapped in the reach, including 2 mid-channel bars, 6 alternating point bars, and 4 side bars (Figure 24). A total of 3227 feet, or 99% of the reach length, has been straightened. The only area that is not mapped as straightened is directly at the downstream end of the reach, where the river enters the tight meander loops that constitute the majority of Reach 7A. As noted above, 34% of the east bank has erosion, and it is in these locations where the river is attempting to meander, a process typical of straightened river reaches.

Figure 24. Typical view of Reach 7B, looking upstream in this photo. Note the presence of the gravel bars, and the leaning trees, indicative of bank erosion.

Stream Sensitivity

The stream was classified as a C4, and with a Poor condition, produced a sensitivity of Very High. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	5
Channel Aggradation	11
Widening Channel	4
Change in Planform	5
Condition Rating	0.31



Map 7B. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 7B.

Reach 8

Reach 8 is 3054 feet long, and extends from the confluence with the former west path of the Suncook River around Bear Island, upstream to the point where the newly avulsed channel entered the original east path of the Suncook River as it flowed around Bear Island (i.e., the downstream location of the newly avulsed section of river). This reach was assessed by Field Geology Services on September 24, 2013. It should be noted that prior to the May 2006 avulsion, this reach was a component of one of two flow paths that comprised the Suncook River, each of which flowed around Bear Island to the west. This path flowed to the east of Bear Island. Prior to the avulsion, the Suncook River split just upstream of the Huckins Mill Dam, and thus only carried a portion of the total Suncook River flow. As a result of the avulsion, the Suncook River abandoned the path that contributed to the channels around Bear Island, and now, this reach receives the full flow of the Suncook River, and thus, carries a greater quantity of water at all times than it did prior to the avulsion.

Figure 25. Example view of Suncook River, Reach 8. In this view, you are looking downstream at the upstream extent of the reach (just downstream of the avulsion).

Valley and River Corridor

The estimated valley width in this reach is 1200 feet. No grade controls are present in the reach. The lands adjacent to the river are largely free from buildings or roads, except for the area near the upper end of Round Pond. On both sides of the river, the adjacent hillsides are hilly (slopes of 4-8%), and sometimes approach the river to where they adjoin the streambanks. These adjacent hillsides are comprised of sand.

Stream Channel

Based on a representative cross-section surveyed in the reach, the channel width is 98 feet, with a maximum bankfull depth of 7 feet. Topography of the river bed is fairly uniform (Figure 26). The width of the floodprone area is about 600 feet. Riffles are complete, and are spaced an average distance of 1100 feet apart. The bed material can be classified as 65% gravel, 21% sand and 14% cobble.

Figure 26. Typical view of Reach 8, looking downstream. While there is sun glare in this photo, note the relatively level topography of the streambed, the predominantly gravel composition, and the very shallow conditions. The mid-channel bar (the area raised and not covered by water) in the photo appears to be comprised of cobbles.

Riparian banks, buffers and corridors

Streambank slopes are typically steep, and are comprised of sand throughout. Eroding banks are prevalent in the reach, with a total of 1621 feet of erosion on the east bank, and 2493 feet on the west bank, with average heights of 5.4 and 6 feet. Sections of the bank have also been rip-rapped, with a total length of 202 feet on the east bank, and 65 feet on the west bank. Lands adjacent to the channel on both sides are comprised of mixed forests, with shrubs and saplings also present, but to a lesser extent. The channel canopy is open.

Flow Modifiers

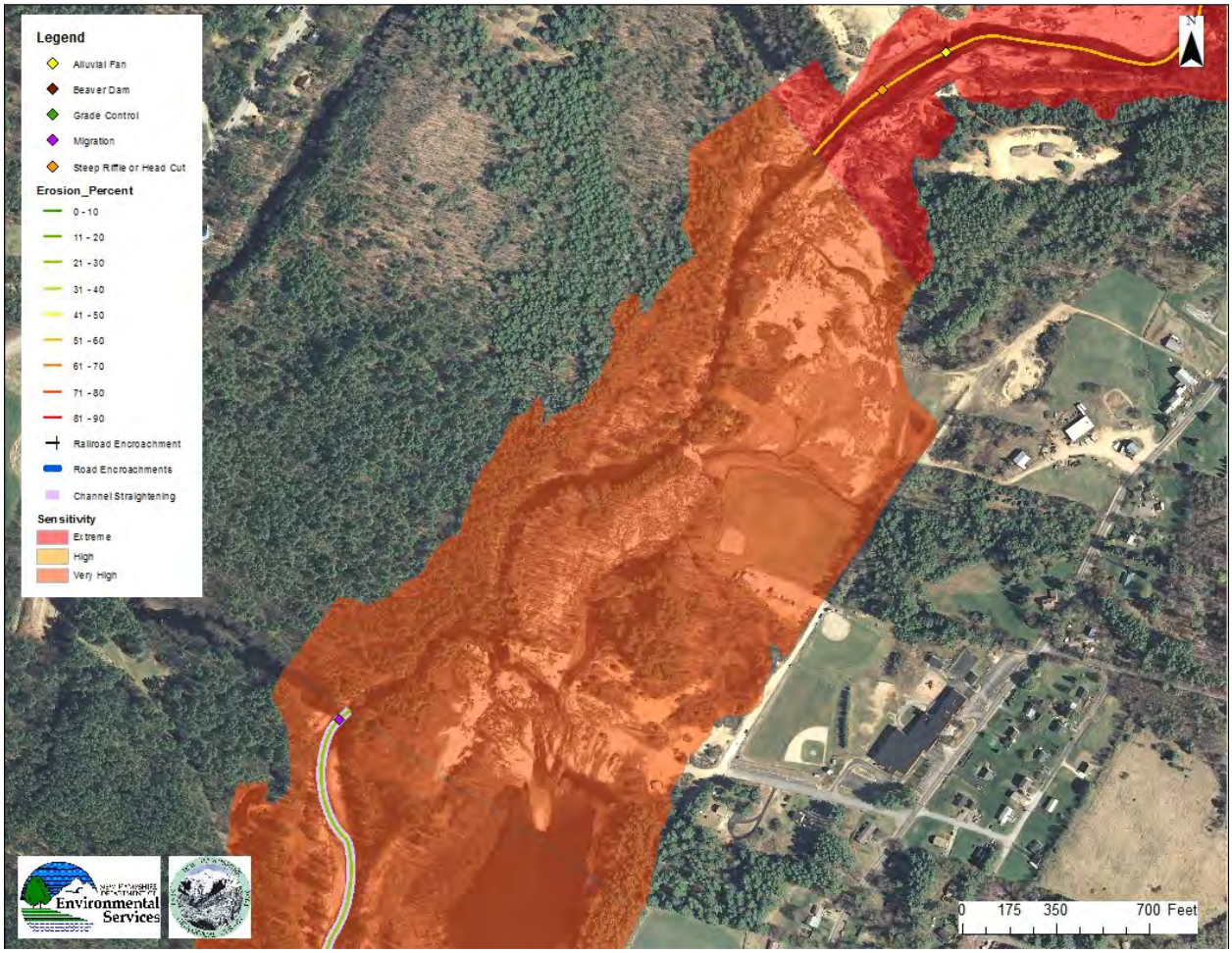
Springs, seeps, tributaries and adjacent wetlands are minimal in this reach. However a total of 5 debris jams were assessed and are present. No stormwater inputs or constrictions are present in the reach.

