# APPENDICES FOR

# THE WATERSHED IMPROVEMENT PLAN AND RECOMMENDATIONS FOR A TOTAL MAXIMUM DAILY LOAD (TMDL) FOR SEDIMENT

**ALLEN BROOK**
**WILLISTON, VERMONT**

**Waterbody ID: 08-02**

**FINAL REPORT – March 30, 2003**


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## Appendix A: The Allen Brook Watershed

### A.1 Background

In the fall of 2000, the Vermont Agency of Natural Resources' (ANR) Department of Environmental Conservation (DEC) retained the services of a team of experts to develop a watershed restoration plan for the 14.5 square mile ($mi^2$) Allen Brook watershed, located in the Town of Williston. The goal of the restoration plan is to restore Allen Brook to meet Vermont Water Quality Standards.

DEC is particularly interested in developing a new approach to the development of watershed restoration plans for waterbodies impaired primarily by nonpoint sources. (Nonpoint source pollution is diffuse, entering a waterbody from a wide geographic area. Point source pollution enters a waterbody from a single point, such as a discharge pipe, making it much easier to identify and control.)

Traditionally, a restoration plan, under the Clean Water Act's Total Maximum Daily Load (TMDL) program, contains a quantification of the actual amount of pollutant loading coming from all sources of the problem pollutants. The potential high cost of determining the pollutant loading from nonpoint sources caused DEC to investigate alternative approaches. DEC requested that the team of experts develop an alternative restoration plan over a two-year time frame that focuses on quantifiable control actions, rather than quantifiable loads. Work completed includes:

- Compiled existing studies, maps, aerial photos, historic channel cross-sections, and data for the Allen Brook watershed.
- Compiled all existing digital spatial data for the watershed into ArcView or ArcInfo.
- Commenced a literature search on pollutant removal capability of control actions.
- Conducted rapid field assessments at 35 sites, and walking Allen Brook and the major tributaries in order to characterize the habitat and the geomorphic and riparian condition of the stream.
- Installed and surveyed three permanent cross-sections, including pebble counts and rapid assessments.
- Conducted a pollution prevention survey, identifying potential stream rehabilitation sites and candidate sites for structural and non-structural remediation options.
- Developed quantifiable measurements for monitoring the TMDL.
- Conducted public walks, meetings with Town personnel, and outreach events for the local community.
- Identified opportunities to incorporate stormwater management into the Town Plan and local ordinances (see Appendix E).

Allen Brook varies from low gradient wetlands in the lower and middle portion of the watershed to steep cascades by Industrial Avenue, and upstream of Interstate 89. The presence of two bedrock falls by Industrial Avenue offers stability to the lower watershed.

Actively eroding sites are found throughout the watershed from storm drainage systems and via the tributaries. The 150 foot setback along the mainstem of Allen Brook and natural grade control in the watershed has helped protect the mainstem from incision. Recommendations will include: (1) expanding the buffer to include all tributaries, ephemeral, intermittent and perennial; and, (2) developing a better surface water layer of all tributaries to effectively reduce the input of sediment via these pathways into Allen Brook.

## A.2 Description of the Allen Brook Watershed

The Allen Brook watershed is located in the Town of Williston in Chittenden County, Vermont. Figure 1 is a map of the watershed. Allen Brook drains an area of about 14.5 $mi.^2$ The Brook flows northwest to join Muddy Brook just prior to its confluence with the Winooski River, which in turn flows west into Lake Champlain.

Topographic relief in the watershed is low; the highest point is 908 feet above sea level and the lowest point is 210 feet. The mainstem of Allen Brook is approximately 11 miles long and has an average gradient of 1 percent. The eight tributaries shown on the 7.5 minute topographic map are mostly ephemeral, with drainage areas generally less than 1 $mi.^2$

## A.3 Bedrock Geology

Allen Brook watershed contains two distinctly different types of rocks formed around 450 –500 million years ago. These rock types define the watershed, and explain why the lower part of the watershed is relatively flat, and the upper part has steeper topography.

The lower part of the watershed downstream from the village contains a complex stratigraphy of different types of relatively easily eroded calcium-rich marbles and calcium and magnesium-rich dolomites, with some outcrops of slate and sandstone. These rocks were formed from sediment deposited in a warm shallow sea, the Iapetus Ocean. Marble and dolomite are high in calcium, which is an important nutrient for aquatic life. Calcium raises the pH of the water, and increases the productivity of the stream.

The upper part of the watershed contains more resistant rocks (and thus more topographic relief) than the lower part of the watershed. These rocks were formed under high temperature and pressure when the continents collided together to form the Green Mountains. They are metamorphosed phyllites and schists, formed from sedimentary silts and mud, and schistose greywackes, which formed from a coarser grained sedimentary sandstone. (Wright, 1999, Doll, 1961.)

## A.4 Surficial Geology

Two geological events occurred to define the Allen Brook watershed. Approximately 13,000 years ago and up to approximately 650 feet in elevation, the Champlain Valley was filled with the south-flowing Glacial Lake Vermont. After the glacier receded, between 12,500 and 10,000 years ago, the Atlantic Ocean flowed south into the depression caused by the weight of the ice. Seawater filled the Champlain valley in Williston up to an elevation of approximately 300 feet and became the Champlain Sea. The deposits of the Champlain Sea and the bottom of Lake Vermont contain fine-grained clay and silt deposits. The clays and silts have low permeability. Water runs rapidly off of them. The sands have higher permeablity and higher infiltration rates. Unlike the clay deposits, the sandy deposits are not cohesive and are easily eroded.

This geologic history means that the surficial deposits in the watershed are primarily unconsolidated deposits with relatively low infiltration, and high runoff potential and are relatively easily eroded.

Above the shoreline of Glacial Lake Vermont the bedrock is blanketed with glacial till, a conglomerate of many different grain sizes of rock that was plastered on the bedrock at the base of the glacier. (Wright, 1999; Doll, 1970).

## A.5 Hydrology and Geomorphology

There is a limited amount of both hydrologic and geomorphic data on streams in the Champlain Basin. Allen Brook is not gauged. Existing data from the U.S. Geological Survey (USGS ) for small streams in the Champlain Valley (under 20 $mi^2$) drainage area with slopes less than 4 percent) were used to determine hydrology and return frequency flows. Geomorphic measurements from Champlain streams that drain primarily disturbed urban areas were used for width/depth and cross-sectional area shown in Figure 1 (Center for Watershed Protection, 1999). Recently the USGS has begun to monitor Englesby Brook, a one square-mile, steep, urbanized watershed with greater than 20 percent imperviousness in Burlington. Englesby Brook may be used as a proxy stream for monitoring some aspects of Allen Brook.

**Figure 1: Small Champlain Urban Streams, Low Slopes**

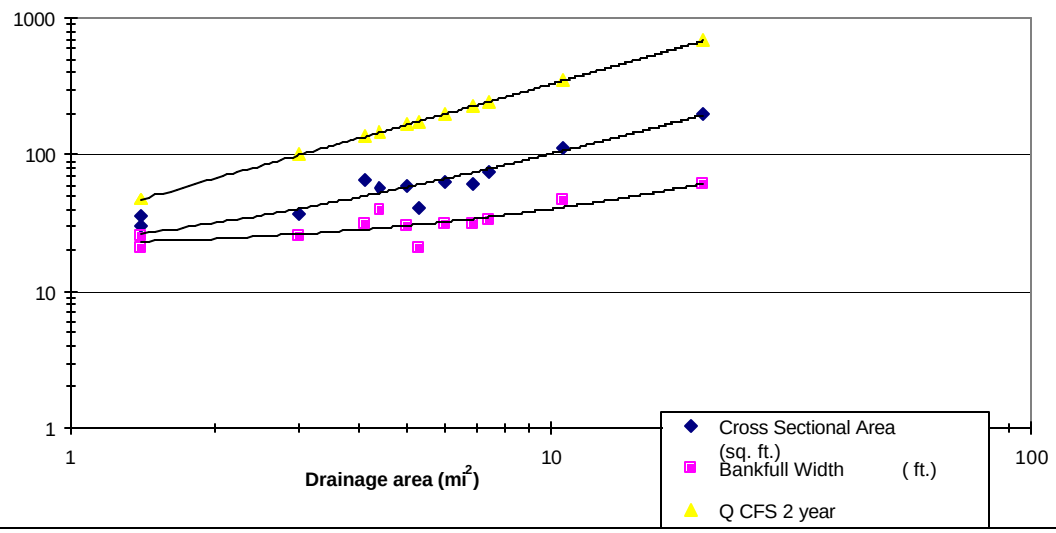


**Table 1: Two-Year Return Frequency Flows: Champlain Valley Small Streams**

| Station | DA sq. mi | 2 year return flow (cfs) | cfsm |
|---|---|---|---|
| Stone Bridge Brook Near Georgia Plains, Vt | 8.05 | 153.7 | 19 |
| Saxe Brook Near Highgate Springs, Vt | 2.79 | 54.3 | 19 |
| Little Otter Creek Tributary Near Bristol, Vt | 1.48 | 30 | 20 |
| Neshobe River At Brandon, Vt | 20.1 | 680.7 | 34 |
| Moon Brook At Rutland, Vt | 2.17 | 73.9 | 34 |
| Missisquoi River Tr At Sheldon Junction, Vt | 1.69 | 63.2 | 37 |
| Lewis Creek Tributary #2 Near Rockville, Vt | 1.07 | 41.5 | 39 |
| Beaver Brook At Cornwall, Vt | 1.11 | 59.5 | 54 |
| Lewis Creek Tributary At Starksboro, Vt | 5.31 | 296 | 56 |
| Mettawee River Near Pawlet, Vt | 70.2 | 1748 | 25 |

Data source-USGS frequency analysis for VT and NH, 1998, Systematic Record (gage data)
Geomorphic Data: Center for Watershed Protection

| Stream Name | Transect # | Drainage Area (sq. mi) | Cross Sec-tional Area (sq. ft.) | Bank-full Width ( ft.) | Bank-full Max Depth (ft.) | Mean Depth (ft) | ER H/L | W/D Ratio | % Slope |
|---|---|---|---|---|---|---|---|---|---|
| Moon Brook | 1 | 5.3 | 41.3 | 21 | 3.3 | 0.9 | l | 23.3 | 0.12 |
| Moon Brook | 2 | 3 | 37.4 | 25.7 | 3.3 | 0.7 | l | 36.7 | 0.22 |
| Stevens Brook | 8 | 1.4 | 30.4 | 25.1 | 1.9 | 0.9 | h | 27.9 | 0.4 |
| Potash Brook | 2 | 6 | 63.6 | 30.9 | 2.6 | 1.9 | l | 16.3 | 1.16 |
| Potash Brook | 1 | 7.4 | 75.6 | 33.1 | 3.4 | 2.2 | l | 15.0 | 1.21 |
| Cold Brook | 4 | 20.7 | 201.2 | 61 | 4.5 | 2.6 | l | 23.5 | 1.39 |
| Tenney Brook | 1 | 4.4 | 57.7 | 39.6 | 2.4 | 1.5 | l | 26.4 | 1.56 |
| Potash Brook | 3 | 5 | 59.9 | 30 | 2.4 | 1.7 | l | 17.6 | 1.82 |
| Cold Brook | 6 | 10.6 | 110.3 | 46 | 3.3 | 2.7 | l | 17.0 | 2.28 |
| Stevens Brook | 7 | 1.4 | 35.6 | 20.6 | 1.9 | 1.7 | h | 12.1 | 2.43 |
| Cold Brook | 5 | 4.1 | 65.5 | 30.9 | 2.3 | 1.8 | l | 17.2 | 2.46 |
| Stevens Brook | 9 | 6.9 | 60.3 | 31.7 | 2.6 | 2.2 | h | 14.4 | 3.41 |

## A.6 Land Use Change

In 1995, the Allen Brook watershed was approximately 50 percent agricultural, 25 percent forest, and 25 percent developed residential/commercial, with imperviousness at 5 percent. Land use distribution in 1999, described in the 2000 Williston Comprehensive Plan, shows a marked change in land uses (see Table 2). Farmland deceased to 21 percent, and the residential/commercial/industrial land make up 35 percent. Allen Brook is presently still adjusting its dimensions and slope to the new hydrological regime that accompanies development.

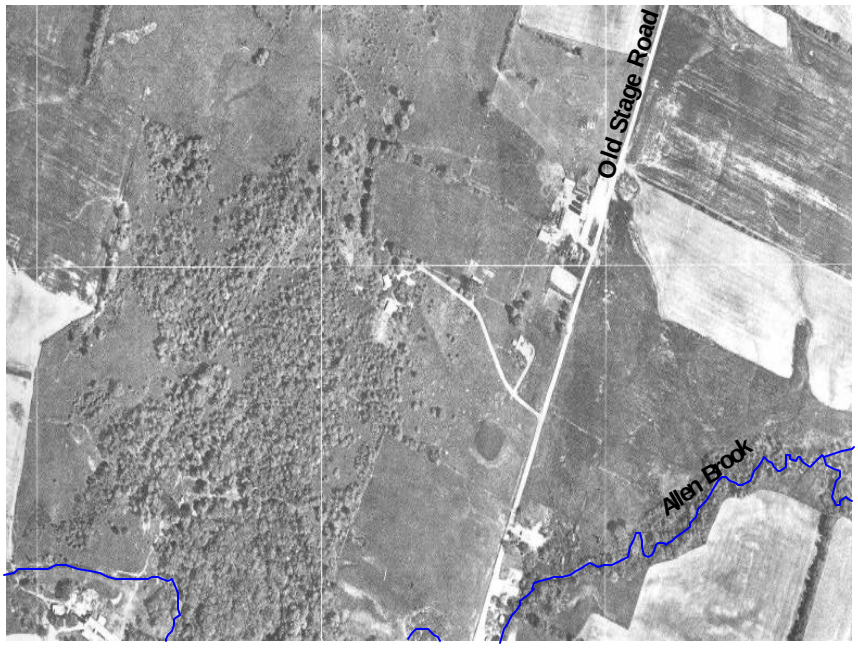
Development is expected to continue. The Vermont Center for Rural Studies predicts that the population of Williston will grow 46 percent between 1990 and 2015. Increases in impervious cover are inevitable, as population grows. Figure 2 are ortho-photos of Old Stage Road and part of Allen Brook for years 1978 and 1999, depicting land use changes.

The Town of Williston's Zoning Ordinance, in Section 3.16, allows for the lower watershed to reach a full build-out, or maximum lot coverage, of 65% in Commercial I and II Districts and 70% in the Industrial District.

**Table 2: Land Use**

| Land Use | Year = 1995 (Pease, 1997a) | **Year = 1999 (Williston Comprehensive Plan, 2000) | |
|---|---|---|---|
| Ag/Open (%) | 50 | 21 | |
| Forest (%) | 25 | Unavailable at this time | |
| Res/Dev (%) | 25 | 43 | |
| Imperviousness (%) | 5.5 | Unavailable at this time | |
| Annual Snowfall (inches) | 78 | Annual Precipitation (inches) | 35 inches |

* Averages of three cross-sections at each surveyed permanent monumented cross-section.
** Land use coverage data are currently being calculated.




Year: 1978

Year 1999

**Figure 2: Ortho-photos of Old Stage Road and Part of Allen Brook for Years 1978 and 1999**

**Appendix B: Biological Assessment Summary Fact Sheet – Allen Brook (DRAFT 9/03/02)**
**Vermont Agency of Natural Resources Bio-monitoring Unit**

I. Current condition and status

1. Description of impaired water body

   - Allen Brook located in Chittenden County in the Town of Williston;
   - 5.5 miles of stream extending from mile 1.0 (approx. 0.8 miles downstream from the Industrial Avenue crossing) to mile 6.5 (just below the North Williston road crossing).
   - Classified as Class B/Coldwater fish habitat water pursuant to the Vermont Water Quality Standards;
   - Segments of Allen Brook containing a mix of pools, runs and riffles are designated as Warm Water Moderate Gradient (WWMG) wadeable macroinvertebrate stream types and as Mixed Water Index of Biotic Integrity (MWIBI) wadeable fish community stream types for the purposes of biological community assessments; the remaining segments consist of mostly pool habitat and are not classified according to biological stream type.
   - Land use within the impaired segment watershed is currently exhibiting a trend of conversion from agricultural use to residential and commercial use.

2. Description of Data used to characterize impairment.

   - Fish community – six (6) assessments from five (5) sites within the waterbody designated as impaired;
   - Macroinvertebrates – three (3) assessments at two sites;
   - Only two sites have been assessed since 1991; the majority of the assessment data are more than ten (10) years old;
   - Two of three assessments conducted since 1992 at two sites have indicated possible improvements in biological condition;
   - Biological assessments conducted downstream of mile 1.0 (fish community three times 1997-2000) and upstream of mile 6.5 (macroinvertebrates three times 1992-2000) have consistently indicated good to excellent biologic condition.
   - Fish community assessments (6) – Two “poor” ratings at the same site during different years; two “fair” ratings; two “good” ratings: Macroinvertebrate community assessments (3): one “fair” rating; two “good” ratings.
   - Ongoing geomorphological and physical assessments will provide additional information for overall assessment;
   - Observations by field staff have consistently described a generally enriched environment and the abundance of silts and sediments in riffle habitats;

3. Summary statement - overall “weight-of-evidence” summary of findings from 2 above:

- Biological assessment data for Allen Brook provide the basis for impairment designation. These data are of high quality and demonstrate a pattern of impairment over time and space. The data indicate that the level of impairment is relatively moderate and is defined primarily by certain characteristics of the fish community. The bulk of the data indicating impairment is currently more than ten years old and requires updating.

