Flushing Flow Estimation and Detailed Habitat Assessment of the Farmington River Wild and Scenic Reach

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Prepared for:
Farmington River Coordinating Committee

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FLUSHING FLOW ESTIMATION STUDY

Results
The objective of this study was to estimate the flushing flows required to mobilize the full range of sediments in the 14 mile study reach of the Farmington River with the intention of informing dam-release management decisions in the future. To achieve this objective, the basic hydraulic characteristics of the study reach were characterized through topographic surveys of channel cross sections and documentation of large roughness elements such as woody debris and in-channel vegetation.

Cross sections were established at 33 locations (Figure 1 and Appendix A). Metal stakes were driven into the bank to establish permanent cross-section endpoints. Using an electronic total station, a detailed profile of the cross-section was surveyed. Sediment particle size distributions at each cross section were documented using the cross section Wolman count procedure (Wolman, 1955) (Appendix B). Large roughness elements such as large woody debris and in-stream vegetation are virtually absent from the channel and so do not contribute to channel roughness in any meaningful way. Particle sizes ranges from sand (2mm) to very large boulders (1900mm), and the average particle size was large cobble (120mm). Three cross sections (11, 23 and 30) were re-surveyed following a significant flow event, but no changes were observed in cross section morphology. Only cross section 30 displayed any observable shift in grain size distribution, with a coarsening of both the D_{50} and D_{84} (Appendix B).

Using information from the surveys and particle counts, reach-averaged shear stress values (the stress exerted on the bed by flow) were calculated based on bankfull discharge conditions for each cross section and compared to critical shear stress values (the stress required for sediment mobilization). For each size of sediment grain, there is a minimum amount of force required to move a grain of that size – the critical shear stress

(Table 1). If reach-averaged shear stress values exceed critical shear stress values for the sediment grains in that reach, one could expect that sediment to mobilize and transport in the flow. However, the initiation of sediment transport in natural rivers is complex, particularly in rivers with a mixture of bed material grain sizes such as the Farmington River. In such situation, the larger grains on the bed will shield the smaller grains, preventing initiation of motion of most sediment until the larger particles start moving. Consequently, sediment transport estimates are usually based on the D_{84} particle grain size (the size which is larger than 84% of the sediment grains on the bed).

Based on these comparisons, a discharge of 4,000 cfs (bankfull discharge) should theoretically produce bed shear stresses capable of mobilizing all but the largest sediment grains found in the Farmington River (boulders greater than 1 m in diameter would require larger discharges for initiation of motion) (Table 2). At this discharge, the D_{84} critical shear stress is exceeded at each cross section.