Channel Bed and Planform Changes

A total of 3 mid-channel bars and 8 point bars are present. No sections of this reach have been artificially straightened in the past.

Stream Sensitivity
The stream was classified as a C4, and with a Poor condition, produced a sensitivity of Very High. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	10
Channel Aggradation	10
Widening Channel	3
Change in Planform	3
Condition Rating	0.325



Map 8. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 8.

Reach 9

This reach extends for a total of 2420 feet, and corresponds to the newly created channel of the Suncook River as a result of the May 2006 avulsion. This reach did not exist on the landscape prior to the May 2006 avulsion, when the area that the river flows through today was largely a

wetland, and part of a former sand and gravel mining operation (Figures 27 through 29). Reach 9 was surveyed by Field Geology Services on September 19, 2013.

Figure 27. Aerial view of Suncook River in Epsom in 2005, prior to the avulsion.

Figure 28. Aerial view of the Suncook River in Epsom, taken in 2011.

Figure 29. View of Suncook River looking downstream along the new channel resulting from the 2006 avulsion. The section of the channel in the foreground was a wetland area prior to the avulsion. A former sand and gravel operation can be seen in the distance to the right (or west) of the river in the distance.

Valley and River Corridor

An alluvial fan is present in the reach, and is located adjacent to the east bank approximately 630 feet upstream of the boundary where the river flows beside the former sand and gravel operation. Width of the valley is estimated at about 800 feet. No grade controls are present in the reach. A path (former road into the area) runs adjacent to the river to the east for an approximate length of 817 feet, and is about 30 feet higher than the stream channel. The adjacent hillsides have slopes of 4-8%, are sometimes concurrent with the streambanks, and are composed of sand, on both sides of the river.

Stream Channel

Based on a representative cross-section surveyed in the reach, the channel width is about 129 feet, with a maximum bankfull depth of 6.1 feet. Width of the floodprone area at the representative cross-section is about 150 feet. Riffles are present and complete, with an average spacing of about 1000 feet. Channel bed material is dominated by gravel (66%), followed by silt/clay (18%) and sand (16%). Bed topography at locations in the reach are fairly uniform.

Riparian banks, buffers and corridors
Streambank slopes are typically steep, and are comprised of sand throughout. Mass failures and bank erosion are present along the east bank downstream of the Leighton Brook tributary confluence to the end of the reach. Length of the mass failure that begins at Leighton Brook extends for 720 feet downstream along the outside of the meander bend, with bank erosion continuing for another 765 feet downstream (average height of 15.5 feet) (Figure 30). Along the west bank, a total of 994 feet of erosion is measured, with an average height of 12 feet. The river continues to erode downward into the landscape and into the banks, and thus, widening continues. No bank revetment is present in the reach.

Figure 30. Looking east toward the outside of the meander bend on the Suncook River near the Leighton Brook tributary input. The mass failure on this bend can be clearly seen.

Flow Modifiers
There are minimal springs, seeps, tributaries and adjacent wetlands in this reach. A total of 2 log jams are present. No stormwater inputs or constrictions were noted in the reach.

Channel Bed and Planform Changes
The main change of note is that Reach 9 is a new length of river that results from the 2006 Suncook River avulsion, and this length of river did not exist prior to that time. Currently, the river flows through a former wetland, and part of a former sand and gravel mining operation. A

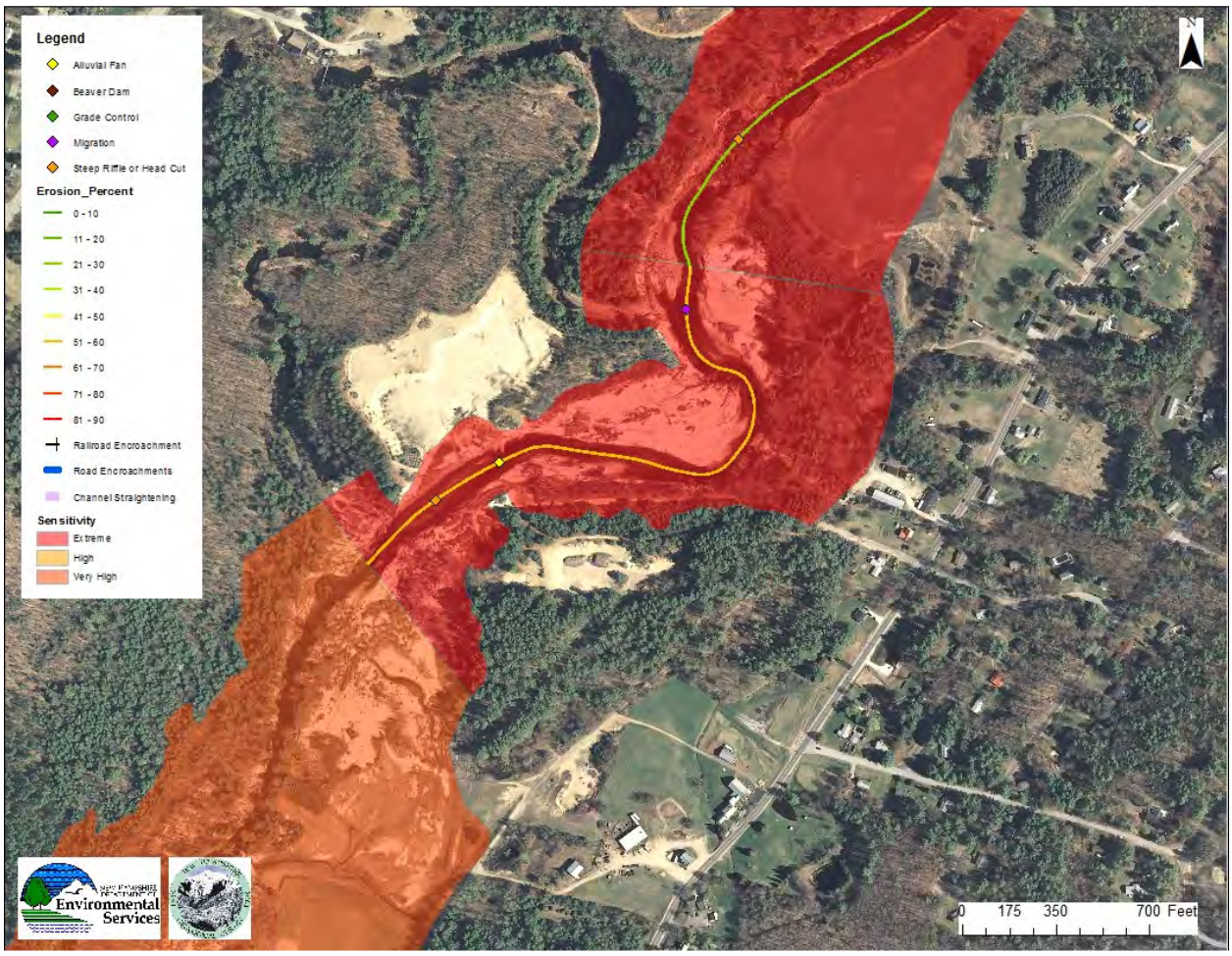
sizeable number of depositional features (bars) are present in Reach 9, including 6 mid-channel bars, 3 point bars, 3 side bars, and 1 diagonal bar. A steep riffle exists at the lower end of the reach, and consists of an accretion of gravel and sand in the channel (Figure 31).