4. Confidence: past, present, future:

    - DEC has high confidence in the application of biological assessments to Allen Brook. DEC is confident that the reference conditions and MWIBI evaluations applied the Allen Brook assessments are appropriate.

    - The bulk of the data indicating impairment were collected during active construction within the watershed adjacent to Allen Brook. Development within the watershed has continued since that time. The most recent assessment data suggest improved conditions. The recent data, while suggestive, are not adequate to alter initial findings of impairment.

    - Future watershed management actions resulting from TMDL development are expected to result in improved biologic condition. Geomorphological adjustments in response to management actions may have a significant effect on the time needed to effect a full recovery of the biological communities in Allen Brook. In the absence of comprehensive geomorphological assessment, very little confidence can be placed in "time to recovery" predictions.

5. Recommendations - recommended assessment needs:

    - Current biological condition should be evaluated at sites demonstrating historical impairment.

    - Biomonitoring should continue at several key reaches of stream that are likely to respond to watershed improvements. It is recommended that priority be given to monitoring sites 1.8 (a more representative site than the historic 2.2 site), 4.1, and 5.6 to determine their long-term biological condition and response to storm-water management planned in the watershed. Although the lowest site 0.6 has been assessed as good it should also be evaluated periodically. The uppermost site 7.1, which has been used as a reference site, should be assessed if development of the upper watershed occurs.

    - Geomorpholgy monitoring and characterization: completion of Phase II characterization.

    - Water Quality and Habitat monitoring and characterization: focus on parameters and effects related to sediment loading and dynamics.

## Attachment A – Allen Brook Biological Assessment

**Allen Brook -** The portion of Allen Brook between river miles 1.0 and 6.5 has been identified by the State of Vermont as impaired pursuant to the Clean Water Act, Section 303(d). The primary impairment has been to the aquatic biota.

*Present Assessment*

**Assessment results** - The fish and or macroinvertebrate communities of Allen Brook have been sampled a total of 17 times at 10 different stream locations since 1987. Eight of the ten sites are located within the section of Allen Brook identified as impaired. One site is located above, and one site below the impaired section. **Table 1** below summarizes the biological assessment history of the Allen Brook sites. The Department used the data in Table 1 to determine that impairments existed and to identify the upstream and downstream boundaries of the impairment.

1. The boundaries of the impaired reach were established based on consistently good to excellent findings at river mile 0.6 and 7.1:

   - Three years (1997-2000) of fish community data from site 0.6 in the lower part of Allen Brook provides the basis for non-impairment determination for the lower mile of Allen Brook. Fish community demonstrated **good** condition for all three sampling events. Macroinvertebrate communities have not been assessed in this section of the brook due to the unavailability of appropriate habitat conditions.

   - Three years (1989-2000) of macroinvertebrate community data from site 7.1 above I-89 collected between 1992 and 2000 provides the basis for non-impairment determination for the section of the brook upstream of mile 6.5, the next downstream assessment location. The macroinvertebrate community has been assessed as **very good to excellent** all three years. The fish community was sampled four times at this site between 1989 and 1995 but not rated due to too few species present to run a fish community Index of Biotic Integrity.

2. Eleven sampling events between river miles 1.0 and 6.5 have provided the data for the Departments determination that this section of Allen Brook is impaired.

   - Macroinvertebrate data have been collected at two sites within the impaired section of Allen Brook. 1991 data indicated **good** conditions at river mile 2.2. Data collected at river mile 1.8 showed **fair** conditions in 1999 and **good** conditions in 2000.

   - From 1987 to 1991, the fish community was sampled seven times at six sites. Of those seven assessments, two were **poor**, two were **fair**, one was **good**, and two were not rated due to habitat and sampling effort limitations. A fish community assessment at river mile 4.1 in 1999 resulted in a finding of **good** condition.

3. The Department has used standard protocols for determining biological condition and making assessments of impairment.

   - The Mixed Water Index of Biotic Integrity (MWIBI) was used to evaluate fish community biologic condition. The MWIBI requires a minimum of five species of native fish in order to be reliably calculated. Sampling guidelines require that the section of sampled stream exhibit a representative mix of habitat types found in the stream.

   - Macroinvertebrate community data was assessed using threshold criteria developed for Warm Water Moderate Gradient (WWMG) wadeable streams in Vermont. Analysis of

data from reference streams throughout Vermont indicates that small streams within the Champlain valley are appropriately evaluated using this model.

4. The most recent macroinvertebrate community monitoring in 1999 and 2000 has taken place at the uppermost site 7.1 and at site 1.8. The uppermost site supports a diverse macroinvertebrate community. The community is moderate to low in density, but high in both total taxa richness and EPT (mayflies, stoneflies, and caddisflies) taxa richness. The densities of tolerant Diptera *Chironomidae* and *Oligocheata* have been low with EPT species dominating the community. The Bio Index has been consistently in the very good to excellent range indicating organic enrichment is not altering the community at site 7.1.

   The lower site 1.8 has consistently had a high density of animals and a relatively high Bio Index value (about 5.5 compared to 3.5 at site 7.1). These two metrics seem to indicate that organic enrichment of the lower portion of the stream is elevated and significantly altering the macroinvertebrate community composition. In 1999 this resulted in a community rating of fair. In 2000 conditions seem to have improved slightly to good. The year 2000 however was exceptionally dry with little non-point runoff, which may have resulted in the improved condition of the stream macroinvertebrate community. The enriched stream condition is also evident in the functional group composition, with the percent algae shredders elevated both years. This is primarily due to high densities of the filamentous algae shredding midge *Cricotopus spp* , and stonefly *Taeniopteryx sp*.

   Two uncommon mussel species were observed at the lower site 1.8. These are the Creek Heelsplitter *Lasmigona costata* , and the Triangle Floater *Alasmindota undulata*. Several live animals of the Creek Heelsplitter were observed, but only fresh shells of the Triangle Floater were found.

**Assessment discussion** – The finding of impairment of aquatic life use in the designated section of Allen Brook (river mile 1.0-6.5) has been driven by biological conditions observed by the Department between 1987 and the present. Fish community data collected prior to 1995 within the section of Allen Brook identified as impaired provide the strongest evidence of impairment. Four of five fish assessments conducted at four sites during that time period resulted in assessments of poor to fair condition. Three biological assessments have been made by the Department within the impaired section since 1995, with one of three finding fair condition, with good conditions at the two. A single fish assessment at river mile 4.1 in 1999 demonstrated good conditions.

During the late 1980's and early 1990's when the majority of the assessments were made, there was significant construction activity occurring on lands adjacent to the section of Allen Brook currently designated as impaired. Recent data suggest that current biological conditions within the impaired section may be better than observed in 1987-1991. However, in the absence of more recent assessment data, findings of impairment must remain until biological survey data in the section can be updated.
Fish community data were collected from two sites, river miles 4.2 and 4.3, in 1989. These sites were not assigned a condition description because a) the length of segment sampled was shorter than required by Department protocols, and b) habitat variability required by Department protocols was not met. The segments sampled were 100 percent pool habitat; department protocols require a mix of pool, riffle, run in order to apply the Index of Biotic Integrity.

Fish community data collected from river mile 7.1 likewise have not been assigned a condition description due to too few species present to run a fish community Index of Biotic Integrity. Only three species of fish have been collected at river mile 7.1 from four sampling events. At river mile 6.5, a little more than a half-mile downstream, seven species have been collected. The excellent condition of the

macroinvertebrate community as well as best professional judgment of habitat conditions at the site suggest that the low species richness at river mile 7.1 is a result of natural conditions.

The Mixed Water Index of Biotic Integrity (MWIBI) was used to evaluate fish community condition in Allen Brook. Due to minimum species richness and sampling requirements for use of the MWIBI, data from several sampling events could not be evaluated.

The Warm Water Moderate Gradient (WWMG) model was used to evaluate macroinvertebrate data. The Department has conducted biological analyses that demonstrate the validity of using the WWMG model in streams in the Champlain valley, such as Allen Brook. Samples are collected from riffle areas within the stream with substrate characteristics matching those from selected reference sites. The Department is confident that macroinvertebrate communities inhabiting riffles in Allen Brook are appropriate indicators of overall biological condition for the brook, even if the riffle habitat is not the dominant overall habitat type in the brook.

The Department is highly confident that the portion of Allen Brook currently listed as impaired was impaired during the time that the majority of sampling occurred: 1987 to 1992. At the time of sampling there was significant construction activity in the vicinity of the impaired sites. In the absence of more recent comprehensive biological assessment data demonstrating that conditions have changed since that time, the Department maintains the impaired designation. Recent assessment data suggests that the biological condition of Allen Brook may be improving. Recent data are inadequate, however, to convincingly demonstrate any significant and consistent improvements.

*Recommended monitoring*

**Biomonitoring** should continue at several key reaches of stream that have shown impaired biological communities in past years. It is recommended that priority be given to monitoring sites 1.8 (a more representative site than the historic 2.2 site), 4.1, and 5.6 to determine their long-term biological condition and response to storm-water management planned in the watershed. Although the lowest site 0.6 has been assessed as good it should also be evaluated periodically. The uppermost site 7.1, which has been used as a reference site, should be assessed if development of the upper watershed occurs.

**Geomorphology** monitoring and characterization: completion of Phase II characterization

**Water Quality and Habitat** monitoring and characterization: focus on parameters and effects related to sediment loading and dynamics.

**Table 1: Biomonitoring Sites on Allen Brook for Fish and/or Macroinvertebrates – Summary**

| Location (river mile) | Description | Community | Assessment Dates and Results |
|---|---|---|---|
| Allen Brook 0.6 | At Phase 1 Griswold Farm section | Fish | 1997 Good<br>1998 Good<br>2000 Good |
| Allen Brook 1.8 | Just upstream of Industrial Avenue crossing | Macroinvertebrates | **1999 Fair**<br>2000 Good |
| Allen Brook 2.2 | Located 20 meters above Rt. 2 A crossing | Macroinvertebrates and Fish | **1987 Poor (F)**<br>**1991 Poor (F)**<br>1991 Good (M) |
| Allen Brook 4.1 | Located approx. 170m below bridge next to swim pool @ Tafts Cors. Condos | Fish | 1999 Good |
| Allen Brook 4.2 | Located approx. 100m below bridge next to swim pool @ Tafts Cors. Condos | Fish | NA |
| Allen Brook 4.3 | Located imm. Below bridge next to swim pool @ Tafts Cors. Condos | Fish | NA |
| Allen Brook 4.4 | Located 10m above bridge next to swim pool @ Tafts Cors. condos | Fish | **1989 Fair** |
| Allen Brook 5.6 | Located 50m above Rd. to Turtle Crossing Development | Fish | 1989 Good |
| Allen Brook 6.5 | Located 10m below N. Williston Rd. bridge. | Fish | **1989 Fair** |
| Allen Brook 7.1 | Located immediately above South Rd. culvert (above I-89) | Macroinvertebrates and Fish | 1992 Very Good (M)<br>1995 Good-Very Good (M)<br>2000 Excellent (M) |

**Table 2:** Fish community assessments Allen Brook
*(Most recent results in italics)*

| Location | Station | Date | MW_IBI | Community Assessment |
|---|---|---|---|---|
| *Allen Brook* | *0.6* | *Sep-97* | *31* | *Good* |
| *Allen Brook* | *0.6* | *Aug-98* | *35* | *Good* |
| *Allen Brook* | *0.6* | *Oct-00* | *31* | *Good* |
| Allen Brook | 2.2 | Aug-87 | 23 | **Poor** |
| Allen Brook | 2.2 | Aug-91 | 25 | **Poor** |
| *Allen Brook* | *4.1* | *Oct-99* | *31* | *Good* |
| Allen Brook | 4.2 | Aug-89 | | NA |
| Allen Brook | 4.3 | Aug-89 | | NA |
| Allen Brook | 4.4 | Aug-89 | 27 | **Fair** |
| Allen Brook | 5.6 | Aug-89 | 35 | Good |
| Allen Brook | 6.5 | Aug-89 | 29 | **Fair** |
| Allen Brook | 7.1 | Aug-89 | | NA |
| Allen Brook | 7.1 | Sep-92 | | NA |

**Table 3:** Fish community metrics from stations on Allen Brook.

| Location | Station | Date | Richness | Intolerant Species | Benthic Insectivores | % Generalist Feeder | % Insectivore | % CC&WS | % Top Carnivore | % Anomolie | Density | % Blacknose Dace |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Allen Brook | 0.6 | Sep-97 | 13 | 0 | 2 | 45.0 | 53.0 | 19.5 | 1.9 | 0.2 | 137 | 43.3 |
| Allen Brook | 0.6 | Aug-98 | 16 | 1 | 2 | 49.7 | 50.3 | 12.6 | 0.0 | 0.8 | 93 | 24.0 |
| Allen Brook | 0.6 | Oct-00 | 15 | 1 | 1 | 73.6 | 25.9 | 17.7 | 0.5 | 0.3 | 140 | 8.3 |
| Allen Brook | 2.2 | Aug-87 | 7 | 0 | 2 | 64.9 | 35.1 | 39.8 | 0.0 | 0.0 | 58 | 9.5 |
| Allen Brook | 2.2 | Aug-91 | 7 | 0 | 2 | 65.1 | 34.9 | 57.4 | 0.0 | 0.0 | 97 | 19.5 |
| Allen Brook | 4.1 | Oct-99 | 10 | 0 | 2 | 77.4 | 22.6 | 8.8 | 0.0 | 0.0 | 202 | 17.8 |
| Allen Brook | 4.2 | Aug-89 | 6 | 0 | 1 | 64.1 | 35.9 | 44.8 | 0.0 | 5.6 | 167 | 10.1 |
| Allen Brook | 4.3 | Aug-89 | 6 | 0 | 1 | 61.5 | 38.5 | 22.2 | 0.0 | 6.1 | 180 | 2.5 |
| Allen Brook | 4.4 | Aug-89 | 8 | 0 | 2 | 76.0 | 24.0 | 36.8 | 0.0 | 3.0 | 208 | 6.4 |
| Allen Brook | 5.6 | Aug-89 | 7 | 0 | 2 | 27.7 | 72.3 | 8.3 | 0.0 | 0.0 | 802 | 67.0 |
| Allen Brook | 6.5 | Aug-89 | 7 | 0 | 1 | 55.4 | 41.3 | 45.4 | 3.3 | 0.0 | 269 | 36.7 |
| Allen Brook | 7.1 | Aug-89 | 2 | 0 | 0 | 10.4 | 89.6 | 10.4 | 0.0 | 0.0 | 99 | 89.6 |
| Allen Brook | 7.1 | Sep-92 | 3 | 0 | 0 | 28.5 | 71.5 | 28.5 | 0.0 | 2.0 | 203 | 71.5 |
| Allen Brook | 7.1 | Aug-94 | 3 | 0 | 0 | 40.2 | 59.8 | 40.2 | 0.0 | 0.4 | 155 | 59.8 |
| Allen Brook | 7.1 | Oct-95 | 3 | 0 | 0 | 25.8 | 74.2 | 25.8 | 0.0 | 0.0 | 61 | 74.2 |

**Table 4:** Macroinvertebrate community metrics from three reaches on Allen Brook.
*(Most recent results in italics)*

| Location | Station | Date | Density | Richness | Ept | PMA-O1 | BI | Oligo% | Ept/EptChiro | PPCS-F1 | Assessment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Allen Brook* | *1.8* | *Oct-99* | *3990* | *42.0* | *16.0* | *67* | *5.69* | *0.0* | *0.52* | *0.46* | ***Fair*** |
| *Allen Brook* | *1.8* | *Oct-00* | *5594* | *51.0* | *24.0* | *64* | *5.33* | *0.0* | *0.75* | *0.42* | *Good* |
| Allen Brook | 2.2 | Aug-91 | 3010 | 44.0 | 17.5 | 69 | 4.84 | 0.0 | 0.79 | 0.51 | Good |
| Allen Brook | 7.1 | Sep-92 | 1184 | 47.0 | 19.5 | 69 | 3.98 | 0.1 | 0.62 | 0.58 | V-good |
| Allen Brook | 7.1 | Oct-95 | 936 | 40.0 | 19.0 | 70 | 3.22 | 1.0 | 0.93 | 0.61 | Vg-Good |
| *Allen Brook* | *7.1* | *Oct-00* | *1836* | *51.5* | *22.5* | *78* | *3.12* | *0.6* | *0.87* | *0.76* | *Exc* |

