Chapter 4: Trout Brook in Cape Elizabeth and South Portland

Headwaters
(October 2003)

Wetland Station (W-093)
(June 2003)

Late Upstream Station (S675)
(September 2003)

Downstream Station (S302)
(June 2003)

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STREAM DESCRIPTION

Trout Brook, one of the four Urban Streams[1] in the Urban Streams Project, is located in Cape Elizabeth and South Portland in southern Maine (Fig. 1 in Ch. 1), and is of moderate length (~2.5 miles) and watershed size (~1,700 acres, Fig. 1). The stream originates in a woodland west of Spurwink Avenue near Valley Road; from there Trout Brook flows northward through a vegetable farm, a former wetland (where a number of drainage ditches flow into the stream), and a dense residential area before flowing into Mill Cove, the estuarine Fore River, Portland Harbor and Casco Bay. There are three tributaries to Trout Brook: the most upstream one enters the stream near the headwaters, the middle one enters it just upstream of Mayberry Street, and the most downstream one, Kimball Brook, enters Trout Brook immediately below the Highland Avenue culvert. The outline of the watershed as shown in Fig. 1 is based on information received from the City of South Portland (P. Cloutier, pers. comm.[2]), on 10 m contour lines, and actual stormwater drainage systems. In terms of water quality requirements, the Maine legislature designated the Cape Elizabeth section of Trout Brook (headwaters to dense residential area including upstream tributary) as statutory Class B, while the South Portland section (dense residential area to Mill Cove, middle tributary and Kimball Brook) is designated as Class C (see Ch. 1, Introduction).

The Maine Department of Environmental Protection (MDEP) Biological Monitoring Program has been studying four stations on Trout Brook since 1997 (Fig. 1). The downstream station just above the Highland Avenue road crossing, S302, and the middle station, S454, at the end of Mayberry Street (only studied in 2000), are both located in the lower third of the watershed (Fig. 1). The newly (2003) established upstream station, S675, ~100 m above Boothby Avenue, is located in the lower half of the watershed. The wetland station, W-093, ~400 m above Sawyer Street, is located approximately in the middle of the watershed. All stations receive runoff from the surrounding, largely residential area. They also experience effects of the upstream wetland area and the vegetable farm in the upper part of the watershed. All stations are furthermore influenced by a significant input of spring water just above the upstream station. During baseflow conditions in the summer of 2003, the upstream and downstream stations had a wetted width of 2.3 – 3.5 m, and a water depth of 4 – 8 cm with a flow velocity of 10 – 16 cm/s. Channel width at the two stations was 7.0 and 2.5 m, respectively, reflecting an overwidened channel structure at the upstream station. During summer baseflow conditions in 2000, the middle station had a wetted and channel width of ~2 m, and a water depth of ~15 cm with a flow velocity of 12 cm/s. The substrate at the upstream and downstream stations was dominated by rubble (40-45 %) with some gravel (20-25 %), sand (20-35), and some boulders (5-10 %) while the middle station was dominated by gravel (50 %) with some rubble (30 %) and sand (20 %). Trout Brook's surficial geology type is the "Presumpscot formation" which in this watershed is characterized by silts and clay with some sand; this suggests that any fine sediment observed in the stream is partly natural in origin. The riparian zone near the upstream station consists of trees and understory plants and is fairly undisturbed (width >10 m). Near the middle and downstream stations, some of the riparian buffer has been replaced with lawns and invasive plants such as Japanese Knotweed (*Polygonum cuspidatum*).

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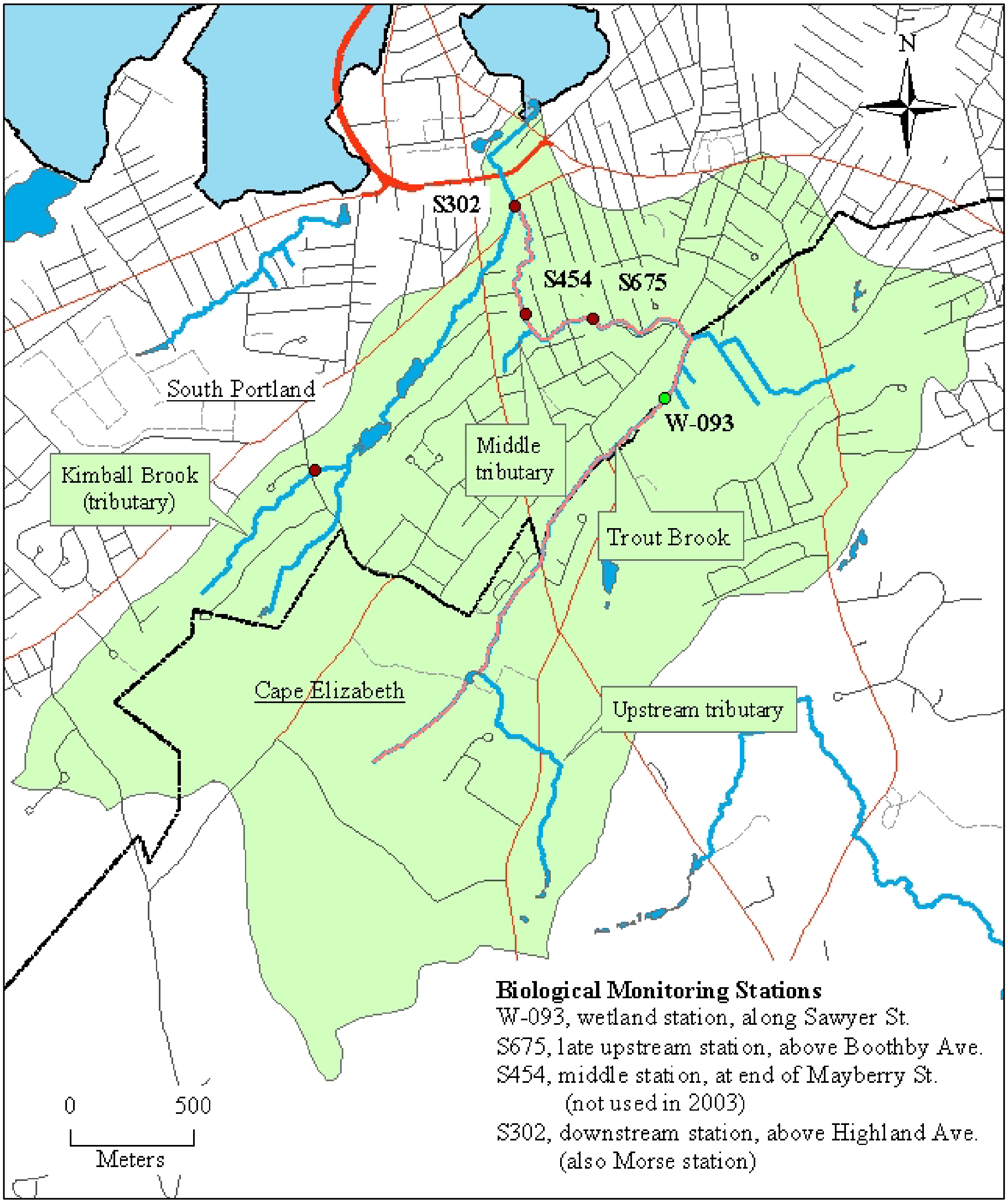
[1] Note that "Urban Streams" refers to the four streams included in this study, not to the universe of "urban streams" in Maine or elsewhere.

[2] Information on persons providing personal communications is given in the References

Most of the watershed is impacted by development (i.e., low/high intensity residential and dense residential development: 53 %; urban/industrial and commercial-industrial-transportation development: 7 %), resulting in a moderate percentage of the watershed being covered by impervious surfaces (13 %; calculated using the method shown in MDEP 2001b). Other landuse types are forests (26 %), grassland/crops/shrub-scrub (8 %),and wetlands (5 %). As a result of the elevated imperviousness, most of Trout Brook is affected by a variety of urban stressors typically associated with residential development and an extensive road system. Data collected by the MDEP Biological Monitoring Program in 1997 and 2000 at one station (S302), and in 2000 at a second station located further upstream (S454; Fig. 1), indicated that both stations had a degraded macroinvertebrate community that violated the Class C aquatic life criteria. In 1999, the downstream met Class C criteria. In addition, Morse (2001; see Previous studies, below) found habitat degradation and impaired macroinvertebrate communities in Trout Brook. Because of the aquatic life violations found in 1997 and 2000, the stream is scheduled for Total Maximum Daily Load (TMDL; see Ch. 1, Introduction, MDEP Urban Streams Project) development based on the data gathered in the Urban Streams Project.

This report presents the data available as of December 2004, and puts them into the context of overall stream health. Information contained in this report will form the basis for the development of a stream-specific Total Maximum Daily Load (TMDL; see Ch. 1, Introduction, MDEP Urban Streams Project) plan in 2005. The MDEP Biological Monitoring Program again monitored the macroinvertebrate community at the downstream and late upstream stations in Trout Brook in the summer of 2004; further sampling events may occur in future years depending on developments in the watershed, funding availability, and program needs.

Fig. 1. Trout Brook, Cape Elizabeth and South Portland. Watershed is shown in green, impaired segment in pink, town line in black.



PREVIOUS STUDIES

MDEP Biological Monitoring Program

The Biological Monitoring Program of the MDEP's Bureau of Land and Water Quality (BLWQ) collected macroinvertebrate data in the summers of 1997, 1999, and 2000 at the downstream station (S302), and in 2000 at the middle station (S454, Fig. 1). Sample collection and processing methods are detailed in App. A i, and briefly described in Ch. 2, Methods, Biological Monitoring, item 1. Macroinvertebrate samples were identified by either Lotic, Inc (Unity, ME; 1997, 2000) or Freshwater Benthic Services (Petosky, MI; 1999). The MDEP analyzed taxonomic data using a statistical model which assigned samples to one of three State of Maine water quality classes (A[1], B, or C) or to a Non-Attainment category. Analysis results were reported in the MDEP's Surface Water Ambient Toxics (SWAT) Monitoring Program technical reports (MDEP 2000, 2001a, 2002a).

Model results indicated that in 1997 and 2000, macroinvertebrates at the downstream station did not meet Class C aquatic life criteria with the dominant organisms consisting of tolerant crustaceans (predominantly amphipods, few isopods) and few chironomids (midge larvae; Table 1). In 1999, macroinvertebrates met Class C aquatic life criteria as amphipods made up a smaller proportion of the sample and some Ephemeroptera (mayflies) were found. In all years, an intermediate number of organisms was present (486 – 628, Table 1). A good general indicator of the quality of a macroinvertebrate community is the percentage of non-insects in a sample, as this increases with decreasing water quality. The percentage of non-insects at the downstream station was very high in all sampling years, namely 94, 76 and 98 % in 1997, 1999, and 2000, respectively. Water quality data collected at this station indicated adequate dissolved oxygen concentrations (7.1, 8.7, and 9.2 mg/L), high conductivity levels (792, 832 and 695 μS/cm), and low water temperatures (13.0, 15.0, and 14.6 ºC). Continuous water temperature data collected August 13 to September 8, 1997 (measurements taken every 5 min), and August 1 to 30, 2000 (measurements taken every 15 min) showed that daily mean temperatures were low, i.e., favorable for healthy macroinvertebrate communities. Daily maximum temperatures were slightly higher but still below 20 ºC (Figs. 2 and 3). Water chemistry sampling in 2000 (Table 2) showed that Total Nitrogen was the only parameter to exceed available Water Quality Criteria.

For the middle station, model results indicated that macroinvertebrates did not meet Class C aquatic life criteria in the single sampling year (2000) with the dominant organisms consisting of tolerant crustaceans (amphipods) and a few worms (oligochaetes) (Table 1). The number of organisms found was intermediate (387) while the percentage of non-insects was very high (82 %). No dissolved oxygen data are available, but the conductivity level was high (693 μS/cm) and water temperature low (14.4 ºC). Continuous water temperature data collected August 1 to 30, 2000 (measurements taken every 15 min) were very similar to those recorded at the downstream station (Fig. 3). No water chemistry parameters were sampled at this station.

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[1] For the purposes of the statistical model, State of Maine water quality classes AA and A are combined.

Table 1. Summary version of 1997, 1999, and 2000 macroinvertebrate model reports

Model variable	**Downstream (S302)**			**Middle (S454)**
	1997	**1999**	**2000**	**2000**
Total abundance of individuals	628	487	603	387
Generic richness	14	31	8	33
Plecoptera / Ephemeroptera abundance	0 / 0	1.3 / 14.7	0 / 0	0 / 0
Shannon-Wiener diversity index	0.63	2.03	0.23	2.52
Hilsenhoff biotic index	4.07	4.22	4.03	4.24
Relative abundance Chironomidae	0.03	0.07	0.01	0.11
EPT[1] generic richness	5	12	2	6
EP[1] generic richness/14	0	0.36	0	0
Presence of Class A indicator taxa/7	0.14	0.43	0	0.14
Five dominant taxa (%)	*Gammarus* (92) *Tvetenia* (3) *Caecidotea* (2) *Diplectrona* (2) *Hydropsyche* (1)	*Gammarus* (70) *Hydropsyche* (9) *Caecidotea* (4) *Cricotopus* (2) *Rheotanytarsus* (1)	*Gammarus* (97) *Caecidotea* (1) *Tanytarsus* (1) *Rhyacophila* (<1) *Hydatophylax* (<1)	*Gammarus* (51) *Tubifex* (20) *Limnodrilus* (9) *Tvetenia* (4) *Simulium* (3)
Model outcome (%)	NA (100)	Class C (BPJ[2])	NA (100)	NA (100)

[1] EPT are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EP are Ephemeroptera and Plecoptera.

[2] BPJ, Best Professional Judgment indicates that the model outcome was adjusted (in this case from a "B" to a "C") based on data interpretation by a professional MDEP biologist.

Fig. 2. Continuous water temperature at downstream station in 1997

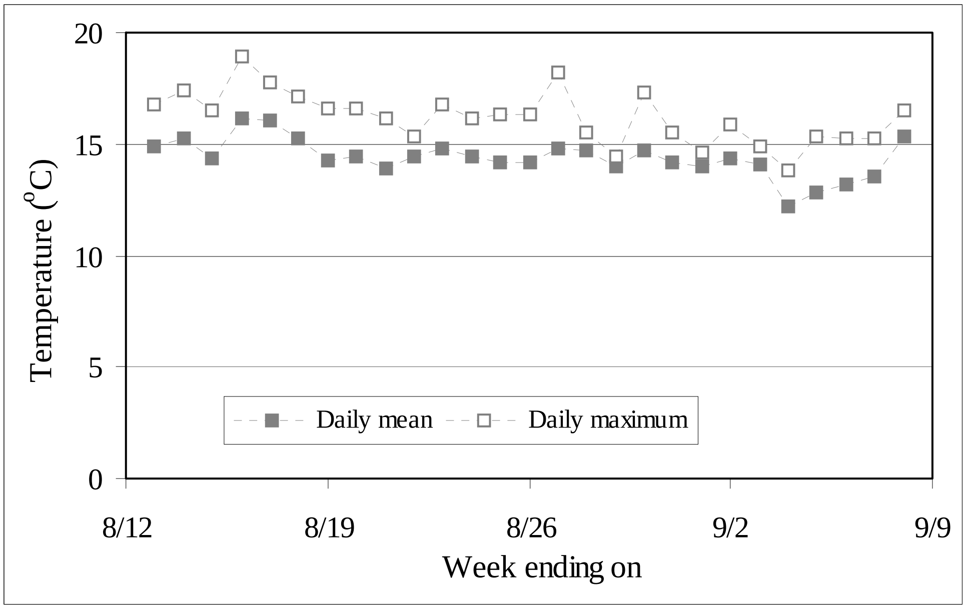

Fig. 3. Continuous water temperature at downstream and middle stations in 2000

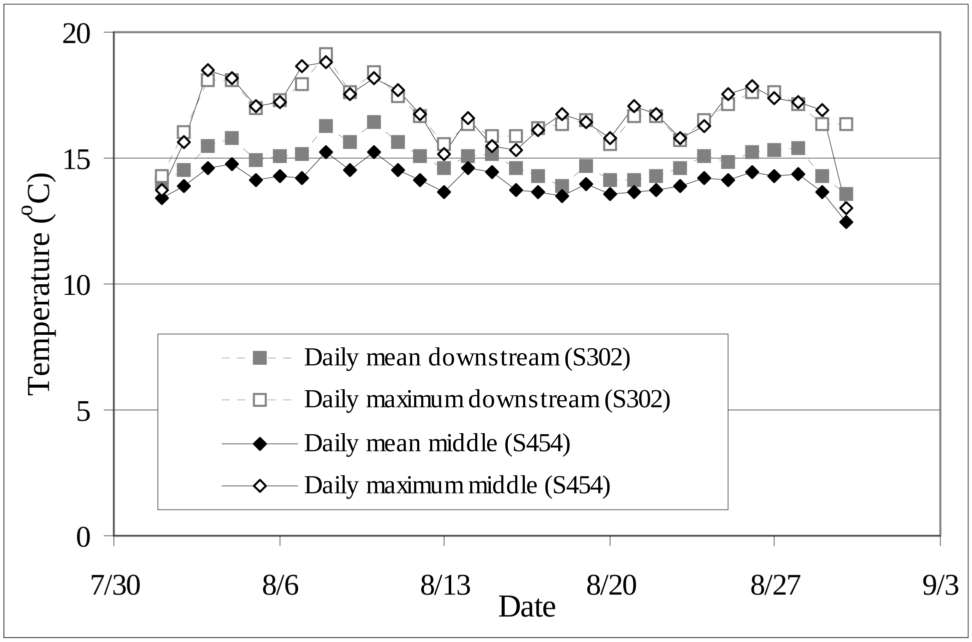

Table 2. Water chemistry data for downstream station from summer 2000. Highlighted field indicates problem parameter.

Parameters (unit)	**Downstream (302)**	**Water Quality Criteria**	
Nutrients (mg/L)			
Ammonia-Nitrogen	0.05	NC	
Nitrate-Nitrite-N	0.6	NC	
Total Nitrogen	0.77	0.71[1]	
Total Phosphorus	0.017	0.031[1]	
Dissolved Organic Carbon	1.7	NC	
Total Suspended Solids	1.8	NC	
Metals (µg/L)		**CMC**[2]	**CCC**[2]
Cadmium	ND 0.05	0.64	0.32
Chromium	ND 0.5	16	11
Iron	432	NC	1,000
Lead	ND 0.5	10.52	0.41
Zinc	3.41	29.9	27.1

NC, No Criteria; ND, Not Detected, i.e., below stated detection limit of test.

[1] Criteria recommended by EPA for Ecoregion XIV, which includes Trout Brook.

[2] CMC and CCC are types of Maine Statewide Water Quality Criteria (SWQC; MDEP SWQC). CMC (Criteria Maximum Concentration) and CCC (Criteria Continuous Concentration) denote the level of pollutants above which aquatic life may show negative effects following brief (acute) or indefinite (chronic) exposure, respectively.

University of Maine study

Chandler Morse, a graduate student at the University of Maine in Orono, studied one station on Trout Brook, namely the MDEP downstream station, in the summer and fall of 1998, and spring of 1999 (S302, Fig. 1; Morse 2001). Like the MDEP biomonitoring studies, Morse also found that the macroinvertebrate community in Trout Brook was degraded: taxa richness was low (18 taxa in both fall of 1998 and spring of 1999), and there were no Ephemeroptera[1] (mayflies) or Plecoptera (stoneflies) taxa, and only few (6) Trichoptera (caddisflies) taxa . The density of organisms per sample was intermediate (~284 and 365). Summer water temperature, predawn DO concentrations, and pH were good, and nutrient levels were quite low, but conductivity (SPC) was elevated in fall and spring (Table 3). According to Morse's analysis, landuse types in the watershed of Trout Brook were predominantly urban (47 %), with a significant amount of forests (33 %), and some wetlands and agriculture (11 and 7 %, respectively; from Fig. 6 in Morse 2001). A qualitative habitat survey, which integrated 10 different metrics indicating habitat quality, resulted in a Marginal ranking (110, range is 60 – 119; ranking categories are Poor, Marginal, Suboptimal, Optimal; overall worst/best score is 0/240). A Stream Reach Inventory and Channel Stability Index assessment, which integrated 15 metrics and evaluated the channel for instability and erosion/deposition, resulted in a Fair ranking (95, range is 77 – 114; ranking categories are Excellent, Good, Fair, Poor; overall best/worst score is 33/162). Morse's conclusion from his study was that Trout Brook, like other urban streams he studied with >6 % impervious surfaces (including Barberry Creek and Birch Stream), showed a variety of impacts related to urban development, mainly declining habitat quality and decreased diversity of macroinvertebrate taxa (Morse 2001).

Table 3. Morse (2001) data. Highlighted field indicate problem parameter.

Parameter	**Summer 1998**	**Fall 1998**	**Spring 1999**
Water temperature (ºC)	15.4	4.6	7.5
DO, predawn (mg/L)	9.1	12.4	11.9
pH	7.7	7.3	7.9
Specific conductance (SPC; µS/cm)	217	455	577
NO_3-Nitrogen (mg/L)	0.199	0.429	0.27
Total Phosphorus (mg/L)	0.010	0.006	0.005
Total Suspended Solids (mg/L)	3.2	3.8	4.3

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[1] Ephemeroptera, Plecoptera, and Trichoptera are often collectively referred to as EPT taxa.

RESULTS OF 2003 STUDY

Biological Monitoring

1. Macroinvertebrate samples collected from rock bags in August (downstream) and September (late upstream[1]) after an exposure period of four weeks in the stream showed that both stations failed to meet Class C aquatic life criteria (Table 4; full model outputs for the 2003 sampling events are shown in App. B ii). Both stations had degraded communities with a reduced generic richness, scarcity of sensitive taxa, predominance of tolerant organisms (crustaceans, midge larvae), low to intermediate diversity index, and an intermediate to high Hilsenhoff biotic index, resulting in a model outcome of "Non-Attainment" for both stations. Compared to the late upstream station, the following community attributes are noteworthy at the downstream station: the large dominance of the amphipod *Gammarus*; the occurrence of the MDEP Class A indicator *Glossosoma* and six additional Trichoptera genera (some sensitive); and the extremely high percentage of non-insects (80 % *versus* 17 %). Analysis results were reported in the MDEP's 2002-2003 SWAT Monitoring Program technical report (MDEP 2004c).

Table 4. Summary version of 2003 macroinvertebrate model reports

Model variable	**Downstream (S302)**	**Late upstream (S675)**
Total abundance of individuals	208	477
Generic richness	29	38
Plecoptera / Ephemeroptera abundance	0 / 0	0 / 0
Shannon-Wiener diversity index	1.97	3.42
Hilsenhoff biotic index	4.27	6.40
Relative abundance Chironomidae	0.06	0.73
EPT[1] generic richness	7	1
EP[1] generic richness/14	0	0
Presence of Class A indicator taxa/7	0.14	0
Five dominant taxa (%)	*Gammarus* (70) *Dubiraphia* (7) *Caecidotea* (5) *Glossosoma* (4) *Tvetenia* (2)	*Tanytarsus* (33) *Micropsectra* (20) *Rheotanytarsus* (7) *Caecidotea* (7) *Dubiraphia* (6)
Model outcome (%)	NA (100)	NA (100)

[1] EPT are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EP are Ephemeroptera and Plecoptera.