Figure 31. Upstream view through much of Reach 9. The area in view upstream of this location is a former wetland. Note the accumulation of gravel and sand in the stream channel, which constitutes the steep riffle noted above.

Stream Sensitivity

The stream was classified as a F4, and with a Poor condition, produced a sensitivity of Extreme. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	1
Channel Aggradation	11
Widening Channel	1
Change in Planform	3
Condition Rating	0.20



Map 9. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 9.

Reach 10

Reach 10 extends for a distance of 3472 feet, from the location where the Suncook River changed course and abandoned its historic channel in 2006, upstream to the Route 4 bridge crossing in Epsom. This reach was assessed by Field Geology Services on September 23, 2013.

Valley and River Corridor
The valley width in the reach is estimated at about 2000 feet. No grade controls are present. The lands adjacent to the river are largely undeveloped (in terms of roads and buildings) for much of its length. Toward the upstream end, near Route 4, a road parallels the channel for about 488 feet to the west, and there are buildings here as well, for about 211 feet. To the west of the river, the adjacent land consists of level terrain, while to the east, the adjacent hillside comprises slopes of 4 to 8%, though the hillside never comes to within about 125 feet of the channel.

Stream Channel
Based on a representative cross-section, the channel width is 123 feet, with a maximum bankfull depth of 8.5 feet. Width of the floodprone area at the cross-section is about 149 feet at the

surveyed cross-section. The reach contains riffles, which are complete, and are spaced an average distance of 830 feet apart, thus producing a riffle-pool bed type. Bed material is comprised of sand, though gravel and silt/clay are also present in similar proportions. The river through this reach has been eroding downward, which has led to the weakening of the base of banks and consequent erosion as the result of upstream migrating headcuts, which themselves are a consequence of the river's response to the avulsion (Figures 32 and 33).

Figure 32. Looking at the west bank of the Suncook River from a depositional bar. Note the erosion on the bank, and the distance between the water surface and the top of the bank, which is the elevation of adjacent floodplain.

Figure? 33. View upstream. Route 4 bridge is in the distance beyond the green sapling in the channel, which appears to have recently fallen into the channel. The feature to the left of the photo is one of the head cuts that are present in this reach.

Riparian banks, buffers and corridors

Streambank slopes are typically steep, and consist of a cohesive silt/clay base overlain by non-cohesive sand on both sides of the channel. On the east bank, erosion is present for a total length of 231 feet, with an average height of 18.5 feet, while to the west, erosion is present for a length of 611 feet, and an average height of 22 feet. No bank revetment is present on the east bank, while a measured length of 310 feet of riprap is present on the west bank. Farm fields/pasture are present to the east of the channel, with forest patches, while to the east a mixed forest predominates the landscape, with residences also present toward the upstream end of the reach near Route 4. The channel canopy is open.

Flow Modifiers

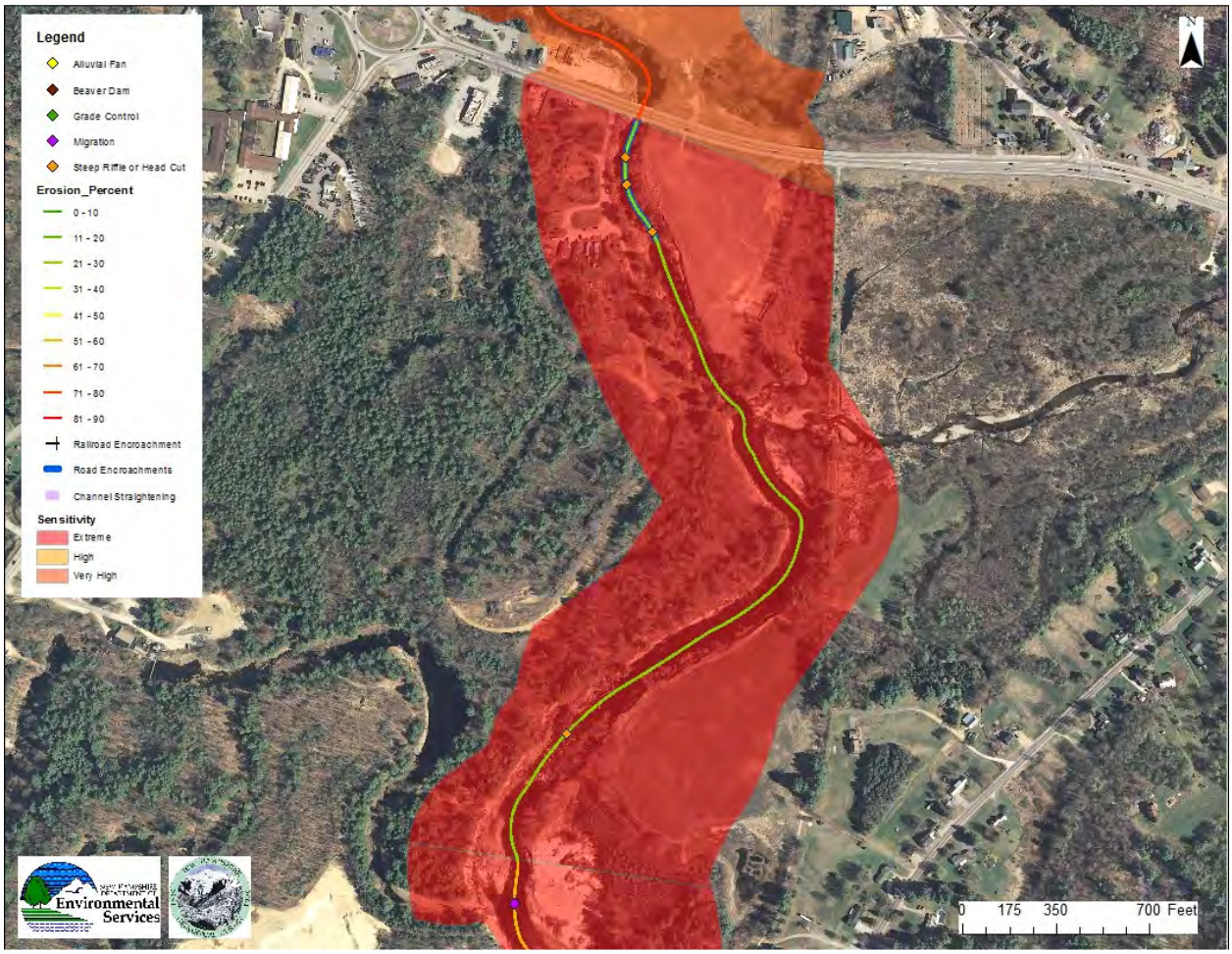
A minimal amount of springs, seeps and tributaries are present in this reach, with no adjacent wetlands. Six (6) debris jams were surveyed in the reach. No stormwater inputs were noted. One bridge (Route 4) is functioning as both a river channel and floodprone/floodplain constriction, with scour noted both upstream and downstream of the structure.