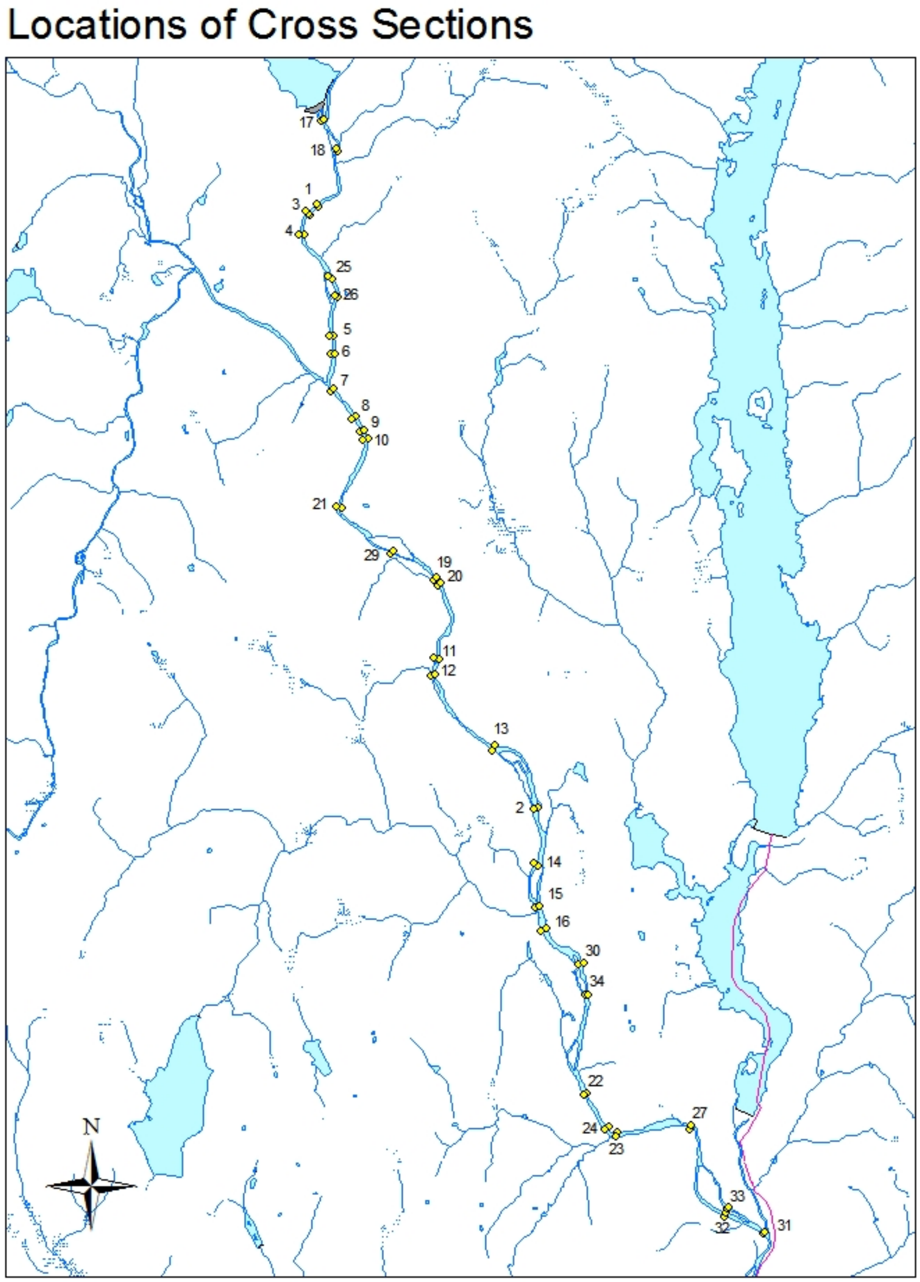

Figure 1. Locations of permanent surveyed cross sections, Farmington River Wild and Scenic Reach.

Table 1. Critical shear stresses required to transport grains of various size classes.

Sediment Size Class	**Diam (in)**	**Diam (mm)**	**Ctirical Shear Stress (N/m^2)**
Boulder	80	2032	167.63428
	40	1016	83.81714
	20	508	41.68446
	10	254	21.06634
Cobble	5	127	10.30906
	2.5	63.5	4.93042
Gravel	1.3	33.02	2.420388
	0.6	15.24	1.12055
	0.3	7.62	0.537864
	0.16	4.064	0.268932
	0.08	2.032	0.134466
Sand	0.04	1.016	0.044822
	0.02	0.508	0.0268932
	0.01	0.254	0.0179288

Table 2. Measured grain size and estimated bankfull shear stresses at each cross section.

Cross Section	D_{50} (mm)	D_{84} (mm)	Bankfull Shear Stress (N/m^2) (Q~4,000 cfs)
1	45	128	68.67
2	90	180	39.24
3	90	200	41.202
4	180	230	45.126
5	128	200	54.936
6	128	250	33.354
7	128	180	23.544
8	64	128	25.506
9	32	128	31.392
10	90	330	33.354
11	128	200	15.696
12	90	180	27.468
13	45	180	27.468
14	128	180	15.696
15	90	128	19.62
16	45	180	37.278
17	45	90	58.86
18	128	300	23.544
19	32	128	33.354
20	90	230	19.62
21	64	180	13.734
22	128	250	33.354
23	90	180	19.62
24	45	90	66.708
25	128	470	78.48
26	180	520	76.518
27	45	128	17.658
28	90	180	62.784
29	128	220	41.202
30	64	128	37.278
31	64	180	29.43
32	64	128	31.392
33	45	90	48.6576

Interpretation and Recommendations

The above results must be interpreted within the broader geomorphic context of the Farmington River system. Despite the above discharge estimate to produce sediment transport, this river has experienced discharges greatly exceeding 4,000 cfs with no significant observed sediment transport. In fact, a study (Wolman and Eiler, 1958) of the Farmington River after the 1955 flood event (57,000 cfs peak flow, up to 18ft deep floodplain inundation) indicated very little morphologic change – with the notable exception of scour at a USGS cross-section located at a bridge. It seems clear that the bridge served to constrict flow and locally increase bed shear stresses enough to induce scour – a condition that was not met in the remainder of the channel despite the magnitude of the flow.

All indications are that the Farmington River is in a geomorphically “locked” or “armored” condition characterized by very little sediment transport and virtually no channel adjustment. This is supported by the lack of evidence of normal bank erosion caused by channel migration, the lack of over-bank flood deposits, the absence of in-channel sediment bars, and the presence of mature vegetation on channel islands.