**Table 5:** Percent composition of Macroinvertebrate orders from sites on Allen Brook

| Location | Station | Date | Coleoptera | Diptera | Ephemeroptera | Plecoptera | Trichoptera | Oligochaeta | Other Orders |
|---|---|---|---|---|---|---|---|---|---|
| Allen Brook | 1.8 | Oct-99 | 10.6 | | 12.4 | 10.5 | 22.2 | 0.0 | 0.5 |
| Allen Brook | 1.8 | Oct-00 | 4.2 | 26.9 | 8.0 | 14.2 | 46.6 | 0.0 | 0.1 |
| Allen Brook | 2.2 | Aug-91 | 19.5 | 17.6 | 11.4 | 0.3 | 49.6 | 0.0 | 1.6 |
| Allen Brook | 7.1 | Sep-92 | 22.0 | 31.1 | 7.0 | 4.5 | 34.0 | 0.1 | 1.3 |
| Allen Brook | 7.1 | Oct-95 | 17.6 | 8.7 | 8.0 | 28.2 | 31.1 | 1.0 | 5.4 |
| Allen Brook | 7.1 | Oct-00 | 6.6 | 16.4 | 17.4 | 15.3 | 38.0 | 0.6 | 5.8 |

**Table 6:** Percent composition of Macroinvertebrate functional feeding guilds from sites on Allen Brook

| Location | Station | Date | ColGatherer | CollFilterer | Predator | ShredDetritus | ShredHerbivore | Scraper |
|---|---|---|---|---|---|---|---|---|
| Allen Brook | 1.8 | Oct-99 | 26.3 | 20.4 | 2.3 | 0.5 | 33.4 | 14.2 |
| Allen Brook | 1.8 | Oct-00 | 16.5 | 44.1 | 2.7 | 0.0 | 26.3 | 8.2 |
| Allen Brook | 2.2 | Aug-91 | 17.0 | 38.1 | 4.8 | 0.0 | 0.4 | 37.3 |
| Allen Brook | 7.1 | Sep-92 | 25.9 | 31.9 | 9.6 | 0.5 | 0.2 | 30.8 |
| Allen Brook | 7.1 | Oct-95 | 9.6 | 26.3 | 13.1 | 18.6 | 4.5 | 21.2 |
| Allen Brook | 7.1 | Oct-00 | 22.8 | 31.0 | 15.9 | 1.2 | 4.6 | 17.4 |

**Appendix C: Literature Search For Quantifiable Controls For TMDLs**

Outline for Appendix C

Section 1.0: Results of Literature Search
Section 2.0: Better Site Design
Section 3.0: Erosion and Sediment Control
Section 4.0: Management and Maintenance:
Section 5.0: Riparian Buffers, Filter Strips and Grass Swales
Section 6.0: Best Management Practices
- 6.1 Street Sweeping
- 6.2 Storm-Drain Clean-Out
- 6.3 Road Sanding
- 6.4 Snow Disposal

Section 7.0 Transportation and Infrastructure
- 7.1 Bridge and Culvert Sizing
- 7.2 Bridge Assessment
- 7.3 Restoration and Maintenance Near Road Corridors
- 7.4 Culverts

Section 8.0 Structural Practices
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Section 9.0: Quantifiable Controls: Phosphorus Removal, Urban and Agriculture
Phosphorus Offset References - Jim Pease ANR
References

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## Section 1. 0 Results of Literature Search

The results of the literature search are presented in the following categories:

1. Better Site Design
2. Erosion and Sediment Control
3. Maintenance and Management of Stormwater Facilities
4. Riparian Buffers
5. Stormwater Best Management Practices:
   - Structural Stormwater Controls
     - Wetlands, ponds, open channels, filtering systems, infiltration systems,
     - Urban and Rural
6. Best Management Practices
   - Street Sweeping
   - Drain Cleanout

The first four sections provide the most "bang for the buck". They are methods that are aimed at preventing the problem from occurring in the first place as well as ensuring on-going maintenance of existing facilities. The results of the literature search can be used to model offsets to reduce sediment and nutrient loading to the watershed. This appendix provides pertinent data from previous studies. In this appendix, tables are copied from the literature if they provide a basis for determining "quantifiable controls". The original sources should be consulted if further detail is required.

The literature does not have many quantifiable studies of removal capacity of Best Management Practices for agriculture, construction and development, road building, logging, road salting, golf courses, site excavation, sand and gravel operations, pollution hot-spots, snow disposal, sludge, septic; and educational efforts such as pet waste management, lawn care, disconnection of impervious areas, illicit connection detection, or reduction of sediment due to properly sized bridge and culverts for stream crossings, nor on the creation of a stormwater utility. Despite the lack of quantifiable studies in these areas, experience has shown that these BMP's provide water quality benefits and should be included as part of a watershed management plan.

**Table C-1. Examination Objectives of the Literature Review.**

| Structural Approaches | Non-structural Approaches |
|---|---|
| **Wetlands, ponds, open channels, filtering systems, infiltration systems, etc.** | Riparian buffers, STPs for agriculture, construction and development, road building, logging, road salting, golf courses, site excavation, sand and gravel operations, pollution hot-spots, snow disposal, sludge, septic; better site design, and educational efforts such as pet waste management, lawn care, disconnection of impervious areas, street sweeping, illicit connection detection, etc. |

**Section 2.0: Quantifiable Controls: Better Site Design**

The methods, and benefits of Better Site Design are in Table C–2 through C-5. They are quantified as a *reduction* in phosphorus loading, cost, and stormwater runoff and an *increase* in infiltration. Better Site Design is the art of 'prevention". Better Site Design is one of the methods that provides the most "bang for the buck" in terms of cost-savings to the developer and reduction in nutrient and sediment loading.

**Table C-2: BMP's for Better Site Design**

| **Better Site Design includes:** | **BMP's for Better Site Design include:** |
|---|---|
| Clustering development<br>Skinnier and shorter residential streets<br>Eliminating or minimizing cul-de-sacs<br>Smaller parking lots<br>Smaller parking stalls<br>Alternative paving surfaces<br>Open channel drainage<br>Preservation of natural open space, leaving areas undisturbed<br>Forest and natural area conservation<br>Source level runoff retention<br>Riparian buffers<br>Disconnecting roof top runoff.<br>Careful grading of land to promote infiltration, including subtle depression, terracing and small berms. | Reducing impervious cover<br>Spreading runoff over pervious areas<br>Utilizing open channel drainage<br>Conserving forests and natural areas<br>Reducing the amount of managed turf and lawn<br>Creating more effective stream buffers and riparian areas, minimum 100 feet.<br>Increasing separation distances and setbacks for conventional septic systems<br>Employing advanced septic system technologies |
| **Methods to reduce impervious cover:** | |
| Wood chip paths through community open space instead of sidewalks along road, stone walks to houses.<br>Overflow parking as grid pavers<br>Shorter driveways<br>Compact parking spaces<br>Narrower streets, smaller turn-arounds, shorter driveways, less sidewalk.<br>Providing bus depot in commercial office space | |

(CWP, 1998a)

**Table C-3: Impervious Cover Reduction and Cost Savings of Conservation Development**

| Location | Techniques Used | Impervious Cover Reduction (%) | Cost Savings (%) |
|---|---|---|---|
| Sussex County, DE | Reduced street widths (from 28' to 20')<br>Smaller lots (from 1/2 acre to 1/8 acre)<br>Cluster Development<br>Preserve woodland areas<br>Use Vegetated BMPs that promote infiltration on site | 38 | 52 |
| New Castle County, DE | Houses clustered into attached units around courtyards<br>Reduced street widths (from 28' to 20')<br>Preserve woodland areas<br>Use Vegetated BMPs that promote infiltration on site | 6 | 63 |
| Kent County, DE | Reduced street widths (from 28' to 20')<br>Minimum disturbance boundary<br>Smaller lots (from 1 acre to ½ acre)<br>Cluster Development<br>Preserve woodland areas<br>Use Vegetated BMPs that promote infiltration on site | 24 | 39 |

(DEDNREC, 1997, Table 30)

**Table C-4: Reductions in cost, impervious cover and stormwater runoff, and increased infiltration through Better Site Design.**

| Development Scenario | Medium Density Residential | Low Density Residential | Retail Shopping Center | Commercial Office Park |
|---|---|---|---|---|
| | 45 acres, 108 units, 9000 sq. ft lots | 8 units on 3 – 5 acre lots | 9.3 acres site with 6.5 acres impervious cover. 343 parking spaces | 12.8 acre site with 8.7 acres impervious cover. 778 parking spaces |
| Conventional | $1,539,298 | $143,553 | $782,452 | $948,900 |
| Innovative | $1,238,751 | $126,430 | $746,270 | $788,432 |
| $ Savings | $300,547 | $17,123 | $36,182 | $160,468 |
| **Percent $ savings** | **20%** | **12%** | **5%** | **17%** |
| **PERCENTAGE CHANGE FROM A CONVENTIONAL TO INNOVATIVE DESIGN WITH BMP'S** | | | | |
| Reduction In Impervious cover | 24% | 35% | 18% | 22% |
| Reduction in Stormwater Runoff | 25% | 23% | 17% | 21% |
| Increase in Stormwater Infiltration | 55%8 | 12% | Decrease of 2% | 42% |

(CWP, nutrient loading)

**Table C-5: Changes In Type Of Stormwater Treatment In Conventional And Innovative Development**

| Structural Treatment | Medium Density Residential | Low Density Residential | Retail Shopping Center | Commercial Office Park |
|---|---|---|---|---|
| **Conventional** | Dry Extended Detention | Wet Pond | Single Infiltration facility, rest of site with oil and grit separators | Two stormwater wetlands |
| **Innovative** | Treatment train of bioretention and wet extended detention facility | Bioretention area and dry swale | On-site bioretention, sand filter and infiltration trench, filter strip | Series of bioretention facilities, dry swale in combination with a wet retention pond |

(CWP, 1998a)

The Center for Watershed Protection (2000) has developed a model for determining benefits from impervious cover reduction. They provide the following:

*Example Calculation – Impervious Cover Reduction:*

*A community plans to redevelop approximately 200 acres within a 5,000 acre, 50% impervious watershed. The current urban stormwater nitrogen load in the watershed is 51,000 lbs/yr. On redevelopment projects, the site impervious cover will be reduced by approximately 5%. 75% of these projects are expected to be implemented within the timeframe of the TMDL, so that the load reduction will be:*

$$R = 51{,}000*(200*5\%)/(5000*5\%)*0.75 = 153 \text{ lbs/year}$$

## Section 3.0 Erosion and Sediment Control

The following tables (EPA 1993) summarize the changes in sediment, nutrients, metals and cost from implementing erosion and sediment control practices.

**Table C-6: TSS Concentrations from Maryland Construction Sites with ESC (Scheuler 1987)**

| **Treatment at Construction Sites** | **TSS concentration (mg/l)** |
|---|---|
| Natural, undisturbed | 25 |
| Uncontrolled disturbed | 4150 |
| **Increase from natural to disturbed with no controls** | **166 x greater** (25/4150) |
| with 60% efficient sediment control | 1,650 |
| with 80% efficient sediment control | 800 |
| with 65% erosion control | 700 |
| with 60% efficient sediment control and erosion control | 300 |
| with 80% efficient sediment control and erosion control | 150 |
| **Increase from natural to disturbed site using erosion AND sediment controls** | **6 x greater** (25/150) |

*(EPA 1993, Figure 4-7)*

**Table 4-7. Effectiveness of Management Practices for Control of Runoff From Newly Developed Areas**

| Management Practice | | Removal Efficiency (%) TSS | TP | TN | COD | Pb | Zn | Factors | References |
|---|---|---|---|---|---|---|---|---|---|
| INFILTRATION BASIN | Average: | 75 | 65 | 60 | 65 | 65 | 65 | • Soil percolation rates<br>• Basin surface area<br>• Storage volume | NVPDC, 1979; EPA, 1977; Schueler, 1987; Griffin, et al, 1980; EPA, 1983; Woodward-Clyde, 1988 |
| | Reported Range: | 45-100 | 45-100 | 45-100 | 45-100 | 45-100 | 45-100 | | |
| | Probable Range[a] | | | | | | | | |
| | SCS Soil Group A | 60-100 | 60-100 | 60-100 | 60-100 | 60-100 | 60-100 | | |
| | SCS Soil Group B | 50-80 | 50-80 | 50-80 | 50-80 | 50-80 | 50-80 | | |
| | No. Values Considered: | 7 | 7 | 7 | 4 | 4 | 4 | | |
| INFILTRATION TRENCH | Average: | 75 | 60 | 55 | 65 | 65 | 65 | • Soil percolation rates<br>• Trench surface area<br>• Storage volume | NVPDC, 1979; EPA, 1977; Schueler, 1987; Griffin, et al, 1980; EPA, 1983; Woodward-Clyde, 1988; Kuo et al., 1988; Lugbill, 1990 |
| | Reported Range: | 45-100 | 40-100 | (-10)-100 | 45-100 | 45-100 | 45-100 | | |
| | Probable Range[b] | | | | | | | | |
| | SCS Soil Group A | 60-100 | 60-100 | 60-100 | 60-100 | 60-100 | 60-100 | | |
| | SCS Soil Group B | 50-90 | 50-90 | 50-90 | 50-90 | 50-90 | 50-90 | | |
| | No. Values Considered: | 9 | 9 | 9 | 4 | 4 | 4 | | |
| VEGETATED FILTER STRIP | Average: | 65 | 40 | 40 | 40 | 45 | 60 | • Runoff volume<br>• Slope<br>• Soil infiltration rates<br>• Vegetative cover<br>• Buffer length | IEP, 1991; Caiman, 1990; Glick et al., 1991; VADC, 1987; Minnesota PCA, 1989; Schueler, 1987; Hartigan et al., 1989 |
| | Reported Range: | 20-80 | 0-95 | 0-70 | 0-80 | 20-90[e] | 30-90[f] | | |
| | Probable Range[c] | 40-90 | 30-80 | 20-60 | -- | 30-80 | 20-80 | | |
| | No. Values Considered: | 7 | 4 | 3 | 2 | 3 | 3 | | |
| GRASS SWALE | Average: | 60 | 20 | 10 | 25 | 70<br>3-100[e] | 60 | • Runoff volume<br>• Slope<br>• Soil infiltration rates<br>• Vegetative cover<br>• Swale length<br>• Swale geometry | Yousef et al., 1985; Dupuis, 1985; Washington State, 1988; Schueler, 1987; British Columbia Res. Corp., 1991; EPA, 1983; Whalen, et al., 1988; Pitt, 1989; Caiman, 1990 |
| | Reported Range: | 0-100 | 0-100 | 0-40 | 25 | 10-20 | 50-80[f] | | |
| | Probable Range[c] | 20-40 | 20-40 | 10-30 | -- | 10 | 10-20 | | |
| | No. Values Considered: | 10 | 8 | 4 | 1 | | 7 | | |
| POROUS PAVEMENT | Average: | 90 | 85 | 85 | 80 | 100 | 100 | • Percolation rates<br>• Storage volume | Schueler, 1987 |
| | Reported Range: | 80-95 | 85 | 80-85 | 80 | 100 | 100 | | |
| | Probable Range: | 80-90 | 80-90 | 80-90 | 80-90 | 80-90 | 80-90 | | |
| | No. Values Considered: | 2 | 2 | 2 | 2 | 2 | 2 | | |
| CONCRETE GRID PAVEMENT | Average: | 90 | 90 | 90 | 90 | 90 | 90 | • Percolation rates | Day, 1981; Smith, et al, 1981; Schueler, 1987 |
| | Reported Range: | 85-100 | 85-100 | 85-100 | 85-100 | 85-100 | 85-100 | | |
| | Probable Range: | 80-90 | 80-90 | 80-90 | 80-90 | 80-90 | 80-90 | | |
| | No. Values Considered: | 2 | 2 | 2 | 2 | 2 | 2 | | |
| SAND FILTER/FILTRATION BASIN | Average: | 80 | 50 | 35 | 55 | 80 | 85 | • Treatment volume<br>• Filtration media | City of Austin, 1988; Environmental and Conservation Service Department, 1990 |
| | Reported Range: | 60-95 | 0-90 | 20-40 | 45-70 | 30-90 | 50-80 | | |
| | Probable Range: | 60-90 | 0-80 | 20-40 | 40-70 | 40-80 | 40-80 | | |
| | No. Values Considered: | 10 | 6 | 7 | 3 | 5 | 5 | | |
| WATER QUALITY INLET[a] | Average: | 35 | 5 | 20 | 5 | 15 | 5 | • Maintenance<br>• Sedimentation storage volume | Pitt, 1986; Field, 1985; Schueler, 1987 |
| | Reported Range: | 0-95 | 5-10 | 5-55 | 5-10 | 10-25 | 5-10 | | |
| | Probable Range: | 10-25 | 5-10 | 5-10 | 5-10 | 10-25 | 5-10 | | |
| | No. Values Considered: | 3 | 1 | 2 | 1 | 2 | 1 | | |
| WATER QUALITY INLET WITH SAND FILTER[a] | Average: | 80 | NA | 35 | 55 | 80 | 85 | • Sedimentation storage volume<br>• Depth of filter media | Shaver, 1991 |
| | Reported Range: | 75-85 | NA | 30-45 | 45-70 | 70-90 | 50-80 | | |
| | Probable Range: | 70-90 | -- | 30-40 | 40-70 | 70-90 | 50-80 | | |
| | No. Values Considered: | 1 | 0 | 1 | 1 | 1 | 1 | | |
| OIL/GRIT SEPARATOR[a] | Average: | 15 | 5 | 5 | 5 | 15 | 5 | • Sedimentation storage volume<br>• Outlet configurations | Pitt, 1985; Schueler, 1987 |
| | Reported Range: | 0-25 | 5-10 | 5-10 | 5-10 | 10-25 | 5-10 | | |
| | Probable Range: | 10-25 | 5-10 | 5-10 | 5-10 | 10-25 | 5-10 | | |
| | Number of References | 2 | 1 | 1 | 1 | 1 | 1 | | |
| EXTENDED DETENTION DRY POND | Average: | 45 | 25 | 30 | 20 | 50 | 20 | • Storage volume<br>• Detention time<br>• Pond shape | MWCOG, 1983; City of Austin, 1990; Schueler and Helfrich, 1988; Pope and Hess, 1989; OWML, 1987; Wolinski and Stack, 1990 |
| | Reported Range: | 5-90 | 10-55 | 20-60 | 0-40 | 25-65 | (-40)-65 | | |
| | Probable Range[c] | 70-90 | 10-60 | 20-60 | 30-40 | 20-60 | 40-60 | | |
| | No. Values Considered: | 6 | 6 | 4 | 5 | 4 | 5 | | |
| WET POND | Average: | 60 | 45 | 35 | 40 | 75 | 60 | • Pool volume<br>• Pond shape | Wotzka and Oberts, 1988; Yousef et al., 1986; Cullum, 1985; Driscoll, 1989; Driscoll, 1986; MWCOG, 1983; OWML, 1983; Yu and Benemouffok, 1988; Heller, 1989; Martin, 1988; Dorman et al., 1989; OWML, 1982; City of Austin, 1990 |
| | Reported Range: | (-30)-91 | 10-85 | 5-85 | 5-90 | 10-95 | 10-95 | | |
| | Probable Range: | 50-90 | 20-90 | 10-90 | 10-90 | 10-95 | 20-95 | | |
| | No. Values Considered: | 18 | 18 | 9 | 7 | 13 | 13 | | |
| EXTENDED DETENTION WET POND | Average: | 80 | 65 | 55 | NA | 40 | 20 | • Pool volume<br>• Pond shape<br>• Detention time | Ontario Ministry of the Environment, 1991, cited in Schueler et al., 1992 |
| | Reported Range: | 50-100 | 50-80 | 55 | NA | 40 | 20 | | |
| | Probable Range: | 50-95 | 50-90 | 10-90 | 10-90 | 10-95 | 20-95 | | |
| | No. Values Considered: | 3 | 3 | 1 | 0 | 1 | 1 | | |
| CONSTRUCTED STORMWATER WETLANDS | Average: | 65 | 25 | 20 | 50 | 65 | 35 | • Storage volume<br>• Detention time<br>• Pool shape<br>• Wetland's biota<br>• Seasonal variation | Harper et al., 1988; Brown, 1985; Wotzka and Oberts, 1988; Hickock et al., 1977; Barten, 1987; Melorin, 1988; Morris et al., 1981; Sherberger and Davis, 1982; ABAG, 1979; Oberts et al., 1989; Rushton and Dye, 1990; Hey and Barrett, 1991; Martin and Smoot, 1986; Reinelt et al., 1990, cited in Woodward-Clyde, 1991 |
| | Reported Range: | (-20)-100 | (-120)-100 | (-15)-40 | 20-80 | 30-95 | (-30)-80 | | |
| | Probable Range[c] | 50-90 | (-5)-80 | 0-40 | --- | 30-95 | --- | | |
| | No. Values Considered: | 23 | 24 | 8 | 2 | 10 | 8 | | |