Channel Bed and Planform Changes

A number of depositional features were surveyed in the reach, including: 3 point bars, 1 side bar, 1 delta, 2 islands and 1 steep riffle. Erosional features were also noted, consisting of 3 head cuts.

Stream Sensitivity
The stream was classified as a F5, and with a Poor condition, produced a sensitivity of Extreme. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	1
Channel Aggradation	15
Widening Channel	1
Change in Planform	8
Condition Rating	0.31



Map 10. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 10.

Reach 11

Reach 11 extends from the Route 4 bridge in Epsom upstream to the Depot Road bridge in Chichester, which constitutes the original reach. However, the Suncook River assessment for the lower portion of the valley does not extend into Chichester, and thus, conditions are reported only for the section of the reach in Epsom. This reach was surveyed by Field Geology Services on September 27, 2013.

Valley and River Corridor
The estimated valley width in the reach is 1270 feet. No grade controls are present. The lands adjacent to the river are developed with buildings and roads. To the east of the river, lands are developed for a length of 1881 feet, while to the west, such development extends for 1415 feet. Slopes of the adjacent hillsides range 9-15% to the east of the river, and >25% to the west. These slopes do not adjoin the river to the east, but do to the west. These adjacent hillsides are comprised of sand to the west and till to the east.

Stream Channel
Based on a representative cross-section assessed in the reach, the channel width is about 86 feet, with a maximum bankfull depth of 8.8 feet. Width of the floodprone area at the cross-section is 372 feet. Riffles are complete, with an average spacing of 500 feet, producing a riffle-pool type bed. The bed material is dominated by gravel (60%), with a lesser quantity of sand (39%) and cobble (1%) also present.

Riparian banks, buffers and corridors
Streambanks are typically steep, and are comprised of a mixture of multiple particle sizes that are cohesive at the bases, that is overlain by non-cohesive sand. Bank erosion is occurring, with 6827 feet of erosion on the east bank (average height of 9.5 feet), and 5427 feet on the west bank (average height of 8 feet). Bank revetment, in the form of riprap, is also present in the reach, with 890 feet on the east bank, and 1061 feet on the west. Land adjacent to the channel is mostly comprised of mixed forests, with the presence of residences constituting a subdominant land use. The channel canopy is open.

Flow Modifiers
The quantity of springs, seeps and tributaries in the reach is minimal, while adjacent wetlands are not present in the reach. A total of two (2) log jams were counted in the reach.

Channel Bed and Planform Changes
In this reach, the following features are present: 1 mid-channel bar, 13 point bars, 11 side bars, and 1 delta. Additionally, 6 flood chutes and 2 instances of migration are present. The length of the stream that has been straightened in the past is 4089 feet.

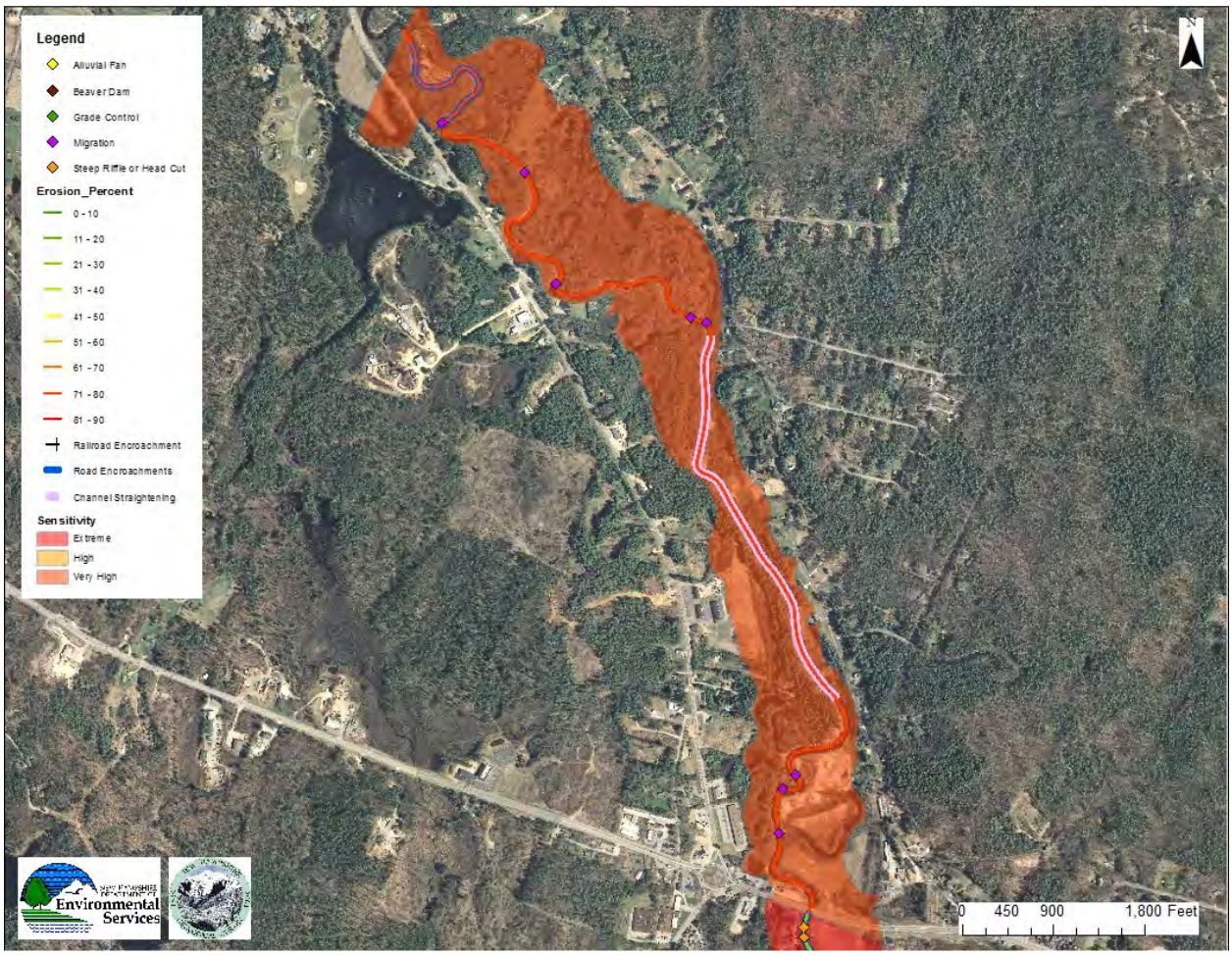
Stream Sensitivity
The stream was classified as a C4, and with a Fair condition, produced a sensitivity of Very High. Inputs to this scoring are as follows:

Category	Score
Channel Degradation	10
Channel Aggradation	14

Widening Channel	11
Change in Planform	5
Condition Rating	0.50

Figure 34. Example view of Suncook River, Reach 11.