2. The fish assemblage at the downstream station was investigated on June 19, and consisted of 23 brook trout (*Salvelinus fontinalis*; 2-12") including 4 young-of-the-year, and 19 American eels (*Anguilla rostrata*; 3-20" in length). Fish were not investigated at the upstream station.

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[1] The new station (S675) was initially established in a section of stream that began to dry out in early July. To avoid sampling problems, the station was moved ~50 m downstream in mid-July. In the Results of 2003 Study section in this chapter, data from the upstream station are graphed and discussed in terms of "early" and "late" to indicate this downstream shift in sampling location.

3. The algae sample collected on July 9 from the stream bottom ~40 m above the downstream station has not yet been analyzed for species composition and abundance. A visual assessment of the site showed a sand and gravel substrate with a small amount of algae growing on available rocks. Aquatic plant biomass was low, with the dominant type of aquatic vegetation (rooted submergent, especially *Vallisneria*) covering only ~2% of the stream reach assessed. A similar situation was found on July 6, 2004.

4. The algae samples (epiphytic algae, phytoplankton) collected on June 12 at the wetland station ~400 m above Sawyer Street have not yet been analyzed for species composition and abundance. Dominant macropytes at this station were grasses and water lilies (*Nuphar*). The macroinvertebrate samples showed a low abundance (38 organisms), an intermediate generic richness (31), a predominance of tolerant organisms (chironomids, oligochaetes) and few sensitive organisms [1 *Paraleptophlebia* (mayflie), 1 *Enallagma* (dragonfly), 2 Limnephilidae (caddisflies)].

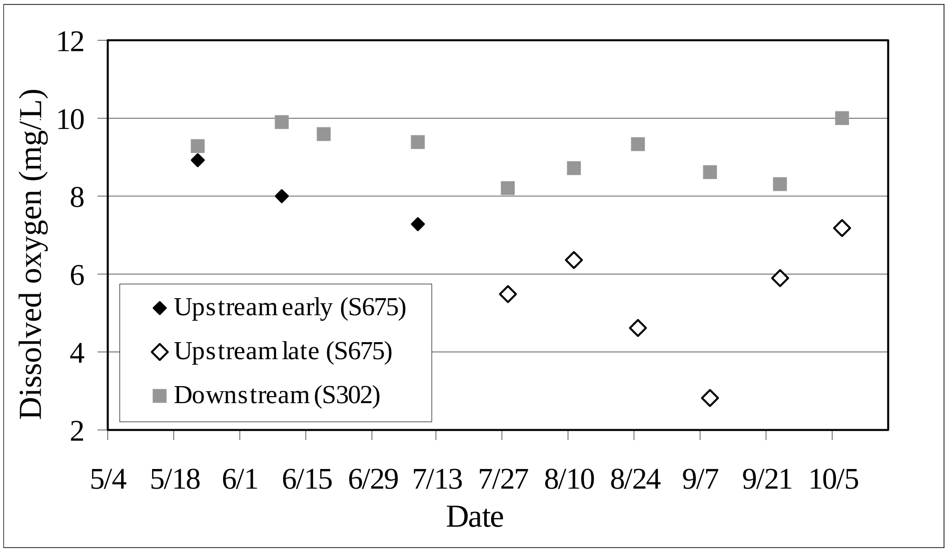
Water Quality Monitoring

1. Standard water quality parameters

a) Instantaneous dissolved oxygen

Instantaneous dissolved oxygen (DO) concentrations at the downstream station on Trout Brook were usually high, ranging from 8.2 - 10.0 mg/L (gray squares in Fig. 4). At the upstream station, DO concentrations differed markedly between the early and late locations, ranging from 7.3 - 8.9 mg/L at the early location (black diamonds in Fig. 4), and from 2.8 - 7.2 mg/L at the late location (open diamonds in Fig. 4). The single DO measurement taken at the wetland station on June 12 was 9.0 mg/L. Measurements taken on May 8, 2004, at the downstream and late upstream stations were 9.5 and 8.2 mg/L, respectively. On July 6, 2004, DO was at 9.2 mg/L at the downstream station.

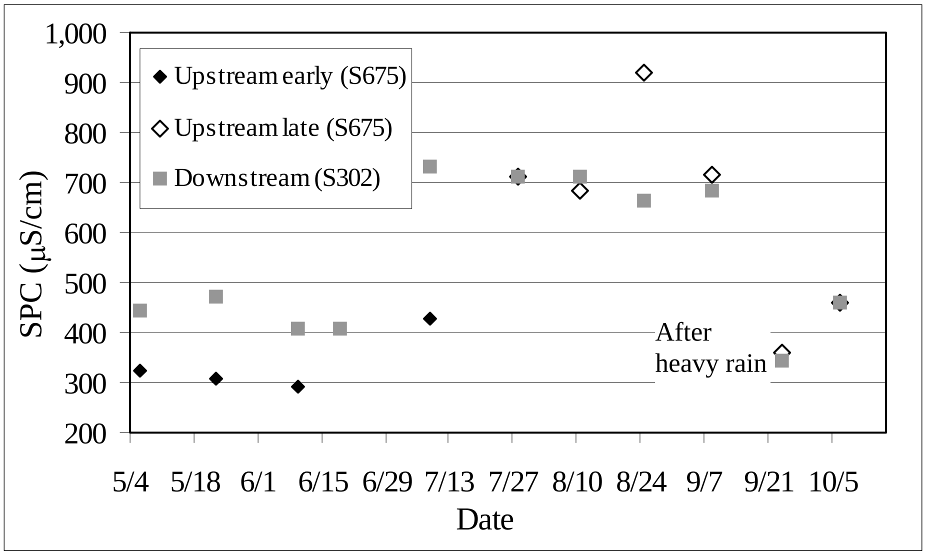
Fig. 4. Instantaneous dissolved oxygen



b) *Instantaneous specific conductance*

Instantaneous levels of specific conductance (also conductivity or SPC) at the downstream station were generally high but varied widely throughout the sampling season, ranging from 346 - 734 μS/cm (gray squares in Fig. 5). At the early upstream station, conductivity levels were lower and less variable, from 291 - 430 μS/cm (black diamonds in Fig. 5). At the late upstream station, conductivity levels were quite high and variable, from 360 - 922 μS/cm (open diamonds in Fig. 5). As shown on Figure 5, low conductivity was recorded on September 24 after heavy rain (0.6") the previous day had diluted the ions in the water. The single conductivity measurement taken at the wetland station on June 12 was 318 μS/cm; a water sample taken at the same time and analyzed in the laboratory measured SPC at 429 μS/cm. Measurements taken on May 8, 2004, at the downstream and late upstream stations were 453 and 455 μS/cm, respectively. On July 6, 2004, SPC was at 673 μS/cm at the downstream station.

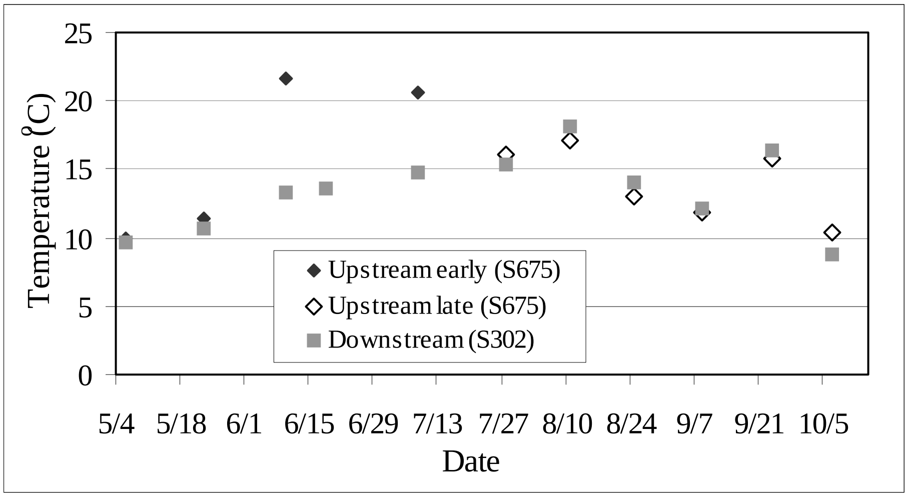
Fig. 5. Instantaneous specific conductance



c) *Instantaneous water temperature*

Instantaneous water temperature was quite variable at all stations, ranging from 8.8 - 18.2 ºC at the downstream station (gray squares in Fig. 6), from 10.0 - 21.6 ºC at the early upstream station (black diamonds in Fig. 6), and from 10.4 - 17.1 ºC at the late upstream station (open diamonds in Fig. 6). The single temperature measurement taken at the wetland station on June 12 was 20.7 ºC. Measurements taken on May 8, 2004, at the downstream and late upstream stations were 13.6 and 13.0 ºC, respectively. On July 6, 2004, water temperature was at 16.0 ºC at the downstream station.

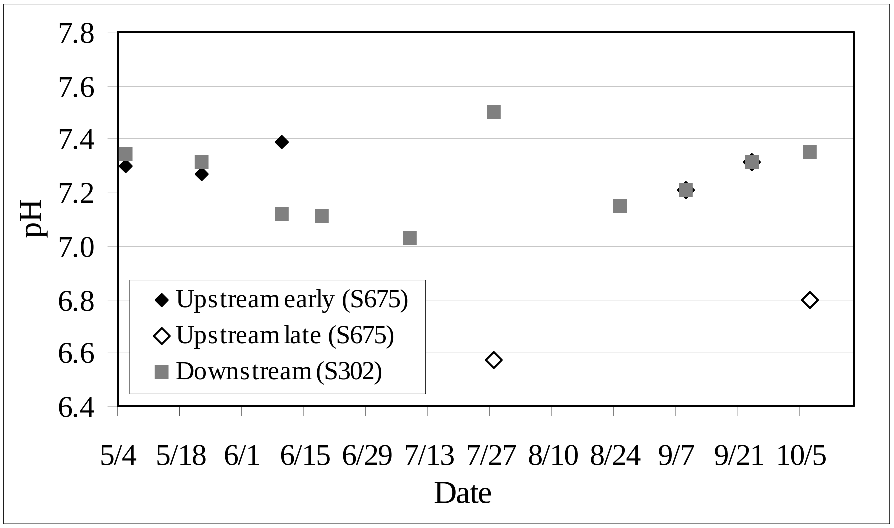
Fig. 6. Instantaneous water temperature



d) Instantaneous pH

Instantaneous measurements of pH did not vary widely at any measurement location: at the downstream station, pH ranged from 7.0 - 7.5 (gray squares in Fig. 7); at the early upstream station, it ranged from 7.3 - 7.4 (black diamonds in Fig. 7); and at the late upstream station, it ranged from 6.6 - 7.3 (open diamonds in Fig. 7). The single pH measurement taken at the wetland station on June 12 was 7.4; air equilibrated pH was measured at 7.5 at this station. On July 6, 2004, a pH of 7.2 was measured at the downstream station.

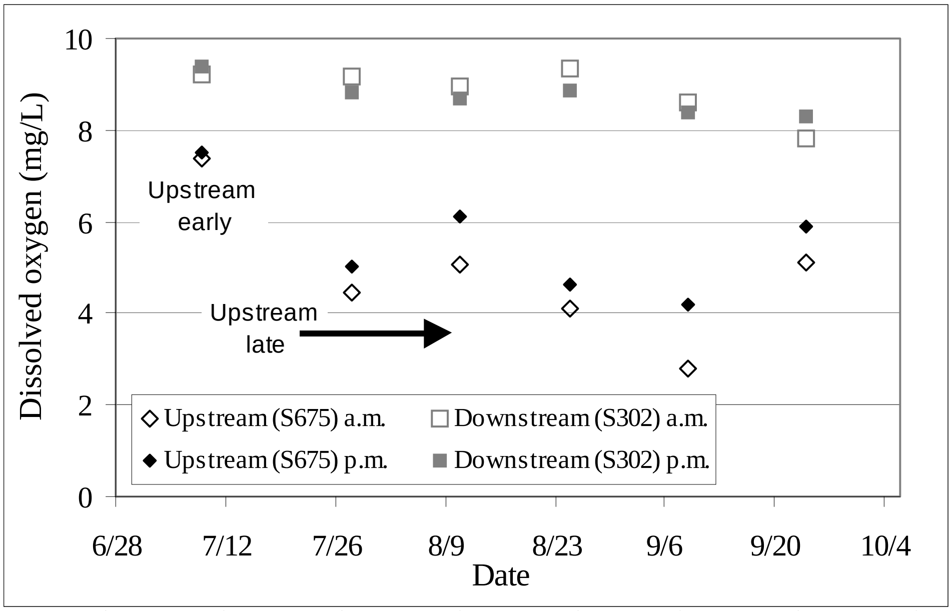
Fig. 7. Instantaneous pH



2. Diurnal dissolved oxygen

Dissolved oxygen concentrations measured at the downstream station in early morning and mid-afternoon were quite similar throughout the summer with a maximum diurnal difference of 0.5 mg/L (squares in Fig. 8). The single measurement that was collected at the early upstream station showed a diurnal difference of 0.1 mg/L (diamonds in Fig. 8). At the late upstream station, DO concentrations were much lower than at the downstream station and the diurnal range was greater (maximum difference of 1.4 mg/L; diamonds in Fig. 8).

Fig. 8. Diurnal dissolved oxygen

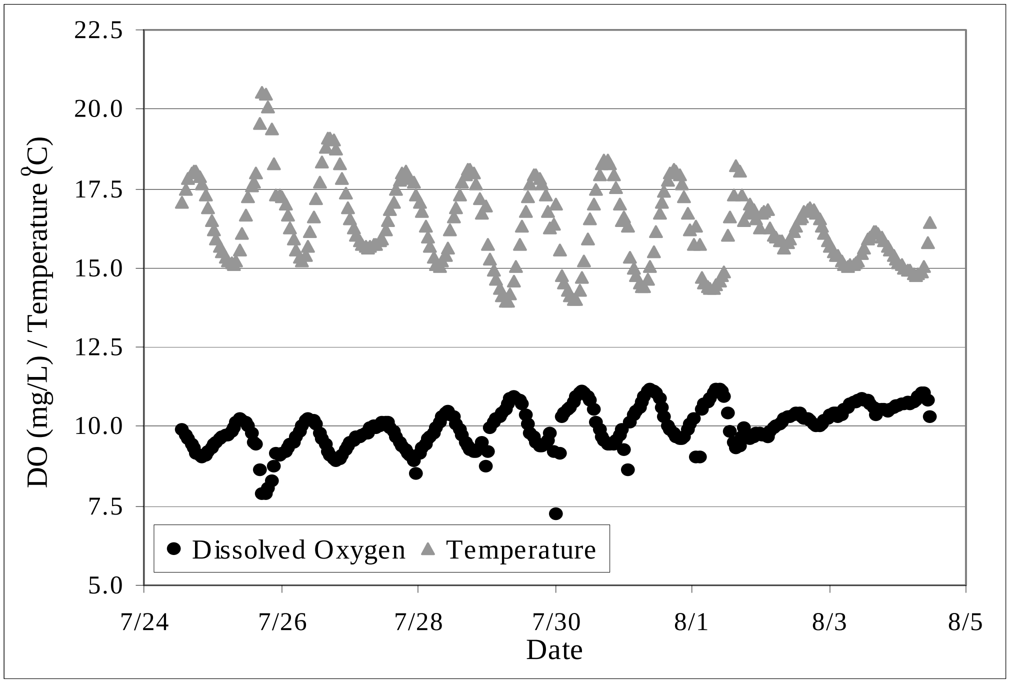


3. Continuous data collection below downstream station (below Highland Avenue culvert; 12 days, July 24 to August 4)

a) Continuous dissolved oxygen and water temperature

Mean hourly dissolved oxygen (DO) and water temperature calculated from records collected every 10 min indicated that both variables showed strong diurnal fluctuations (Fig. 9). Dissolved oxygen concentrations were highest in the early morning soon (~2 hours) after water temperatures were lowest while, conversely, DO concentrations were lowest in early evening soon after water temperatures were highest. Except for one reading at 7.3 mg/L, all DO concentrations were above 7.9 mg/L. Diurnal differences exceeded 2 mg/L on 4 out of the 10 full days of measurements (minimum/maximum difference was 0.5/3.9 mg/L). Water temperatures were >20 ºC during one 2.5 hour period, but most of the time they were much cooler than that.

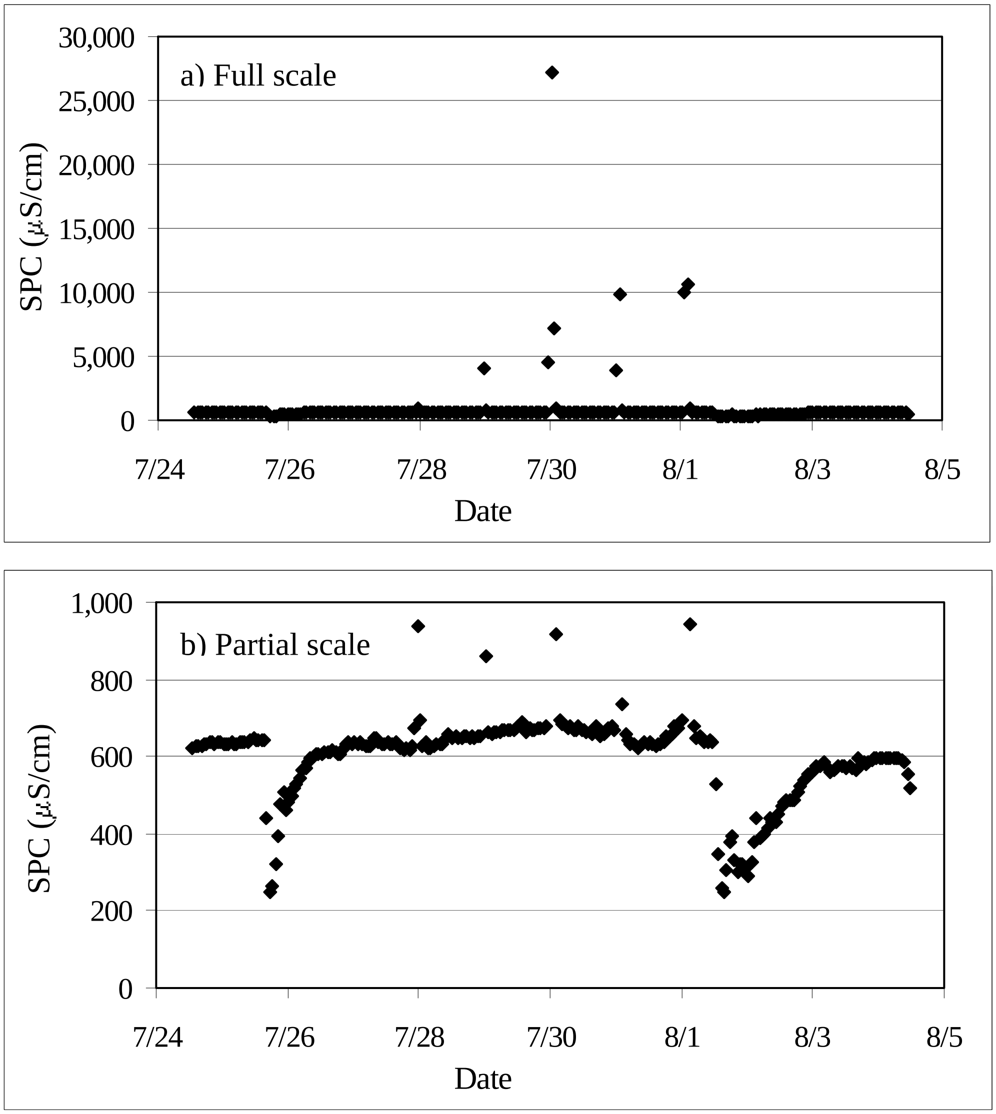
Fig. 9. Continuous dissolved oxygen and water temperature at downstream station (12 days)



b) Continuous specific conductance

Mean hourly conductivity calculated from records collected every 10 min showed remarkable variation, ranging from 246 to 27,162 μS/cm (Fig. 10 a and b; same data with different scales). The majority of the time, conductivity ranged from 500 - 700 μS/cm (Fig. 10 b). Several values >20,000 μS/cm (maximum value 30,903 μS/cm) were recorded on three successive nights (7/30 and 31, 8/1) between midnight and 2 a.m. Note that only the first spike on 7/30, which lasted for ~80 min, appears in the mean hourly averages (Fig. 10 a) while the subsequent, shorter spikes (20-30 min) are evened out by substantially lower measurements. It is not known conclusively what caused those spikes but consultation of tide tables for the Fore River showed that high water occurred at 12:13 a.m., 12:54 a.m., and 1:38 a.m. on the three nights in question, suggesting that salt water intrusion caused the spikes. Decreases in conductivity occurred following rain events: light rain (0.13”) on July 25 caused a strong decrease lasting ~18 hours while heavy rain (1.0”) on August 1 followed by light rain (0.06”) on August 2 caused a similar decrease lasting ~48 hours.

Fig. 10. Continuous specific conductance at downstream station (12 days)



c) Continuous turbidity

Mean hourly turbidity calculated from records collected every 10 min showed large variation, ranging from 1 - 657 NTU (Fig. 11 a and b; same data with different scales). The maximum instantaneous value measured was 1,787 NTU. The majority of the time, turbidity ranged from 1 - 10 NTU (Fig. 11 b), and the EPA-recommended criterion of 3.04 NTU (EPA 2000b) was exceeded 30 % of the time. The two spikes recorded on July 25 and August 1 (Fig. 11 a) occurred during rain events and are likely related to the turbulence created by rainwater and storm runoff entering the stream causing sediment to be stirred up (App. G, Fig. 6), and likely also bringing sediment into the stream. Small spikes, i.e., those reaching ~10 NTU (Fig. 11 b), occurred on several days and were not associated with rain events; instead these small spikes showed a temporal pattern in that they always occurred around midnight[1].