NA - Not available.
[a] Design criteria: storage volume equals 90% avg runoff volume, which completely drains in 72 hours; maximum depth = 8 ft; minimum depth = 2 ft.
[b] Design criteria: storage volume equals 90% avg runoff volume, which completely drains in 72 hours; maximum depth = 8 ft; minimum depth = 3 ft; storage volume = 40% excavated trench volume.
[c] Design criteria: flow depth < 0.3 ft, travel time > 5 min.
[d] Design criteria: low slope and adequate length.
[e] Design criteria: min. ED time 12 hours.
[f] Design criteria: minimum area of wetland equal 1% of drainage area.
[g] No information was available on the effectiveness of removing grease or oil.
[h] Also reported as 90% TSS removed.
[i] Also reported as 50% TSS removed.

**Table 4-12. Items to Consider in Developing an Erosion and Sediment Control Plan (Adapted from Goldman, 1986)**

| Item | Description |
|---|---|
| Schedule grading and construction to minimize soil exposure. | • Schedule projects so clearing and grading are done during the dry season or the time of minimum erosion potential. Many parts of the country have a time of year when erosion potential is relatively low and carefully planned construction scheduling could be very effective.<br>• Stage construction so that one area can be stabilized before another is disturbed. This practice reduces the time that an area is left unstabilized. |
| Retain existing vegetation wherever feasible. | • Clear only those areas that are essential for completing site construction.<br>• Avoid disturbing vegetation on steep slopes or other critical areas and locate material stockpiles, borrow areas, and access roads away from critical areas.<br>• Route construction traffic to avoid existing or newly planted vegetation.<br>• Physically mark off limits of land disturbance with tape, signs, or barriers. This ensures that the bulldozer operator knows the proposed limits of clearing.<br>• Protect natural vegetation with fencing, tree armoring, retaining walls, or tree walls. |
| Stabilize all denuded areas within 15 calendar days after final grading. Disturbed areas that are inactive and will be exposed to rain for 30 days or more should also be temporarily stabilized. | • During favorable seeding dates and in areas where vegetation can be established, the following should be implemented:<br>- Use seeding and fertilizing in very flat, nonsensitive areas with favorable soils.<br>- Use seeding and mulching for less erosive soil or on moderately steep slopes with moderately erosive soils in relatively sensitive areas.<br>- Use seeding with multiple mulching treatments or sodding for highly erosive soil, very steep slopes, or sensitive areas with highly erosive soils.<br>• If stabilization is required during the time of year that vegetation cannot be established, implement the following practices:<br>- On moderate slopes or soil that is not highly erodible, mulching should be employed.<br>- On steep slopes or highly erodible soils, multiple mulching treatments should be used.<br>• If in high elevation or desert site where grasses cannot survive due to harsh environment, at a minimum, plant native shrubs.<br>• Before stabilizing an area, make sure necessary controls (e.g., diversion of runoff) are in place.<br>• Where practical, stockpile topsoil and reapply to revegetate site.<br>• Cover or stabilize topsoil stockpiles.<br>• For high potential for wind-blown sediment transport, prior to stabilization protect with dust controls such as wind barriers, mulching, tillage, or sprinkling. |
| Divert runoff away from denuded areas or newly seeded slopes. | • Above disturbed areas, construct dike or swale or install pipe slope drain to intercept runoff and convey it to a permanent channel or storm drain. |
| Minimize length and steepness of slopes. | • On long or steep disturbed or man-made slopes, construct benches, terraces, or ditches at regular intervals to intercept runoff. |
| Prepare drainageways and outlets to handle concentrated or increased runoff. | • Provide lining for any existing or newly constructed channel on-site or off-site so the 2-year storm channel velocity does not cause erosion.<br>• Check dams should be installed on temporary swales that have erosive velocity but due to their short service life cannot support a vegetative lining. |
| Trap sediment onsite (sediment controls). | • In areas where greater than 5 acres drain to a point, sediment basin should be installed.<br>• In areas where less than 5 acres of concentrated flow leaves the site, silt traps should be installed.<br>• In areas where sheet flow leaves the site and the drainage area is less than 0.5 ac/100 ft of flow, filter fabric fence should be installed.<br>• In areas where sheet flow leaves the site and the drainage area is greater than 0.5 ac/100 ft of flow, perimeter dikes should be installed and flow should be diverted to a sediment trap or sediment basin.<br>• Install inlet protection around all storm drain inlets.<br>• Install construction entrance (gravel pad to collect mud and sediment from wheels) and route all traffic leaving the site to the construction entrance.<br>• Install all sediment controls prior to grading. |
| Inspect and maintain control measures. | • Remove sediment from sediment traps and filter fence when silted to half capacity.<br>• Inspect and repair, as needed, all controls after each storm event. |

NOTE: These are recommendations only and are not intended to be all-inclusive.

**Table 4-15. ESC Quantitative Effectiveness and Cost Summary**

| Practice | Design Constraints or Purpose | Percent Removal of TSS | Useful Life (years)* | Construction Cost | Annual Maintenance Cost (as % construction cost) | Total Annual Cost |
|---|---|---|---|---|---|---|
| Sod | Immediate erosion protection where there is high erosion potential during vegetative establishment. | Average: 99%<br>Observed range: 98% - 99%<br>References: Minnesota Pollution Control Agency, 1989; Pennsylvania, 1983 cited in USEPA, 1991 | 2 | Average: $0.2 per ft²<br>[$11,300 per acre]<br>Range: $0.1 - $1.1<br>References: SWRPC, 1991; Schueler, 1987; Virginia, 1980 | Average: 5%<br>Range: 5%<br>Reference: SWRPC, 1991 | $0.20 per ft²<br>$7,500 per acre |
| Seed | Establish vegetation on disturbed area. | After vegetation established-<br>Average: 90%<br>Observed range: 50% - 100%<br>References: SCS, 1985 cited in EPA, 1991; Minnesota Pollution Control Agency, 1989; Oberts, 1984 cited in City of Austin, 1988; Delaware Department of Natural Resources, 1989 | 2 | Average: $400 per acre<br>Range: $200 - $1000 per acre<br>References: Wisconsin DOT cited in SWRPC, 1991; SWRPC, 1991; Goldman, 1986; Virginia, 1980 | Average: 20%<br>Range: 15% - 25%<br>References: Wisconsin DOT cited in SWRPC, 1991; SWRPC, 1991 | $300 per acre |
| Seed and Mulch | Establish vegetation on disturbed area. | After vegetation established-<br>Average: 90%<br>Observed range: 50% - 100%<br>References: SCS, 1985 cited in EPA, 1991; Minnesota Pollution Control Agency, 1989; Oberts, 1984 cited in City of Austin, 1988; Delaware Department of Natural Resources, 1989 | 2 | Average: $1,500 per acre<br>Range: $800 - $3,500 per acre<br>References: Goldman, 1986; Washington DOT, 1990; NC State, 1990; Schueler, 1987; Virginia, 1980; SWRPC, 1991 | Average: NA*<br>Range: NA<br>References: None | $1,100 per acre |
| Mulch | Temporary stabilization of disturbed area. | Observed range:<br><br>sand:<br>20% slope / 50% slope<br>wood fiber @ 1500 lb/ac: 50-60% / 0-20%<br>wood fiber @ 3000 lb/ac: 50-85% / 50-70%<br>straw @ 3000 lb/ac: 90-100% / 95%<br><br>Silt-loam:<br>20% slope / 50% slope<br>wood fiber @ 1500 lb/ac: 20-60% / 40-60%<br>wood fiber @ 3000 lb/ac: 60-90% / 60-70%<br>straw @ 3000 lb/ac: 80-95% / 70-90%<br><br>Silt-clay-loam:<br>10-30% slope / 30-50% slope<br>wood fiber @ 1500 lb/ac: 5% / --<br>wood fiber @ 3000 lb/ac: 40% / --<br>jute netting: 30-60% / 30%<br>straw @ 3000 lb/ac: 40-70% / 20-40%<br>wood chips @ 10,000 lb/ac: 60-80% / 50-60%<br>mulch blanket: 60-80% / 50-60%<br>excelsior blanket: 60-80% / 50-60%<br>multiple treatment (straw and jute): 90% / 90%<br><br>References: Minnesota Pollution Control Agency, 1989; Kay, 1983 cited in Goldman, 1986 | Straw mulch: 0.25<br><br>Wood fiber mulch: 0.33<br><br>Jute netting: 0.33<br><br>Straw and jute: 0.33 | Straw mulch:<br>Average: $1,700 per acre<br>Range: $500 - $5,000 per acre<br>References: Wisconsin DOT cited in SWRPC, 1991; Washington DOT, 1990; Virginia, 1980<br><br>Wood fiber mulch:<br>Average: $1,000 per acre<br>Range: $100 - $2,300 per acre<br>References: Washington DOT, 1990; Virginia, 1980<br><br>Jute netting:<br>Average: $3,700 per acre<br>Range: $3,500-$4,100 per acre<br>References: Washington DOT, 1990; Virginia, 1980<br><br>Straw and jute:<br>Average: $5,400 per acre<br>Range: $4,000-$9,100 per acre<br>References: Washington DOT, 1990; Virginia, 1980 | Average: NA*<br>Range: NA<br>References: None | Straw mulch:<br>$7,500 per acre<br><br>Wood fiber mulch:<br>$3,500 per acre<br><br>Jute netting:<br>$12,500 per acre<br><br>Straw and jute:<br>$18,000 per acre |
| Terraces | Break up long or steep slopes. | Observed range:<br><br>Land Slope / Reduction in Erosion<br>1-12% / 70%<br>12-18% / 60%<br>18-24% / 55%<br><br>Additionally, if the slope steepness is halved, while other factors are held constant, the soil loss potential decreases 2-1/2 times. If both the slope and length are halved, the soil loss potential is decreased 4 times.<br>References: Goldman, 1986; Beasley, 1972 | 2 | Average: $5 per lin ft<br>Range: $1 - $12<br>References: SWRPC, 1991; Goldman, 1986; Virginia, 1991 | Average: 20%<br>Range: 20%<br>Reference: SWRPC, 1991 | $4 per lin ft |
| All Erosion Controls | Reduce amount of sediment entering runoff. | Average: 85%<br>Observed range: 85%<br>Reference: Schueler, 1990 | -- | Varies but typically low | Varies but typically low | Varies but typically low |

NA - Not available.
* Useful life estimated as length of construction project (assumed to be 2 years).
* For Total Annual Cost, assume Annual Maintenance Cost = 2% of construction cost.