The sediment regime of the Farmington River is constrained by two main factors. Firstly, the surficial geology of the watershed is not a great supplier of sediment to stream channels. Soils have high infiltration capacity and are well vegetated. As a result, even during the most extreme rainfall events, severe sheetwash erosion and gullying are extremely rare if present at all in upland areas of Connecticut (Wolman and Eiler, 1958). This results in essentially no hillslope contribution of sediment to stream channels. While small tributaries with steeper channel slopes do move sediment during large events, this material is deposited at the first break in slope usually located on terraces well away from the main Farmington River channel. So, what sediment is generated in uplands stream channels does not transport to the main channel. Secondly, several dams disrupt sediment transport continuity on the river.

In light of this context, the ability of any reasonable prescribed dam release to induce scour and deepen existing pools is doubtful given the armored nature of the bed material and the stability of the channel morphology. The only way to induce scour in such a situation is to create local areas of flow constriction and increased bed shear stress that mimic natural features such as bedrock constrictions. Bend-way weirs are an example of an engineered structure that may produce conditions required for pool scour. These structures are typically used to protect channel banks from erosion, and they function by deflecting flow away from the toe of banks towards the center of the channel, thereby protecting the bank from erosive shear stresses. A secondary effect of these structures is that they often increase shear stresses at their tips, causing localized scour. Features such as these could be installed in an attempt to locally produce scour during prescribed bankfull flushing flows, however, an engineering study should be conducted to determine the likelihood of stability of the weir and the potential for scour during bankfull flow conditions.

DETAILED HABITAT ASSESSMENT

The purpose of this study is to provide managers with an understanding of what potentially may be “missing” in the river in terms of important habitats (e.g. deep pools for summer heat stress/low flow survival of fish).

Description and Distribution of Hydro-Geomorphologic Mesohabitats

Hydro-geomorphic habitat units (HMU’s) were surveyed during low flow periods (Q=80-250 CFS) and classified according to their relative depths and velocities. While these units are classified according to the dominant hydrology and morphology in the reach, it is important to note that micro-scale variation is always present in HMU’s. Four basic HMU types were identified: run, pool, riffle and confluence (Figures 1a-d). Relative pool and run HMU velocity differences were remarkable consistent within the study reach, with pools displaying mean cross-sections velocities of approximately 50% of run velocities. Riffles were more variable, with mean cross-section velocities ranging from 75%-100% of runs. Several HMU’s displayed characteristics of more than one HMU type. For example, some of the runs on the Farmington are deeper than others, yet maintain faster mean velocities than the pools, so they are identified in this report as deep runs. If large boulders were a dominant feature in a habitat unit, the name of that unit is modified as such (e.g. boulder riffle).

The confluence with the Still River is a unique habitat unit in the study reach. The joining of the two river flows produces an area of unusually high micro-variability in the river channel. Where the two flows join, there is a zone of high velocity turbulent mixing, likely overlying a deep scour pool (impossible to measure due to the turbulent water conditions), but there is also a large deep slow velocity pool immediately adjacent to the mixing zone where the channel is confined by a bedrock exposure.

The morphologic habitat distribution within the Farmington River is not dissimilar to that of many other Connecticut rivers and streams flowing over large-grained glacial tills. The riffle-pool-run mixture of habitat types appears to be the regional norm in non-alluvial valleys in New England. However, the study reach is lacking in general pool habitat area, with deep, slow pools particularly rare. While many of the runs are deep (deep runs, Figures 2a-2d), these habitat units do not provide the same habitat value as deep scour pools. In particular, the velocities measured in the deep runs are still quite fast compared to pool velocities, indicating that the energy environment for fishes is not analogous to the condition in pools.

The lack of deep scour pools is most likely linked to the lack of in-channel mechanisms to locally increase bed-shear stresses, such as large obstacles or constrictions to flow, and cause scour into the armored bed material. Other research on New England streams has shown that many deep pools are not freely formed (as part of a pool-riffle sequence), but are “forced’ pools caused by a localized bedrock constriction or other obstruction to flow.