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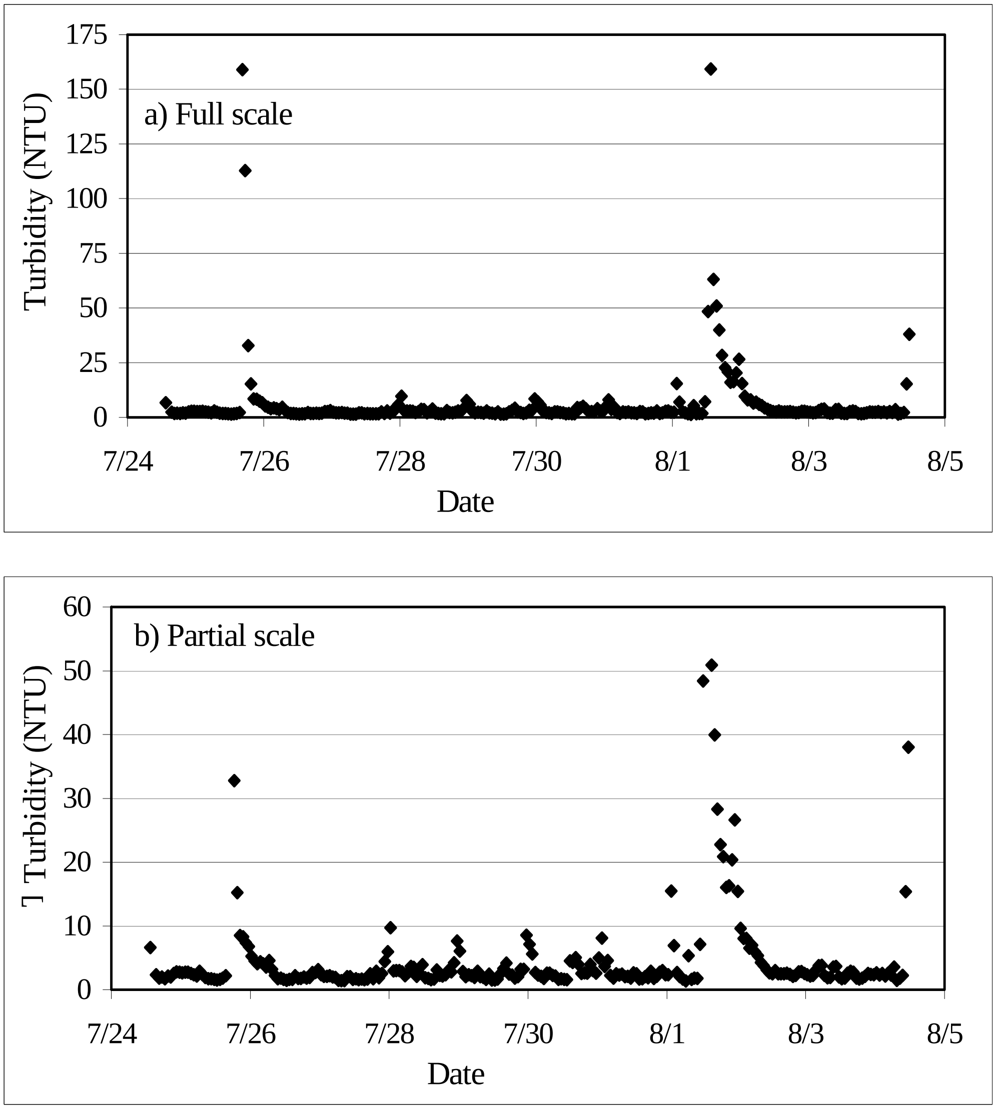
[1] Data collected in 2004 suggest that these turbidity spikes may have been related to saltwater intrusions (see Discussion, Water Quality Monitoring, Saltwater Intrusions, below)

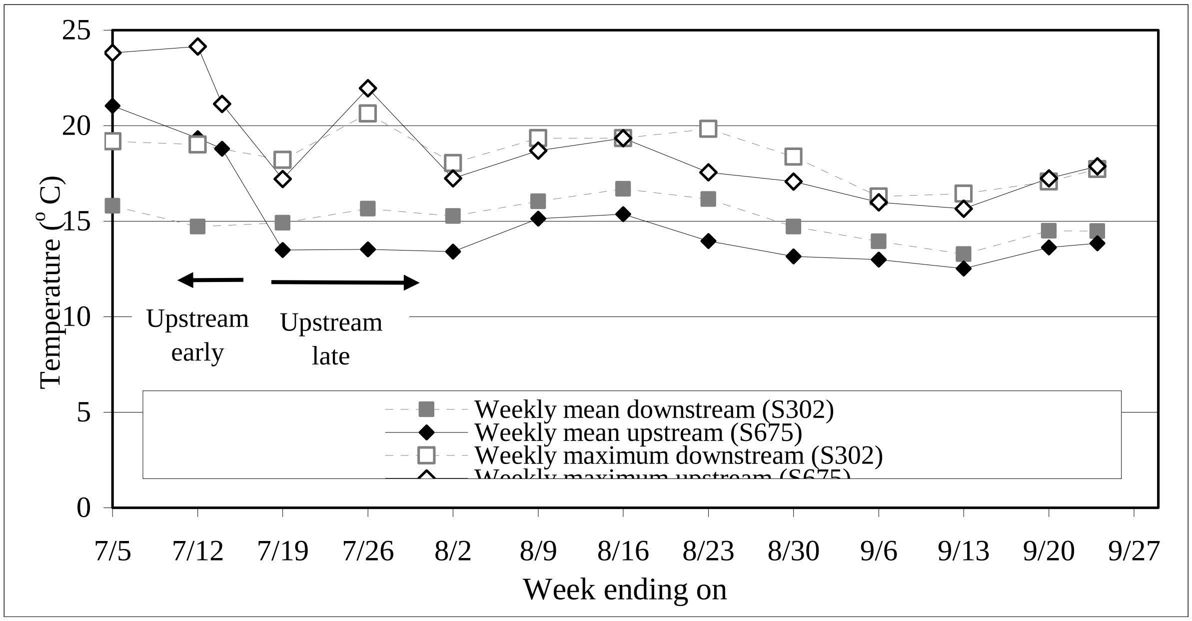
Fig. 11. Continuous turbidity at downstream station (7 days)



4. Continuous water temperature (85 days, July 2 to September 24)

   Continuous water temperature at the downstream station (squares and dashed lines in Fig. 12, measured at 20-min intervals) showed relatively cool and stable weekly mean temperatures between 13.3 and 16.7 ºC, and warmer, more variable weekly maximum temperature between 16.3 and 20.6 ºC. At the early upstream station (diamonds and solid lines in Fig. 12), the weekly mean temperature for the 11 days the temperature logger was in place at this station was quite high, around 20 ºC, and the weekly maximum temperature was even higher, around 23 ºC. At the late upstream station (diamonds and solid lines in Fig. 12), the weekly mean temperature was quite cool, between 12.5 and 15.4 ºC, while the weekly maximum temperature was significantly higher, between 15.7 and 22.0 ºC.

Fig. 12. Continuous water temperature (85 days)



5. Water chemistry

Water chemistry data are summarized in Tables 5 - 7. Table 5 shows the results from five baseflow sampling events at the downstream station and three at the late upstream station, Table 6 shows the results from two stormflow sampling events at both stations, and Table 7 shows the results from one baseflow sampling event at the wetland station. Tables 5 and 6 include numeric criteria for water quality where available. Criteria recommended by EPA for Region XIV present nutrient levels that protect against the adverse effects of nutrient overenrichment (USEPA 2000b). The Maine Statewide Water Quality Criteria (MDEP SWQC) CMC and CCC[1] define acute (brief exposure) and chronic (indefinite exposure) levels, respectively, above which certain compounds can have detrimental effects on aquatic organisms. In general, CMC should be used to interpret results from stormflow samples while CCC should be used to interpret results from baseflow samples. Highlighted fields in the tables indicate cases where the sampling results exceeded the numeric criteria, i.e., cases where negative effects may occur in aquatic organisms.

Table 5. During baseflow conditions, Total Nitrogen (TN) exceeded the EPA-recommended Ecoregion XIV criterion at the downstream station in all sampling events. Bacteria (*E. coli*) exceeded the State of Maine criterion for the mean count of bacterial colonies three times, and the criterion for the instantaneous count once. Note however that Maine's criteria are for *E. coli* of human origin and that the origin was not determined in this study. Lead was the only metal analyzed that exceeded Maine SWQC (MDEP SWQC) chronic criteria although in some cases the sensitivity of the analysis was insufficient to determine whether criteria were exceeded (copper: for CMC and CCC; cadmium and lead: for CCC only). At the late upstream station, TN exceeded the EPA-

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[1] CMC, Criteria Maximum Concentration; CCC, Criteria Chronic Concentration

recommended criterion in the single sampling event, and *E. coli* exceeded State criteria for the geometric mean of counts of bacterial colonies two out of three times. Total and dissolved organic carbon (TOC, DOC) were relatively low at both stations, while TSS usually was below the detection limit of the test but was elevated on one date at the downstream station. Additional data not shown in Table 5 were collected at the downstream station on July 9 during algal sampling: alkalinity, 54 mg/L; and silica (by calculation), 15 mg/L.

Table 6. During stormflow conditions at the downstream and late upstream stations, the following violation of criteria were found: Total Phosphorus (TP) exceeded the EPA-recommended criterion twice at each station (by a factor of 3 - 7); aluminum exceeded the Maine SWQC (MDEP SWQC) acute criterion three times (once downstream, twice late upstream); copper exceeded the acute criterion once at each station; and zinc exceeded the acute criterion once at the late upstream. The TP values recorded during stormflow conditions were up to 20 times higher than during baseflow conditions (Table 5; no aluminum data were collected at baseflow; Cu and Zn were non-detects at baseflow). There are no criteria for Total Suspended Solids (SSD) but SSD values at stormflows were up to ~35 times higher than during baseflows (Table 5).

In addition to the data shown in Table 6, two TP stormflow samples were collected on February 24 and 26, 2004 at the downstream station, with values of 0.021 and 0.1 mg/L, respectively. Only the second of these samples exceeded the EPA-recommended criterion (0.031 mg/L; by a factor of 3).

Rainfall amounts for storm sampling events were as follows: May 26: 0.91” mostly in early evening, May 27: 0.03” at 12:30 am; November 20: 0.72” during mid to late morning, November 21: 0.28” at ~4 - 9 a.m.; February 23 - 26, 2004: no precipitation but daytime highs were 1-3 ºC, i.e., some melting likely occurred (Weather Underground 2003/2004).

Table 7. Several of the parameters analyzed for water chemistry ranked among the top 10 % of all samples ever collected in ME wetlands by the biomonitoring unit: nutrients (NO_2-NO_3-N, TN), anions and cations (Ca, Mg, K, NA), chloride, conductivity, alkalinity, and hardness. Total Nitrogen and values TP were higher than baseflow values for the downstream and late upstream stations (Table 5).

Table 5. Water chemistry data (baseflow) from summer 2003. Highlighted fields indicate problem parameters.

Parameters	**Station (#)**	**Upstream late (S675)**			**Downstream (S302)**					**Water Quality Criteria**	
	Sample date	**15-Jul**	**11-Aug**	**9-Sep**	**15-Jul**	**11-Aug**	**25-Aug**	**28-Aug**	**9-Sep**		
Nutrients	**Unit**										
Total Kjeldahl N	mg/L		0.2		0.2	~0.3	0.2	0.7	0.2	NC	
Nitrate-Nitrite-N	mg/L		0.54		0.78	0.58	0.8	<0.01	0.74	NC	
Ammonia-Nitrogen	mg/L						0.02			NC	
Total Nitrogen	mg/L		0.74		0.98	~0.88	1.02	0.7	0.94	0.71 [1]	
Ortho-phosphate	mg/L		0.004		0.007	0.007			~0.006	NC	
Total Phosphorus	mg/L		0.014		0.018	0.019	0.013		0.011	0.031 [1]	
Dissolved Organic Carbon	mg/L		2.8			2.6	2.5			NC	
Total Organic Carbon	mg/L		4.3			3.8				NC	
Chlorophyll *a*	mg/L		~0.0014		~0.0013	~0.0015		~0.0121	~0.0007	0.00375 [1]	
Total Suspended Solids	mg/L		ND 2		3		ND 2	17	ND 2	NC	
Total Dissolved Solids	mg/L						480			NC	
Diesel Range Organics	µg/L		<50			<50				NC	
Bacteria *(E. coli)*	# col./100 ml	166	161	104	1300	344		613	161	949 [2, 3]	142 [2, 3]
Metals										**CMC**[4]	**CCC**[4]
Cadmium	µg/L		ND 0.5		ND 0.5	ND 0.5			ND 0.5	0.64	0.32
Copper	µg/L		ND 5		ND 5	ND 5			ND 5	3.89	2.99
Iron	µg/L		300		340	490			140	NC	1,000
Lead	µg/L		ND 3		ND 3	ND 3			3	10.52	0.41
Zinc	µg/L		ND 5		ND 5	ND 5			ND 5	29.9	27.1
Chromium	µg/L		ND 1			ND 1				16	11
Nickel	µg/L		5.5			5				363.4	40.4
Chloride	mg/L		156			147				860	230

NC, No Criteria; ND, Not Detected, i.e., below stated detection limit of test

[1] Criteria recommended by EPA for Ecoregion XIV, which includes Trout Brook. Total Nitrogen is the sum of preceding three parameters.

[2] Criteria (instantaneous/geometric mean counts of the # of *E. coli* colonies) defined by Maine's Water Classification Program for Class C waters.

[3] Results are for bacteria of any origin while Maine standards are for bacteria of **human** origin. Note that in some studies where the origin of bacteria has been investigated, the majority of bacteria were not of human origin.

[4] CMC and CCC are types of Maine Statewide Water Quality Criteria (SWQC; MDEP SWQC). CMC (Criteria Maximum Concentration) and CCC (Criteria Continuous Concentration) denote the level of pollutants above which aquatic life may show negative effects following brief (acute) or indefinite (chronic) exposure, respectively.

Table 6. Water chemistry data (stormflow) from 2003. Highlighted fields indicate problem parameters.

Parameters	**Station (#) Date**	**Upstream late (S675)**		**Downstream (S302)**		**Water Quality Criteria**	
	Unit	**27-May**	**21-Nov**	**27-May**	**21-Nov**		
Total Phosphorus	mg/L	0.22	0.11	0.15	0.094	0.031[1]	
Total Suspended Solids	mg/L	70	29	50	29	NC	
Metals						**CMC** [2]	**CCC** [2]
Arsenic	µg/L	ND 3	ND 3	ND 3	ND 3	360	190
Aluminum	µg/L	2,000	850	970	500	750	87
Cadmium	µg/L	0.6	ND 2	0.5	ND 2	0.64	0.32
Chromium	µg/L	4	2	2	1	16	11
Copper	µg/L	7	ND 5	6	ND 5	3.89	2.99
Iron	µg/L	4,600	1,800	2,500	1,100	NC	1,000
Lead	µg/L	8	3	6	3	10.52	0.41
Nickel	µg/L	9	4	6	3	363.4	40.4
Silver	µg/L		ND 1		ND 1	0.25	NC
Zinc	µg/L	~31	16	~22	10	29.9	27.1
Calcium	mg/L	16	17	20	18	NC	
Magnesium	mg/L	3.1	3.3	3.8	3.4	NC	
Potassium	mg/L	2.7	4.0	3.1	3.9	NC	
Sodium	mg/L	25	24	34	27	NC	
Manganese	mg/L	0.52	0.15	0.30	0.08	NC	

NC, No Criteria; ND, Not Detected, i.e., below stated detection limit of test.

[1] Criteria recommended by EPA for Ecoregion XIV, which includes Trout Brook.

[2] See footnote 4 in Table 5.

Table 7. Water chemistry data (baseflow, wetland station) from June 2003. Highlighted fields indicate problem parameters.

Parameters	**Station (#)**	**Wetland (W-093)**	
	Unit	**Value**	**Rank[1]**
Total Kjeldahl Nitrogen	mg/L	0.5	42 (of 54)
Nitrate-Nitrite-N	mg/L	0.67	1 (of 25)
Ammonia-Nitrogen	mg/L	0.03	70 (of 113)
Total Nitrogen	mg/L	1.2	8 (of 88)
Soluble Reactive Phosphate	mg/L	0.01	
Total Phosphorus	mg/L	0.04	47
Chlorophyll *a*	mg/L	0.004	78
Dissolved Organic Carbon	mg/L	5.80	124
Calcium	mg/L	27	10
Magnesium	mg/L	4.7	12
Potassium	mg/L	3.3	8
Sodium	mg/L	38	10
Chloride	mg/L	73	10
Conductivity	µS/cm	429	4 (of 101)
Alkalinity	mg/L	53	18
Color	PCU	42	120
Hardness[2]	mg/L	86.77	3 (of 48)

[1] Rank out of 142 samples except where noted. Rankings in the worst 10% of each category are highlighted.
[2] Water with a hardness of 0-60 mg/L is considered “soft”; 61-120 mg/L “moderately hard”.

Habitat Assessments

1. Flow regime

a) *Instantaneous flow velocity*

Instantaneous flow velocity was similar and quite variable at both stations (including visual estimates, which were reduced to 0.8 of observed surface flow to account for the lower velocity at mid-depth[1]): downstream it ranged from 12 - 24 cm/s with a mean of 16 cm/s (gray squares in Fig. 13); at the early upstream station, flow was recorded at 15 and 9 cm/s on the two measurement dates, i.e., at a mean of 12 cm/s (black diamonds in Fig. 13); and at the late upstream station, it ranged from 10 - 22 cm/s with a mean of 14.5 cm/s (open diamonds in Fig. 13).

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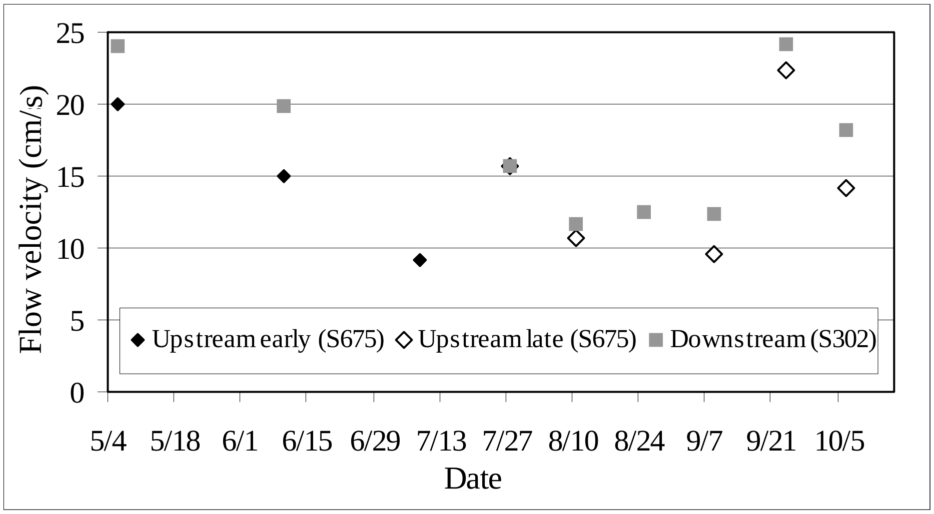
[1] See Ch. 2, Methods for further explanation.

Fig. 13. Instantaneous flow velocity



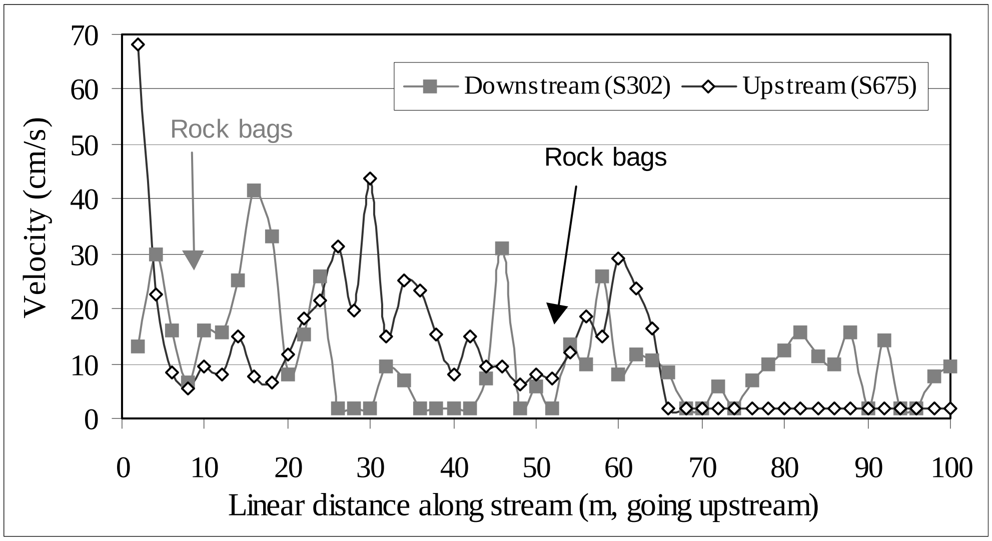
Note that first data point at both stations is visual estimate.

b) Thalweg velocity

At the downstream station, the survey started just below the rock bag location and proceeded upstream. At the late upstream station, the survey started at the rock bag location and proceeded upstream for ~50 m where the stream channel became indistinct because of braiding; to obtain data for a full 100-m stretch, measurements were then taken for ~50 m downstream of the rock bag location.

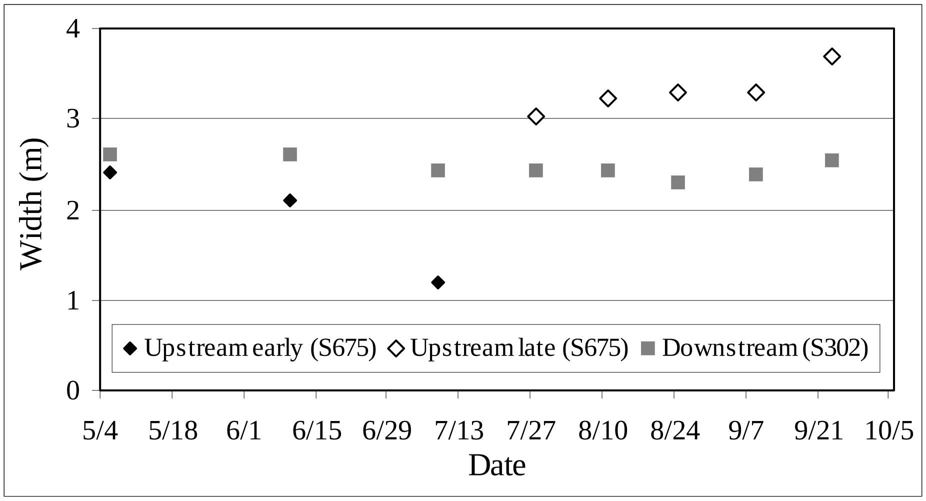
The thalweg velocity at and above the downstream station was highly variable, with velocities ranging from approximately 1 - 42 cm/s with a mean of 11 cm/s (gray squares in Fig. 14). At the late upstream station, a similarly variable flow regime with velocities ranging from approximately 1 - 68 cm/s and a mean of 12 cm/s was measured in the lower ~65 m of the 100 m stretch, but no flow was registered above this point, where the stream was dammed up by a small cobble dam (open diamonds in Fig. 14).