**Table 4-16. ESC Quantitative Effectiveness and Cost Summary for Sediment Control Practices**

| Practice | Design Constraints or Purpose | Percent Removal of TSS | Useful Life (years)[a] | Construction Cost | Annual Maintenance Cost (as % construction cost) | Total Annual Cost |
|---|---|---|---|---|---|---|
| Sediment basin | Minimum drainage area = 5 acres, maximum drainage area = 100 acres | Average: 70%<br>Observed range: 55% - 100%<br>References: Schueler, 1990; Engle, BW and Jarrett, AR, 1990; Baumann, 1990 | 2 | Less than 50,000 ft³ storage<br>Average: $0.60 per ft³ storage<br>($1,100 per drainage acre[b])<br>Range: $0.20 - $1.30 per ft³<br><br>Greater than 50,000 ft³ storage<br>Average: $0.3 per ft³ storage<br>($550 per drainage acre[b])<br>Range: $0.10 - $0.40 per ft³<br>References: SWRPC, 1991 | Average: 25%<br>Range: 25%<br>References: Denver COG cited in SWRPC, 1991; SWRPC, 1991 | Less than 50,000 ft³ storage<br>$0.40 per ft³ storage<br>$700 per drainage acre[b]<br><br>Greater than 50,000 ft³ storage<br>$0.20 per ft³ storage<br>$900 per drainage acre[b] |
| Sediment trap | Maximum drainage area = 5 acres | Average: 60%<br>Observed range: (-7%) - 100%<br>References: Schueler, et al., 1990; Tahoe Regional Planning Agency, 1989; Baumann, 1990 | 1.5 | Average: $0.60 per ft³ storage<br>($1,100 per drainage acre[b])<br>Range: $0.20 - $2.00 per ft³<br>References: Denver COG cited in SWRPC, 1991; SWRPC, 1991; Goldman, 1986 | Average: 20%<br>Range: 20%<br>References: Denver COG cited in SWRPC, 1991; SWRPC, 1991 | $0.70 per ft³ storage<br>$1,300 per drainage acre[b] |
| Filter Fabric Fence | Maximum drainage area = 0.5 acre per 100 feet of fence. Not to be used in concentrated flow areas. | Average: 70%<br>Observed range: 0% - 100%<br>sand: 80% - 99%<br>silt-loam: 50% - 80%<br>silt-clay-loam: 0% - 20%<br>References: Munson, 1991; Fisher et al., 1984; Minnesota Pollution Control Agency, 1989 | 0.5 | Average: $3 per lin ft<br>($700 per drainage acre[c]<br>Range: $1 - $8 per lin ft<br>References: Wisconsin DOT cited in SWRPC, 1991; SWRPC, 1991; Goldman, 1986; Virginia, 1991; NC State, 1990 | Average: 100%<br>Range: 100%<br>References: SWRPC, 1991 | $7 per lin ft<br>$850 per drainage acre[c] |
| Straw Bale Barrier | Maximum drainage area = 0.25 acre per 100 feet of barrier. Not to be used in concentrated flow areas. | Average: 70%<br>Observed Range: 70%<br>References: Virginia, 1980 cited in EPA, 1991 | 0.25 | Average: $4 per lin ft<br>($1,600 per drainage acre[d]<br>Range: $2 - $6 per lin ft<br>References: Goldman, 1986; Virginia, 1991 | Average: 100%<br>Range: 100%<br>References: SWRPC, 1991 | $17 per lin ft<br>$6,800 per drainage acre[d] |
| Inlet Protection | Protect storm drain inlet. | Average: NA<br>Observed Range: NA<br>References: None | 1 | Average: $100 per inlet<br>Range: $50 - $150<br>References: SWRPC, 1991; Denver COG cited in SWRPC, 1991; Virginia, 1991; EPA cited in SWRPC, 1991 | Average: 60%<br>Range: 20% - 100%<br>References: SWRPC, 1991; Denver COG cited in SWRPC, 1991 | $150 per inlet |
| Construction Entrance | Removes sediment from vehicles wheels. | Average: NA<br>Observed Range: NA<br>References: None | 2 | Average: $2,000 each<br>Range: $1,000 - $4,000<br>References: Goldman, 1986; NC State, 1990<br><br>With washrack:<br>Average: $3,000 each<br>Range: $1,000 - $5,000<br>References: Virginia, 1991 | Average: NA[e]<br>Range: NA<br>References: None | $1,500 each<br><br>$2,200 each |
| Vegetative Filter Strip | Must have sheet flow. | Average: 70%<br>Observed Range: 20% - 80%<br>References: Hayes and Hairston, 1983 cited in Casman, 1990; Dillaha et al., 1989, cited in Glick et al., 1991; Virginia Department of Conservation, 1987; Nonpoint Source Control Task Force, 1983 cited in Minnesota PCA, 1989; Schueler, 1987 | 2 | Established from existing vegetation-<br>Average: $0<br>Range: $0<br>References: Schueler, 1987<br><br>Established from sod-<br>Average: $11,300 per acre<br>Range: $4,500 - $48,000 per acre<br>References: Schueler, 1987; SWRPC, 1991 | Average: NA<br>Range: NA<br>References: None | NA |

NA - Not available.
[a] Useful life estimated as length of construction project (assumed to be 2 years)
[b] For Total Annual Cost, assume Annual Maintenance Cost=20% of construction cost.
[c] Assumes trap volume = 1800 cf/ac (0.5 inches runoff per acre).
[d] Assumes drainage area of 0.5 acre per 100 feet of fence (maximum allowed).
[e] Assumes drainage area of 0.25 acre per 100 feet of barrier (maximum allowed).

**Table 4-17. Existing Development Management Practices Effectiveness Summary**

| Management Practice | | % Removal | | | | | | Main Removal Efficiency Factors | References |
|---|---|---|---|---|---|---|---|---|---|
| | | TSS | TP | TN | COD | Pb | Zn | | |
| Water Quality Inlet - Catch Basin (1) | Average: | 15 | 5 | 5 | 5 | 15 | 5 | • Maintenance<br>• Sedimentation storage volume | Pitt, 1986; Field, 1985; Schueler, 1987 |
| | Reported Range: | 10-95 | 5-10 | 5-10 | 5-10 | 10-55 | 5-10 | | |
| | Probable Range: | 10-25 | 5-10 | 5-10 | 5-10 | 10-25 | 5-10 | | |
| | No. Values Considered: | 2 | 1 | 1 | 1 | 3 | 1 | | |
| Water Quality Inlet - Catch Basins With Sand Filter (1) | Average: | 80 | NA | 35 | 55 | 80 | 65 | • Sedimentation storage volume<br>• Depth of filter media | Shaver, 1991 |
| | Reported Range: | 75-85 | NA | 30-45 | 45-70 | 70-90 | 50-80 | | |
| | Probable Range: | 70-90 | -- | 30-40 | 40-70 | 70-90 | 50-80 | | |
| | No. Values Considered: | 1 | 0 | 1 | 1 | 1 | 1 | | |
| Water Quality Inlet - Oil/Grid Separator (1) | Average: | 15 | 5 | 5 | 5 | 15 | 5 | • Sedimentation storage volume<br>• Outlet configurations | Pitt, 1986; Schueler, 1987 |
| | Reported Range: | 10-25 | 5-10 | 5-10 | 5-10 | 10-25 | 5-10 | | |
| | Probable Range: | 10-25 | 5-10 | 5-10 | 5-10 | 10-25 | 5-10 | | |
| | Number of References | 1 | 1 | 1 | 1 | 1 | 1 | | |
| Dry Pond Modified into Ed Dry Pond | Average: | 45 | 25 | 35 | 20 | 45 | 20 | • Storage volume<br>• Detention time<br>• Pond shape | MWCOG, 1983; City of Austin, 1990; Schueler and Helfrich, 1988; Pope and Hess, 1989; OWML, 1987; Welinski and Stack, 1990 |
| | Reported Range: | 5-90 | 10-55 | 20-60 | 0-40 | 25-65 | (-40)-65 | | |
| | Probable Range (2): | 70-90 | 10-60 | 20-60 | 30-40 | 20-60 | 40-60 | | |
| | No. Values Considered: | 6 | 6 | 4 | 5 | 4 | 5 | | |
| Dry Pond Modified into Wet Pond | Average: | 60 | 45 | 35 | 40 | 70 | 60 | • Pool volume<br>• Pond shape | Wetzka and Oberta, 1988; Yoosef et al., 1986; Collum, 1985; Driscoll, 1983; Driscoll, 1986; MWCOG, 1983; OWML, 1983; Wu et al., 1988; Holter, 1987; Martin, 1988; Darmay et al., 1989; OWML, 1982; City of Austin ,1990 |
| | Reported Range: | (-30)-91 | 10-85 | 5-85 | 5-90 | 10-95 | 10-95 | | |
| | Probable Range: | 50-90 | 20-90 | 10-90 | 10-90 | 10-95 | 20-95 | | |
| | No. Values Considered: | 11 | 10 | 7 | 4 | 8 | 7 | | |
| Dry Pond or Wet Pond Modified into ED Wet Pond | Average: | 80 | 65 | 55 | NA | 40 | 20 | • Pool volume<br>• Pond shape<br>• Detention time | Ontario Ministry of the Environment, 1991 |
| | Reported Range: | 50-100 | 50-80 | 55 | NA | 40 | 20 | | |
| | Probable Range: | 50-95 | 50-80 | -- | -- | -- | -- | | |
| | No. Values Considered: | 1 | 1 | 1 | 0 | 1 | 1 | | |
| Streambank Stabilization | Average: | NA | NA | NA | NA | NA | NA | | MWCOG, 1990 |
| | Reported Range: | NA | NA | NA | NA | NA | NA | | |
| | Probable Range: | -- | -- | -- | -- | -- | -- | | |
| | No. Values Considered: | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Riparian Forest (assumed same as Vegetated Filter Strip) | Average: | 70 | 50 | 60 | 70 | 20 | 50 | • Runoff volume<br>• Slope<br>• Soil infiltration rates<br>• Vegetative cover<br>• Buffer length | IEP, 1991; Casman, 1990; Glick et al., 1991; VADC, 1987; Minnesota CA, 1989; Schueler, 1987; Hartigen et al., 1989 |
| | Reported Range: | 20-80 | 30-95 | 40-70 | 60-80 | 20 | 50 | | |
| | Probable Range (3): | 40-90 | 30-80 | 20-60 | -- | 30-80 | 20-50 | | |
| | No. Values Considered: | 6 | 3 | 2 | 1 | 2 | 2 | | |
| Wetland (assumed same as Constructed Storm Water Wetlands) | Average: | 65 | 25 | 20 | 50 | 65 | 35 | • Storage volume<br>• Detention time<br>• Pool shape<br>• Wetland's biota<br>• Seasonal Variation | Harper et al., 1986; Brown, 1985; Wotzka and Obert, 1988; Hickack et al., 1977; Barten, 1987; Meloria, 1986; Morris et al., 1981; Sherberger and Davis, 1982; ABAG, 1979; Oberts et al., 1989; Rushton and Dye, 1990; Hey and Barrett, 1991 |
| | Reported Range: | (-20)-100 | (-120)-100 | (-15)-40 | 20-80 | 30-95 | (-30)-80 | | |
| | Probable Range (6): | 50-90 | (-5)-80 | 0-40 | -- | 30-95 | -- | | |
| | No. Values Considered: | 14 | 14 | 6 | 2 | 6 | 4 | | |

**Section 4.0: Management and Maintenance**

Table C-12 summarizes a review by the Vermont ANR of 527 stormwater systems which found that of the 35 systems reviewed in Williston that 29% of these were not built or maintained properly. This is higher than the results statewide. (VT ANR 1995)

**Table C-12: Summary of Results of Vermont Stormwater BMP Study 1995**

| **Treatment Type** | **Catch Basin** | **Detention Pond** | **Overland Flow** | **Sedimentation Basin** | **Swale** | **Other** | **Total** | **Not maintained or built properly** |
|---|---|---|---|---|---|---|---|---|
| **Number of Systems** | **103** | **63** | **143** | **25** | **165** | **28** | **527** | |
| Maintained | 68 | 42 | 105 | 19 | 120 | | 354 | |
| Not maintained | 35 | 21 | 28 | 6 | 45 | | 135 | 27.6 % |
| Constructed per plan | 79 | 44 | 115 | 20 | 129 | | 387 | |
| Non constructed per plan | 24 | 17 | 28 | 5 | 28 | | 102 | 20.9 % |
| Completed | 93 | 53 | 123 | 21 | 137 | | 427 | |
| Not completed | 10 | 8 | 20 | 4 | 20 | | 62 | 12.7 % |
| Properly located | 91 | 55 | 124 | 22 | 129 | | 421 | |
| Not properly located | 12 | 6 | 19 | 3 | 28 | | 68 | 13.9 % |
| Properly sized | 89 | 51 | 133 | 23 | 146 | | 442 | |
| Not properly sized | 14 | 10 | 10 | 2 | 18 | | 54 | 10.9 % |
| ***Williston -Total Number of Systems*** | | ***35*** | ***Williston-not maintained or built properly*** | | | | ***10*** | ***29 %*** |

(ANR Vermont Stormwater Best Management Practices Assessment Study, March 1995)

It is recommended that management of stormwater treatment facilities should use a system for evaluation based on the "Stormwater Management System Inspection Forms" by the Watershed Management Institute (Watershed Management Institute, 1997). Enforceable maintenance agreements for structural practices and stormwater filtering systems and buffers, and/or an agency such as a stormwater utility which is responsible for maintenance can help to ensure that systems are performing optimally.

**Section 5.0: Riparian Buffers, Filter Strips, Grass Swales**

This section summarizes reductions from riparian buffers. Buffer efficiency increases with wider buffers. Variables include slope and length of slope and area of contributing zone, vegetation and soil characteristics. Steeper slopes need wider buffers to provide the same removal capacity. Buffers should only be accepted as stormwater filtering system if basic maintenance such as annual removal of accumulated sediments and edge of areas can be assured through an enforceable maintenance agreement or other method.

**Table C-13: Percent Reduction of Filter strips and Grass Swales**

| Type | TSS (%) | TP (%) | Pesticide (%) | Notes |
|---|---|---|---|---|
| Filter Strips | 65 | 75 | | EPA 1993 T2-1, p 2-15 |
| Filter Strips | 60 | 85 | | EPA 1993, T2-9, p2-37 |
| Filter Strips | - | - | 0-10 | EPA 1993, T2-16,17, pp 2-66,67 |
| Filter Strips | 65 | 40 | | Needs level spreading device, densely vegetated, at least as long as contributing runoff area, need to be large in relation to area being drained, relatively flat, and have a relatively low groundwater level. Rhode Island recommends against considering home lawns as part of buffer strip. |
| Probable range | 40 - 90 | 30 - 80 | | |
| Grassed swales | 60 | 20 | | Permeability of soil will limit the utilization of swales for infiltration of runoff. There should be a minimum distance of 2 feet between the bottom of the swale and the seasonal high water table. |
| Probable range | 20-40 | 20-40 | | |

(EPA 1993)

In the Allen Brook watershed, NRCS Hydrologic Group C or D (high runoff, low infiltration) should not be used for stormwater treatment through infiltration. Infiltration basins and trenches can be used in NRCS hydrologic group A and B soils (Table C-14).

**Table C-14: Allen Brook Soils Suitable for Infiltration**

| Soils suitable for Infiltration | Soils Not Suitable for Infiltration |
|---|---|
| **NRCS Hydrologic Group A and B** | **NRCS Hydrologic Group C and D** |
| Adams,<br>Belgrade,<br>Hartland,<br>Hinesburg,<br>Munson-Belgrade,<br>Winooski, | Covington,<br>Enosburg-Whately,<br>Farmington,<br>Stockbridge,<br>Limerick,<br>Munson-Raynham,<br>Scantic<br>Au Gres<br>Terrace escarpments, silt and clay |

***"Slope and Length of Slope and Area of Contributing Zone:***
*Slope and length of slope of the contributing area affect velocity of runoff and therefore are critical to filter strip and buffer design. Wong and McCuen (1982) site research utilizing sod buffer strips that suggests strips produce an effective " removal of medium silt sized sediment when the ratio of the slope length of the contributing area to the buffer strip length is 10 percent."*

***Slope and Length of the Filter Strip:*** *Both the slope of the filter strip itself as well as its length are critical, as they determine the potential for pollutant removal to occur. The state of Ohio (Ohio DER 1966) has tabularized pollutant removal effectiveness of vegetated filter strips for different slopes and strip widths as shown in Table C-15.*

| ***Table C-15: Filter Strip Length as a function of slope and trapping efficiency*** | | |
|---|---|---|
| ***Slope of Filter (%)*** | ***70% Particulate Trapping efficiency. Width of Buffer in feet.*** | ***90% Particulate Trapping efficiency. Width of buffer in feet*** |
| *1* | *10* | *50* |
| *2* | *30* | *120* |
| *3* | *40* | *135* |
| *4* | *60* | *170* |
| *5* | *75* | *210* |

***Vegetation Characteristics:*** *Clearly, type of vegetative cover is an essential consideration in developing filter strips and buffers. A high quality forest floor with a rich and highly absorptive humic layer or zone with thick, low understory performs quite well. High quality grassed buffers, when kept mowed so that blades are erect and not inundated by runoff also perform well. Turf grass should be kept at a minimum length of 3 – 5 inches and a maximum length of 12 inches. Overall, filter design should strive for a dense and deep-rooted vegetation mat which will serve to slow runoff flows as well as keep soils permeable. It is also important to choose vegetation based on the type of runoff expected from a particular area. For example, filters located near roadways and parking lots require vegetation, such as tall fescue, that can withstand salt and heavy metals.*

***Soil Characteristics:*** *In general, as soil particle size increases, permeability increases, thereby promoting infiltration across the filter strip. For newly constructed filter strips, effort should be taken to minimize soil manipulation and compaction which reduce permeability.*

*While all these factors significantly contribute to filter strip effectiveness, it is important to recognize that the single greatest threat to filter strip performance is channelization and concentration of flows"* (1997, Delaware DNR).

**Reduction of TSS, bacteria and TP on Vermont Streams**
A 6 year study on small agricultural watersheds near the Canadian border in the Champlain valley showed reduction in bacteria, sediment and nutrients in watershed 1, by fencing out livestock, and planting a narrow riparian buffer, and a 34% reduction in TSS, 29% reduction in e. coli, and 15% reduction in TP. (Meals, 2000)

**ANR Proposed Riparian Buffer Procedure (2001)**
Information on removal rates can be found in the technical appendices on sediment and nutrient removal capability of different width riparian buffers. Buffers protect water quality by removing sediment and nutrients, and providing shade that maintains a higher water temperature. Buffers provide habitat for terrestrial and aquatic communities, and reduce damage from flooding. (See ANR website for a copy of the Procedure:
http://www.anr.state.vt.us/dec/buffproc/BuffProcDft072701.PDF)

## Section 6.0: Best Management Practices

### 6.1 Street Sweeping

Bannerman (2000) models reduction in loads through street sweeping. His models quantify reductions by landuse.