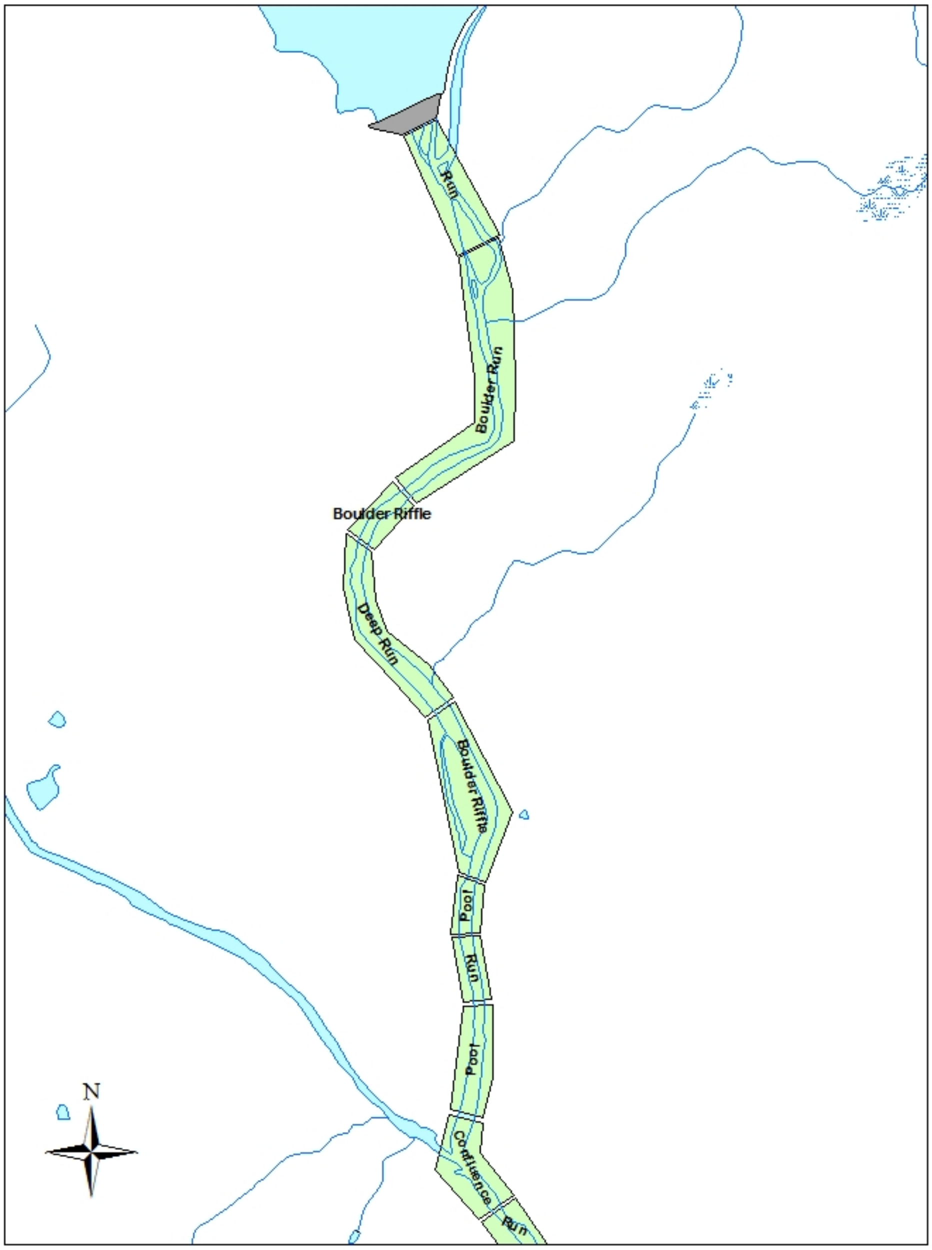

Figure 2a. Hydro-geomorphic habitat units identified in the Farmington River.