Fig. 14. Thalweg velocity



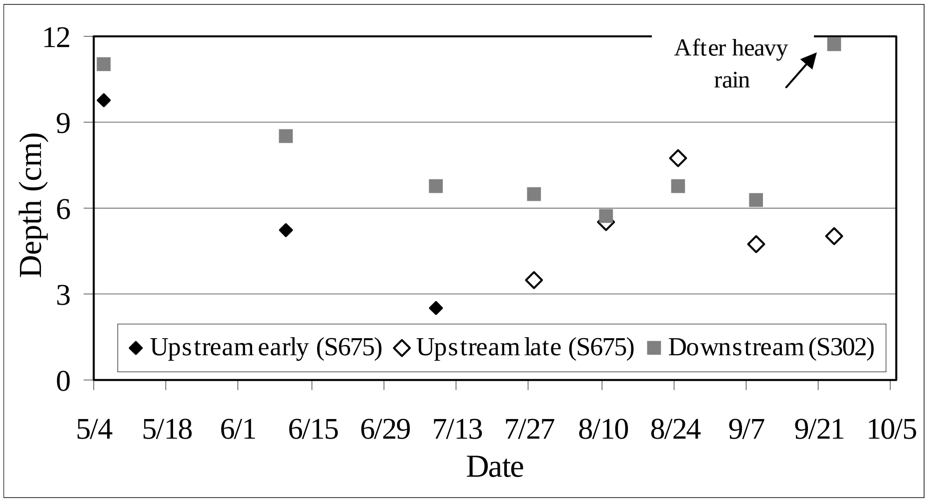
2. Mean stream width (wetted) at the downstream station was quite stable throughout the sampling period, ranging from 2.3 - 2.6 m with a mean of 2.5 m (gray squares in Fig. 15). At the early upstream station, wetted width declined significantly, from 2.4 - 1.2 m (black diamonds in Fig. 15), while at the late upstream station, it increased over time, from 3.0 - 3.7 m (open diamonds in Fig. 15). Bankfull width at the downstream station was much smaller than at the late upstream station (4.3 *versus* 6.0 m; Field 2003, Table 2, Reaches 2 and 4, respectively).

Fig. 15. Mean stream width (wetted)



Mean stream depth was quite variable throughout the sampling period at all stations. At the downstream station, it ranged from 5.8 - 11.8 cm with a mean of 7.8 cm (gray squares in Fig. 16). However, during the summer months, depth was quite stable at this station, between 5.8 and 6.8 cm. At the early upstream station, depth declined significantly, from 9.8 to 2.5 cm (black diamonds in Fig. 16). At the late upstream station, depth was variable, ranging from 3.5 - 7.8 cm with a mean of 5.6 cm (open diamonds in Fig. 16).

Fig. 16. Mean stream depth



3. Large woody debris (LWD, >5 cm mean diameter) above the downstream station was abundant (41 pieces) with a good size distribution (mean diameter of 5 - 25 cm; gray squares in Fig. 17). Around the late upstream station, much fewer pieces were found (22) and the size distribution was more limited (5 - 17 cm; open diamonds in Fig. 17). Note that LWD of >20 cm mean diameter was virtually absent. Small woody debris (2 - 5 cm diameter, >100 cm length) was more abundant at the late upstream station (65 pieces; open diamonds in Fig. 18) than at the downstream station (42; gray squares in Fig. 18).

Fig. 17. Distribution of large woody debris (>5 cm mean diameter)

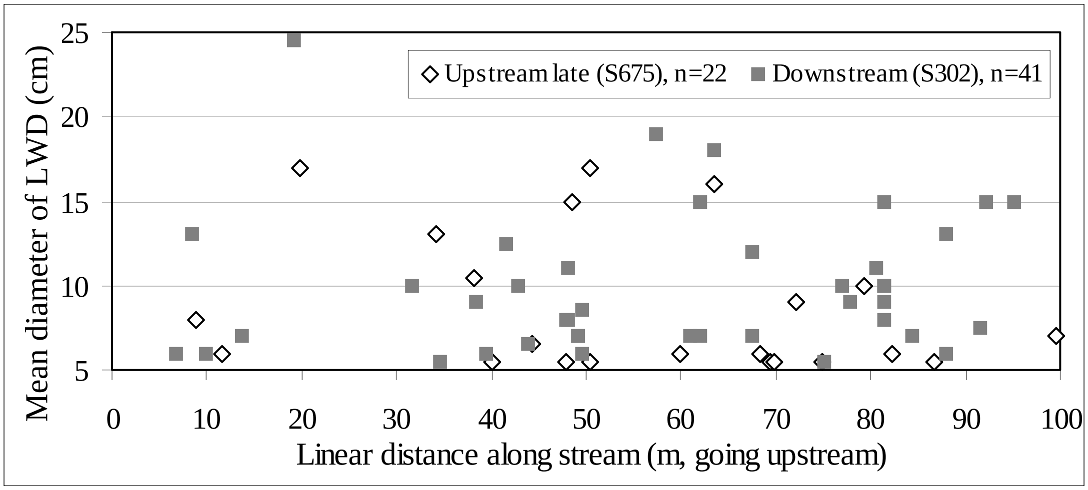
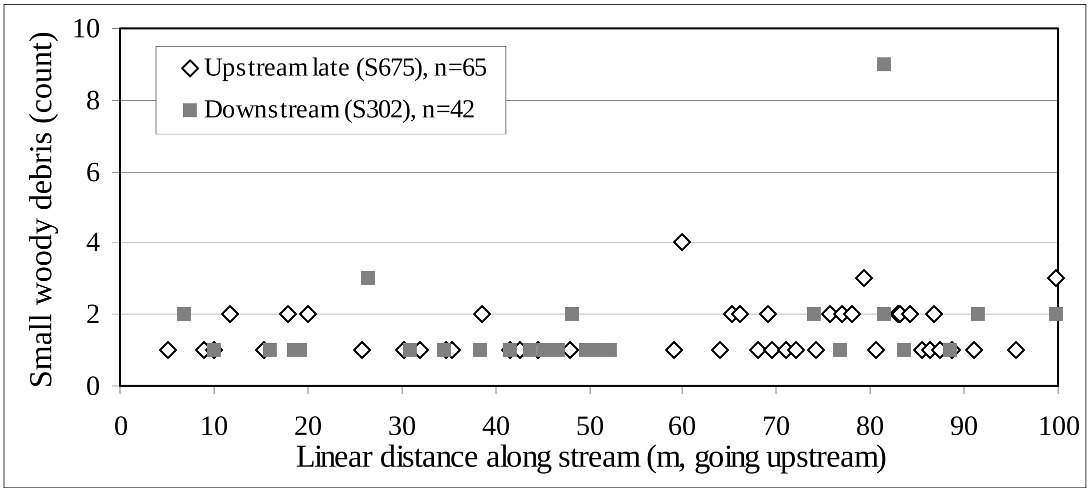
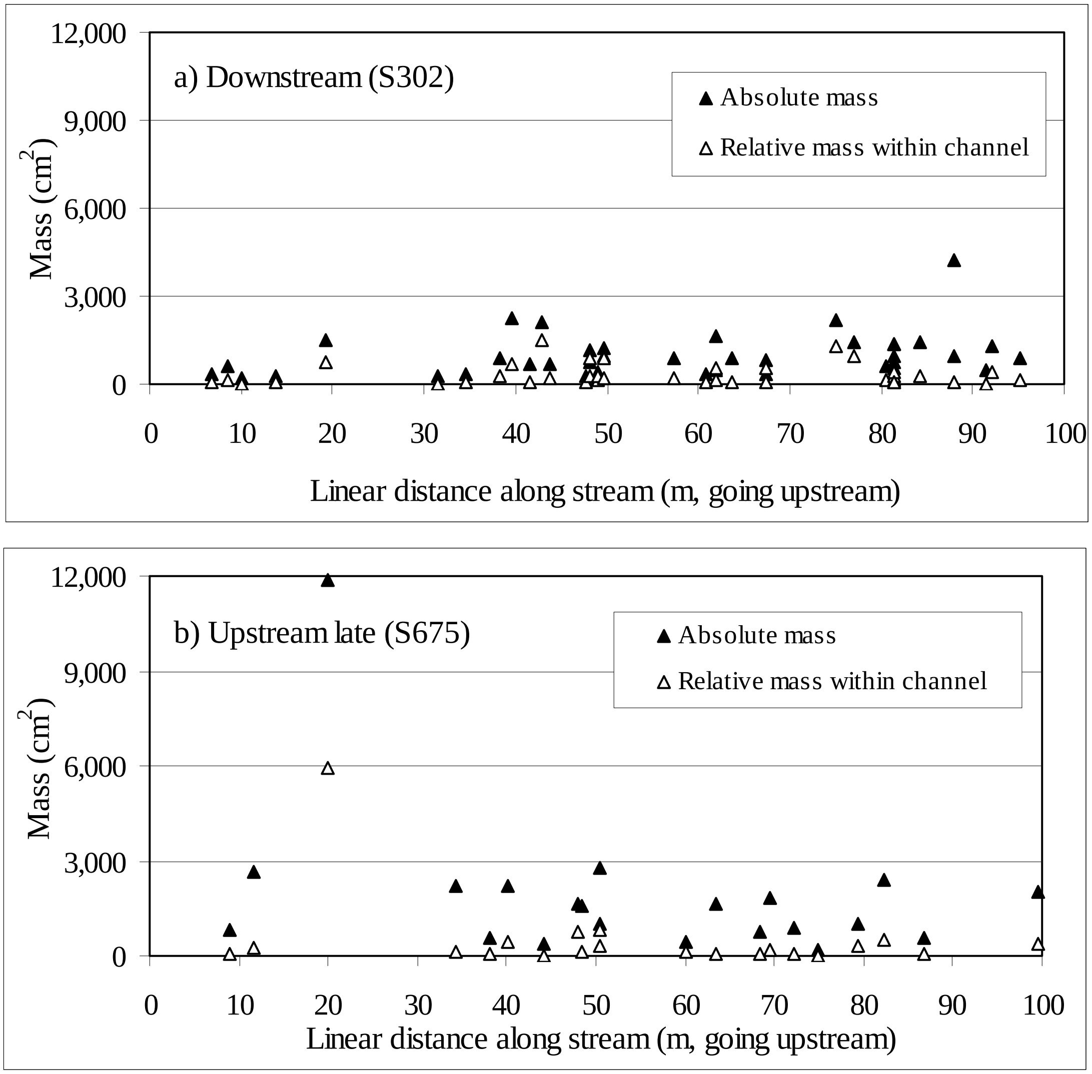


Fig. 18. Distribution of small woody debris (2-5 cm diameter, >100 cm length)



Absolute mass of LWD pieces (mean diameter * length) was similar at both stations, ranging largely from ~200 - 3,000 cm^2, with one outlier at each station (4,200 cm^2 downstream, 11,900 cm^2 upstream; black triangles in Figs. 19 a and b, respectively). Relative mass of LWD pieces (absolute mass * % spanning channel) was greater at the downstream station (23 - 1,470 cm^2, mean of 319 cm^2, open triangles in Fig. 19 a) than at the late upstream station (18 - 825 cm^2, with one outlier at 5,950 cm^2, overall mean of 512 cm^2, open triangles in Fig. 19 b). The decrease from absolute to relative mass was smaller at the downstream than at the late upstream station (Figs. 19 a and b), reflecting the higher mean percent of the channel spanned by pieces of LWD at the downstream station (30 *versus* 18 %).

Fig. 19. Absolute and relative mass of large woody debris



4. Results from the Physical Characterization assessment at the downstream and late upstream stations are summarized in Table 8. Observed problems were obvious sources of NPS pollution, moderate local watershed erosion, some channelization, and a sewage smell of the water.

Table 8. Summary version of completed Physical Characterization form

Parameter	Sub-Parameter	Downstream (S302)	Upstream late (S675)
Stream Characterization	Stream subsystem	Perennial	
	Stream type	Coldwater	
	Stream origin	Mixture of origins (spring-fed, swamp and bog)	
Watershed Features	Predominant surrounding landuse	Residential	
	Local watershed NPS pollution	Obvious sources	
	Local watershed erosion	Moderate	
Riparian Vegetation	Dominant type	Trees, herbaceous	Trees
Instream Features	Canopy cover	Partly open	
	Proportion of reach by stream morphology types	25% Riffle, 10% Pool, 65% Run	40% Riffle, 20% Pool, 40% Run
	Channelized	No (not recently)	Yes (not recently)
	Dam present	No	Yes (small, cobble)
Aquatic Vegetation	Dominant type (portion of reach with aquatic vegetation)	Rooted submergent (*Vallisneria*, 2 %)	Rooted submergent (10%)
Water Quality	Water odors	Sewage (slight)	Sewage
	Water surface oils	None	
	Turbidity	Stained (slightly)	
Sediment/ Substrate	Odors	None	
	Oils	Absent	
	Deposits	None	
	Undersides of stones black?	No	
Substrate Type	Boulder	5	0
	Cobble	50	40
	Gravel	20	30
	Sand	25	30
	Detritus (sticks, wood, coarse plant materials)	10	5

The Habitat Assessment at the downstream and late upstream stations resulted in scores of 124 out of a possible 200 (10 categories * 20 points) for optimal habitat, i.e., in the middle of the spectrum (Table 9). At the downstream station, the lowest scores were recorded for riparian vegetative zone width, vegetative protection, and pool variability. At the late upstream station, the lowest scores were recorded for channel sinuosity, and pool variability, sediment deposition, and channel flow status.

Table 9. Summary version of completed Habitat Assessment form (low gradient stream)

Habitat Parameter	Downstream (S302)	Upstream late (S675)
1. Epifaunal Substrate/ Available Cover	**14**, suboptimal[1] (30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations, presence of additional substrate in the form of newfall but not yet prepared for colonization)	**13**, suboptimal (as on left)
2. Pool Substrate Characterization	**14**, suboptimal (Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present)	**13**, suboptimal (as on left)
3. Pool Variability	**11**, suboptimal (Majority of pools large-deep; very few shallow)	**10**, marginal (Shallow pools much more prevalent than deep pools)
4. Sediment Deposition	**14**, suboptimal (Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools)	**10**, marginal (Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent)
5. Channel Flow Status	**17**, optimal (Water reaches base of both lower banks, and minimal amount of channel substrate is exposed)	**10**, marginal (Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed)
6. Channel Alteration	**15**, suboptimal (Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, greater than past 20 yrs) may be present, but recent channelization is not present)	**14**, suboptimal (as on left)
7. Channel Sinuosity	**13**, suboptimal (The bends in the stream increase the stream length 1-2 times longer than if it was in a straight line)	**9**, marginal (as on left)
8. Bank Stability (score each bank, left/right)	**7/5**, suboptimal/marginal (7: as Late Upstream) (5: Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods)	**6/6**, suboptimal (Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion)
9. Vegetative Protection (score each bank, left/right)	**6/2**, suboptimal/poor (6: as on right) (2: Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 cm or less in average stubble height)	**8/8**, suboptimal (70-90% of streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; >½ of potential plant stubble height remaining)
10. Riparian Vegetative Zone (score each bank, left/right)	**6/0**, suboptimal/poor (6: Width of riparian zone 12-18 m; human activities have impacted zone only minimally) (0: Width of riparian zone <6 m; little or no riparian vegetation due to human act.	**8/9**, suboptimal/optimal (8: as 6 on left) (9: Width of riparian zone >18 m; human activities, i.e., parking lots, clear-cuts, lawns, or crops, have not impacted zone)

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[1] For parameters 1-6, possible scores are 0-5 (poor), 6-10 (marginal), 11-15 (suboptimal), and 16-20 (optimal). For parameters 7-10, scores are given for left and right bank with bin sizes of 0-2, 3-5, 6-8, and 9-10.

The Human Disturbance Ranking Form used at the wetland station resulted in a score of 29 out of a possible 125 (5 points * 5 categories * 5 sections; Table 10). This score indicated very high disturbance, and ranked as the 10th worst score recorded in the 157 wetlands assessed by the MDEP biomonitoring program to date (highest score recorded was 44). Impervious surfaces areas in the watershed had the highest score of the five subsections, followed by the potential for NPS pollution, and hydrologic modifications to the wetland.

Table 10. Summary version of completed Human Disturbance Ranking Form

Factor assessed	**Score**	**Section Total**
Section 1. Hydrologic modifications to the wetland		
Man-made dikes or dams	0	4
Causeways, roads or railroad bed crossings, culverts	0	
Ditching, draining, dewatering	3	
Filling or bulldozing	1	
Other	0	
Section 2. Vegetative modifications to the wetland		
Timber harvesting in wetland	0	2
Other clearing/removal of vegetation	2	
Plowing, mowing or grazing in wetland	0	
Evidence of herbicide use in wetland	0	
Other	0	
Section 3. Evidence of chemical pollutants		
Discharge pipes	0	1
Oil, petroleum, chemicals observed, chemical odor present	1	
Soil staining, stressed/dying vegetation	0	
Trash, chemical containers, demolition debris, drums, etc.	0	
Other	0	
Section 4. Impervious surface areas in watershed		
Residential development	4	12
Commercial/industrial development	2	
Recreational development	1	
Roads and highway bridges	3	
Other (parking lots)	2	
Section 5. Potential for NPS pollution		
Excess sediment accumulation and eroding soil from human activities	3	10
Alterations to wetland buffer	2	
Livestock, feedlots, manure piles	0	
Evidence of fertilizer or pesticide use	3	
Other (grass clippings)	2	

5. An analysis of historic landuse changes in the Trout Brook watershed undertaken as part of the geomorphological assessment found that 35 % of the watershed had been built-up by 1964; this percentage rose to 54 % by 1998 (Table 1 in Field 2003). Over the same

time period, forest land declined from 29 to 27 %, agriculture from 22 to 9 %, and barren land from 13 to 9 %. No significant changes in channel position or dimension occurred during that period. Large sections of Trout Brook were, however, channelized in the past (Table 11): the upper part of the watershed above Ocean Street, and also above Boothby Avenue and from Highland Avenue down to Mill Cove. The effect of channelization on the section immediately below Highland Avenue is reflected in the low entrenchment[1] ratios measured here (1.6 and 1.4 for two cross-sections; Table 6 in Field 2003). This means that flows above the bankfull stage do not spread out into a floodplain but instead remain confined within the high banks created by channelization. During high flows, this condition can create erosive forces that can cause the transport of sediment originating from both the sandy substrate and stream banks. Overall, entrenchment was observed in a total of 51 % of Trout Brook (Table 11).

Table 11. Selected results from geomorphological survey

Feature		Length (m)	Percent
Channelization	Channelized	2,430	59.6
	Encroachment	426	10.5
	Unaltered channel	1,218	29.9
Entrenchment (entrenchment ratio)	Deeply entrenched (<1.4)	405	10.0
	Slightly entrenched (1.4 - 2.2)	1,650	40.6
	Not entrenched (>2.2)	2,014	49.5
Bank stability	Major erosion	186	2.3
	Minor erosion	1,299	15.9
	Armoring / Riprap	150	1.8
	Stable	6,550	80.0
Riparian buffer width	Absent (0 m)	3,221	39.4
	Narrow (1-10 m)	1,366	16.7
	Wide (>10 m)	3,595	43.9

The geomorphological survey showed only few areas where bank stability was identified as a problem (i.e., major erosion), predominantly in the lower part of the watershed, between Broadway and Mill Cove (Table 11; Fig. 20 a; Fig. 5a in Field 2003). Channel armoring with riprap was seen in only two places, where Broadway and Providence Avenue/Marsh Road cross the stream (Table 11). Buffer width was identified as a more extensive problem (Table 11; Fig. 20 b; Fig. 5a in Field 2003). Aggradation, i.e., deposition of sediment in the channel, was identified as an issue in the section between Highland Avenue and Broadway (Trout Brook Site 1 in Field 2003). Here, the original channel was constructed too large for the dominant discharge, and the channel is trying to re-establish an equilibrium through a reduction in bankfull width. This section is in Stage III of Schumm's Channel Evolution Model (see Fig. 8 and Table 6 in Field 2003), i.e., is approaching the equilibrium stage (Stage V), which generally makes restoration efforts to re-establish sinuosity a good option.

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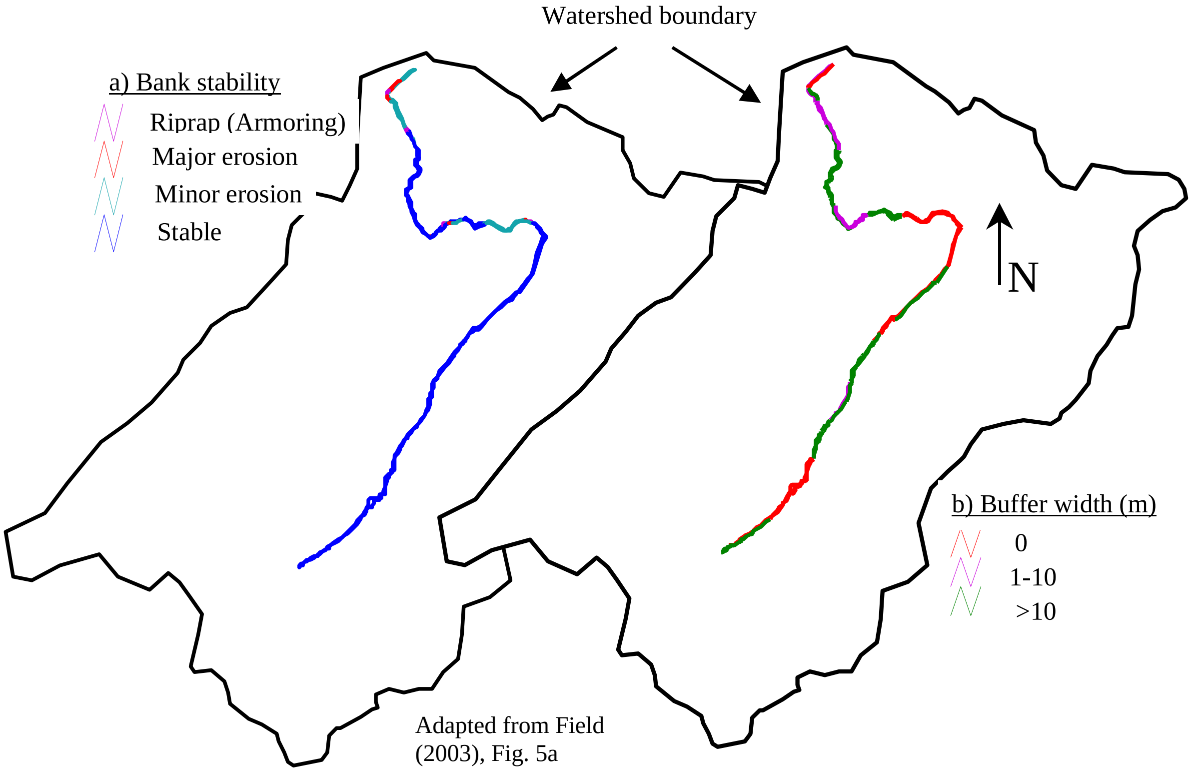
[1] Entrenchment is the ratio of the channel width at two times the bankfull depth to the width at the bankfull stage (Field 2003).