Figure 35. Example view of Suncook River, Reach 11.



Map 11. Geomorphic features, reach sensitivity and fluvial erosion hazard meander belt for Reach 11.

Appendix A
Explanation of reach conditions score and sensitivity ratings

Upon completion of the assessment in a reach, another form is compiled for each reach, termed the "Rapid Geomorphic Assessment" (RGA) form, which includes both quantitative parameters from the cross-sections, and qualitative factors from having assessed the reach (Figure A-1). The form is divided into four parts, each of which evaluates four different components of river processes: degradation (river bed and bank erosion), aggradation (accumulation of sediment), widening, and planform (overall form and configuration of river channel). Within each of the four process groupings, there are 5 or 6 distinct parameters. For each parameter, the assessor selects one of four categories, which fulfills the best description of that parameter for the reach: reference, good, fair or poor. A score is assigned for each of the four categories based on the spread of the selection of parameters for that process category, or if the channel and floodplain conditions (top parameters in each category) score "Poor," the category score for that parameter will be lowered greatly.

VT RAPID GEOMORPHIC ASSESSMENT ---- CONFINED STREAMS

For narrowly and semi-confined valley types (confinement ratio < 4)

Stream Name:_____ Segment I.D:_____
Location:_____ Date:_____
_____ Town:_____
Observers:_____ Elevation:_____ ft.
Organization /Agency:_____ Weather:_____
Reference Stream Type _____ ☐ Modified Rain Storm within past 7 days: Y / N
(Bedrock controlled gorge, alluvial fan, or naturally braided system see Handbook Protocols)

Adjustment Process	Condition Category: Reference	Good	Fair	Poor
7.1 Channel Degradation (Incision) • Exposed till or fresh substrate in the stream bed and exposed infrastructure (bridge footings). • New terraces or recently abandoned flood prone areas. • Headcuts, or nickpoints significantly steeper bed segment and comprised of smaller bed material than typical steps. • Freshly eroded, vertical banks. • Alluvial sediments that are imbricated (stacked like dominoes) high in the bank. • Tributary rejuvenation, observed through the presence of nickpoints at or upstream of the mouth of a tributary. • Depositional features with steep faces, usually occurring on the downstream end. **Stream Type Departure** ☐ **Type of STD:**_____	☐ Little evidence of localized slope increase or nickpoints.	☐ Minor localized slope increase or nickpoints.	☐ Sharp change in slope, head cuts present, and/or tributaries rejuvenating.	☐ Sharp change in slope and / or multiple head cuts present. Tributaries rejuvenating.
	☐ Incision Ratio ≥ 1.0 < 1.2 **and** Where channel slope < 4% Entrenchment ratio > 1.4 Where channel slope ≥ 4% Entrenchment ratio > 1.2	☐ Incision Ratio ≥ 1.2 < 1.4 **and** Where channel slope < 4% Entrenchment ratio > 1.4 Where channel slope ≥ 4% Entrenchment ratio > 1.2	☐ Incision Ratio ≥ 1.4 < 2.0 **and** Where channel slope < 4% Entrenchment ratio > 1.4 Where channel slope ≥ 4% Entrenchment ratio > 1.2	☐ Incision ratio ≥ 2.0 **and** Where channel slope < 4% Entrenchment ratio ≤ 1.4 Where channel slope ≥ 4% Entrenchment ratio ≤ 1.2
	☐ Step-pool systems have full complement of expected bed features, steps complete with coarser sediment (≥ D80).	☐ Step-pool systems have full complement of expected bed features, steps mostly complete.	☐ Step-pool systems with incomplete (eroded) steps, dominated by runs.	☐ Step-pool bed features eroded and replaced by plane bed features.
	☐ No significant human-caused change in channel confinement.	☐ Only minor human-caused change in channel confinement.	☐ Significant human-caused change in channel confinement but no change in valley type.	☐ Human caused change in valley type.
	☐ No evidence of historic / present channel straightening, dredging, and/or channel avulsions.	☐ Evidence of minor historic dredging and/or channel avulsion.	☐ Evidence of significant historic channel straightening, dredging, or gravel mining, and/or channel avulsions.	☐ Extensive historic channel straightening, commercial gravel mining, and/or recent channel avulsions.
	☐ No known flow alterations (i.e., increases in flow and/or decreases in sediment supply).	☐ Some increase in flow and/or minor reduction of sediment load.	☐ Major historic flow alterations, greater flows and/or reduction of sediment load.	☐ Major existing flow alterations, greater flows and/or reduction of sediment load.
Score: **Historic** ☐	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
7.2 Channel Aggradation • Shallow pool depths. • Abundant sediment deposition on side bars and unvegetated mid-channel bars and extensive sediment deposition at obstructions, channel constrictions. Islands may be present. • Most of the channel bed is exposed during typical low flow periods. • Coarse gravels, cobbles, and boulders may be embedded with sand/silt and fine gravel. **Stream Type Departure** ☐ **Type of STD:**_____	☐ Step-pool systems have full complement of expected bed features, complete steps and deep pools.	☐ Step-pool systems with full complement of bed features. Pools filling with fine sediment and may be only slightly deeper and wider than runs.	☐ Step-pool systems with incomplete steps, dominated by runs. Pools filling with fine sediment and may be absent with runs prevailing.	☐ Step-pool bed features are filled with sediment and stream appears as a plane bed.
	☐ Minor side or delta bars present. Minor depositional features typically less than half bankfull stage in height.	☐ Single to multiple mid-channel, side or diagonal bars present. Minor depositional features typically less than bankfull stage in height.	☐ Multiple unvegetated mid-channel, side or diagonal bars present. Sediment buildup at constrictions leading to steep riffles and/or flood chutes.	☐ Multiple unvegetated mid-channel, side or diagonal bars or islands present, splitting or braiding flows even under low flow conditions.
	☐ No apparent increase in gravel / sand substrates (pebble count).	☐ Some increase in small gravel / sand substrates that may comprise over 50% of the sediments.	☐ Large increase in gravel / sand substrates that may comprise over 70% of the sediments.	☐ Homogenous gravel/sand substrates may comprise over 90% of the sediments. Fine sediment feels soft underfoot.
	☐ Low width/depth ratio ≤ 20 for channel slopes < 4% ≤ 12 for channel slopes ≥ 4%	☐ Low to moderate W/d ratio > 20 ≤ 30 for slopes < 4% > 12 ≤ 20 for slopes ≥ 4%	☐ Moderate to high W/d ratio > 30 ≤ 40 for slopes < 4% > 20 ≤ 30 for slopes ≥ 4%	☐ High width/depth ratio > 40 for channel slopes < 4% > 30 for channel slopes ≥ 4%
	☐ No known flow alterations (i.e., decrease in flow and/or increase in sediment supply).	☐ Minor reduction in flow and / or increase in sediment load. Flood-related sediment working through reach, seen as enlarged bars.	☐ Major historic flow alterations, reduction in flows and / or increase in sediment load.	☐ Major existing flow alterations, extreme reduction in flows and / or increase in sediment load.
	☐ No human-made constrictions causing upstream deposition.	☐ Human-made constrictions smaller than floodprone width, causing minor to moderate upstrm / dwnstrm deposition.	☐ Human-made constrictions significantly smaller than floodprone width, causing major upstrm / dwnstrm deposition.	☐ Human-made constrictions significantly smaller than bankfull width, causing extensive upstrm / dwnstrm deposition and flow bifurcation.
Score: **Historic** ☐	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Figure A-1. Example page from rapid geomorphic assessment form.