**Table C-16 Washoff Reductions for Weekly Street Sweeping (%)**

| Street Type/Sweeper Type | % TSS Removal | % N/P Removal |
|---|---|---|
| **Residential Street** | | |
| Mechanical | 30 | 24 |
| Regenerative Air | 64 | 51 |
| Vacuum Assisted | 78 | 62 |
| **Major Road** (applied to all but residential) | | |
| Mechanical | 5 | 4 |
| Regenerative Air | 22 | 18 |
| Vacuum Assisted | 79 | 63 |

(Claytor, 1999a; Sutherland and Jelen, 1997; Jurahashi and Associates, 1997, Table 12.7)

**Example: Street Sweeping**

*– Orlando sweeps over 40,000 curb miles per year. There are 72 residential routes, seven industrial/commercial routes, and five downtown/near downtown routes. Over 27,000 cubic yards of material is removed annually by the street sweeping program. This materials taken to a landfill for disposal….Chamberlin, W. "Assessing the Effectiveness of Orlando's BMP Strategies in* National Conference on Retrofit Opportunities for Water Resource Protection in Urban Environments., EPA/625/R-99/002, July 1999 (CWP, 2000)

**Table C-17. Sweeper Cost Data**

| Sweeper Type | Life (Years) | Purchase Price ($) | Operation and Maintenance Costs ($/curb mile) | Sources |
|---|---|---|---|---|
| Mechanical | 5 | 75,000 | 30 | Finley, 1996<br>SWRPC, 1991 |
| Vacuum-assisted | 8 | 150,000 | 15 | Satterfield, 1996;<br>SWRPC, 1991 |

(CWP, Costs and Benefits of Storm Water BMP's Final Report 9/14/98, Table 25)

*"New street sweeping technology promises much higher removal efficiencies. High efficiency sweepers can remove over 95 percent of the solids on the street. This high efficiency is achieved with a vacuum assisted pick-up system and a series of filters that remove most of the small particles from the air flow. If the estimates of suspended solids loads reductions are correct, the high efficiency sweepers could lower the annual loading of solids from a residential area by about 50 percent. This level of reduction has not been verified with a water quality monitoring project. We are testing the water quality benefits of a high efficiency sweeper in a cooperative project with the Wisconsin DOT and the U. S. Geological Survey. We are doing the monitoring on a section of interstate highway in Milwaukee, Wisconsin. The six lanes of freeway carries about 180,000 vehicles each day. Short sections of the freeway are being used for a test and*

*control site. Automated sampling stations are being used to collect water quality data from the sites during periods of sweeping and non-sweeping. We are evaluating the difference between the sites by looking for differences in the regression relationships for sweeping and non-sweeping periods. The paired site design helps us to normalize the data for the influences of non-sweeper related variables, such as rainfall patterns. …The data is not only showing water quality differences in runoff from swept sections of freeway, but is also providing more valuable information on the quality of freeway runoff. We are also using the data to calibrate models capable of estimating the pollutant loads from urban surfaces and to predict the benefits of street sweeping.*" (Bannerman, 2000)

### 6.2: Storm-Drain Clean-Out

**The Value of More Frequent Cleanouts of Storm Drain Inlets**
*by Phillip Mineart & Sujatha Singh, Woodward-Clyde Consultants, Oakland, CA*

"Pitt (1985) in a study in Bellevue, Washington, concluded that catch basins could trap and retain sediments up to about 60% of their total basin volume. However, large storm events often flush out the trapped sediments and convey them downstream. The following questions were addressed by this study: (1) If urban pollutants are present within the trapped sediments, would more frequent cleaning have any value as a stormwater treatment practice? (2) If so, would cleanouts be a feasible and cost-effective strategy compared to other stormwater practices?

The study examined both the volume and quality of trapped sediments within 60 residential, commercial and industrial storm drain inlets that had been cleaned with either a monthly, quarterly, semi-annual, or annual frequency. For industrial inlets, monthly cleanouts removed nearly six times more sediment than annual cleanouts.

However, a substantial amount of trapped sediment flushes out prior to operation when the operation is performed only once or twice a year (Figure 1) and therefore, a much greater annual mass of sediment could be removed through monthly cleaning.

The study concluded that the modest pollutant removal benefit of more frequent clean outs of storm inlets needs to be balanced by the significant jump in municipal costs and staffing it would create.*" (CWP, Article 12)*

### 6.3 Road Sanding

"Determine application rate, tons per year per mile of road. Default Model assumption is that 90% of the sediment is delivered to the receiving water in closed section roads, while only 35% is delivered in open section roads." (CWP, 2000)

### 6.4 Snow Disposal Guidelines

"The environmental effects of disposed snow result from high levels of sodium chloride, sand, debris and contaminants from automobile exhaust. The method of disposal determines the potential environmental effects: disposal in surface water; adjacent to surface water; or away from surface water where meltwater will discharge to groundwater.
Each disposal alternative poses different problems. Chlorides, metals, and other such contaminants are a threat to groundwater, and to some extent, surface water. Sand and silt threaten aquatic life in surface water but pose no threat to groundwater. Debris can create a water quality problem if dumped with snow into surface water.

**Recommended Guidelines for Snow Disposal**
The following guidelines reflect the view of DES that the greatest long-term harm would occur from contamination of groundwater, but that surface water must also be protected, and that aesthetic concerns cannot take a higher priority than the environmental concerns:

- Disposed snow should be stored near flowing surface waters, but at least 25 feet from the high water mark of the surface water;
- A silt fence or equivalent barrier should be securely placed between the snow storage area and the high water mark;
- The snow storage area should be at least 75 feet from any private water supply wells, at least 200 feet from any community water supply wells, and at least 400 feet from any municipal wells. (Note: Snow storage areas are prohibited in wellhead protection areas [class GAA groundwater]);
- All debris in the snow storage area should be cleared from the site prior to snow storage; and
- All debris in the snow storage area should be cleared from the site and properly disposed of no later than May 15 of each year the area is used for snow storage.

## Section 7.0: Transportation And Infrastructure

### 7.1 Bridge And Culvert Sizing

Bridge design needs to take into account the following factors:
*"In projecting future trends based on measured past developments, allowance needs to be made for:*

- *Watershed land-use changes over the life of the structure;*
- *The past flow history in comparison with projected flows occurring over the life of the structure, the duration of floods or flows near bankfull stages probably being more important than the flood magnitudes;*
- *That lateral migration can fluctuate along a given reach and markedly from one period tot he next, sometimes occurring only episodically; and*
- *That following a disturbance, an initially stable channel typically oscillates between aggradation and degradation before the channel restabilizes* (Melville, 2000).

Reducing scour at bridges needs to be based, not just on hydrology and hydraulics, but an understanding of fluvial geomorphology. This may include the use of regime equations, data from field work, the Vermont Regional Hydraulic Curve (2001) and other sources that can be used to better understand the fluvial geomorphic cross-sectional requirements to adequately move both water and sediment (Simon 1995).

Bridge construction: Size bridges for geomorphic stability (Melville, Coleman 2000). Minimum of bankfull width except at meander bends, should be 1.5 times bankfull width. Streams with access to floodplain (not entrenched) consider sizing for floodprone width, this will not only provide long-term flood benefits, but will also facilitate animal passage along the riparian corridor.

Examine enlargement curve from Phase II study (CWP et al., 1999). Use Williston buildout analysis to predict channel enlargement and size bridges for predicted channel enlargement.

Size culverts to avoid backwater effects, channel constriction and downstream scour . This will reduce sediment loads into the watershed.

## 7.2 Bridge Assessment

Data collected during an assessment includes the presence of bed protection, the type of bed material, the stage of Channel Evolution, the number of piers in the channel, the percentage of horizontal and vertical channel blockage, the presence of bank erosion and pier skew, the distance of the meander impact point, the presence of mass wasting at pier, the degree of high-flow angle of approach, and the percent woody vegetative cover (Simon, 1995, Johnson, 1999). These factors are used to rank bridges for instability. New bridges and stream crossings should be designed to reduce instability and promote stability within the fluvial system.

Assessment methods at existing or proposed stream crossings should reduce the likelihood of causing lateral and vertical instability and scour. Instability introduces sediment into the stream system. In the absence of any detailed assessment it is recommended that stream crossings are a minimum of bankfull width, and 1.5 x bankfull width at meander bends (Melville, 2000). This will reduce contraction scour, and decrease the sediment load into the system.
*"Channel adjustment by erosion can be expected to occur if stream-power values lie above the threshold stream-power curve and conversely, adjustment by deposition can be expected to occur if stream power values fall below the threshold stream-power curve. Thus the likelihood of channel instabilities can be assessed in a general manner for study sites in a given drainage basin "(*Simon and Downs, 1995).

## 7.3 Restoration And Maintenance Near Road Corridors

1. Change hydrology along road corridors
    a) fill in swales
    b) put in level spreaders for all drainage within corridor (from and to road)
    c) disperse existing flow that has been concentrated either draining from the roads or, draining towards the roads. This could be done through the use of constructed wetlands, level spreaders etc.....to disperse flow
2. Bridge maintenance, ensure sediment isn't swept from bridges into streams.
3. Develop a maintenance and management plan for culverts and other infrastructure, based on Watershed Management Institutes Operation, Maintenance and Management suggestions (Watershed Management Institute. 1997).
4. Better Back roads (Windham Regional Commission. 1995), use all applicable suggestions.

## 7.4 Culverts

ANR 1999 finds that:
"*These cheap culvert crossings were often undersized or did not match the stream morphology well; causing undesirable headwater depths, inlet stream channel deposition and instability, high outlet velocity, bed scour and erosion and would experience frequent washouts and maintenance requirements. Where single pipes wouldn't or didn't work, multiple tubes were installed. These caused even greater incompatibility with the channel morphology, increased debris blockage problems, and provided little or not hydraulic improvement or reduction in frequency of damage."* Private drives and public roads should be sized *"to efficiently transport the water flows **and sediment** produced by the watershed". "Significant energy or head losses occur at the inlet to stream crossing structures. The magnitude of this energy loss varies by type of structure, by tits hydraulic capacity and other inlet conditions such as alignment with the channel, stream gradient and the physical characteristics of the structure opening.*

*As these energy losses occur, the stream flow slows down and builds up head, or a higher water surface elevation , ahead of the inlet to the structure. As the velocity drops, the stream loses its ability to transport its sediment load past the culvert or bridge. The result is excess deposition and build-up (aggradation) of the bed elevation upstream of the inlet to the structure. After a few years, streambank erosion associated with the unstable bed elevation typically results in the stream attempting to outflank the structure and setting the stage for a flood induced failure. Downstream of the structure there also occur undesirable morphological changes to the channel due to the interruption of sediment transport. As the coarse sediment is trapped upstream, the stream is still exercising its energy and ability to mobilize sediment downstream. The bed and banks continue to be scoured away but little or no coarse material is brought down from above to provide the balance required to maintain stability. In a natural situation, there would always be an equal volume of material being transported from above to replace whatever is being eroded away. This is the way a stream naturally maintains its stability over time and how this process is being adversely affected by an inadequate state and federal design standard for stream crossing structures. In the absence of any known technical analysis, it may be appropriate to apply a lesser maximum HW/D value for stream crossing designs on high bed load streams."*

Reduce the use of culverts, and do not use double culverts (SEI, 1998).

A study of flood damage for the State of Vermont of 7 towns found that *"The result is a range of 29 to 58 percent of the total number of damage incidents that could have been avoided."* A large majority of the avoidable damage is due to undersized culverts (SEI, 1998).

**Section 8.0 Channel Protection and Structural Practices**

**8.1: Channel Protection**

The Vermont stormwater management manual suggests reduction of erosive flows through channel protection.

*"Research studies indicate that this method [post-development peak flows are held to two-year pre-development rates] frequently does not protect channels from downstream erosion and may actually contribute to erosion since banks are exposed to a longer duration of erosive bankfull and sub-bankfull events (MacRae, 1993 and 1996, McCuen and Moglen, `988). Facilities with two-year control often release water above a critical discharge for effective work ($Q_{crt}$) for a longer period of time, which results in greater transport of sediment and bedload…MacRae also documented that facilities employing two-year control can cause channel expansion by as much as three times the pre-development condition. The primary reason is that while the magnitude of the peak discharge doesn't change under developed conditions, the duration and frequency of erosive flows sharply increases. As a result "effective work': on the channel is shifted to more frequent runoff events that range from the half-year event up to the 1.5 year runoff event (MacRae, 1993).* (ANR, 2001)

*"The increase in runoff rate and volume associated with urbanization has been associated with accelerated rates of geomorphic activity often resulting in destabilization of the stream channel. Stormwater Management ponds have been constructed to control instream erosion potential based on the 1:2 year frequency post – to pre-development peak flow shaving concept…..Theoretical analyses of the magnitude and transverse distribution of excess boundary shear stress indicated that despite operation of the facility, erosion potential in the mid-bed increased by 2.4 pre-development values under existing land use conditions….An alternate*

*design criteria based on a zero net change in the transverse distribution of shear stress about a channel perimeter using an erosion index method is proposed."*-(MacRae, 1996)

**Example Calculation – Channel Protection**

Within a subwatershed, channel erosion causes 750,000 pounds per year of sediment load. The TMDL calls for stabilizing 80% of the stream channel, and applying retrofits that control small storm events throughout 50% of the subwatershed. Thus, the load reduction is:

L(CP) = (750,000 lbs/yr) (80%)(0.5) = 300,000 lbs/yr (CWP, 2000)

Based on this research retrofitting existing stormwater management facilities to 1 year extended detention facilities or using Distributed Runoff Control (MacRae, 1996, ANR, 2001) will reduce channel erosion and sediment load.

The Phase II study can be used to predict channel enlargement in the Williston watershed based on Total percent impervious (TIMP). With predicted build-out of 65 to 70% in the lower part of the watershed (Town of Williston Zoning Ordinance, 2000) the channel can be expected to increase substantially in width.

**

## 8.2 Structural Stormwater Treatment Facilities

Different studies report different ranges of removal for sediment, nutrients, metals and bacteria for similar structural and non-structural practices. *"As always, extreme caution should be exercised when stormwater management performance studies are compared. Individual studies often differ in the number of storms sampled, the manner in which pollutant removal efficiency is computed (e.g., as a general rule, the concentration-based technique often results in slightly lower efficiency than the mass-based technique), the monitoring technique employed, the internal geometry and storage volume provided by the practice design, regional differences in soil type, rainfall, latitude, and the size and land use of the contributing catchment." (CWP Article 64)* This section summarizes average rates of removal from various studies.

**Table C-18: Stormwater Treatment Practice Selection Matrix 5. Pollutant Removal Median**

| Practice | TSS (%) | TP (%) | TN (%) | Metals (1) (%) | Bacteria (%) | Hydro carbons (%) |
|---|---|---|---|---|---|---|
| **Wet Ponds** | 80 | 51 | 33 | 62 | 70 | 81 (2) |
| **Stormwater Wetlands** | 76 | 49 | 30 | 42 | 78 (2) | 85 (2) |
| **Filtering Practices** | 86 | 59 | 38 | 69 | 37 (2) | 84 (2) |
| **Infiltration Practices** (3) | 95 (2) | 80 | 51 | 99 (2) | Na | Na |
| **Water Quality Swales** (4) | 84 | 34 | 84 (2) | 70 | Na | 62 (2) |
| **Quantity Control Ponds** (2, 5) | 3 | 19 | 5 | 7.5 | 78 | Na |

1. Average of zinc and copper. Only zinc for infiltration
2. Based on fewer than five data points (i.e., independent monitoring studies)
3. Includes porous pavement, which is not on the list of approved practices for Vermont.
4. Higher removal rates for dry swales.
5. Quantity control ponds (a.k.a. dry detention basins or vaults) do not meet the WQv requirement and must be used in conjunction with acceptable water quality STPs.