Fig. 20. Bank stability (a) and buffer width (b) along Trout Brook



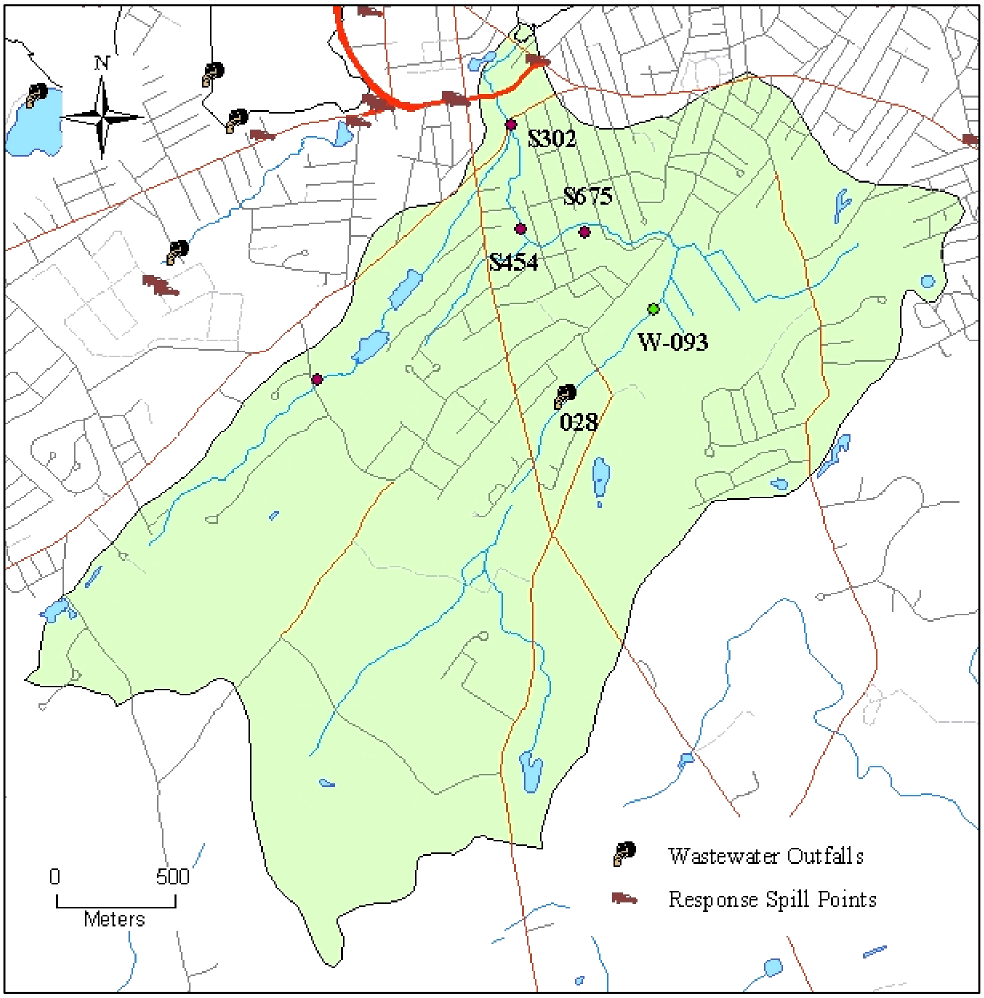
Adapted from Field (2003), Fig. 5a

The survey furthermore included two qualitative assessments of the entire stream. A Rapid Habitat Assessment (as in Table 9, above) showed that most of Trout Brook has a Fair ranking (ranking categories are Poor, Fair, Good, Reference; top score is 200; Table 3 in Field 2003). Specifically, the stream near the downstream biomonitoring station had a Good ranking (131, range is 71 - 130), while it had a Fair ranking near the upstream station (124, range is 71 - 130), and also a Fair ranking (103) near the wetland station. A Rapid Geomorphic Assessment, which is used to evaluate degradation, aggradation, widening, and planform adjustment processes showed that most of Trout Brook is near the high end of the Fair or the Good ranking (ranking categories are Poor, Fair, Good, Reference; top score is 80). Specifically, the stream near the downstream biomonitoring station had a Good ranking (60, range is 41 - 60), while it had a Fair ranking near the upstream station (38, range is 21 - 40), and a Good ranking near the wetland station (58).

6. An analysis of spills documented by the MDEP's Bureau of Remediation and Waste Management between 1976 and 2003 showed that few spills occurred within the watershed (App. E). The spills were confined to the time period between 1989 and 2002. Spatial (GIS-linked) information is currently available for only one of those spills (Fig. 21). In some cases the records contained no information on potential effects of a spill on nearby surface waterbodies, and it was hence not possible to determine whether those spills affected Trout Brook. All incidents concerned spills of heating oil with amounts ranging from <1 - 199 gallons. There was at least one case where a spilled product reached the stream. In that case, 100 gallons of oil were spilled in 1992 on Boothby

Avenue, approximately halfway between the downstream and late upstream stations (75 gallons were recovered, App. E).

Fig. 21. Spill points and wastewater outfalls (CSOs)



There is only one wastewater outfall (or combined sewer overflow, CSO; # 028; Fig. 21) in the watershed. It is located ~500 m above the wetland monitoring station, ~1,250 m above the late upstream station, and ~2,000 m above the downstream station. Discharge data for the last five years for this outfall are shown in Table 12. It is clear that a relatively large amount of stormwater mixed with sewage has been discharged into the stream, with the largest discharge occurring the year the macroinvertebrates attained class at the downstream station (1999; Table 1). As discharges occur above all monitoring stations, there may have been an effect on the 2003 data presented here.

Table 12. Discharge data for CSO # 028 going into Trout Brook

Year	Number of events	Gallons discharged
2003	4	52,688
2002	5	34,896
2001	6	170,460
2000	1	77,437
1999	4	254,903

DATA SUMMARY

The two stream stations studied on Trout Brook were quite similar in many respects. Summary results from all sampling events and assessments are listed in Table 13 and discussed below (in the Discussion), but briefly, both stations had impaired macroinvertebrate communities, high conductivity, elevated TN at baseflow and TP at stormflow, and several violations of metal criteria at stormflow, but relatively cool water and overall adequate habitat (but note geomorphological and riparian zone problems of stream as a whole). Dissolved oxygen concentration was good at the downstream station but low at the late upstream station. “Conclusions and Recommendations”, below, contains recommendations on how to maintain good conditions, and suggestions for best management practices (BMPs) and remedial actions aimed at improving poor conditions.

Table 13. Data summary for 2003. Highlighted fields indicate problem parameters.

Parameter	Downstream (S302)	Upstream late (S675)	Wetland (W-093)
Biota			
Macroinvertebrates	Model result “Non-Attainment” (very low diversity, no E or P, 7 T, 1 Class A indicator, 80 % non-insects, intermediate Hilsenhoff Index)	Model result “Non-Attainment” (no E or P, 1 T, no Class A indicators, 17 % non-insects, high Hilsenhoff Index)	Low abundance, medium richness, few EOT[1]
Fish	Low diversity, but many brook trout		
Algae	(observation: few algae)	(observation: few algae)	
Water Quality Parameters			
Dissolved oxygen	Almost always >8 mg/L; diurnal fluctuations <0.6 mg/L	Usually <7 mg/L (as low as 3 mg/L); diurnal fluctuations <1.5 mg/L	Good (9.0 mg/L)
Specific conductance	High (usually 400-700 µS/cm); spikes up to 30,000 µS/cm due to tidal influence	Relatively high (usually ~700 µS/cm)	High (429 µS/cm)

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[1] For wetlands, “O” (Odonata, dragonflies) are more appropriate indicators of community quality than “P” (Plecoptera) (J. diFranco, pers. comm.).

Table 13 (continued)

Parameter	**Downstream (S302)**	**Late upstream (S675)**	**Wetland (W-093)**
Water Quality Parameters (continued)			
Summer temperature	Cool (mean usually <18 ºC)	Warm (21 ºC)	Normal
Turbidity/ Suspended solids	Turbidity slightly elevated (usually 5-10 NTU); SSD at baseflow <2–17 mg/L, at stormflow 29 and 50 mg/L	No data for turbidity; SSD at baseflow <2–3 mg/L, at stormflow 29 and 70 mg/L	
Nutrients and bacteria	TN and bacteria exceed criteria at baseflow, TP at stormflow	TN and bacteria exceed criteria at baseflow, TP at stormflow	Nutrients and anions/ cations high compared to other ME wetlands
Metals/Anions and cations	No metal violations at base-flow; Al and Cu exceed CMC criteria at stormflow	No metal violations at baseflow; Al, Cu, and Zn exceed CMC criteria at stormflow	
Habitat Assessments			
Flow regime	Quite variable	Partly variable, partly slow	
Stream width/depth	Stable throughout summer		
Woody debris (mean % spanning channel)	Fairly good LWD and SWD, absolute mass greater than relative mass (30 %)	Limited LWD, good SWD, absolute mass much greater than relative mass (18 %)	
Physical characterization	Qualitative assessment: some problems (obvious sources of NPS pollution, moderate erosion)		
Habitat assessment (top score is 200)	Intermediate score (124)		
Human disturbance (best/worst score recorded in ME is 1/44)			Relatively high level of disturbance (score of 29)
Fluvial geomor-phology survey	Major channelization, moderate entrenchment, few erosion problems, no/narrow riparian buffer along more than half of stream; Fair to Good Geomorphic Assessment (score 38-60; top score is 80); Fair habitat assessment (score 72-131; top score is 200)		
Spill points	Few spills		
Wastewater outfalls	One, upstream of wetland station, annual discharge 35,000 –170,500 gallons, to be removed in 2004/2005		

DISCUSSION

Biological Monitoring

The macroinvertebrate community observed at the downstream and late upstream stations consisted largely of tolerant organisms, such as amphipods, chironomids and isopods (Table 4). Noteworthy is the repeated dominance of the community at the downstream station by the brackishwater taxon *Gammarus* (up to 97 %), even in 1999 when the community attained Class C; this abundance pattern may be partly related to the periodic intrusion of saltwater into Trout Brook (see Specific Conductance, below). Of further interest is the occurrence of *Glossosoma* at the downstream station, a Class A indicator and sensitive trichopteran that requires cool water and high DO. Generic richness at both stations was intermediate but did not include any Ephemeroptera or Plecoptera although some Trichoptera were found, particularly at the downstream station. Macroinvertebrate data from the downstream station from 2003 (Table 4) are quite similar to those from previous years (1997, 1999, and 2000; see Previous Studies, Table 1), with the exception of total abundance which was lower in 2003 than in other years (208 *versus* 486 – 628). In five of six total sampling events, Trout Brook failed to meet the required Class C aquatic life criteria , i.e., conditions were insufficient to "*maintain the structure and function of the resident biological community …" (*Maine Water Quality Criteria for Classification of Fresh Surface Waters; Title 38 MRSA §465). Although Maine has not yet developed aquatic life criteria for macroinvertebrate communities in wetlands, a comparison between data from the wetland station on Trout Brook with those from high-quality wetlands also indicates that the community was impaired (J. DiFranco, pers. comm.). The continued evidence of impairment is not unexpected given that conditions in the watershed have not changed appreciably in recent years. Also, degraded macroinvertebrate communities similar to the one found in Trout Brook were found in the other three streams included in the Urban Streams Project (excluding the upstream station on Capisic Brook) as well as in other urban streams sampled by the MDEP's Biological Monitoring Program (unpublished data). However, to a certain extent, the result is unexpected because some water quality and habitat parameters (see below) appear sufficient to support functioning macroinvertebrate communities.

The relatively high abundance of healthy-looking brook trout, a fish that is sensitive to water pollution, at the downstream station is likely facilitated by the high dissolved oxygen concentration (generally >8 mg/L; Figs. 4, 8, and 9) and relatively low water temperature measured in this section of the stream (mostly <18 ºC; Figs. 6, 9 and 12). The presence of young-of-the-year trout indicates that this fish is reproducing in the stream. A review of the literature on temperature effects on salmonids by McCullough (1999) showed that adults have an upper thermal tolerance of a mean weekly temperature of 22.3 ºC or a maximum temperature between 19 and 25.6 ºC. Temperatures found in Trout Brook were generally well below the tolerance limits of adults.

The abundance of brook trout in the lower section of this stream is encouraging as it indicates that water quality is good enough to support a sensitive fish species. American eels, although known to be tolerant to water pollution, also occur in unpolluted waters, and their presence in Trout Brook is likely related to the proximity of this stream to the Fore River estuary. Both fish species are carnivores (brook trout consume primarily aquatic insects but also fish and small crustaceans; American eels consume mainly fish and invertebrates), and the absence of other fish species as well as the composition of the resident macroinvertebrate community may be influenced by the abundance of these two fish species.

Maine does not have aquatic life criteria for algal assemblages in streams, and taxonomic data for the downstream station are as yet outstanding, but a visual assessment indicated that algae were not very abundant (see Results, Biological Monitoring, item 3).

The data available by late May 2004 were analyzed with the goal of identifying specific stressors that are responsible for the observed impairment in the macroinvertebrate community in Trout Brook. The stressor identification process (see Ch. 1, Introduction, MDEP Urban Streams Project, and below) pointed to toxicants as the most likely factor to cause impairments at both stations, followed by degraded riparian habitat and altered hydrology at the downstream station, and degraded instream habitat, altered hydrology, and low DO concentrations at the late upstream station. The Total Maximum Daily Load plan (TMDL plan; see Ch. 1, Introduction, MDEP Urban Streams Project) will need to address these factors to enable the restoration of healthy aquatic communities in Trout Brook.

Water Quality Monitoring

Dissolved oxygen

The dissolved oxygen (DO) concentration (instantaneous, diurnal, and continuous, Figs. 4, 8, and 9, respectively) in Trout Brook at the downstream station always was favorable for healthy macroinvertebrate communities. This positive finding is likely attributable to four main factors: 1) the cool temperatures existing in this stretch of the stream (see below) allow the water to hold a high concentration of DO; 2) the low abundance of algae means that oxygen levels are not depleted due to algal respiration and decomposition; 3) the variable flow regime favors (re)aeration of the water, and 4) only few problems exist with high nutrient levels, which helps minimize algal growth.

The DO concentration at the late upstream station (instantaneous and diurnal, Figs. 4 and 8, respectively) was always below 7 mg/L, i.e., below what is generally considered an adequate level for biota. On several occasions, the concentration dropped below the Class C numeric criterion for DO (5 mg/L). One factor involved in lowering DO concentrations at the late upstream station in the summer may be a low flow velocity within the stream above this station as water flows through a marshy area (see Habitat Assessments, Flow velocity, below). However, the main reason for the low DO concentration recorded at this station is probably a significant input of spring water just above this station, in a channel/tributary entering the stream from the left (looking downstream). In the summer, this spring water is the main water source for the upstream station (pers. obs.), and thus it has a large influence on water quality. Based on observations at the station, this spring water likely is not groundwater coming from greater depths (which generally has a DO of ~6 - 10 mg/L) but instead ‘perched groundwater’, i.e., groundwater that collects in the surficial geology layer (Presumpscot Formation) and resides there for some time before draining into a stream (J. Hopeck, pers. comm.). This type of groundwater can have a low DO content due to chemical and biological processes occurring in the surface soils. The iron deposits observed in the area of springs near the station support the hypothesis of perched groundwater: in low-DO perched groundwater, iron is present in soluble form (Fe^{2+}) but upon meeting higher-DO surface water, it becomes oxidized (Fe^{3+}) and precipitates out. Further supporting evidence for the low DO concentrations being the result of the spring water influx is found in the high (8.2 mg/L) concentration measured in late spring of 2004, when (low-DO) spring water constituted only a fraction of total stream flow at the late upstream station.

The hypothesis that low DO values are attributable to (perched) groundwater was confirmed with a DO profile collected in the stream itself and in the small “tributary” coming from the area of springs (“Trout” and “Trib.”, respectively, in Fig. 22). Measurements were taken as described in Ch. 2, Methods, Water Quality Monitoring, item 1. The profile shows one area (at 26 m, Trib.) with strong gradients in DO and temperature between bottom and surface water (depth of ~20 cm), namely a DO concentration of 1.8 *versus* 7.8 mg/L, and a temperature of 13.9 *versus* 18.5 ºC. Smaller gradients also were found in the tributary at 27 and 28 m (Fig. 22). A gradient furthermore existed at 12 m in Trout Brook where DO was measured at 3.6 and 5.5 mg/L at the bottom and at mid-height, respectively (i.e., over ~10 cm; no temperature measurement was taken at the bottom but a pocket of cold bottom water was indicated by the “cold-feet test”[1]). Such gradients are unusual for a shallow channel and strongly indicate point sources of spring water influx. A marked decline in the DO concentration in the stream itself (from 6.5 to 3.6 mg/L) occurred where the tributary flows into Trout Brook (between 24 and 22 m in Fig. 22). No bottom *versus* surface measurements were taken in Trout Brook above the tributary but the “cold-feet test” did not indicate any signs of spring water influx. This section of Trout Brook is fed largely by water coming from upstream, where DO and temperature were similar as at the 40-m mark in Fig. 22. Additional evidence that groundwater inputs were localized included measurements taken above a culvert ~ 40 m further upstream that showed a DO concentration of 6.7 mg/L and a water temperature of 20.2 ºC, values more indicative of surface water rather than groundwater. The patterns encountered above the late upstream station suggest that the DO concentration at this station likely represents a natural situation which may have a negative effect on the composition of the resident macroinvertebrate community.

The DO concentration at 1:30 p.m. in Trout Brook at the wetland station was quite high given the water temperature (9.0 mg/L at 20.7 ºC). Percent DO saturation was not measured, but can be estimated using the water temperature to have been at ~100 %. This section of stream had abundant emergent vegetation (water lilies, grasses) which likely contributed to the high DO concentration. For comparison, at the downstream station, which had very few plants or algae, the DO concentration at a temperature of 20.7 ºC was only 7.8 mg/L or ~85 % (continuous sonde data, Fig. 9), suggesting that algae and plant contributed to oxygen enrichment at the wetland station. No diurnal measurements of DO were collected at this station, and it is unknown whether diurnal DO fluctuations exceeded 2 mg/L.

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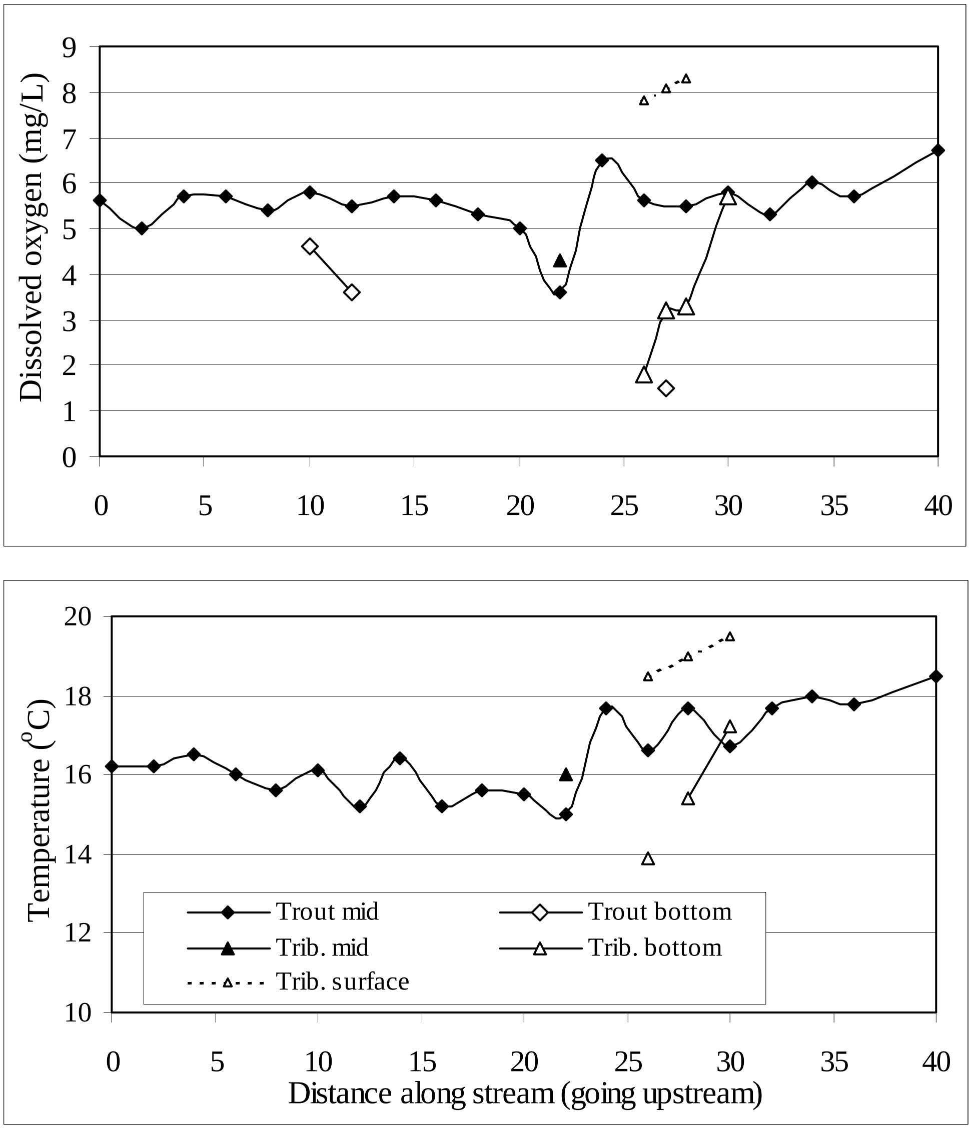
[1] Areas of spring-water influx were initially located by observing a noticeable chilling of feet in rubber boots.

Fig. 22. DO and water temperature profile at late upstream station in July 2004



“Trout”, stream channel; “Trib.”, tributary; “mid”, “bottom”, “surface”: mid-water, at bottom, near surface of water.

Dissolved oxygen is required for respiration by all aquatic animals, but some organisms such as stoneflies, mayflies, and brook trout require relatively high oxygen concentrations for healthy functioning. Tolerant organisms like midge larvae or some worms on the other hand can survive at low DO concentrations. In 2003, DO levels generally were high enough to support healthy aquatic communities at the downstream station on Trout Brook, but not at the late upstream station.

Specific conductance

The levels of conductivity (instantaneous and continuous, Figs. 5 and 10, respectively) in Trout Brook are similar to those found in the other three streams included in the Urban Streams Project as well as in other urban streams sampled by the MDEP’s Biological Monitoring Program (unpublished data). These levels are often much higher than those that would be encountered in minimally impacted streams in Maine, where conductivity is typically below 75 μS/cm (L. Tsomides, pers. comm.). While certain types of geological formations and certain soil types in a watershed can cause conductivity levels to be elevated naturally, it is likely that runoff from the extensive impervious surfaces near the monitoring stations contributes to high conductivity in this stream (also see discussion on Metals, below). Wetland data indicated that ion (Ca, Mg, K, Na) concentrations in Trout Brook were in the top 10 % of concentrations measured in Maine wetlands (Table 7), which may partly explain the occurrence of high conductivity, and identify some of the components responsible for it. It is noteworthy that conductivity decreased substantially (to ~200 μS/cm) following rain events (Fig. 10) indicating that an input of rain and stormwater temporarily diluted the ions measured with this parameter. Data from previous sampling events in 1997, 1999, and 2000 show that the conductivity levels at the downstream and middle stations have been high for several years (see Previous Studies), i.e., that water quality has been impaired for several years.

While little is known about how elevated conductivity in and of itself may impact biological communities, it is known that metals, which can cause high conductivity levels, can have negative effects on aquatic life (see discussion on Metals and chloride, below). To reduce conductivity levels in Trout Brook, it would be helpful to reduce the quantity of runoff the stream receives, or to improve runoff quality for example by channeling it through an infiltration or stormwater treatment system.