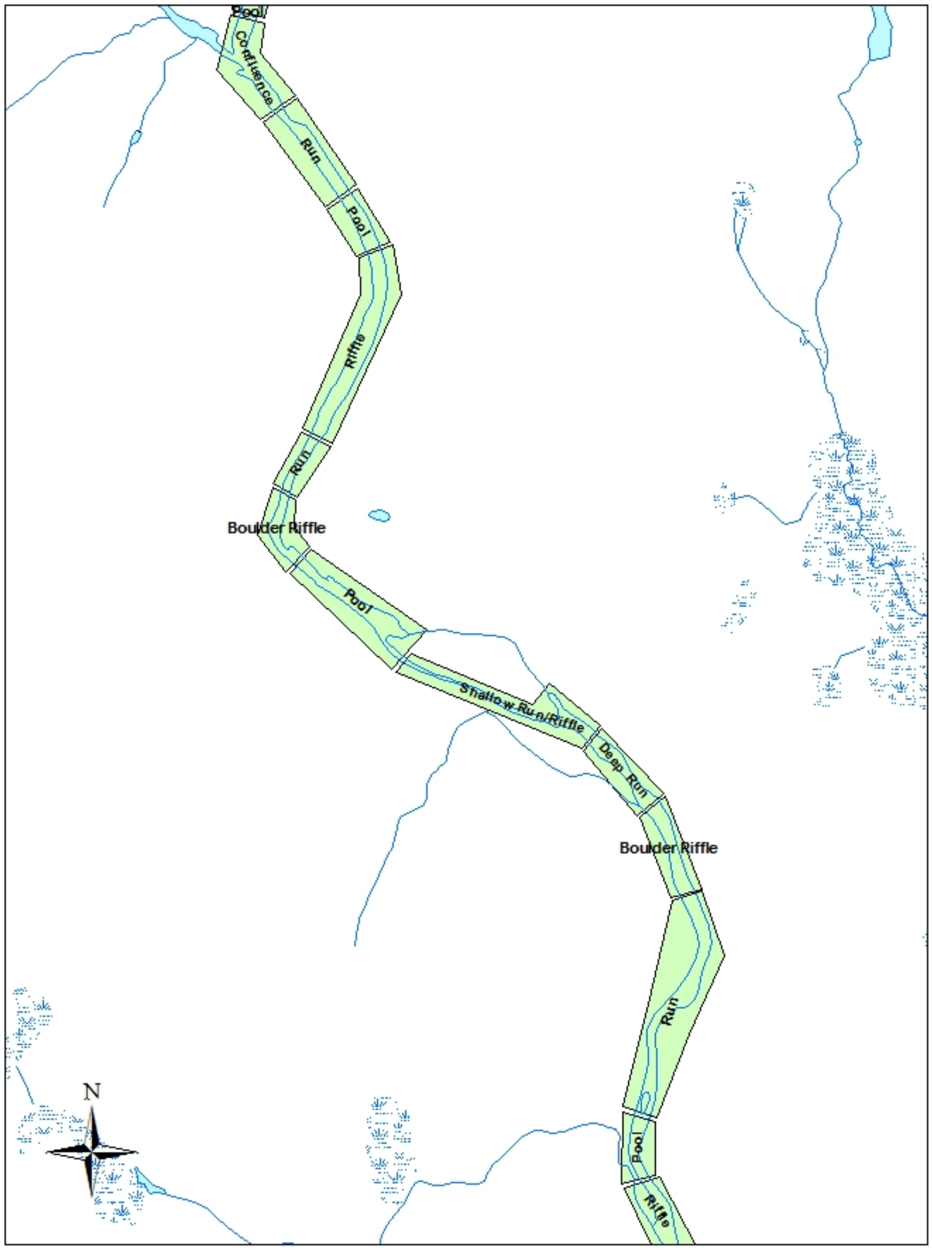

Figure 2b. Hydro-geomorphic habitat units identified in the Farmington River, continued.