N/A: Data not available
(Vermont Stormwater Management Handbook, public review draft November 2001)

**Table C-19 Percent Reduction in Nitrogen, Total Suspended Sediment and Total Phosphorus Removal of Stormwater Treatment Practices for Water Quality**

| Group | Practice | N | TSS Removal | TP Removal | Notes |
|---|---|---|---|---|---|
| Pond | Micropool Extended Detention Pond | 0 | ND | ND | This practice is presumed to have removal rates similar to the wet extended detention pond. While this practice has not been monitored the pollutant removal mechanisms are similar. |
| | Wet Pond | 29 | 79% | 49% | Wet pond performance is highly variable, with some practices in the database with poor design features. Practices that follow the recommended criteria will exceed 80% TSS removal consistently (See Final Handbook). |
| | Wet Extended Detention Pond | 14 | 80% | 55% | |
| | Multiple Pond System | 1 | 91% | 76% | Although only based on one study, it is presumed that this practice will consistently exceed the 80% removal. The design should result in slightly higher removals than the wet pond. |
| | Pocket Pond | 5 | 87% | ND | Pocket ponds are a subgroup of other pond designs, including all ponds with drainage areas less than 10 acres. |
| Wetland | Shallow Marsh | 23 | 83% | 43% | |
| | Extended Detention Wetland | 4 | 69% | 39% | The database is dominated by highly undersized practices. No ED wetland in the database treats more than 0.15 watershed inches. Even among these, one practice achieves 80% removal. It is commonly accepted that practices that follow required performance criteria will achieve 80% TSS removal consistently. |
| | Pond/Wetland System | 10 | 71% | 56% | The current database is biased by poorly designed facilities. Removals similar to the Wet Pond and Shallow Marsh designs are anticipated. Also, removals were highly variable. Four of the 10 practices actually had higher than 90% removals. It is commonly accepted that practices that follow required performance criteria will achieve 80% TSS removal consistently. |
| | Gravel Wetland | 2 | 83% | 64% | |
| | Quality Control Pond<br>Dry Extended Detention Pond | <5 | 3 %<br>61 % | 19 %<br>20 % | |

**(Table C-19 continued)**

| Group | Practice | N | TSS Removal | TP Removal | Notes |
|---|---|---|---|---|---|
| Infiltration | Infiltration Trench | 3 | ND | 100% | Infiltration practices are difficult to monitor, but are presumed to have high removal rates based on filtration processes of the soil and pollutant land application studies. |
| | Infiltration Basin | 0 | ND | ND | |
| Filtering Practices | Surface Sand Filter | 8 | 87% | 59% | |
| | Underground Sand Filter | 0 | ND | ND | Presumed similar removal to other filtering practices. |
| | Perimeter Sand Filter | 3 | 79% | 41% | Result impacted by one study with very low inflow concentrations. Presumed similar removal to other filtering practices. |
| | Organic Filter | 7 | 88% | 61% | |
| | **Bioretention** | 1 | ND | 65% | GOOD PRACTICE TO PROMOTE |
| | Vertical Sand Filter | | 58% | 45% | Low Removal Rates |
| Open Channels | Dry Swale | 4 | 93% | 83% | |
| | Wet Swale | 2 | 74% | 28% | The two wet swale designs in the database actually achieve relatively low outflow concentrations. Results are biased by relatively low inflow concentrations. |
| | Grass Channel | 3 | 68% | 29% | The current database is slightly biased by poorly designed facilities. Removals similar to the Dry Swale are anticipated with appropriate design. |
| | Open Channels with low removal rates | | 31% | -16% | Ditches |
| | Notes: Removals represent median values from Winer (2000)<br>N = number of studies<br>TSS = total suspended solids; TP = total phosphorus<br>ND = no data | | | | |

(Vermont Stormwater Management Manual Table D4-1)

*"Removal of other pollutants may be an important consideration for many applications as well. For most pollutants, insufficient data are available to make conclusions about individual practices. Therefore, the Handbook will present data or presumed removals for the practice groups as guidance on appropriate STP selection. Similar to TSS and TP, these data are based on pollutant removals reported in Winer (2000) (Table D4.2)."*
(Vermont Stormwater Management Handbook, public review draft November 2001)

**Table C-20: Percent Reduction of Sediment Control Measures**

| BMP LIST | Design Rate (%) | Range of Average TSS removal rates (%) | Brief Design Requirements |
|---|---|---|---|
| Extended Detention Pond | 70 | 60 –80 | Sediment Forebay |
| Wet Pond | 70 | 60 –80 | Sediment Forebay |
| Constructed Wetland | 80 | 65 –80 | Designed to infiltrate or retain. |
| Water Quality Swale | 70 | 60 –80 | Designed to infiltrate or retain. |
| Infiltration Trench | 80 | 75 –80 | Pretreatment critical |
| Infiltration Basin | 80 | 75 –80 | Pretreatment critical |
| Dry Well | 80 | 80 | Uncontaminated rooftop runoff |
| Sand Filter | 80 | 80 | Pretreatment |
| Organic Filter | 80 | 80 | Pretreatment |
| Water Quality Inlet | 25 | 15 –35 (with cleanout) | Off – line only, 0.1" min Water Quality Volume Storage |
| Sediment Trap (forebay) | 25 | 25 with cleanout | Stormflows from 2 year event must not cause erosion. 0.1% minimum WQV storage |
| Drainage Channel | 25 | 25 | Check dams, non-erosive for 2 year. |
| Deep Sumps (hooded catch basin) | 25 | 25 with cleanout | Deep sump general rules 4" pipe diameter or 4 " for pipes 18" or longer |
| Street Sweeping | 10 | 10 | Discretionary non-structural credit, part of approved plan. |

Source: Stormwater Management, Volume 1 Stormwater Policy Handbook, March 1997, MDEP, MCZB, based on Scheuler 1996 and EPA 1993

## Section 9.0 Phosphorus Removal, Urban And Agriculture

A 1999 study of phosphorus movement into Lake Champlain found that urban areas are a disproportionate source of the problem. Urban land constituted 5.5 % of the Champlain drainage basin, but contributed 37% of the phosphorus. Agricultural land, which constituted 17% of the land area, accounted for approximately 56% of the phosphorus (Meals, 2000).

**Table C-21**. Urban land areas and current urban nonpoint source loading estimates used in the phosphorus load reduction targeting procedure.

| | Hectares urban area | urban load (mt/yr) | Kg/yr per hectare | kg/yr/acre |
|---|---|---|---|---|
| Main Lake, Vt, Winooski River | 15,429 | 17.52 | 1.13 | 0.516 |
| **Allen Brook watershed 14.5 SQ. MI.** | | | | |
| Total watershed acres | 5.5% in 1995 total acres = TIMP acres | Kg/Yr Phosphorus loading urban land –TIMP only, not all urban land 510acres*0.516 kg/yr/acre | | |
| 9280 | 510 | 263.2351 = 579 lbs/yr | | |

(DEC 1997, Table 35)

Better Site Design also results in a reduction in phosphorus loading Table C-22.

**Table C-22:Phosphorus output in Each Development Scenario: lbs/year with minimum 100 ft buffer.**

| | **Medium Density Residential** | **Low Density Residential** | **Shopping** | **Office** |
|---|---|---|---|---|
| Predeveloped | 3.6 | 36.2 | 1.1 | 1.5 |
| Conventional w/o BMPs | 27.7 | 45.7 | 13 | 17.5 |
| Innovative w/o BMPs | 22.2 | 23.2 | 10.9 | 13.8 |
| **% reduction conventional to innovative without BMP's** | **20%** | **49%** | **16%** | **21%** |
| Conventional w/BMPs | 24.2 | 43.8 | 10.6 | 11.3 |
| Innovative w/BMPs | 9.8 | 21.7 | 5.7 | 6 |
| **% reduction conventional to innovative with BMP's** | **60%** | **50%** | **46%** | **47%** |

(CWP, 1998a)

A report by the Vermont Department of Environmental Conservation modeled phosphorus load reduction from point and non-point sources using agricultural BMP's. Loads were modeled on the basis of animal unit (au) with each animal unit =1000 lbs or 454 kg. animal weight.

**Table C-23.** Cost and assumed phosphorus reduction effectiveness of agricultural nonpoint source controls in the Lake Champlain basin, from US NRCS models. Costs are total capital and annual operation and maintenance costs, expressed on a present value basis (30 years at 5% discount rate). "NA" indicates data not available and treatment not considered.

| **Treatment** | **Cost $/animal unit** | **Phosphorus Reduction (kg/au/yr** |
|---|---|---|
| Milkhouse effluent treatment | 81 | 0.091 |
| Waste utilization | 334 | 0.136 |
| Barnyard runoff treatment | 130 | 0.227 |
| Erosion control | 341 | 0.363 |
| Grazing Management | 45 | 0.227 |
| Nutrient management | 108 | 0.091 |
| Riparian zone management | NA | NA |

(DEC 1997, Table 32)

**Table C-24: Percent Reductions TSS and TP –Agricultural BMP's**

| TOTAL SUSPENDED SEDIMENT | | REPORTED REDUCTION % | | | CALCULATED REDUCTION % | | |
|---|---|---|---|---|---|---|---|
| **BMP Type** | **TreatCnt** | **low** | **Avg.** | **high** | **Low** | **Avg.** | **high** |
| Animal Waste BMP Systems | 4 | -114 | -48.5 | 17 | -114.3 | -40.1 | 17.4 |
| Critical Area Planting | 1 | | | | 74.7 | 74.7 | 74.7 |
| Cropland and Livestock BMP Systems | 1 | 19 | 19 | 19 | 18.7 | 18.7 | 18.7 |
| Cropland BMP System | 1 | -51 | -51 | -51 | -51.3 | -51.3 | -51.3 |
| Infiltration Basin or Trench | 1 | | | | 98.9 | 98.9 | 98.9 |
| Residue Management | 2 | | | | 5.5 | 35.1 | 64.8 |
| Residue Management, No-till and Strip Till | 3 | 87.3 | 87.3 | 87.3 | 85.1 | 89.9 | 97.3 |
| Residue Management, Reduced tillage | 3 | | | | 21.2 | 50.4 | 69.4 |
| Spring Development | 2 | | | | -194.9 | -51.2 | 92.5 |
| Vegetative Filter Strip | 1 | | | | 53.7 | 53.7 | 53.7 |
| **TOTAL PHOSPHORUS** | | **REPORTED REDUCTION %** | | | **CALCULATED REDUCTION %** | | |
| **BMP Type** | **TreatCnt** | **low** | **Avg.** | **high** | **low** | **Avg.** | **high** |
| Animal Waste BMP Systems | 6 | 10 | 17.5 | 25 | -150.0 | -19.1 | 45.7 |
| Constructed Wetland | 1 | | | | 11.1 | 11.1 | 11.1 |
| Controlled Drainage | 2 | 31 | 31 | 31 | 30.9 | 39.4 | 47.9 |
| Cover and Green Manure Crop | 1 | 48 | 48 | 48 | 47.9 | 47.9 | 47.9 |
| Critical Area Planting | 1 | | | | 52.5 | 52.5 | 52.5 |
| Crop Rotation | 1 | | | | 39.9 | 39.9 | 39.9 |
| Cropland and Livestock BMP Systems | 1 | 54 | 54 | 54 | 53.9 | 53.9 | 53.9 |
| Cropland BMP System | 6 | 4 | 20.3 | 36 | -135.5 | -0.2 | 67.1 |
| Drip Irrigation | 1 | | | | -8.8 | -8.8 | -8.8 |
| Gully Treatment | 1 | | | | 60.4 | 60.4 | 60.4 |
| Infiltration Basin or Trench | 1 | | | | 97.6 | 97.6 | 97.6 |
| Mulching | 1 | | | | 11.1 | 11.1 | 11.1 |
| Nutrient Management | 4 | | | | -42.5 | -19.8 | 15.2 |
| Pasture BMP Systems | 1 | | | | 27.0 | 27.0 | 27.0 |
| Residue Management | 6 | 78.5 | 78.5 | 78.5 | -50.0 | 38.9 | 94.2 |
| Residue Management, No-till and Strip Till | 7 | 90.4 | 91.95 | 93.5 | -170.0 | 21.5 | 94.4 |
| Residue Management, Reduced tillage | 5 | | | | -26.3 | 18.0 | 51.0 |
| Residue Management, Ridge Till | 1 | | | | 46.6 | 46.6 | 46.6 |
| Residue Management, Seasonal | 1 | | | | 23.5 | 23.5 | 23.5 |
| Riparian Forest Buffer | 2 | | | | -80.0 | 3.6 | 87.1 |
| Spring Development | 2 | | | | -37.8 | 28.7 | 95.1 |
| Subsurface drainage | 1 | 36 | 36 | 36 | 30.6 | 30.6 | 30.6 |
| Terrace | 1 | | | | 2.5 | 2.5 | 2.5 |
| Vegetative Filter Strip | 3 | | | | -19.9 | 25.5 | 68.4 |
| Water and Sediment Control Basin | 2 | 29 | 29 | 29 | 28.9 | 28.9 | 29.0 |
| Water Table Management | 5 | 16.4 | 32.8 | 49.2 | 45.3 | 66.1 | 80.4 |

(Chesapeake Bay Program BMP Effectiveness Database)

The Vermont ANR conducted the following literature review of phosphorus offsets.

**PHOSPHORUS OFFSET REFERENCES - JIM PEASE ANR** Page 1

**WATERSHED PROTECTION MEASURES-ANR Phosphorus Removal**

*(References refer to page 2 of ANR Phosphorus removal document)*

| **BMP** | P-REMOVAL | COST | REFERENCE |
|---|---|---|---|
| Buffers on wetlands | 0-40% | ? | **1**, page 4-40 |
| Performance criteria for site planning | 0-40% | ? | **1**, page 4-41 |
| Riparian buffer criteria | 30-95% | ? | **1**, page 4-92, 7-49 |
| (a) Exists as a secondary BMP for all new development | | | |
| (b) Flow velocity into buffer < 1 foot/sec | | | **3**, page 110 |
| (c) Infiltration of buffer receiving flow >.25" | | | **5**, page 17,21 |
| (d) Buffer must provide 9 minute residence time or be extended to meet criteria | | | |
| (e) Slope of buffer <10% | | | |
| (f) Soil type not SCS D-series | | | |
| Impervious surface area reduction techniques | 0-20% | Reference | **1**, page 4-41<br>**4**, page 100<br>**3**, page 33 |
| **SOURCE CONTROL MEASURES** | | | |
| Lawn/fertilizer regulations: | 30-40% | ? | **1**, page 4-41 |
| (a) fertilizer reduction use in 300' buffer of all streams | | | **2**, page 121 |
| (b) lawn size limits | | | **13** |
| (c) restriction of fertilizer use on high infiltrating soils (A-series) | | | |
| (d) xerio landscaping | | | |
| (e) inorganic fertilizer ban | | | |
| Public education/outreach- | ? | ? | **1**, page 7-1,7-47, 7-33 |
| streambank stabilization | | | 4-92, **6** |
| Erosion/sediment control ordinance | Reference | Reference | **1**, page 4-63, 4-75<br>**4**, page 145 |
| Illicit discharge detection and elimination | | | **1**, page 4-119 |
| Municipal Maintenance Program/Housekeeping | | | **1**, page 4-119 |
| (a) catch basin cleaning, 2x/yr | 5-20% | $30/yr | **1**, page 4-30<br>**4**, page 129<br>**7**, page 6 |
| (b) street sweeping, 6-120x/yr | 0-20% | $20/curb mile | **7**, page 8<br>**1**, page 4-152 |
| (c) roadside swale maintenance for pollutant removal | 40% | $800/acr/yr | **1**, page 4-152 |
| Onsite disposal system (OSDS) maintenance | 35% | $50-100/yr | **1**, page 4-41 |
| Alternative septic system requirements | 60-90% | Reference | **1**, page 4-104 |
| Maintenance of sediment basins (dry) | 10-30% | Reference | **2**, page 55<br>**14** |
| Maintenance of infiltration basins | 40-80% | Reference | **2**, page 68<br>**14** |

STRUCTURAL CONTROL MEASURES

| | | | |
|---|---|---|---|
| Bioretention w/pretreatment | %80 | Reference | **8**, page 495 |
| (a) all residential/commercial uses where practical | | | **9** |
| Infiltration requirement w/pretreat. | %60 | Reference | **2**, page 80 |
| (a) all residential uses where practical | | | **10** |
| Wetpond w/pretreatment | | | |
| (a) retention >48 hours | %60 | Reference | **2**, page 51 |
| (b) retention >14 days | %90 | | **11**, page ix |
| Retrofit of existing dry to wet ponds | %50-90 | $1000/basin | **1**, page 4-91 |

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## Appendix D: Summary Of Best Management Practices Costs and Maintenance Information From Literature Search

### Outline for Appendix D

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Section 2.0: Cost of BMP's
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### Section 1.0 Summary

Although there are some references on the cost of BMP's, it is still difficult to estimate the exact cost. The references in this Appendix should be seen as general guidelines. The results of the literature search are summarized below:

1) Prevention is less expensive than restoration. Better Site Design, Erosion and Sediment Control, Riparian Buffers, use of the 6 credits in the Vermont Stormwater Manual, management and maintenance and education can be considered as the first phase of prevention. For example, in Heritage Meadows a homeowner dumped gasoline down a stormdrain and caused the evacuation of neighborhood due to gas fumes, and thousands of dollars in clean-up costs. An inexpensive education campaign including storm-drain stenciling could have prevented the clean-up costs, and human health impacts associated with the spread of gasoline fumes into houses in the neighborhood.
2) Positive economic results in terms of increased property values, lower development costs can be associated with stormwater facilities designed with conservation benefits, property that is adjacent to conserved land, or well-designed developments using "Better Site Design" (CWP, 1998b)
3) Structures are more expensive. Structural treatment of stormwater is more expensive than non-structural treatment.
4) Transportation infrastructure including culverts and bridges are very expensive. These structures should be sized to consider full build-out in the watershed and channel widening associated with the proposed level of imperviousness. Increases in impervious area cause increases in runoff and decreases in infiltration, the channel responds by widening, and deepening and more frequent flooding. The Phase II (CWP, 1999) relaxation curve should be used to properly size bridges for full watershed build-out.
5) Increased flooding and property damage often occur as areas develop. For example, the bankfull, or channel forming flood (the flows responsible for carrying the majority of water and sediment in a watershed) may occur every 1 – 2 years in an undeveloped

watershed, and as frequently as every few months in an urbanized watershed. Associated costs include loss of land, buildings and infrastructure in addition to costs associated with stream restoration or stabilization. Stabilization, restoration and flood prevention costs can be up to hundreds of thousands of dollars per mile of stream for design and implementation.