Once a score is assigned for each process category, the scores are summed for all, and are divided by the maximum to obtain the score for the reach. This score is used to provide a condition rating for the reach (Figure A-2).

0.85 – 1.0	Reference Condition
0.65 – 0.84	Good Condition
0.35 – 0.64	Fair Condition
0.00 – 0.34	Poor Condition

Figure A-2. Total RGA scores ranges, and corresponding condition category ratings.

Each assessed reach is assigned a geomorphic stream type. Based on data from a river cross-section and bed material pebble count, a river reach can be assigned a letter/number grouping that classifies the general channel slope, bed material, and the degree to which the river is directly connected, and has access, to its floodplain, for a river reach. Stream types start with a letter, which range from "A" through "G." For example, an "A" stream is typically steep, often cascading, with steps and pools, and are capable of producing high energy flows. "B" streams have riffles, and often have rapids, with infrequently spaced scour pools at bends or areas of constriction. Stream types of "C," "E," and "F" are low-gradient streams, that flow through wide valleys. "C" and "E" streams typically have good access to their floodplains, and are sinuous, while "F" streams are usually cut down into the adjacent floodplain. "G" streams are gullies, while "D" streams are channels with multiple braids or threads of flow, typically found in rivers with very high sediment loads ("D" streams are not prevalent in New Hampshire). Each letter is followed by a number, ranging from 1 through 6, that illustrates the median bed material particle size found on the bed. These numbers are as follows:

1 Bedrock
2 Boulder
3 Cobble
4 Gravel
5 Sand
6 Silt/Clay

The letter/number grouping provides an overall classification of the general channel form and bed material for a river reach. So, for example, a stream typed as a C4, common in New Hampshire, tells us that we have a river with a gravel bed, which meanders in a well-developed floodplain that the river channel is connected to.

Based on the overall features typically present for different stream types, the potential, or sensitivity, to future change can be inferred. Poorer conditions for a stream can increase a stream's sensitivity to change, or the likelihood that it will respond to a disturbance, typically the result of a flood or high flow event. Thus, the stream type, when combined with the condition score, can be used to assign a sensitivity rating for a reach, as follows:

Field-determined stream type	Sensitivity		
	Condition = Reference or Good	Condition = Fair	Condition = Poor
A1, A2, B1, B2	Very Low	Very Low	Low
C1, C2	Very Low	Low	Moderate
B6	Low	Moderate	Moderate
F1, F2, G1, G2	Low	Moderate	High
B3, B4, B5, C3, E3	Moderate	High	High
A6	Moderate	High	Very High
G6	High	High	Very High
C4, C5	High	Very High	Very High
A3, A4, A5, F3, F6, G3	High	Very High	Extreme
F4, F5, G4, G5	Very High	Very High	Extreme
D3, D4, D5, D6	Extreme	Extreme	Extreme
C6, E4, E5, E6	High	Extreme	Extreme

Figure A-3. Sensitivity ratings that correspond to stream type and condition combinations.

Sensitivity can be defined as the potential of a river to respond to flood events, through bank erosion and lateral migration (across the floodplain) processes. Rivers, as a result of the combination of the surrounding terrain in which they are located, and extent of past alterations, will vary in their likelihood to experience flood-event driven rapid changes. Past actions, such as for example channel straightening, can increase the potential for change in a flood. Reaches with erosion are prone to such rapid changes, given the exposed bank materials available for the power of water to erode into. The occurrences of such features are included into the sensitivity rankings, where generally, the greater the number of features present that can cause changes, the higher the assigned sensitivity for a reach. Broadly, assignment of an "Extreme" category means a reach that has sizeable erosion of its beds and banks, and often has flood chutes and meander cutoffs that increase the potential for changing flow paths and further erosion during a large flood. Conversely, a rating of "Very Low" is often found in a bedrock gorge, where the flow path will not change on time scales of concern to people.

Rivers can and do change over time. However, the potential for a bank to erode; or for the river to flow down the path of a new flood chute; or a change in flow path during and after a flood, cannot, unlike flood inundation, be assigned a risk percentage value, as the precise location and time of such events are very hard to predict. So, we cannot say that a reach in the Extreme category has a certain % chance of experiencing change during a flood. Rather, the sensitivity categories are relative to each other. So, when rivers are most active, during high flow, a reach with a category of Extreme is more likely to experience issues than a reach in the High category, for example.

Appendix B
Enhanced woody material survey

During the state's response to the Suncook River avulsion, and the many town meetings that followed, officials in towns in the lower Suncook River valley expressed concerns about the potential for large wood (i.e., trees) to become mobile during high flow events, and clog bridge openings or accumulate in jams. Towns requested more detailed information regarding the distribution of wood, to an extent greater than NHDES normal protocols specify. Thus, the New Hampshire Geological Survey designed, and applied, an enhanced large wood assessment protocol for the Suncook River assessment. A brief description of this protocol and a report and discussion of the results is presented here, which follows a brief description of the presence of large wood in rivers in general.

General comments regarding large wood in rivers

As a result of the Suncook River geomorphic assessment, the state has developed a dataset relative to the locations of woody material and its volume. Key findings from that assessment are presented in the results section below. The datasets are available in GIS format, and may be obtained from the New Hampshire Geological Survey (NHGS) at the Department of Environmental Services. The Central New Hampshire Planning Commission (CNHRPC) also has a copy of this dataset, in GIS format, and has developed Large Woody Material maps for Allenstown, Pembroke and Epsom for use in their Hazard Mitigation Plans.

A few caveats are noteworthy relative to this survey and the results. It is important to remember that the presence of wood in rivers is natural and normal in highly forested regions such as New Hampshire. The presence of trees will be greater in a river that has considerable tree fall, such as from increased bank erosion, which has occurred on the Suncook River. Wood also decomposes in rivers and thus can produce smaller pieces with time, which results in uneven distributions of wood. In many settings, trees can provide increased integrity to the banks by helping to slow flow velocities and reduce the energy available to erode the beds and banks. While not the main focus of the work presented here, trees often produce pools downstream of them which can provide fish habitat benefits. These factors should be considered before removing many trees in a reach of river en masse. If any such actions are ever considered for the Suncook River, staff within NHGS can provide technical assistance on the removal of trees. Contact information is provided at the end of this Appendix.

Protocol

The data collection scheme allows the density of wood within a reach or segment of river to be determined. For the purposes of this assessment, the collected data on each piece of wood was used to calculate its density, and the summation of the density of the pieces is reported for equal lengths on the Suncook River of 200 feet.

For each piece of wood encountered in the river, the diameter of the end of each piece, and piece length, are measured, and its location is recorded with a GPS unit.