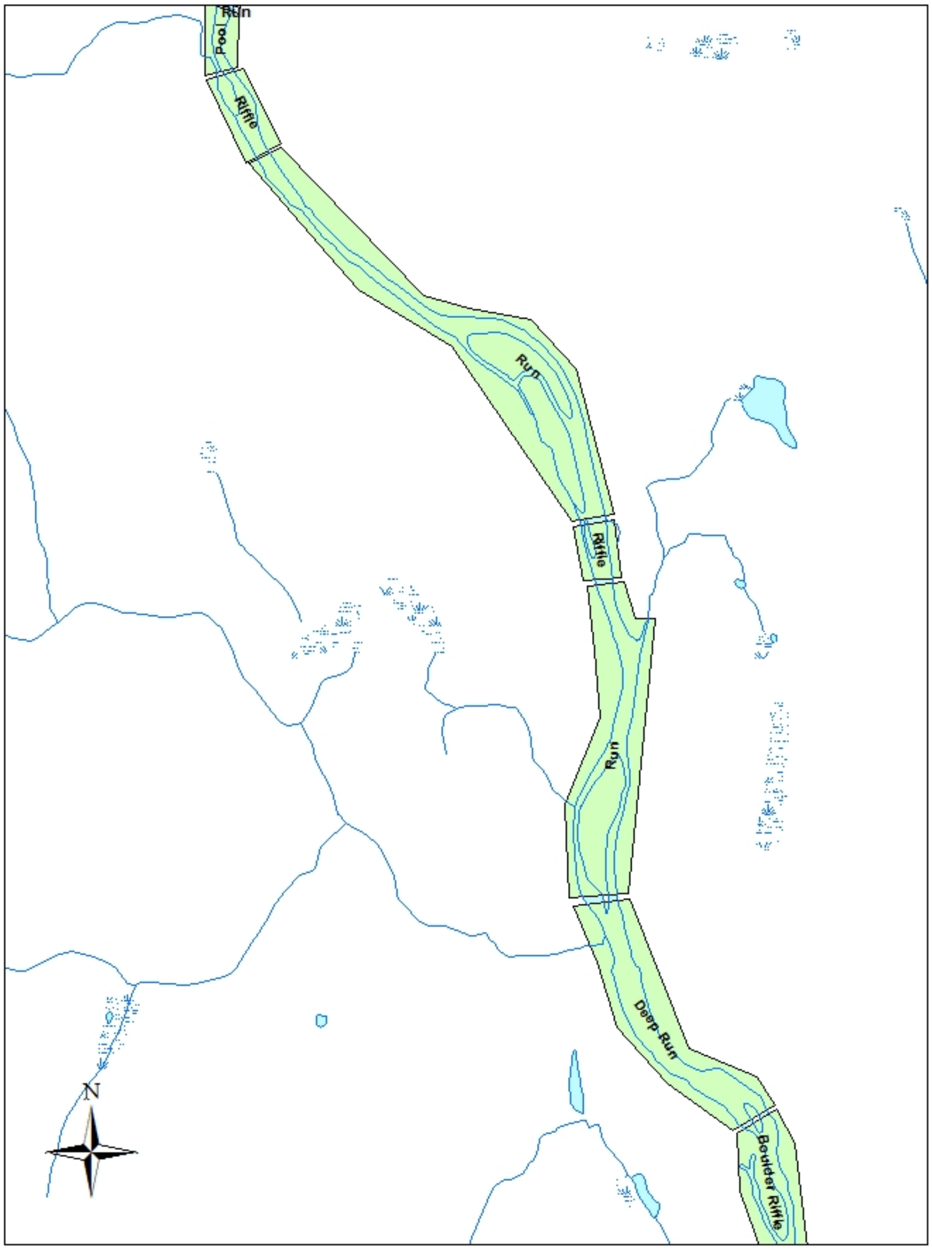

Figure 2c. Hydro-geomorphic habitat units identified in the Farmington River, continued.