Saltwater intrusions

As shown in Fig. 10, continuous records of conductivity revealed large variations in this parameter that were not picked up by instantaneous measurements. Significant spikes in conductivity (~31,000, 21,000, and 25,000 μS/cm) were recorded during three consecutive nights (at 12:10, 1:00 and 2:00 a.m.) in July 2003, and examination of tide tables showed that high tide in the Fore River/Portland Harbor occurred around those times on the nights in question, suggesting an intrusion of saltwater into Trout Brook. In an attempt to clarify the situation, continuous conductivity data were again collected in early July 2004 with the goal of answering the following questions:

1) Are SPC spikes (>10,000 μS/cm in summer) always related to high tides in the Fore River/Portland Harbor?
2) At what tidal height do saltwater intrusions occur?
3) Do intrusions occur above as well as below the Highland Avenue culvert? (In 2003, continuous SPC measurements were taken only below the Highland Avenue culvert.)

Measurements were taken between June 30 (5 p.m.) and July 7 (1 p.m.), 2004, and raw data collected every 20 min are shown in Fig. 23. Data showed remarkable variation, ranging from 590 to 35,080 μS/cm (Fig. 23) with a clear periodicity of ~25 h for the maxima, which closely tracked the occurrence of high tides (Table 14). Measurements of >10,000 μS/cm[1], which correspond to a salinity of 6.9 ppt at 16 ºC, lasted between 20 and 100 min, starting between 42 min before the time of high tide (at the highest tide level), and 6 min after the time of high tide (at the lowest tide level producing a signal; Table 14). Conductivity always increased very rapidly (between two measurement intervals) at the start of a saltwater intrusion but usually was slower to decrease from >10,000 μS/cm to previous levels (over two

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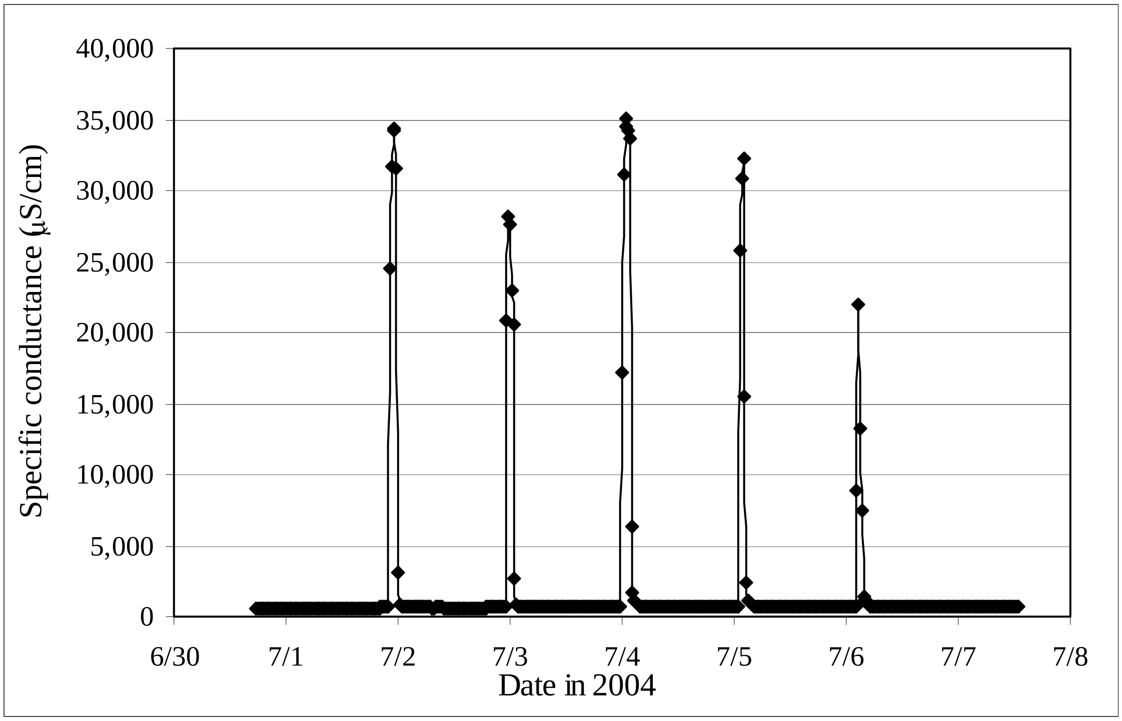
[1] A level of 10,000 μS/cm was chosen here as a convenient measurement indicating a conductivity clearly exceeding what could be expected in an urban stream during baseflow conditions in the summer.

to four measurement intervals, i.e., 40 - 80 min). The lowest tidal height producing a signal was 11.0 feet, and no signal was detected at 10.4 feet (Table 14).

Fig. 23. Continuous specific conductance at downstream station in July 2004



Data sondes were deployed both above and below the Highland Avenue culvert but only data from the above-culvert location (i.e., from the downstream station) are presented here (Fig. 23). Data collected below the culvert showed a very similar pattern to those collected above the culvert, with somewhat higher maximum conductivities (up to 40,470 µS/cm), longer occurrence times of SPC >10,000 µS/cm (up to 2 h 40 min), a higher frequency (as above culvert but also on 6/30 and 7/7), and lower minimum tidal heights required for a signal (10.4 feet). The likely reason for the stronger tidal influence below the culvert is the slight elevation difference between the two measurement stations,- and the barrier the culvert presents to water flowing upstream.

Table 14. Tidal and conductivity data from early July 2004 at downstream station. Problem tides are highlighted.

Date in 2004	High tide information	Start of SPC >10,000 μS/cm	Maximum SPC[1]	Duration of SPC >10,000 μS/cm[2]
6/30	9:54 p.m., 11.2 ft	n.a.	620 μS/cm	0 min
7/1	10:40 a.m., 9.4 ft	n.a.	620 μS/cm	0 min
	10:50 p.m., 11.5 ft	10:21 p.m.	34,300 μS/cm at 11:21 p.m.	80 min
7/2	11:37 a.m., 9.6 ft	n.a.	630 μS/cm	0 min
	11:46 p.m., 11.6 ft	11:21 p.m.	28,130 μS/cm at11:41 p.m.	80 min
7/3	12:34 p.m., 9.7 ft	n.a.	650 μS/cm	0 min
7/4	12:42 a.m., 11.6 ft	12:00 midnight	35,080 μS/cm at 1:01 a.m.	100 min
	1:29 p.m., 9.8 ft	n.a.	650 μS/cm	0 min
7/5	1:38 a.m., 11.4 ft	1:21 a.m.	32,230 μS/cm at 2:01 a.m.	60 min
	2:24 p.m., 9.8 ft	n.a.	670 μS/cm	0 min
7/6	2:35 a.m., 11.0 ft	2:41 a.m.	21,930 μS/cm at 2:41 a.m.	20 min
	3:19 p.m., 9.7 ft	n.a.	640 μS/cm	0 min
7/7	3:32 a.m., 10.4 ft	n.a.	690 μS/cm	0 min

[1] Whenever maximum conductivity was <1,000 μS/cm, measurements were relatively constant over extended periods of time, and no time is specified in the table.

[2] Duration is calculated as the time between two measurements taken at 20 min intervals. Because measurements >10,000μS/cm likely also occurred (shortly) before/after the first/last elevated measurement, periods given in the table are minimum durations.

Conductivity data collected in July 2004 clearly indicate that the downstream station on Trout Brook is subject to tidal influence. The occurrence of saltwater intrusions appears to be limited to the highest tides, that is those of 11 feet or greater. Consultation of tide tables for 2004 showed that during the entire year, only 34 high tides (out of ~700) reached or exceeded 11 feet, with the majority of cases occurring in June/July and December. The arbitrary conductivity level of 10,000 μS/cm chosen here to indicate the beginning of a marine intrusion corresponds to a salinity of 6.9 ppt at 16 ºC, while the highest conductivity measured (35,080 μS/cm at 16.7 ºC) corresponds to a salinity of 26.8 ppt. For comparison, seawater has a salinity of ~35 ppt but an estuary such as the Fore River would have a lower salinity. While only few insects occur in marine waters, insect density and diversity can be quite high in estuaries, particularly in the more upstream reaches (Williams and Williams 1998; Williams and Hamm 2002). For instance, Williams and Hamm (2002) found that in three estuaries in New Brunswick, Canada, EPT taxa as well as some Coleoptera (beetles) and Diptera (flies, here: chironomids) dominated sites inundated by 25 % of high tides. The sensitive trichopteran *Glossosoma*, which was observed at the downstream station in Trout Brook, occurred at a site inundated by 33 % of high tides in an estuary in Wales, U.K. (Williams and Williams 1998). The literature therefore suggests that the mere occurrence of a limited number of saltwater intrusions would not necessarily have a negative impact on the macroinvertebrate community.

Water temperature

The relatively cool mean temperatures (continuous temperature in 1997 and 2000, Figs. 2 and 3; instantaneous, and short and long-term continuous temperature in 2003, Figs. 6, 9 and 12) at the downstream and late upstream stations on Trout Brook were favorable for sensitive biota. Maximum temperatures at these stations were mostly below 20 ºC, but occasionally reached up to 22 ºC, which is warmer than ideal for most aquatic organisms. These maxima occurred only for relatively short periods of time (~1.0 - 1.5 hours) before dropping below 20 ºC, and may thus not have had a major impact on animal health. Compared to the other Urban Streams, Trout Brook had the second lowest temperatures after the upstream station on Capisic Brook (App. C ii). Studies have shown that sensitive macroinvertebrates such as certain mayflies or stoneflies prefer temperatures below 17 ºC (see references in Varricchione 2002), while sensitive fish such as brook trout prefer mean temperatures below ~22 ºC (see Biological Monitoring, above). Factors responsible for the good temperature regime, especially at the late upstream station, are the closeness to a number of springs, which provide most of the flow in summer, and a riparian zone with many trees providing good shading along some reaches. It is important to preserve these conditions to ensure that favorable temperatures are maintained in Trout Brook, especially for the resident brook trout population.

One exception to the generally favorable temperature regime was the early upstream station where high temperatures were measured in a shallow area with little flow in early June and July, shortly before this location began to dry out (see Ch. 2, Methods). In late spring and in summer, this area did not show a definite stream channel but rather was made up of a network of small rivulets slowly draining into a marshy area. Furthermore, throughout the upper 1/3 of the watershed, down to Sawyer Street (~400 m above the early upstream station), Trout Brook flows largely through open, partly marshy areas with little flow in the summer, conditions that allow the water to warm up significantly. Given the conditions above and at the early upstream station, high summer temperatures may be natural for this location. If so, this area may not be good habitat for fish and aquatic invertebrates because of elevated temperatures and very low summer flows.

pH

In natural waters, pH usually falls between 6.5 and 8.5, and a range of 6.0 - 9.0 protects most aquatic life. All measurements taken on Trout Brook were within a range that favors healthy macroinvertebrate and fish communities.

Turbidity

Like the other Urban Streams, Trout Brook lies within the Presumpscot formation, a surficial geology type dominated by fine sediments. At all Urban Streams, silt and clay dominate over sand, contributing to an increase in turbidity during high flows due to suspended fines (App. G). Analysis of the data indeed showed that high flow events following rain storms caused large turbidity spikes on July 25 and August 1 (Fig. 11 a). During baseflow conditions, turbidity in Trout Brook was quite low (Fig. 11 b), although the turbidity criterion of 3.04 NTU recommended by EPA for Ecoregion XIV (USEPA 2000b), which includes Trout Brook, was exceeded 31 % of the time (485 out of 1,582 records). Total suspended solids were generally low in Trout Brook during baseflow conditions (Table 5, App. C iii) but elevated during stormflow conditions (Table 6).

Suspended solids, which affect the turbidity of a stream, can be of natural origin (clay, silt, sand, decaying vegetation, phytoplankton) or man-made (industrial wastes, sewage, winter road sand). Land use (e.g., urban *versus* forested) and local soil type (e.g., silt and clay *versus* bedrock) are important factors that influence turbidity levels in a stream. High concentrations of suspended solids can affect streams and the organisms living in them in a variety of ways: by modifying light penetration which affects plant growth; by smothering benthic organisms thus affecting their health; by increasing substrate embeddedness; by reducing available invertebrate living space; by reducing the flow of oxygen-rich surface water through stream gravels and cobbles where salmonid fish eggs may be incubated; by reducing the ability of visual predators to find prey; by clogging the gills of fish; and by potentially darkening the water which may lead to an increase in temperature through increased absorption of heat from sunlight. Turbidity in Trout Brook generally was not high enough to have a major negative effect on biota in the stream although some effects, particularly during storm events, may occur.

Nutrients and bacteria

The surface water samples collected at the downstream and late upstream stations during baseflow conditions exceeded the recommended EPA water quality criterion for Total Nitrogen (TN) on all sampling dates (Table 5). A similar result was found in 2000 at the downstream station (Table 2), and during limited sampling in the summer of 2004 at both stations (App. C iii). Furthermore, samples collected in August of 2004 at both stations exceeded the EPA criterion for Total Phosphorus (TP; App. C iii). Compared to the other impaired Urban Stream stations, Trout Brook in 2003 was generally similar in baseflow TN levels (App. C iii), the abundance of algae (low), and canopy cover (high) to both stations on Birch Stream and the middle station on Barberry Creek. Compared to the downstream station on Capisic Brook, which had excessive algal growth and an open canopy, TN levels in Trout Brook at baseflow were lower. During stormflow conditions, Total Phosphorus (TP) exceeded the EPA criterion on three out of four dates (Table 6). Compared to the other Urban Streams, Trout Brook had the highest stormflow TP values in the spring of 2003 and on one date in February 2004, but intermediate values in the fall of 2003, and low values on a second date in February 2004 (App. C iv). Data from the wetland sampling showed that nitrogen (nitrate-nitrite-N, TN) values were among the highest measured in Maine wetlands by the biomonitoring program (Table 7).

Nutrient levels are often increased in urban streams as runoff from land includes material that is high in nitrogen, such as animal waste, fertilizers, septic system effluent, or road dirt (CWP 2003). In Trout Brook, nutrient load may also be increased by runoff from the vegetable farm in the upper part of the watershed: a water sample collected ~300 m below the farm in summer 2004 showed elevated TN and TP values exceeding EPA-recommended nutrient criteria (App. C iii). (Water quality data upstream of the farm are not available.) Furthermore, many cities, including South Portland, operate a combined sewer overflow (CSO) system which can allow raw sewage to enter a stream during storm events. When this happens, the bacterial and nutrient load in the stream increases (see Spills and wastewater overflows, below). The MDEP's Biological Monitoring Program has found that, depending on site characteristics, elevated nutrient levels in urban streams may impact macroinvertebrate communities. This can occur for example when exposure of the stream to sunlight promotes excessive plant and algae growth which in turn may cause temporary DO depletion (L. Tsomides, pers. comm.). The small amount of algal growth, adequate dissolved oxygen concentrations, limited exceedances of nutrient criteria, and low Chl *a* values suggest that nutrients are not a significant stressor at the downstream station in Trout Brook. The same is likely true at the late upstream station where little algal growth and nutrient enrichment was observed also; at this station, however, dissolved oxygen concentrations were always low, likely due to natural causes (see discussion Dissolved oxygen, above). It is unclear why nitrogen levels at the wetland station ranked so high compared to other locations in Maine but potential reasons are the presence of a CSO ~500 m above the wetland station and runoff from the vegetable farm in the upper part of the watershed.

Maine's criterion for the mean count of bacteria (*E. coli*) colonies of human origin was exceeded at both stations on all sampling dates (by up to a factor of 9). However, it is not known whether this constitutes a true criterion violation as the analysis performed in this study did not differentiate among various sources for bacteria (pets, wildlife, birds, CSOs, leaking sewer systems). Most of these sources are present in the Trout Brook watershed: pet waste near the stream was observed during a watershed survey in April 2003 (pers. obs.); wildlife and waterfowl use the stream and surrounding area as a resource (pers. obs.); and large amounts of storm water mixed with raw sewage enter Trout Brook from a CSO each year (Table 12). According to information obtained from the City of South Portland (D. Pineo, pers. comm.), two other potential sources of bacteria (a few homes with septic systems on Kaler Road, and sewer pipes paralleling Trout Brook in the wetland and along Marsh Road) are unlikely to be major issues.

Although nutrients and bacteria may not be a significant issue in Trout Brook, simple measures to control them should be initiated. Such measures could include keeping pets away from the stream, picking up pet waste, minimizing fertilizer use on lawns in the vicinity of the stream or its tributaries, and ensuring that sewer and septic systems in the watershed are in good working order. Furthermore, the maintenance or re-planting of a vegetated riparian buffer along the stream corridor would allow for the filtration of lawn or yard runoff. However, to effectively control nutrient, and likely bacterial, loads in Trout Brook, entry of raw sewage into the stream needs to be prevented. To this end, the City of South Portland is currently working on separating the CSO in the wetland section, thus eliminating this potential stressor. Furthermore, the farm in the upper part of the watershed should be encouraged to minimize fertilizer use as nutrient levels were found to be elevated below the operation.

Metals and chloride

None of the metals sampled during baseflow conditions in 2003 exceeded Maine Statewide Water Quality Criteria (SWQC; Table 5) at the late upstream or downstream station. The same result was also found in 2000 at the downstream station (Table 2). Limited sampling in the summer of 2004 showed that aluminum exceeded the chronic criterion (CCC) once at each station (App. C iii). At the same time, copper was below the CCC at both stations, and lead was below the acute criterion (CMC; detection limit was above CCC). One sample collected below the farm in the upper part of the watershed showed that aluminum was at the CCC, copper was below it, and lead was below the acute criterion (detection limit for lead was above CCC; App. C iii). During stormflow conditions in 2003, aluminum, copper, and zinc exceeded Maine SWQC at one or both stations (Table 6). Unfortunately, for some samples the detection limits for certain metals were above the water quality criteria, for example in 2003 in the case of copper for both chronic and acute criteria. Varricchione (2002) studied a stream (Long Creek) in a highly developed area in South Portland, and found that copper, lead, and zinc exceeded acute criteria during three storm events. Compared to Varricchione's results, Trout Brook showed slightly fewer criteria violations.

The metals detected in Trout Brook likely originated as metal pollutants that had adsorbed onto particles of road dirt which were subsequently blown or washed into the stream. Beasley and Kneale (2002) and CWP (2003 and references therein) cited as sources for metal pollution in urban streams vehicles (tires, brakes, fuels, and oils), pavement (concrete, asphalt), rooftops, exterior paints, and surface debris (litter, winter road sand and salts). Lead may also enter the stream from CSO pipes (J. True, pers. comm.). Aluminum and iron can also occur naturally in streams as these metals are very abundant, and can leach out of soils with low pH-buffering capacity. Zinc can also originate from galvanized steel pipes used for culverts or storm drain systems. Sediment entering the stream from construction sites, winter sanding activities, or soil erosion also may carry metals (e.g., CWP 2003). Finally, spills of hazardous substances and CSO input also can add metals to a waterbody. Impacts of metals on streams can occur in the form of chronic or acute toxicity to aquatic organisms, contamination of sediments, and bioaccumulation in plants or animals (CWP 2003 and references therein). Negative effects of metals on macroinvertebrates and fish have been confirmed in several studies. Effects include declines in the rates of growth and reproduction, reduced population size, changes in community structure, and death (Paul and Meyer 2001, and Beasley and Kneale 2002, and references therein). To reduce metal pollution in Trout Brook, road runoff needs to be diverted away from the stream or treated before entering the stream. Also, sand left in parking lots and on roads after the end of the winter sanding season should be removed to reduce the sediment influx into the stream. While the City of South Portland has a road sweeping program in place (D. Pineo, pers. comm.) and is thus minimizing sand influx into the stream, it is not known whether businesses and schools in the lower part of the watershed also remove sands from their premises. If they do not, they should be encouraged to initiate this practice. Rigorous application of BMPs by construction companies and the greening of bare surfaces also would help reduce sediment/metal input into Trout Brook.

Chloride levels during baseflow conditions in the summers of 2003 and 2004 were far below the chronic criterion at the late upstream and downstream stations, and below the farm (App. C iii). Chloride concentrations are expected to be low in the summer as this pollutant predominantly reaches waterbodies as road runoff during the winter and spring. No winter/spring data exist for Trout Brook, and this data gap should be filled, preferably by deploying a continuous data sonde measuring conductivity. Conductivity is strongly affected by chloride because this anion typically occurs in high concentrations (in contrast to metals, it is measured in mg/L rather than μg/L), making SPC measurements a convenient way to determine chloride loads in winter and spring. Conductivity levels of up to ~23,000 μS/cm have been seen in studies of urban streams in the winter (S. Corsi, pers. comm.). This indicates high chloride toxicity as conductivities of 853 and 2,855 μS/cm correspond to the Maine SWQC (MDEP SWQC) chronic and acute criteria of 230 and 860 mg/L chloride, respectively (D. Heath, pers. comm.). According to storm drain maps obtained from the City of South Portland (D. Pineo), most snow that melts on roads, parking lots, or driveways in the watershed flows into Trout Brook either directly or via the storm drain system with outfalls located on Norman Street, at the intersection of Providence Avenue and Marsh Road, above Highland Avenue, and below Broadway. Additional outfalls are located on the tributaries to Trout Brook. The South Portland public works garage off Cottage Road, which includes sand/salt stored in a shed, drains into the Trout Brook watershed but this should not present a pollution hazard as the entire facility is connected to the sewer system (D. Pineo, pers. comm.).

Habitat Assessments

Flow regime

The variable flow regime found at the downstream and most of the late upstream station (instantaneous flow velocity and thalweg velocity, Figs. 13 and 14) is a positive feature of these sections of the stream as it provides aquatic organisms with a wide variety of environments to occupy, thus increasing the potential for a diverse biological community. Furthermore, a swift flow regime reduces siltation, and promotes re-aeration of the stream with dissolved oxygen.

Flow velocity in the upper ~35 m of the section around the late upstream station (Fig. 14) was very low, which is likely in part a natural condition. Above this section, near the early upstream station, the stream in the summer lacks a distinct channel but rather consists of a network of small rivulets slowly draining into a marshy area. At the outflow of this area (at the ~95 m mark in Fig. 15), a spring-fed channel joins the stream and helps re-establish a defined channel leading to the late upstream station where a small (~12” tall) cobble dam creates a pond-like situation before a distinct channel with good flow is re-established (at the ~65 m mark in Fig. 15). Above the dam, the stream bottom consists of fine sediment, indicating a significant siltation problem. Removal of the dam likely would improve flow patterns and reduce siltation for an additional ~25 m, leaving only the uppermost ~10 m within the marshy area to be less favorable habitat for macroinvertebrates in terms of flow velocity.