Calculation of density of each piece of wood assessed
Using the values of the diameters at each end, the volume of a piece may be computed using the following equation (Lienkaemper and Swanson, 1987):

$$Volume = \frac{\pi(D_1^2 + D_2^2)L}{8}$$

Where

$\pi = 3.14$
D_1, D_2 = Diameter at each end of piece
L = Length

Results

The density of each piece of wood assessed was calculated using the equation above. The Suncook River was subdivided into lengths of 200 feet, and the densities of each individual piece within each 200 foot length were summed to provide a length density volume total in cubic feet.

With only a few exceptions, the lengths of river with the highest densities of wood within the assessed reaches of the Suncook River are located in the vicinity of the avulsion in Epsom, either directly downstream, or upstream of it. This is a result of erosion that has occurred on the channel banks downstream. The erosion itself is likely a result of the greater quantity of flow available after the avulsion, or from the results of the headcut that has migrated upstream of the avulsion, leading to bank failures and slumping of material into the channel.

The segment with the highest density of wood in any given 200-foot length is located between the area of the former gravel operation and Round Pond, where the density is 1948 ft^3. This density value certainly results from the large log jam present there (Figures B-1 and B-2). This jam is located in a reach of river experiencing extensively mapped bank erosion, with an additional log jam present between this location and Round Pond, which has a density of wood in that 200-foot segment of 639 ft^3 (Figure B-3). In the next bend downstream, just below the side channel into Round Pond, is a 200-foot river segment with a woody material density of 624 ft^3.

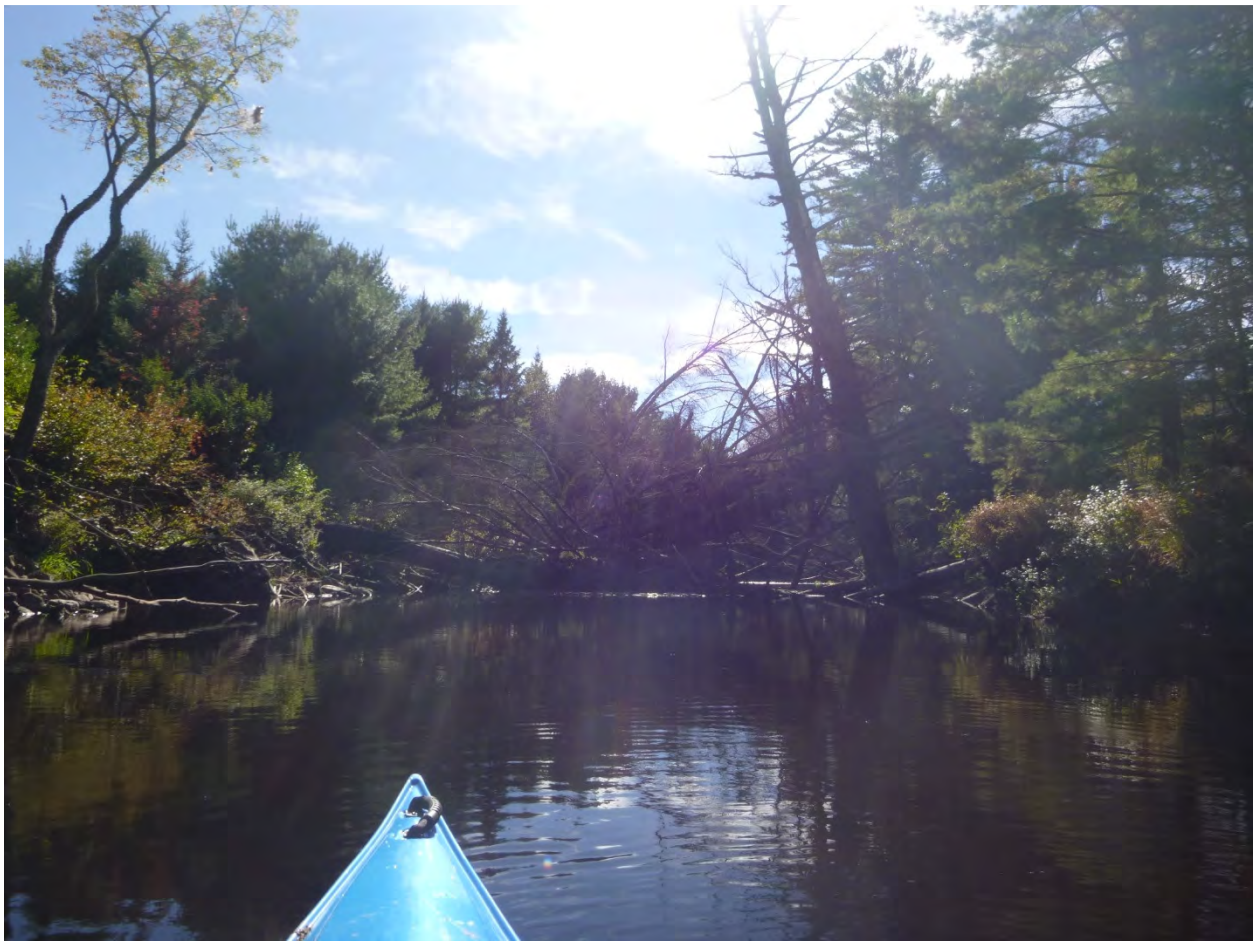


Figure B-1. View looking downstream at the very large log jam in the Suncook River between the former gravel operation and Round Pond. (Photo 1 of 3 from highest density segiment.)

Figure B-2. View looking upstream at the very large log jam on the Suncook River. (Photo 2 of 3 from highest density segment.)

Figure B-3. Upstream view of log jam, located in the Suncook River directly upstream of Round Pond. (Photo 3 of 3 from highest density segment.)

The second highest concentration of wood in the channel is just upstream of the avulsion. Here, as the river has eroded downward into the landscape in response to the avulsion and created a headcut, an area of boulders has been exposed (Figure B-4). It is here where the river has shown extensive field evidence of eroding its banks to the east, and where there has been treefall, and thus, an accretion of wood. It is in this 200-foot length of river that the total density is 1732 ft^3, with a total of 41 pieces of wood, the highest number of pieces on the Suncook River reaches that were assessed (Figures B-5 and B-6). Downstream, is the area of the Suncook River affected by the avulsion.

Figure B-4. View of the area upstream of the avulsion with the second highest densities and highest individual piece count in the Suncook River assessment, shown within the tan circle on map.

Figure B-5. View looking downstream through the area of exposed boulders. Note the many pieces of wood in the photo.

Figure B-6. View looking upstream in the area with the large boulders. Note the pieces of wood across the bed.

The third highest total density of wood in the channel is located in the 200-foot length of river directly upstream, where the total density equals 1155 ft^3, from a total of 15 individual wood pieces. Directly upstream of this segment is another 200-foot long segment of river with a density of 685 ft^3 (fifth highest total) from a total of 11 pieces. Also in this general area, directly upstream of the avulsion where the river abandoned its old channel, is a segment with a density of 604 ft^3.