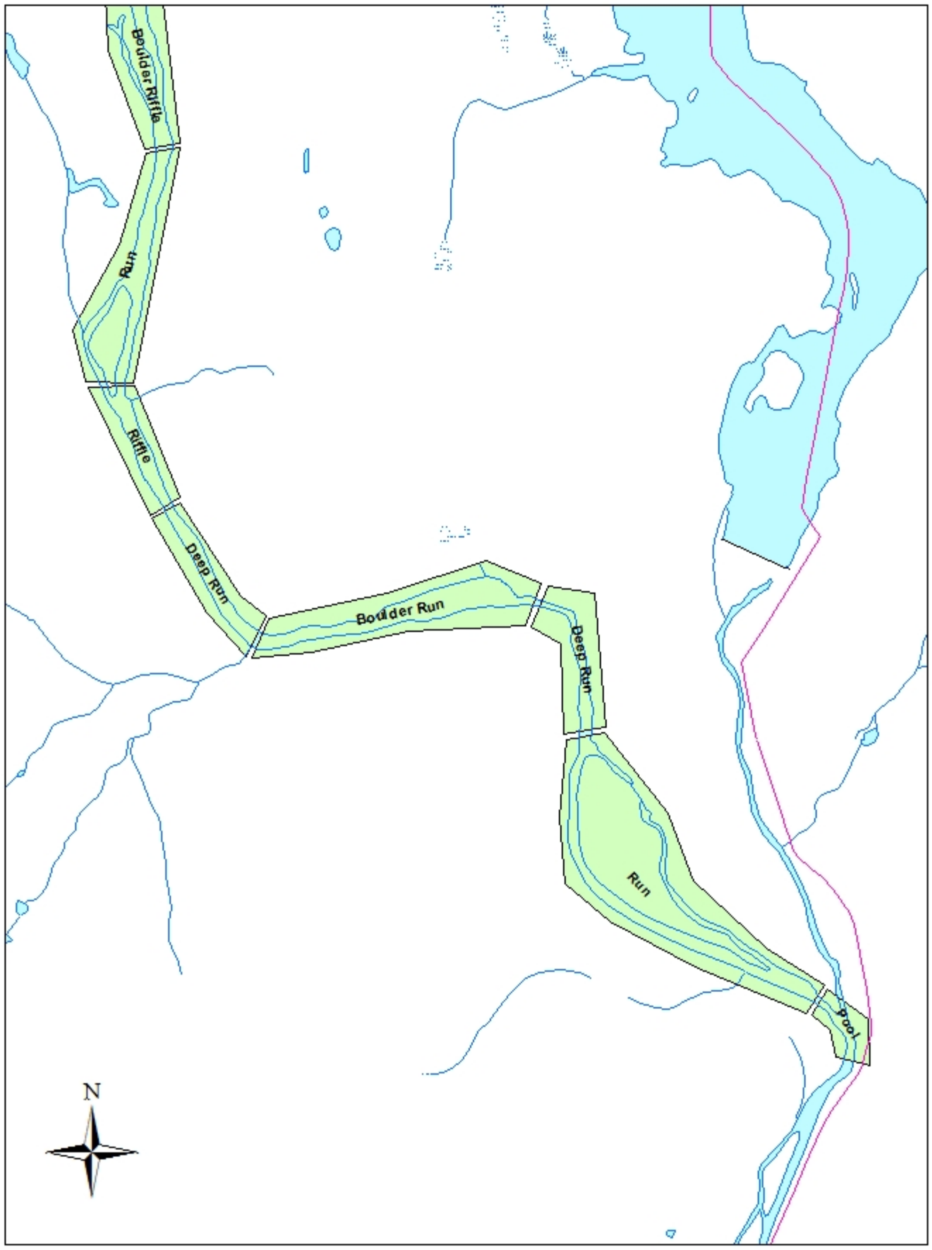

Figure d. Hydro-geomorphic habitat units identified in the Farmington River, continued.

Cover Habitat Assessment

The Farmington River is severely lacking in cover habitat features such as large woody debris (LWD) accumulations. Thirty-two distinct accumulations of large wood were identified during a low-flow examination of the study reach, the locations of which are illustrated in Figure 3. Large wood accumulations were predominately comprised of single logs with little or no other accumulated organic debris. Single-log type features do provide some cover, but greater benefit is provided by large accumulations of multiple logs and smaller associated debris.

The current condition is due to a lack of LWD delivery to the study reach from riparian and upstream sources. The riparian forest is not yet mature to the point where natural senescence of trees would produce tree-fall into the channel or near-channel environment. The channel planform is very stable, and so channel migration related bank erosion cannot recruit pre-senescent trees into the channel environment. Even if the riparian forest were senescent, over-bank flooding, which could recruit wood from riparian forest floors, is prevented through flow regulation.

Attempts by the DEP to introduce LWD by felling and cableing trees to the bank have met with mixed results. Initially, these installations were successful in providing cover and attracting fish, but the high flow event in Spring of 2007 pivoted and re-set these structures parallel to the bank, limiting their cover function. This is a common problem associated with cabled LWD placements, but alternative options are equally problematic.

One alternative would to be place LWD freely (no cables) in the channel and accept that LWD transport is likely to occur. The advantage of this strategy is that, while the LWD will transit downstream with sufficient flows, at least the LWD will remain in the active channel system. The spatial habitat benefit provided by the LWD will simply shift through time. Disadvantages include: a lack of control over LWD positioning once the first transport occurs, potential accumulations of LWD at bridges or other channel constrictions, and the need to "re-stock" the LWD supply as pieces transit out of the target reach over time.

Another alternative would be to construct more heavily engineered structures, such as log cribs (a series of logs arranged at right angles to one another and cabled together as well as to the bank) that could be more extensively cabled in place. Whole trees can also be harvested and dug into the stream bank with the root-wad end extending into the flow, but this approach required extensive heavy machinery and disturbance of the now very stable stream banks. Disadvantages to these approaches include unnatural appearance, increased cost, and risk of causing bank instability during construction.

Finally, the lack of LWD cover habitat in the Farmington River may be offset to some extent by the numerous large boulders present in the channel, which do provide some cover habitat function but in very small, distributed patches. For example, boulders in habitat units classified as "Boulder Runs" most likely provide meaningful rest habitat for fish seeking low-energy expenditure sites in relatively high velocity reaches.