Stream width and depth

The patterns of stream width and depth (Figs. 15 and 16, respectively) at the downstream station reflect the morphology of the stream channel in this section of Trout Brook: the banks are fairly steep here so that changes in water volume within the channel have a greater effect on depth than width. In contrast, the stream channel at the late upstream station was very broad, with much exposed substrate, and changes in water volume within the channel had a noticeable effect on width. The decrease in depth at the downstream station between spring and summer is related to the usual decrease in baseflow between these two seasons. The depth pattern at the late upstream station may be partly explained by the method used to measure depth (measurements taken at 3 points evenly spaced between left and right edge-of-water rather than at 3 fixed points); at the shallow depth found at this station, taking a measurement on top of a cobble as opposed to on the stream bottom can significantly influence mean depth. At the early upstream station, the strong decrease in width and depth was related to the declining water level in this section of Trout Brook, which, as previously mentioned, led to the abandonment of this station.

On the whole, wetted width and depth at the downstream and late upstream stations on Trout Brook were relatively stable, providing similar amounts of submerged habitat to benthic organisms throughout the sampling period. At the early upstream station, habitat availability was markedly reduced between spring and summer, forcing benthic organisms into a much smaller environment, or else leaving them high and dry. As noted in previous sections, this stretch of Trout Brook provides less than ideal habitat for animal communities for a variety of reasons (low DO, high temperature, low flow velocity), a condition that is likely natural for this location.

Woody debris

Overall, woody debris abundance and size distribution were more favorable at the downstream than the late upstream station. This pattern is likely related to the availability of wood in the riparian zone. Above the downstream station, the riparian buffer width is 1 - 10 m or >10 m for ~900 m, while that distance is only ~100 m at the late upstream station. Furthermore, the wider channel at the late upstream station likely facilitates greater export of large woody debris (LWD) during high flows as pieces of wood are not caught on banks or exposed roots. A difference in LWD export is also indicated in the percentage of LWD spanning the channel, which is lower at the late upstream station (18 % *versus* 30 %). This suggests that flows more readily align LWD parallel to the direction of flow in this location, and subsequently carry LWD pieces away.

Absolute mass of LWD (diameter * length) was similar at both stations, but relative mass was greater at the downstream station. Relative mass takes into account the percent of the channel LWD spans, so that a trunk lying across the entire channel (i.e., spanning 100 %) would have the same absolute and relative mass (i.e., absolute mass * 1) while a trunk lying almost parallel to the flow would have much lower relative than absolute mass (e.g., absolute mass * 0.2). The comparison between these two measures, or the average percent spanning the channel at each station (30 and 18 % at the downstream and late upstream stations, respectively), can give an indication of flow patterns as a high maximum flow velocity tends to align LWD with the flow, thus reducing the percent spanning value. Data then suggest that maximum flows are greater at the upstream station. However, the occurrence of high maximum flows both upstream and downstream was indicated by other observations made at both stations, namely “flattened” herbaceous vegetation in the riparian zone following rain events (pers. obs.), and very high flows following a large storm event (3.3” of rain in 24 h, ending shortly before visit; App. G, Figs. 3 - 5). The greater relative mass (higher percent spanning) at the downstream station can be explained when examining bankfull width, which also influences the percent spanning as LWD is more likely to get snagged in a narrower channel, leading to a higher percentage. As the channel at the downstream station is much narrower than at the late upstream station (4.3 *versus* 6.0 m; Field 2003, Table 2, reaches 5 and 2, respectively), the percent spanning value would be expected to be higher downstream if maximum flow velocities are similar.

A comparison between LWD found in Trout Brook and in two reference streams exemplifies the situation in Trout Brook. For LWD >5 cm diameter, data collected in a reference stream northwest of Bangor showed that LWD abundance was similar in that stream and at the downstream station on Trout Brook (42 *versus* 41 pieces) but that the reference stream had a greater average mean diameter (12 cm *versus* 10 cm), and higher mean percent spanning (41 % *versus* 30 %). Differences between the reference stream and the late upstream station were greater (42 *versus* 22 pieces, 12 cm *versus* 9 cm, and 41 % *versus* 18 %). This suggests that the downstream station on Trout Brook has a more natural LWD composition than the late upstream station, likely because of the more intact riparian buffer and narrower channel. For LWD >20 cm diameter, the geomorphological survey noted an LWD abundance in Trout Brook overall of 0 pieces per 100 feet of channel in 95 % of the stream, 1 - 2 pieces in 5 %, and >3 pieces in 0 % of the stream (Field 2003, Table 4). The corresponding percentages in a reference stream in Cape Elizabeth (adjacent to South Portland) were 18 %, 66 %, and 16 %, indicating that large LWD in Trout Brook is much less abundant than in a natural setting.

The abundance of small woody debris (SWD) at the late upstream station reflects the large number of small trees growing up in that area, especially within the ponded up section above the cobble dam (above ~60 m in Fig. 18). If small trees are excluded, 50 pieces of SWD were found, about the same number as at the downstream station. Small woody debris is less valuable as woody debris than larger pieces because it is exported more readily (unless it is in the form of a live tree), and provides fewer possibilities for shelter, colonization, or trapping of materials.

Woody debris enhances the habitat quality for aquatic organisms by providing stable attachment sites, providing and trapping organic materials to be used as food sources, trapping sediments, increasing habitat diversity and being a food source in and of itself (Dolloff 1994). Trees in the riparian zone, before they become woody debris, also provide leaf litter, which is an important food source for a variety of macroinvertebrates. Trout Brook is fortunate in having a fairly intact riparian buffer for much of its length although ~ 40 % of channel length lacked any streamside/riparian buffer (Table 11). Because of its many advantages, it is important to maintain a wooded buffer where present, and plant trees where the buffer is impacted by lawns. An additional benefit of replanting is the stabilization of stream banks, which show signs of minor erosion in a few sections of Trout Brook (see Geomorphological assessment, below).

Qualitative stream/wetland and habitat assessments

Qualitative assessments of the physical features of the stream and riparian area, the instream and riparian habitat, and the wetland and watershed disturbance status showed that Trout Brook suffers some of the typical problems of a stream located in a highly developed area. Non-point sources of pollution in general (e.g., sediment, fertilizer/pesticide use, dumping of grass clippings and garbage) and impervious surfaces in particular (houses, roads, parking lots) were identified as concerns, as were a slight sewage smell at both stations, and alterations to the stream channel (channelization, reduced bank stability), riparian zone (narrow riparian buffer), and wetland area (draining, filling, removal of vegetation). Some of these issues were also documented in the geomorphological survey (see next section). On the whole, however, assessments and personal observations showed that the physical problems in and around Trout Brook appear limited in extent. This may be partly attributable to the fact that the watershed has been developed for many years, which has allowed the stream to approach a new equilibrium condition (see Geomorphological survey section below). Several of the areas of concern identified can negatively influence aquatic biota, either directly or indirectly. For example:

- High impervious surface cover in a watershed causes an alteration in stream hydrology, an increase in pollutant concentration, a decrease in rainwater infiltration, and direct impacts on the stream channel. These factors can lead to a reduction in habitat quality and stability, in water quality, and in baseflow volume.
- A sewage smell may indicate input of raw sewage (from a CSO or leaking sewer/septic systems) into the stream. This could be harmful for biota as elevated nutrient levels can cause excess algal growth and lowered DO concentrations.
- Channel alterations (i.e., straightening) reduce sinuosity of the stream, thus eliminating habitat diversity.
- Clearing of vegetation along the banks and in the riparian zone reduces bank stability, decreases filtration efficiency of the soil, and eliminates shading of the stream. These factors can cause increased sedimentation, decreased habitat stability, increased pollutant input, and elevated water temperatures.

Some of these areas of concern can be addressed relatively easily, for example by separating the CSOs (this project is underway, see Nutrients and bacteria, above), and by replanting the riparian buffer where lawns currently abut the stream. Other issues, however, such as the high percentage of impervious surfaces and channel alterations will require more effort, for example the installation of stormwater treatment systems, and the re-establishment of a natural channel morphology as described in the following section.

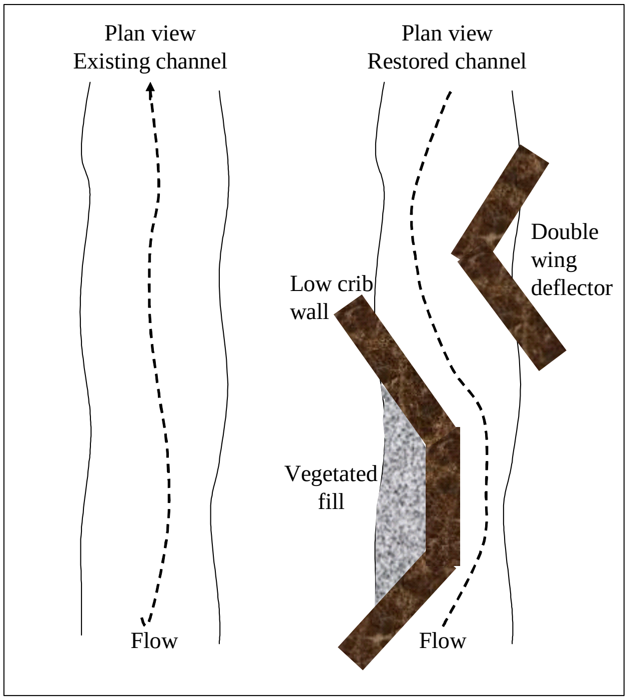
Geomorphological survey

Historical analyses of changes in watershed landuse and channel morphology as well as extensive field work showed that with 54 % of the watershed being built-up, stream geomorphology shows clear signs of damage from human intervention. More than half of the stream has been channelized, half of the stream is slightly or deeply entrenched, ~20 % of the stream shows signs of erosion or is armored, and more than half the stream has a riparian buffer of <10 m (Table 11, Fig. 20). The problems that were documented occurred throughout most of the watershed. Stream habitat was also impacted as shown in the Rapid Habitat Assessment. This assessment indicated that at both stations, stream habitat for biological communities is affected in terms of physical attributes such as epifaunal substrate and available cover, sediment deposition, bank stability, or bank vegetative protection. As discussed in the preceding section, the same assessment also was carried out on a smaller scale, just around each station, with similar results for both stations. Overall, the assessments documented that habitat problems were more pronounced in the lowest section of Trout Brook, near Mill Pond, and in the upper part of the watershed.

A Rapid Geomorphic Assessment showed that most of Trout Brook is near the high end of the Fair or within the Good ranking (ranking scale is Poor, Fair, Good, Reference). This type of assessment is used to document current geomorphological adjustment processes occuring in a stream in response to various watershed, floodplain, and channel modifications by evaluating channel degradation (incision or downcutting, i.e., lowering of stream bed elevation through erosion or scour of bed material), channel aggradation (i.e., raising of stream bed elevation through accumulation of sediment), channel widening, and changes in planform (i.e., the channel shape as seen from above). The assessment documented an overwidened channel, and resulting aggradation, in Trout Brook below the downstream biomonitoring station (below Highland Avenue). This indicates that the channel was constructed too large for the dominant flows when this section of the stream was channelized, and that the stream has subsequently been trying to re-establish equilibrium by reducing bankfull width (Field 2003). Aggradation, likely as a result of channel overwidening, is also evident in the stretch above Boothby Avenue (pers. obs.). While the majority of the aggrading sediment may be naturally derived from the underlying geology (see below), it is likely that some sediment enters the streams from roads, parking lots, or construction sites.

The geomorphological assessment of Trout Brook revealed signs of degradation due to development. Most of these problems are limited in extent, and some sections on Trout Brook are fairly intact, for example the section between Highland Avenue and Boothby Avenue. However, the stream would benefit from simple restoration activities, notably tree plantings in the areas where the riparian buffer is absent (Fig. 20 b), and also from more technically involved actitivities. For example, the previously channelized section above Boothby Avenue where aggradation is occurring may be a good candidate for having some of its sinuosity restored by installing double wing deflectors in the stream, vegetating the bars formed by accumulating sediment, or infilling behind crib walls (Fig. 24). Because this section of the stream was channelized many years ago (likely before 1964, Field 2003), the stream has had time to adjust to the alteration, and it is now approaching a new equilibrium condition.

Fig. 24. Restoration design for middle section (schematic representation, after Field 2003, Fig. 9a)



As a result, little future change should be expected, and a restoration project should be successful if no significant changes in the dominant peak discharge occur. Because of the highly complex nature of fluvial geomorphology, any restoration activity will require the extensive involvement of a trained professional.

Spills and wastewater overflows

An analysis of spill points documented by the MDEP's Bureau of Remediation and Waste Management showed that only few spills have occurred within the watershed, indeed the lowest number of all Urban Streams (App. E). This low number of spills is likely attributable to the low percentage of urban/industrial and commercial-industrial-transportation development within the watershed (7 % of total landuse, compared to 21 - 40 % in the other three streams), and the relatively low percent of impervious surfaces (13 % compared to 24 - 33 %). Because of a lack of detail in spill records, it was not possible to determine whether certain spills shown in App. E affected the stream but at least one spill (100 gallons of heating oil 75 of which were recovered; 1992) reached the stream. The high density of residential development in the middle and upper part of the watershed also suggests that undocumented spills of substances used in private households (e.g., automobile oil, paint or paint thinners, cleaning agents) may occur in the watershed, and may impact water quality in Trout Brook. Indeed, a watershed survey conducted by the South Portland Land Trust in April 2003 documented many signs of hazardous practices thoughout the watershed (pers. obs.; SPLT in prep.). On the whole, spills may have impacted stream quality and the health of resident biota. To reduce the future occurrence of spills in the watershed, outreach efforts targeting private households as well as businesses should be undertaken to inform the public of the negative effects spills of any amount and product may have on stream quality. Such public outreach efforts should be accompanied by suggestions for improvements to current practices of e.g., delivering, handling, and storing fuel oil or other hazardous products. Also, storm drain stenciling has proven useful in alerting the public to the fact that any substance reaching a drain will go into a nearby waterbody where it may cause harm.

Based on the data collected in this study it is not possible to link the observed impairment in the macroinvertebrate community at the downstream station directly to an influx of combined stormwater and raw sewage (Table 12). Two studies that documented organic pollution (i.e., enrichment) in streams due to CSO influx also found evidence for DO depletion (Sztruhar et al. 1997), and an alteration in benthic community structure (Rochfort et al. 2000). For Trout Brook, the available data indicate that enrichment is not a major problem (nutrients were eliminated as a stressor in the SI Process, see next section). One study on CSO discharges failed to establish toxic effects on benthic communities (Rochfort et al. 2000) and, it is unknown whether this is a problem in Trout Brook. To eliminate any potential impacts of raw sewage on the stream, the CSO must be eliminated, and the City of South Portland is currently (2004) working on this issue (D. Pineo, pers. comm.). Because of the particulars of this CSO separation project, this work will not result in an increase in the amount of stormwater runoff the stream receives.

STRESSOR IDENTIFICATION PROCESS

On May 26, 2004, the EPA Stressor Identification (SI) process was applied as described in Ch. 2. The extensive review of available data and discussion among the biologists and engineers present led to the identification of the stressors and their sources as listed below for the downstream and late upstream stations on Trout Brook. Although the stressors are ranked in their importance, all stressors are linked to a certain extent and their effects connected, making it difficult to apply a ranking scale. Consequently, all stressors identified may need to be addressed if the macroinvertebrate community is to recover. Similarly, although the sources for each identified stressor are listed in order of (likely) decreasing importance, sources are often interrelated, or their importance may change over space or time or depending on certain conditions, so that a ranking scale is generally difficult to apply. Where one source is of overriding importance, it is denoted below as "<u>primary source</u>".

<u>Toxicants</u>

This stressor was ranked highest (high importance) for both stations, with a total of 7 "+" and 0 "-"[1] (App. D vi). The role of toxicants in impairing biological communities was indicated by violations of acute criteria for certain metals, an elevated summer level of chloride, high conductivity, and by signals from the macroinvertebrate community (App. D i). As sources for the toxicants (metals, ions), the conceptual model (App. D iv) identified the following:

- *Likely sources:*
    - **Runoff from local roads and parking lots**: the lower half of the watershed has a dense system of roads and residences, most with paved parking areas, as well as a number of schools or other facilities with parking lots. Much of the runoff from those impervious areas enters Trout Brook either directly or through storm drains. As mentioned above (Discussion, Water Quality Monitoring, Metals) several studies have found elevated toxicant levels, especially metals and chloride, in urban stormwater runoff.
    - **Dumping**: instances of illegal dumping of materials were noted in a watershed survey in April 2003 (SPLT in prep.) and on other occasions, and included empty oil and paint containers, yard waste, gray water (septic waste) pipes, old bicycles, and other refuse discarded in or near the stream.
    - **Saltwater intrusion from Portland Harbor** at the downstream station: the large spikes in conductivity (up to 35,000 μS/cm) recorded in the summers of 2003 and 2004 are attributable to high tide events in the harbor spilling into Trout Brook. For many aquatic macroinvertebrates, saltwater intrusions can represent a toxic event. Such intrusions are a natural phenomenon at this location, and will influence biota in the stream regardless of other stressors.

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[1] "+"indicates evidence that a stressor affects macroinvertebrate community.
"-"indicates evidence that a stressor does not affect macroinvertebrate community.

- *Possible sources:*
    - **Winter road sand/road dirt**: road sand accumulations, which were noted around the downstream station in late winter/early spring 2003, can be washed into the stream during storms, and deliver salt particles (including chloride) as well as other toxic compounds. The City sweeps road sand in the spring and also in summer and fall, thus minimizing sand influx.
    - **Natural sources**, i.e., soils: iron and aluminum are very abundant in soils and, depending on the acidity of the environment, can be easily leached out and transported into streams. Cadmium, copper, lead, and zinc are far less abundant naturally, but can occur in high concentrations in some locations.
    - **Atmospheric deposition**: toxicants originating from fossil fuel combustion by vehicles, industry, or power plants can be transported over large distances by air currents, and be deposited directly in a waterbody or on a pervious or impervious surface, from where they can be washed into a stream. In terms of wind patterns, Maine is downstream of many major industries in the central and eastern parts of the country, and depositions of, for example, PAHs and mercury in the state have been attributed to atmospheric transport (see www.maine.gov/dep/air/monitoring/Atmosdepos.htm; 2/4/2005). Overall, however, the magnitude of this source of toxicants for Trout Brook is unknown.
    - **Documented spills**: analysis of spill records indicated that only few spills have been documented within the watershed. Overall the potential for spills to increase the toxicant load in Trout Brook seems relatively low.
    - **Sewage input from CSO** in wetland section: the sewage entering Trout Brook from the CSO during storm events contains largely household waste, which may contain toxic compounds. Note that the City is working on separating this CSO.
    - **Agricultural runoff** in the upper part of the watershed: Maxwell’s Farm is a conventional vegetable grower that is likely to use herbicides and/or pesticides as well as fertilizers in its daily operations. It should be stressed that this study did not investigate the presence of herbicides or pesticides in the stream. It is not known whether these compounds, if they are being applied, have an effect on macroinvertebrate communities at the biological monitoring stations 2.6 – 3.2 km downstream.
    - **Sewage/septic leaks**: the sewer system, which parallels and crosses Trout Brook in a variety of places, is overall in sound condition although in certain sections (at Spurwink Avenue and Sawyer Street) breaks in the pipes may be present (D. Pineo, pers. comm.). Testing for bacteria near these locations could reveal any possible contamination.
    - **Public works garage**: this is located within the Trout Brook watershed (off Cottage Road) but is entirely connected to the sewer system (directly or via catch basins); salt is stored on site in a covered shed (D. Pineo, pers. comm.). The pollution potential from this source is assumed to be minimal.

Degraded Instream Habitat

This stressor was ranked second (medium importance) for the late upstream station with a total of 5 “+” and 1 “-“; it was not considered important for the downstream station with a total of 0 “+” and 5 “-“ (App. D vi). The role of the habitat in impairing biological communities at the late upstream station was indicated by a reduced habitat diversity (due to a combination of reduced sinuosity, low stream depth, and by a reduction in large woody debris). As sources for the impaired instream habitat at the late upstream station, the conceptual model (App. D iv) identified the following:

- *Likely sources:*
    - **Channelization** in this section of the stream (<u>primary source</u>): the reduced sinuosity and homogeneous flow regime caused by channelization as well as the overwidening of the channel and resulting low stream depth and aggradation lead to reduced habitat diversity.
    - **Increased stormflow volume**: high flows resulting from extensive paved surfaces in the watershed can remove pieces of LWD from the stream channel thus reducing habitat complexity, and scour the substrate thus causing habitat disturbance.

<u>Degraded Riparian Habitat</u>

This stressor was ranked second (medium importance) for the downstream station with a total of 3 "+" and 1 "-"; it was not considered important for the late upstream station with a total of 0 "+" and 4 "-" (App. D vi). The role of the riparian habitat in impairing biological communities at the downstream station was indicated by a presumed reduction in the potential for recolonization or recruitment. As sources for the impaired riparian habitat at the downstream station, the conceptual model (App. D iv) identified the following:

- *Likely source:*
    - **Reduced riparian tree cover** (<u>primary source</u>): the narrow width or complete absence of a riparian buffer along some sections of the stream reduces the availability of breeding habitat for adults.

<u>Altered Hydrology</u>

This stressor was ranked third (low importance) for the downstream station with a total of 2 "+" and 3 "-", and also third (medium/low importance, same as DO) for the late upstream station with a total of 4 "+" and 1 "-" (App. D vi). The role of altered hydrology in impairing biological communities was indicated by reduced channel and habitat diversity, observations indicating high peak flows, a potential reduction in baseflow, and by signals from the macroinvertebrate community (App. D i). Both low baseflow and high peak flows were identified as potential problems. As sources for the altered hydrology, the conceptual model (App. D iv) identified the following:

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- *Likely sources:*
    - **High percentage of impervious surfaces**: the watershed has ~13 % impervious surfaces. Imperviousness causes changes in hydrology by increasing runoff volume, increasing peak discharge and flashiness (i.e. rise-to-peak-rate), increasing the frequency and duration of bankfull flows, and decreasing baseflow by reducing groundwater infiltration (CWS 2003).

  - **Stormwater outfalls**: these can create localized erosion problems, and in extreme cases cause the removal of organisms. Outfalls are located on Norman Street, at the intersection of Providence Avenue and Marsh Road, above Highland Avenue, and below Broadway (i.e., below the biomonitoring sampling stations) as well as on the tributaries to Trout Brook.
  - **Channelization**: this reduces channel diversity, thus promoting a uniform flow regime.

- *Possible source:*
  - **Increased consumptive uses**: irrigation with stream water at Maxwell's Farm may reduce baseflow levels in the summer but currently no data or information exist to confirm this hypothesis.

Low Dissolved Oxygen

This stressor was ranked third (medium/low importance, same as altered hydrology) for the late upstream station with a total of 4 "+" and 1 "-"; it was not considered important for the downstream station with a total of 0 "+" and 7 "-" (App. D vi). The role of low DO in impairing biological communities at the late upstream station was indicated by measurements of low DO concentrations, and by signals from the macroinvertebrate community (App. D i). As sources for the low DO at the late upstream station, the conceptual model (App. D iv) identified the following:

- *Likely source:*
  - **Perched groundwater** (primary source): as explained above (Discussion, Water Quality Monitoring, Dissolved oxygen), this type of groundwater has naturally low DO concentrations.