Other locations of high densities are associated with bank erosion or slumps. The fourth highest density of wood, at 691 ft^3, is located in Epsom (Reach 6B) at the location of a mass failure, where the slump carried a tree into the river channel. The sixth highest woody material density of 671 ft^3, is a debris jam in the Suncook River in Reach 11 in Epsom (Figure B-7). This jam is located about 1.1 miles downstream of the Epsom-Chichester town line, or about 2380 feet upstream of the suspension bridge that crosses the Suncook River. This area is experiencing considerable bank erosion and slumps.

Figure B-7. Debris jam in Suncook River within Reach 11 in Epsom. View looking downstream.

Of the remaining river segments that were assessed in Allenstown, Epsom and Pembroke, the woody material density is lower. The distribution of the number of river segments within density value ranges are as follows:

Density Value Range	# of 200-foot length segments in range category
500-599 ft^3	6
400-499 ft^3	6
300-399 ft^3	13
200-299 ft^3	30
100-199 ft^3	63
1-99 ft^3	181
0 ft^3	97

Appendix C
Glossary

Aggradation – The process where a stream actively builds up its river bed by being supplied with more sediment transported from upstream than it is capable of transporting
Bank – The rising ground bordering a river or stream
Bankfull – The elevation of the water surface of a river or stream flowing at the capacity of the channel, which is also referred to as the water surface elevation corresponding with the volume of water that occurs at a location, statistically, on average approximately every 1.5 years
Bar – A mound of bed material formed by the actions of river currents, with influences caused by river channel geometry and obstructions that may be present in the river
Bed – The floor of a river
Bed material – The material of which a river bed is composed of.
Bedrock – The solid rock that underlies gravel, soil, or other superficial material
Berm – A ridge of material, typically placed adjacent to a river channel, with river bed material as the source, to protect floodplain development from flooding
Boulder – A detached rock mass larger than a cobble, having a diameter greater than 10 inches, or about the size of a volleyball, being somewhat rounded or otherwise distinctively shaped by abrasion in the course of transport
Channel – The path of a river or stream in which the water it carries flows through
Cobble – A rock fragment between 2.52" and 5.04" in diameter, thus larger than a pebble and smaller than a boulder, rounded or otherwise abraded
Confinement – Valley width compared to river channel width; the closer these two values are to each other, the more confined (narrower) the river valley is
Constriction – Channel constrictions include any natural or human structure which significantly narrows or "pinches" the width of the bankfull channel or floodprone area
Cross-section – In the context of a river condition assessment, this is a location where a tape is stretched across the river channel so that a profile of the streambed, and channel widths and average depths may be determined and calculated; with the location of a cross-section known, repeat surveys are possible to allow tracking of changes in river widths, depths and cross channel profile with time
Debris jam – *See "log jam"*
Degradation – The general lowering (downward) of the bed of a river by erosive processes, especially by the removal of material through erosion and transportation by flowing water
Delta – Nearly flat tract of land at the mouth of a river or tributary flowing into a river or stream, commonly forming a triangular or fan-shaped plain resembling the Greek letter Δ, in plan view
Erosion – The wearing away of soil and rock by mass failures or the action of streams, ice, waves, wind or underground water
Flood chute – A feature in the adjacent floodplain to a river that could be accessed by a river during high flow and represents a pathway that could be captured by the river as a new channel during a flood or high flow event; normally found on the inside of a meander bend
Floodplain – The portion of the river valley, adjacent to the channel
Floodprone area – The width of the floodprone area is measured at an elevation that corresponds to twice the maximum depth of the bankfull channel and is the width of the river at flood flows, generally including the active floodplain and adjacent low hillsides
Fluvial – Of or pertaining to rivers; running water that shapes the landscape around it, the study of which is termed ***fluvial geomorphology***
Geographic Information System (GIS) – A computer application used to store, view, and analyze geographic information, especially maps
Geomorphic – The form of the Earth or its surface features
Grade control – A dam, ledge or waterfall in the river channel, the presence of which impact the river's ability to move its bed material
Headcut – A sign of bed erosion, a lowering of the streambed elevation through scour of bed material; as water flows over a step on the streambed, water velocity increases and digs away at the bed, causing the step to move (migrate) in the upstream direction
Large woody material (LWM) – Pieces of wood at least 6 feet long and 1 foot in diameter (at the large end) contained at least partially within the bankfull area of the river channel

Ledge – A rocky outcrop of solid rock
Log jam – An accumulation of multiple pieces of large woody material in the channel
Mainstem – The principal channel of a drainage basin to which all other smaller streams flow into
Mass failure – Downslope movement of a portion of the land surface, such as a landslide
Meander bend – A loop in the course of a stream, created as a river or stream swings back and forth in flowing across its floodplain
Mid-channel bar – A deposit of bed material in the center of the river channel by the addition of individual accumulations of material that accompanies movement of bed material through the river channel, particularly during situations where high flow and floodwaters are receding
Migration – The active slow downstream shifting of a system of river or stream meanders, accompanied by enlargement of the meanders themselves
Planform – The form of a river channel, whether it is straight or meandering, and is typically influenced by larger watershed and valley properties, including slope, river flow, and bed material size and availability
Point bar – A deposit of bed material on the inside of a meander bend by the addition of individual accumulations of material that accompanies movement of the outside of the bend further toward the outside bend
Reach – A length of stream with characteristics that are similar throughout, such as valley confinement, valley slope, sinuosity, geology and river bed materials
Revetment – These are hard structures installed in an attempt to stop streambank erosion
Riffle-pool – A system that is comprised of a riffle, which is an expanse of shallow river bottom extending across a river width, over which water flows swiftly with a wavy surface caused by underwater obstructions; downstream of a riffle is found pool, which is a deeper region of water
Riparian buffer – A bank of forest and vegetation (shrubs, grass) situated on the bank of a body of water, especially a river
Rip-rap – Large fragments of broken rock, thrown together irregularly or fitted together; its purpose is to prevent erosion by currents and thereby preserve a surface, slope, or underlying structure; used for river-improvement works and streambank protection
Ripple-dune – Usually associated with low slope and highly meandering channels; dominated by sandy streambeds; streambed does not have distinct riffles, pools or steps
Scour – Concentrated erosive action by river or stream water on the outside curve of a river or stream bend
Seep – A spot where water oozes from the earth, often forming the source of a small tricking stream
Sensitivity – The potential of the river to experience change during high flow events resulting from bank erosion and other channel changes, based upon the evaluated condition of the river reach at time of survey
Steep riffle – A location where bed material accumulates, typically in a wedge where bed material drops out at some point along the river or stream, and forms a steep face of bed material on the downstream side
Streambank – *See "bank."*
Straightening – The removal of natural meanders in a river to allow the river path to be shortened, to permit the water to move faster, or to reduce flooding (floodplain inundation)
Terrace – A level bench or step that breaks an otherwise continuous slope, which can be found near streambanks along rivers
Till - Unconsolidated mix of clay, silt, sand, gravel and boulders deposited directly by glaciers
Tributary – Any river or stream that contributes water to another river or stream
Valley – The low-lying land bounded by higher ground.
Wetland – An area inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal conditions does support, a prevalence of vegetation typically adapted for life in saturated soil conditions