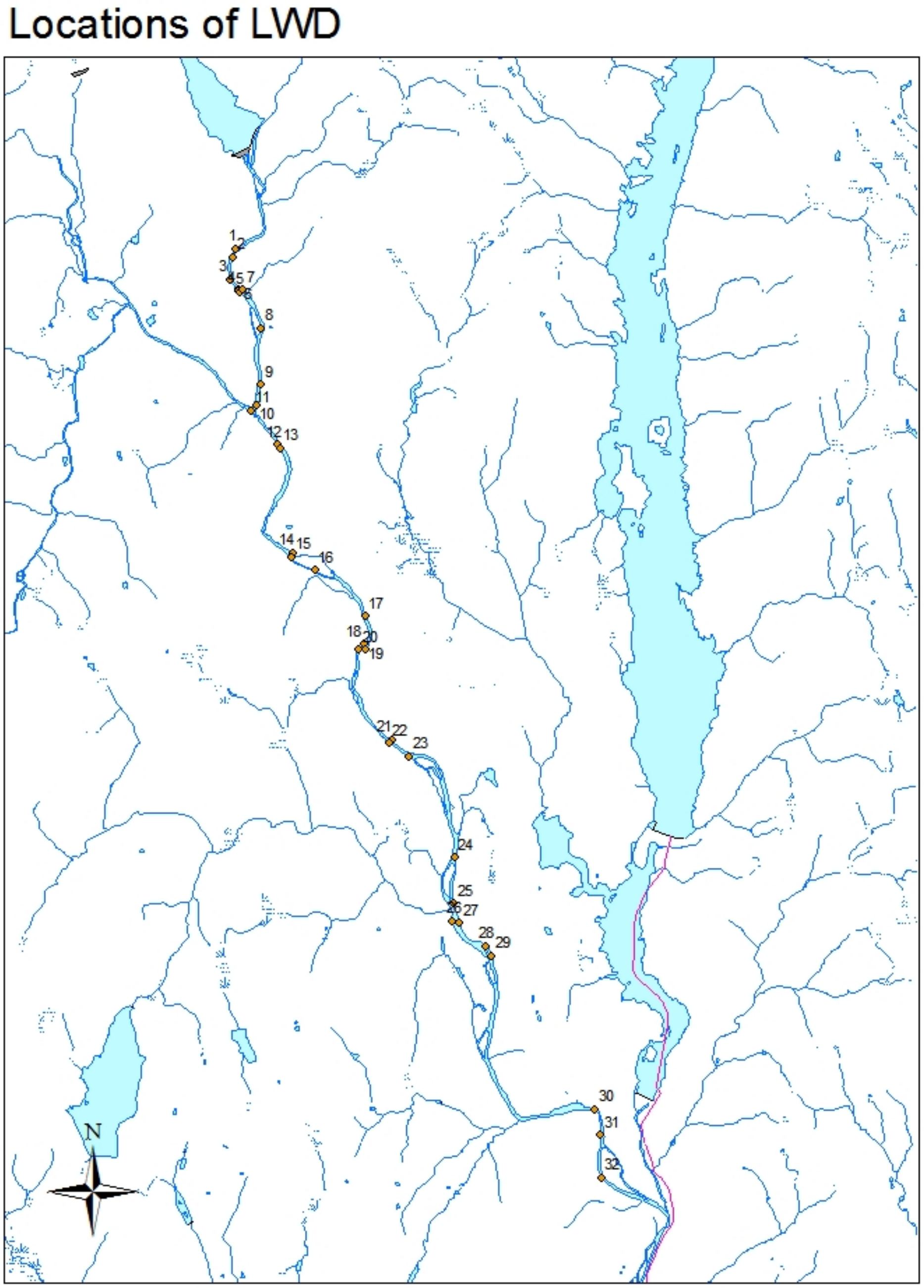

Figure 3. Locations of large woody debris pieces, Farmington River Wild and Scenic Reach.

Table 3. Description of large woody debris pieces in the study reach.

LWD ID	DESCRIPTION	ACCUMULATION
1	single trunk	some small
2	1 trunk w/ limbs	some branches
3	split trunk, some decay	leaves, branches
4	1 trunk w/branches	Minimal
5	1 trunk submerged	None
6	double trunk, rotting	None
7	1 rotting trunk	None
8	single rotting trunk	large limbs
9	installed trunk	None
10	large trunk	Some
11	trunk	None
12	single trunk w/branches	Some
13	living tree	None
14	multiple trunks	Moderate
15	multiple trunks at abutment	leaves, twigs
16	2 trunks w/decay	None
17	4 trunks	None
18	1 trunk	smaller debris
19	multiple trunks up against trees on bank of pool	Debris
20	1 trunk	None
21	single trunk	very little
22	3 long trunks	some debris
23	multiple large trunks	some small
24	multiple mid-size trunks, spread out in pool	submerged debris
25	1 trunk	other debris
26	2 trunks	some smaller limbs
27	1 trunk, left island	Logs
28	installed multi-trunk assembly	None
29	trunks/debris downstream of beaver lodges	None
30	1 large and several small trunks, spread along bank	submerged debris
31	2 trunks	Some
32	double trunk	many logs, limbs

APPENDIX A

CROSS SECTION PROFILES

APPENDIX B

PARTICLE SIZE DISTRIBUTIONS AT CROSS SECTIONS

Reported in phi size classes

Millimeters	Phi
512	-9
256	-8
64	-7
32	-6
16	-5
8	-4
4	-3
2	-2
1	-1