- *Possible sources:*
  - **Low channel gradient and channel modifications**: these factors can reduce the number of riffles in a stream thus reducing the potential for re-aeration.
  - **Sewage input from CSO** in wetland section: this can increase nutrient loads and promote excessive algal growth leading to DO depletion. As no excessive algal growth was observed, sewage influx appears to be a minor source.

Factors that were deemed to be minimal stressors in Trout Brook, and that were thus eliminated from further consideration, were nutrients and water temperature. Factors that were discussed but found to be unimportant as stressors were sedimentation for both stations, DO concentration and instream habitat for the downstream station, and riparian habitat for the late upstream station.

CONCLUSIONS AND RECOMMENDATIONS

Study results showed that macroinvertebrate communities in the lower half of Trout Brook are degraded, and do not meet Maine's aquatic life criteria for a Class C stream. This is largely due to the fact that the majority of macroinvertebrates identified were tolerant (i.e., isopods, midges, flies), and that only few sensitive organisms were found (Table 4). The fish assemblage at the downstream station (above Highland Avenue) showed a low diversity (two species) but had a healthy population of the relatively sensitive brook trout, including young-of-year. These two findings seem somewhat incongruous as the conditions that brook trout require for survival would normally also promote healthy macroinvertebrate communities.

An analysis of general water quality indicators (dissolved oxygen, conductivity, temperature) and chemical parameters (nutrients, bacteria, metals) as well as habitat assessments indicated that Trout Brook shows some, but not all, of the effects often encountered in urban areas. For example, conductivity and total nitrogen levels as well as bacterial concentrations were high at both stations, and the instream and riparian habitat was degraded (because the stream channel was altered in several areas, sinuosity was reduced, the riparian buffer was compromised, wetlands were drained and/or ditched). On the positive side, however, dissolved oxygen levels were high at the downstream station, water temperature was relatively cool at both stations, water chemistry testing revealed few problems at either station (though some toxic problems were observed; Table 6), and some habitat parameters were fairly intact (good flow regime, few areas with major erosion problems). On the whole, it appears that Trout Brook should have a healthier macroinvertebrate community than it currently does. The data summarized in this report formed the basis for the SI process (see previous section), which resulted in a ranking of stressors and identification of sources according to their likely importance for causing impairments. Toxicants were ranked as the most significant stressor at both stations, followed by a degraded instream habitat at the late upstream station and a degraded riparian habitat at the downstream station, altered hydrology at both stations, and low dissolved oxygen concentrations at the late upstream station. Factors that were deemed to be minimal stressors in Trout Brook were nutrients and summer temperature. Factors that were found to be unimportant as stressors were sedimentation for both stations, DO concentration and instream habitat for the downstream station, and riparian habitat for the late upstream station. The stressors and their sources as identified during the SI process were used to develop recommendations for Best Management Practices (BMPs) and remedial actions aimed at removing or alleviating the stressors. Bacteria were not considered as a stressor during the SI process but have the potential to compromise the use of a stream for contact recreation; therefore, BMPs for reducing bacteria levels are presented below also. And finally, although nutrients are not currently considered a stressor in Trout Brook, total nitrogen and total phosphorus did exceed applicable EPA-recommended criteria on occasion and there is the potential that nutrients interact with other stressors to impact biological communities; therefore BMPs aimed at reducing nutrient load are presented as a preventative measure.

Trout Brook is included in Maine's 305 (b) list of impaired waters for non-attainment of the aquatic life criteria that were set for Class C streams (MDEP 2002d, 2004b). As a result, the Maine Department of Environmental Protection is required to develop a TMDL (Total Maximum Daily Load) plan for the impaired section of the stream (namely the section from the headwaters to the downstream station; Fig. 1) aimed at restoring aquatic communities to Class C standards. The BMPs and remedial actions listed below will form the basis for the TMDL plan to be developed in 2005. Other data not yet available, i.e., algal taxonomy, additional water chemistry data, and flow data, also will be utilized in TMDL development. While concentrating on the significant stressors, the TMDL will take into consideration all stressors because physical, chemical, and morphological features of a stream are linked, and interact to affect biological communities.

The list of BMPs and remedial actions provided below is categorized by stressor and source, and provides suggestions as to which broad category of party (or parties) may be responsible for implementing BMPs (i.e., City of South Portland, industry/businesses, public, or all). Because many factors must be considered when choosing specific structural BMPs (e.g., target pollutants, watershed size, soil type, cost, runoff amount, space considerations, depth of water table, traffic patterns, etc.), the list below suggests a variety of BMPs without proposing particular types for particular situations. For detailed information on structural BMPs, their individual effectiveness, and required planning considerations see publications by the MDEP (1995, 2003a) and the City of Nashua (2003). A summary of stressors, goals, and relevant BMPs and remedial actions as presented below and in Ch. 3, 5, and 6 can be found in App. I.

Goal: Reduction in Toxicants

During the SI process, toxicants were identified as the most important stressor at both stations with runoff from impervious surfaces, dumping, and saltwater intrusions (downstream station only) as likely sources, and winter road sand/road dirt, natural sources, atmospheric deposition, documented spills, sewage input from CSO, agricultural runoff, and sewage/septic leaks as possible sources. A reduction in toxicant load would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at reducing toxicant load.

BMPs and remedial actions

1. **Reduce storm runoff from impervious surfaces**: during rain and storm events, the stream receives a large amount of runoff either directly or via the storm drain system. This runoff is contaminated with metals (aluminum, cadmium, copper, iron, lead, zinc; Table 6) that are toxic to aquatic life. Two BMPs/remedial actions can be suggested for this situation:
    a) A reduction in impervious surfaces, and thus runoff quantity, for example through the replacement of asphalt with pervious cover (e.g., porous pavement blocks, grass/gravel pave) or the replacement of conventional roofs with green roofs. In some cases there may also be the potential for replacing impervious cover with bioretention structures (bio-islands/cells). The city could also promote shared parking areas between homes or between facilities that require parking at different times (e.g., business and church), and reconsider its minimum parking requirements for businesses. (All)
    b) Channeling of runoff through a treatment system to reduce runoff quantity and improve runoff quality by promoting infiltration and pollutant absorption/ straining/decomposition. There are several choices for such systems:

- vegetative BMPs (e.g., vegetated buffers or swales);
- infiltration BMPs (e.g., dry wells, infiltration trenches/beds/basins, driveway drainage strips, bio-islands/cells, decorative planters), which may need to be equipped with pre-treatment BMPs to filter out toxicants;
- detention BMPs (e.g., dry/wet ponds, extended detention ponds, created wetlands); and
- filter and separator BMPs (e.g., oil/grit and oil/water separators, flow splitters, Vortechnics^{TM}-type systems, water quality inlets, sand filters, leaf compost filters).

For more information on these BMPs and their effectiveness and planning considerations see MDEP 1995 and City of Nashua 2003. (All)

2. **Reduce the incidence of spills** (both accidental and deliberate, i.e., dumping): a few documented spills of hazardous substances have occurred in the watershed (App. E), and incidences of dumping were observed during a watershed survey. A reduction in spill frequency would likely have a beneficial effect on water quality and biological communities. Outreach efforts are useful for educating the public and businesses about safe ways for handling hazardous substances (e.g., paint and paint thinner, motor oil, gasoline, chemicals, pesticides), and proper ways for disposal. Storm drain stenciling has been shown to be useful in informing the public that any substance reaching a drain will go into a nearby waterbody where it may cause harm. The city might also consider increasing the frequency of their hazardous waste collections. Information material listing non-hazardous alternatives to hazardous substances could also help reduce the number of spills. Finally, where it has not already been done, industry and businesses should seal up floor drains or connect them to the sewer system, as appropriate. (All, MDEP)

3. **Saltwater intrusion from Fore River (downstream station only)**: this is a natural phenomenon at this location and cannot be remedied. To minimize the stressful effects of saltwater intrusions, water quality and habitat parameters must favor healthy biological communities rather than providing additional stressors. Addressing the stressors identified in the SI process will help to provide such conditions. (All)

4. **Reduce input of winter road sand and road dirt**: many toxicants are adsorbed onto sediment particles, and enter a stream in storm runoff. A reduction in metal load by way of loose sediment could be achieved by sweeping winter road sand and road dirt. The City has a road sweeping program in place and should continue it, with special attention given to post-winter clean-up (to remove chloride). If possible, sweeper types that employ a vacuum or regenerative air system should be used for cleaning as these maximize pick-up of fines (which hold the greatest toxicant load). Businesses that do not already sweep their premises are strongly encouraged to initiate this practice. Similarly, private homes with paved driveways/parking areas also should sweep sand and dirt on a regular basis. To capture any loose sediment and attached metals that is not removed by sweeping, runoff should be guided to a treatment system as suggested above under item 1 b. (All)

5. **Natural sources**: iron and aluminum are abundant in soils, and can easily leach out and enter a waterbody. This is a natural phenomenon and cannot be remedied. To

minimize the negative impacts of natural toxicants, water quality and habitat parameters must favor healthy biological communities rather than provide additional stressors. Addressing the stressors identified in the SI process will help to provide such conditions.

6. **Atmospheric deposition**: the pollution potential from this source is difficult to assess and even more difficult to remove. Almost by definition, this type of pollution originates from very diffuse and potentially far-away and wide-spread sources and cannot be addressed by any action the City of South Portland, local businesses, or residents can take. National action is required to deal with this issue. On a local scale, however, a reduction in sources of air pollution (e.g., motor vehicles, power plants, home heating systems, any type of fume) can improve local air quality and contribute to a decrease in atmospheric deposition. (All)

7. **Eliminate sewage input from CSO**: the city has already initiated remedial actions (separation work) for this issue, and no further action beyond completion of this project is required. (City)

8. **Reduce agricultural runoff**: runoff from crop areas can contain pesticides and herbicides that are often toxic to aquatic organisms. The presence of these compounds was not investigated in this study, and it is not known whether there is any effect on macroinvertebrate communities in the stream. To reduce the pollution potential, the farm operation in the upper part of the watershed should consider the following actions:
   - planting a riparian buffer between cropland and the stream (goal: a 15 m/50 ft-wide strip of grass, shrubs, and trees between the normal bank-full water level and cropland; Agroforestry Notes 1997);
   - reducing the amount of pesticides and herbicides applied;
   - increasing the distance between the edge of fields and the stream; and
   - putting infiltration trenches between the edge of fields and the stream.

9. **Eliminate the potential for sewer/septic system leaks**: to ensure that all components of sewer system are in good working order, portions that have not recently been surveyed should be inspected, and repairs or required replacements made as allowed by budgetary constraints. For septic systems, regular maintenance and inspection are critical to ensure proper functioning. Only few homes in the watershed have septic systems, and the pollution potential from this source is deemed to be small. Home owners can ensure that they do not contribute to the toxicant load in the stream by keeping toxic substances out of the sewer/septic system. (City, public)

Goal: Improvement in Instream Habitat Quality at Late Upstream Station

During the SI process, instream habitat quality was identified as a major stressor at the late upstream station with channelization (primary source) and increased stormflow volume as likely sources. An improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at improving instream habitat.

BMPs and remedial actions

1. **Improve channel morphology**: the channelization that occurred at and around the late upstream station resulted in an overwidened and straightened channel, leading to a reduced channel diversity, low water depth, and sedimentation problems. All of these effects cause a reduced habitat diversity and quality, which negatively influence biological communities. To improve channel morphology, the restoration suggestion included in Discussion, Geomorphological survey, above (Fig. 24), should be implemented with the help of a qualified professional such as a fluvial geomorphologist. Such restoration would markedly improve habitat quality by re-establishing channel sinuosity and the habitats associated with it, increasing water depth (and thus vertical relief), and reducing sedimentation problems. (City)

2. **Reduce stormflow volume**: the overwidened and straightened channel causes a major loss of large woody debris (LWD), and likely some scouring of the substrate during high flows. The improvement in channel morphology recommended above should help reduce LWD export but a reduction in stormflow volume would likely be required to keep LWD in place and reduce scour. Various BMPs that can aid in reducing peak flow volume are listed above in “Goal: Reduction in Toxicants”, item 1. (All, but predominantly city and industry/businesses)

<u>Goal: Improvement in Riparian Habitat Quality at Downstream Station</u>

During the SI process, riparian habitat quality was identified as a major stressor at the downstream station with reduced riparian tree cover as the likely (primary) source. An improvement in this parameter would likely increase the recolonization potential, and aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at improving riparian habitat.

BMPs and remedial actions

1. **Replant the riparian buffer**: some areas around the downstream station do not have a riparian buffer, i.e., lawns reach right down to the water’s edge. Many insects require an intact riparian zone to complete their reproductive cycle. In some cases, certain types of vegetation are required. Additionally, leaves and woody debris are an important food resource and habitat requirement for many of these organisms, and the shade afforded by trees helps keep the stream cool. Residents whose lawns reach to the stream should consider planting a variety of native trees and other vegetation along the stream bank so as to attract insects with aquatic life stages. Homeowners should aim for a minimum buffer width of 10 m (35 feet), but increase the width to 15 m (50 feet; CRJC, 2000) or more if possible. This BMP would also help to improve water quality (by filtering lawn runoff), provide LWD to the stream, keep the water temperature low (by providing shading), and minimize erosion problems (by stabilizing stream banks). (Public)

Goal: Restoration of Natural Hydrology

During the SI process, altered hydrology (low baseflow and high peak flow) was identified as a stressor at both stations with high percentage of impervious surfaces, stormwater outfalls, and channelization as likely sources, and increased consumptive uses as a possible source. An improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at restoring .

BMPs and remedial actions

1. **Reduce percentage of impervious surfaces**: high watershed imperviousness alters stream hydrology by increasing runoff volume and peak discharge rate, increasing the frequency and duration of bankfull flows, and decreasing baseflow (by reducing groundwater infiltration). The BMPs and remedial actions listed in “Goal: Reduction in Toxicants”, item 1, should be implemented to address this problem. These measures are also effective for improving baseflow levels as they promote the recharge of groundwater reservoirs with precipitation. (All)

2. **Reduce effects of stormwater outfalls**: the highly localized force of water coming out of a stormwater outfall creates high shear forces that can cause localized erosion problems, and even the removal of organisms. If the removal of outfalls is not practical, the installation of BMPs suggested in “Goal: Reduction in Toxicants”, item 1, is recommended to reduce the amount of stormwater discharged through outfalls. To reduce the effect of an outfall on a stream, it should be located in an area that can withstand high erosive forces (e.g., inside a culvert), and should be designed so as to minimize the shear force (e.g., not pointed straight at a stream bank but more or less parallel to stream flow). (City)

3. **Improve channel morphology**: a straightened (and widened) stream channel tends to have a uniform, generally slow flow regime that does not promote diversity in biological communities. To improve channel morphology, the restoration suggestion included in Discussion, Geomorphological survey, above (Fig. 24), should be implemented with the help of a qualified professional such as a fluvial geomorphologist. Such restoration would help diversify the flow regime by re-establishing channel sinuosity and the associated variability in flow patterns (i.e., slow flow on inside bends *versus* fast flow on outside bends) and water depth (i.e., pools with slow flows and riffles with fast flows). (City)

4. **Minimize consumptive uses**: if Maxwell’s Farm withdraws stream water for crop irrigation, it may lead to a decrease in water levels in Trout Brook, especially during the drier summer months. Farmers should consider using irrigation practices that minimize water usage (e.g., drip irrigation, irrigating early in the day).

Goal: Improvement in Dissolved Oxygen Levels at Late Upstream Station

During the SI process, a low DO concentration in the summer was identified as a stressor at the late upstream station with perched groundwater as the likely (primary) source, and a low gradient and sewage input from CSO as possible sources. An improvement in this parameter would likely aid the recovery of the macroinvertebrate community. The following list provides BMPs and remedial actions aimed at improving the DO concentration .

BMPs and remedial actions

1. **Perched groundwater**: this is a natural situation and cannot be remedied. To minimize the negative effects of the low DO resulting from the influx of perched groundwater, the following conditions must be met:
    a) good water supply from upstream to dilute low-DO groundwater. This can only be achieved by increasing baseflow levels through promoting the infiltration of precipitation, and reducing consumptive uses (if this is a problem).
    b) water quality and habitat parameters must favor healthy biological communities rather than providing additional stressors. A reduction in toxicants, improvement in instream habitat, and restoration of a natural hydrology as described above will help to provide such conditions. (All)

2. **Low gradient**: this is a natural situation and cannot be remedied.

3. **Improve channel morphology**: channel modifications reduce the number of riffles providing re-aeration potential. They need to be reversed by implementing the restoration suggestion included in Discussion, Geomorphological survey, above (Fig. 24), with the help of a qualified professional such as a fluvial geomorphologist. (City)

4. **Eliminate sewage input from CSO**: the city has already initiated remedial actions (separation work) for this issue, and no further action beyond completion of this project is required. (City)

<u>Goal: Reduction in Nutrient Levels</u>

In the SI process, nutrients were deemed to be a minimal stressor, and were not considered extensively. However, total nitrogen and total phosphorus exceeded EPA-recommended criteria on several occasions, and these compounds may interact with other stressors to affect the macroinvertebrate community. Therefore, future increases in nutrient load should be prevented to promote the overall goal of improving aquatic life. The following list provides BMPs and remedial actions aimed at nutrient control.

BMPs and remedial actions

1. **Minimize lawn/landscaping runoff**: fertilizers applied to landscaped areas, lawns, gardens, or crops can be washed into the stream during storms. Reduction or elimination of fertilizer use is an important step in reducing the nutrient load in a waterbody. Soil tests can be a useful way to determine actual nutrient requirements. (All)

2. **Maintain/replant riparian buffer**: a densely vegetated area separating a fertilized green space or an impervious surface from the water's edge will reduce runoff of nutrient-laden water into the stream. As a rule of thumb, a riparian buffer should have a minimum width of 15 m (50 feet; CRJC, 2000), though a width of 75 feet or greater provides better treatment. Shading of the stream will also minimize the risk that

elevated nutrient loads can lead to excess algal growth and a depletion in DO. (All)

3. **Minimize impervious surface runoff**: runoff from roads and parking lots can contribute high levels of nutrients to a stream. BMPs listed above in “Goal: Reduction in Toxicants”, item 1, will help to minimize the amount of nutrient-containing runoff that reaches the stream.

4. **Implement items listed under “Goal: Reduction in bacteria levels”**, below: discharges from a CSO, faulty sewer or septic systems, and pet waste as well as illicit discharges increase the nutrient load in a stream. (All)

5. **Atmospheric deposition**: studies have found that background nitrate concentrations in streams are higher in the Northeast than in other parts of the country. Almost by definition, this type of pollution originates from very diffuse and potentially far-away and wide-spread sources and cannot be addressed by any action the City of Portland or local business or residents can take. National action is required to deal with this issue. On a local scale, however, a reduction in sources of air pollution (e.g., motor vehicles, power plants burning fossil fuels) can improve local air quality and contribute to a decrease in atmospheric deposition. (All)

Goal: Reduction in Bacteria Levels

At this point, Trout Brook is not listed for bacterial violations although *E. coli* concentrations (of unknown origin) exceeded Maine’s criteria for counts of bacterial colonies (of human origin) on most sampling dates (Table 5). Bacteria are not in themselves a stressor for macroinvertebrates, and thus were not included in the SI process. However, the presence of *E. coli* in the water is cause for concern because it can indicate the presence of raw sewage in the stream. Raw sewage, which can originate from the public sewer system, faulty septic systems, or illicit discharges, has the potential to also carry disease-causing organisms (as well as metals and nutrients). Therefore, elevated levels of *E. coli* in the stream suggest that a waterbody may be impaired in several ways. The following list provides BMPs and remedial actions aimed at a reduction in bacteria load.

BMPs and remedial actions

1. **Eliminate sewage input from CSO**: raw sewage can be a major contributor of bacteria to a stream. The City must continue to work towards CSO separation to eliminate this source. (City - already initiated)

2. **Eliminate potential for sewer/septic system leaks**: to ensure that all components of sewer system are in good working order, portions that have not recently been surveyed should be inspected, and repairs or required replacements made as allowed by budgetary constraints. For septic systems, regular maintenance and inspection are critical to ensure proper functioning. (All)

3. **Eliminate illicit discharges**: entities/households with an illicit discharge must eliminate it through either stopping the discharge, or routing it into a septic system/the city sewer. The Center for Watershed Protection recently developed an extensive

manual to help municipalities in the detection and elimination of illicit discharges (CWP 2004). (Industry/businesses, public)

4. **Minimize bacteria input from animals**: in many cases, *E. coli* do not originate from human sources but from warm-blooded animals, including pets, and eliminating this source would likely reduce bacteria levels. Keeping pets away from the stream and always picking up pet waste prevents waste from getting washed into the stream during a storm. Feeding of wildlife near the stream or on ponds connected to the stream is discouraged as animals (especially waterfowl) can contribute to the bacterial load in a waterbody. (Public)

5. **Be a steward of the stream**: alert city personnel if there is a sewage smell in the stream, or if signs of sewage discharge are obvious. Stream bank surveys by stream teams (see General activities that can help Trout Brook) can reveal problems without requiring costly water analyses. (Public)

6. **Eliminate septic systems in watershed**: this could be achieved by connecting residences with septic systems to the city sewer. Because of the cost, this option should be used as a last resort. (City)

General Activities that Can Help Trout Brook

1. **Invest in education and outreach efforts**: alert the public as well as industry and businesses to the role different stressors play in impairing biological communities and water quality in a stream. Encourage all concerned parties to implement BMPs and remedial actions listed here. (City, MDEP, Cumberland County Soil and Water Conservation District)

2. **Promote the formation of a Stream Team** for Trout Brook. Owing to the impaired nature of the stream at this point in time, this initiative may need to be deferred to a later date. However, once stream quality has improved, citizens and/or businesses should be encouraged to become stewards of the stream and collaborate with the City and State to improve Trout Brook's condition. (All, MDEP)

3. **Encourage responsible development**: parts of the Trout Brook watershed are not yet developed, and these wetland and forested areas have an important influence on the stream ecosystem. Future development should take into consideration the findings of this report, and be done so as to minimize the impact on the stream. Practices promoted under smart growth and low impact development (LID) guidelines should be implemented wherever possible. More information on such guidelines can be found at www.epa.gov/smartgrowth/ and www.epa.gov/owow/nps/lid/. The city should consider including such guidelines into the building code, or at least promoting their use when issuing construction permits (City, industry/businesses)

The list of BMPs and remedial actions given above provides guidance for the kinds of actions that could be taken to deal with the urban stressors the SI process identified for the lower section of Trout Brook. This list, or parts of it, will be incorporated into the TMDL plan to be developed by the Maine Department of Environmental Protection in 2005. More detailed recommendations that would be included in a restoration plan will require the input of experts from fields such as biology, geology, and engineering.

Restoring healthy aquatic communities in Trout Brook will require collaboration among several parties (regulatory agencies, the City of South Portland, businesses, concerned citizens) as well as financial resources and time. The TMDL plan will likely estimate target loads for certain pollutants, and implementation of the plan should lead to an improvement in stream health over the next several years. Future biological and water quality monitoring is advisable to determine whether the TMDL plan achieved its goal of restoring the resident aquatic communities to Class C standards, or whether additional actions are required.