6) The Vermont Stormwater Manual recommends that watersheds which have over 8% imperviousness require more careful stormwater treatment to protect the stream. Impervious area in sub-watersheds and the entire watershed should be tracked, and careful attention to implementation of development and stormwater retrofits should be part of any planning process.
7) Expensive structural treatment will fail without proper management and maintenance, the initial costs of structural treatment are wasted unless regular maintenance occurs.
8) Both short –term costs (initial development) and long term costs (maintenance, reconstruction, restoration or replacement of undersized bridges and culverts) need to be considered when making decisions as part of a watershed planning process.
9) Costs must be divided into public, private and development costs. Decision-making based on cost should consider both short and long-term costs. Short-term costs include the development of town ordinances or education and storm-drain stenciling or initial development costs. For example, poor erosion and sediment control practices during a construction project may save the developer money, but will have long-term costs to the Town or homeowners associations, or homeowners. Connected impervious surfaces (roofs and driveways draining directly into stormwater facilities) may solve a problem for the developer, but may create a problem for the Town. Building a driveway on a steep slope that drains onto a public highway, may cause a transfer of cost from private to public, if the public road washes out during floods due to improper construction or maintenance of the driveway and it's ditches and culverts. This is a transfer of private cost to public cost.
10) Some costs such as maintenance and management and education are on-going. Many BMP's may need maintenance on a semi-annual basis (street sweeping, storm drain clean-out, fore-bay cleaning)
11) The most comprehensive information on cost can be found in a 127 page publication available on the web http://www.wcdoe.org/rougeriver/pdfs/stormwater/sr10.html by Ferguson, T, et. Al, 1997. Rouge River National Wet Weather Demonstration Project: Cost Estimating Guidelines: Best Management Practices and Engineered Controls. This publication is not summarized in this appendix. It is recommended that those interested obtain it as an additional reference.

## Section 2.0 Cost Of BMP's

*"Application of other watershed protection tools, however, can help reduce the total cost for Erosion and Sediment Control (ESC) control at a construction site. Forest conservation, buffers and clustering all can sharply reduce the amount of clearing needed at a site, thereby reducing area that must be controlled by ESC practices. ESC controls also provide direct and indirect benefits to both the builder and the adjacent property owner. By keeping soil on the site, a contractor needs to spend less time and labor regrading the site to meet final plan elevations, and less effort stabilizing eroded slopes. Careful phasing of construction within subdivisions also often leads to economies over the entire construction process (see article 54).*

*Stormwater management practices, which include stormwater ponds, wetlands, filtering, infiltration, and swale systems, are among the most expensive watershed protection tools. Stormwater practices are designed to promote recharge, remove pollutants, prevent streambank*

*erosion, and control downstream flooding. Despite their high construction and maintenance costs, stormwater practices can confer several tangible economic benefits, as the following studies show:*

- *The cost of designing and constructing stormwater practices can be very substantial. The most recent cost study indicates the cost of treating the quality and quantity of stormwater runoff ranges from $2,000 to $50,000 per impervious acre (see article 68). The construction costs do not include cost of land used for stormwater. Stormwater practice costs are greatest for small development sites (less than acres), but drop rapidly at larger sites. In general, about a third of every dollar spent on stormwater practice construction is used for quality control, with the rest devoted for flood control.*
- *Stormwater management can also be beneficial for developers, since stormwater ponds and wetlands create a waterfront effect. For example, U.S. EPA (1995) recently analyzed twenty real estate studies across the U.S. and found that developers could charge a per lot premium of up to $10,000 for homes situated next to well designed stormwater ponds and wetlands. In addition, EPA found that office parks and apartments next to well designed stormwater practices could be leased or rented at a considerable premium (and often at a much faster rate). In a comparison of home prices in Minnesota, sale prices were nearly one third higher for homes that had a view of a stormwater wetland compared to homes without any "waterfront" influence. Indeed, the homes near the stormwater wetland sold for prices that were nearly identical to those homes bordering a high quality urban lake (Clean Water Partnership, 1997).*
- *Not all stormwater practices provide a premium. For example, Dinovo (1995) surveyed the preferences of Illinois residents about living or locating next to dry ponds, and found most residents would not pay a premium to live next to a dry pond, and in some cases expected to pay less for such a lot. The study confirmed that wet ponds command a considerable premium and they even scored higher than natural areas, golf courses, and parks in some location decisions (see article 84).*
- *In addition, some stormwater practices, such as grassed swales and bioretention areas, actually are less expensive to construct than enclosed storm drain systems, and provide better environmental results. Liptan and KinsellaBrown (1996) documented residential and commercial case studies where the use of bioretention and swales reduced the size and cost of conventional storm drains needed to meet local drainage and stormwater management requirements. The more natural drainage system eliminated the need for costly manholes, pipes, trenches and catchbasins, while removing pollutants at the same time. …*

*After development occurs, communities still need to invest in watershed management programs. This tool is used to educate residents and businesses about the daily role they play in protecting the quality of their watershed. Thus, many communities now invest in programs of watershed education, public participation, watershed management, monitoring, inspection of treatment systems, low input lawn care, household hazardous waste collection, or industrial and commercial pollution prevention programs. The common theme running through each program is education. The responsibility for ongoing watershed management programs is borne by local government, although many are now employing stormwater utilities to partially finance these programs (for a review of trends in stormwater utilities, see article 69). Nationally, the average residential stormwater utility fee is about 30 dollars per year, of which less than 75 cents is spent on watershed education… Some watershed protection tools have the potential to save developers money, through lot premiums, greater marketability, and lower construction costs. At the same time, a developer has to pay outofpocket for stormwater and sediment control, as well as consultant fees to navigate through the watershed protection maze. As might be expected, the community at large gets the greatest overall benefit associated with watershed protection, and appears to bear the least cost (although they may have to pay more for housing). Reported savings for the three projects ranged from $10,000 to $200,000.*

*Stormwater practices must be maintained, and that cost burden falls on landowners or local government. Over a 20 to 25 year period, the full cost to maintain a stormwater practice is roughly equal to its initial construction costs (Wiegand et al., 1986). Few property owners and homeowner associations are fully aware of the magnitude of stormwater maintenance costs, and most fail to regularly perform routine and nonroutine maintenance tasks. It is likely that performance and longevity of many stormwater practices will decline without adequate maintenance. Therefore, local governments need to evaluate how the future maintenance bill will be paid and who will pay it…"* (Scheuler, Tom, Center for Watershed Protection: The Economics of Watershed Protection. Vol 2 No. 4, June 1997)

**Table D-1: Balance Sheet for Watershed Protection**
**(–) negative economic consequence (+) positive economic or environmental impact**

| Watershed Protection Tools | Developer/Builder | Adjacent Property Owner | Community | Local Government |
|---|---|---|---|---|
| **1. Watershed Planning and zoning** | (–) cost of land<br>(–) locational constraints | (+) property value | (+) business attraction<br>(+) protection from adverse uses | (–) staff and budget resources<br>(+) reduced "clean up" |
| **2. Protect Sensitive Areas** | (+) natural area premium<br>(-) permitting costs<br>(–) locational constraints | (+) property value | (+) habitat<br>(+) fisheries | (–) staff resources<br>(+) reduced "clean up" costs<br>(+) lower cost of services |
| **3. Establish Buffer Network** | (+) buffer premium<br>(–) locational constraints | (+) property value | (+) flooding risk<br>(+) wildlife<br>(+) greenway<br>(+) trails | (–) staff resources<br>(+) fewer drainage complaints |
| **4. Cluster and Open Space Development** | (+) construction costs<br>(+) marketability<br>(+) no lost lots | (+) property value<br>(-) Homeowners Association fees | (+) recreation<br>(+) green space<br>(+) natural area preservation | (–) staff resources<br>(+) lower cost of services |
| **5. Narrow Streets and Smaller Parking Lots** | (+) reduced construction costs | (+) property value<br>(–) parking | (+) better sense of place<br>(+) pedestrian friendly | (–) staff resources |
| **6. Erosion and Sediment Control** | (–) higher cost<br>(+) savings in cleaning/grading | (+) trees saved increase value<br>(+) no off-site sediment | (+) water quality<br>(+) tree conservation | (–) staff resources<br>(+) reduced complaints from downstreamers |
| **7. Stormwater Best Management Practices** | (-) higher costs<br>(+) pond/wetland premium | (-) maintenance<br>(+) waterfront effect (if done right) | (+) protection of water supply<br>(+) stream protection | (–) staff resources<br>(+) reduced waterbody programs/problems |
| **8. Treat Septic System Effluent** | (–) higher design and engineering costs | (–) clean out costs | (+) protection of water supply | (–) staff resources |
| **9. Ongoing Watershed Management** | No impact | (–) annual fee for utility<br>(+) continued healthy environment | (–) annual fee<br>(+) involvement in watershed services | (–) staff resources |
| **ECONOMIC TREND** | **MIXED** | **POSITIVE** | **POSITIVE** | **NEGATIVE** |

*Scheuler, Tom, Center for Watershed Protection: The Economics of Watershed Protection. Vol 2 No. 4, June 1997*

**Table D-2: Range of Cost for Structural Treatment**

| | Wetpond low | Wetpond high | Wetland low | Wetland High | Infiltration Basin Low | Infiltration Basin high |
|---|---|---|---|---|---|---|
| **Cost per acre of watershed** | $112 | $2,247 | $5,618 | $89,896 | $224 | $1,348 |

(Pease, 1997)

| **Table D-3: The Unit Cost of Subdivision Development** | |
|---|---|
| **Subdivision Improvement Unit Costs** | |
| Roads, Grading | $22.00 per linear foot |
| Roads, Paving (26 feet width) | $71.50 per linear foot |
| Roads, Curb and Gutter | $12.50 per linear foot |
| Sidewalks (4 feet wide) | $10.00 per linear foot |
| Storm Sewer (24 inch) | $23.50 per linear foot |
| Clearing (forest) | $4,000 per acre |
| Driveway Aprons | $500 per apron |
| Sediment Control | $800 per acre |
| Stormwater Management | $300 per acre (variable) |
| Water/Sewer | $5,000 per lot (variable) |
| Well/Septic | $5,000 per lot (variable) |
| Street Lights | $2.00 per linear foot |
| Street Trees | $2.50 per linear foot |

(Source: SMBIA 1987 and others, as published in Schueler 1995) (Scheuler, Tom, Center for Watershed Protection: The Economics of Watershed Protection. Vol 2 No. 4, June 1997)

**Table D-4: Typical Unit Base Costs for BMP's**

| BMP | Typical Cost ($/cf) | Notes | Source |
|---|---|---|---|
| Pond | 0.50 – 1.00 | Cost range reflects economies of scale in designing this BMP. The lowest unit cost represents approximately 150,000 cubic feet of storage, while the highest is approximately 15,000 cubic feet. Typically, dry ponds are the least expensive design options among ponds. | Adapted from Brown and Scheuler (1997) |
| Wetland | 0.60 – 1.25 | Although little data are available to assess the cost of wetlands, it is assumed that they are approximately 254% more expensive (because of plant selection and sediment forebay requirements) than ponds. | Adapted from Brown and Scheuler (1997) |
| Infiltration Trench | 4.00 | Represents typical costs for a 100-foot long trench. | Adapted from SWRPC (1991) |
| Infiltration Basin | 1.30 | Represents typical costs for a 0.25 acre infiltration basin. | Adapted from SWRPC (1991) |
| Sand Filter | 3.00 – 6.00 | The range in costs for sand filter construction is largely due to the different sand filter designs. Of the three most common options available, surface sand filters are the most expensive, perimeter sand filters are moderate and underground sand filters are the most expensive. | Adapted from Brown and Scheuler (1997) |
| Bioretention | 5.30 | Bioretention is relatively constant in cost, because it is usually designed as a constant fraction of the total drainage area. | Adapted from Brown and Scheuler (1997) |
| Dry Swale | 4.25 | Very few dry swales have been constructed, but the design is similar to a bioretention facility, with less landscaping. Thus, it is assumed that dry swales cost approximately 80% as much as bioretention | Adapted from Brown and Scheuler (1997) |
| Grass Channel/ Biofilters | 0.50 | Based on cost per square foot, and assuming 6" of storage in the filter. | Adapted from SWRPC (1991) |
| Filter Strip | 0.00 – 1.30 | Based on cost per square foot, and assuming 6" of storage in the filter strip. The lowest cost assumes that the buffer uses existing vegetation, and the highest cost assumes sod was used to establish the filter strip. | Adapted from SWRPC (1991) |

(CWP, 1998, Costs and Benefits of Stormwater BMPs Final Report 9/`4/98, Table 10)

**Table D-5: Comparison of costs of improperly and properly constructed ditches**

| Channel Slope | Lining | Thickness |
|---|---|---|
| 0 – 5% | Grass | |
| 5 – 10% | R#3 (2-6 inch diameter rock) | 7.5 inches |
| >10% | R#4 (3 – 12 inch diameter rock) | 12 inches |
| Cost: $36,000/mile/20 years improperly constructed ditch | Cost: $26,000/mile/20 years properly constructed ditch | |

(Vermont Better Backroads Manual Northern Vermont Resource Conservation and Development Councils, November 1995)

**Table D-6: General Effectiveness and Cost of Various Nonstructural Control Practices (Metropolitan Washington Council of Governments**

| | Nutrient control | Sediment control | Storm-water control | Maint-tenance burden | Longev-ity | Com-munity Ac-ceptance | Costs to Devel-opers | Costs to Local Govern-ments |
|---|---|---|---|---|---|---|---|---|
| **Stream Buffers** | Mod. | Mod. | Low | Low | long-lived | Positive | Mod. | Low |
| **Wetland Buffers** | Mod. | Mod. | Low | Low | long-lived | Positive | High | Low |
| **Steep Soils Limits** | Low | High | Mod. | Low | long-lived | Neutral | Mod. | Low |
| **Septic Limits** | Mod. | Low | High | Low | long-lived | Neutral | High | Mod. |
| **Wetland Protection** | High | High | Mod. | Low | long-lived | Positive | Mod. | Low |
| **Forest Protection** | Low | Mod. | Low | Low | long-lived | Positive | High | Low |
| **Habitat Protection** | Low | Low | Low | Low | long-lived | Positive | Mod. | Low |
| **Open Space Protection** | Low | Low | Low | Low | long-lived | Positive | High | Low |
| **Cluster Development** | Low | Low | Low | Low | long-lived | Neutral | Low | Low |
| **Performance Criteria** | High | High | High | High | short-lived | Negative | High | High |
| **Minimize Imperviousness** | Low | Low | Mod. | - | - | | - | - |
| **Erosion and Sediment Control (Phased Construction)** | Mod. | Mod. | Low | Low | long-lived | Positive | Low | Mod. |
| **Urban Housekeeping** | Low | Mod. | Ineffective | Mod. | short-lived | Neutral | Low | Low |

(Table 4-10 EPA 1993)

**Section 3.0 Maintenance Costs And Schedules BMP's**

**Table D-7: Annual Maintenance Costs**

| BMP | Annual Maintenance Cost (% of Construction Cost)(1) | Cost for a "Typical" Application (See Table 10) | Source(s) |
|---|---|---|---|
| Ponds and Wetlands | 3 – 6% | $ 3,000 to $6,000 | Wiegland et al. 1986<br>Scheuler et. al, 1987<br>SWRPC, 1991 |
| Dry Ponds | -1% | $1,200 | Livingston et. al, 1997<br>Brown and Scheuler, 1997 |
| Wetlands | -2% | $3,800 | Livingston et. al, 1997<br>Brown and Scheuler, 1997 |
| Infiltration Trench | 5 – 20% | $2,300 to $9,000 | Scheuler, 1987<br>SWRPC, 1991 |
| Infiltration Basin | 1 – 3% | $150 to $ 450 (2) | Livingston et. al, 1997<br>SWRPC, 1991 |
| | 5 – 10% | $750 - $1,500 | Wiegland et al. 1986<br>Scheuler et. al, 1987<br>SWRPC, 1991 |
| Sand filters | 11 – 13% | $2,200 | Livingston et. al, 1997<br>Brown and Scheuler, 1997 |
| Swales, grassed channels | 5 – 7% | $200 to $2,000 | (Assumes the same as swales) |
| Bioretention | 5 – 7% | $3,000 to $4,000 | SWRPC, 1991 |
| Filter Strips | $320/acre (maintained) | $1,000 | |
| 1: Livingston et al. (1997) report maintenance costs from the maintenance budgets of several cities, and percentages were derived from costs in other studies.<br>2: This value was extrapolated from the costs for much larger basins. | | | |

(CWP, 1998, Costs and Benefits of Stormwater BMPs Final Report 9/`4/98, Table 19)

**Table D-8: Maintenance Schedules for BMP's**

| BMP | Activity | Schedule |
|---|---|---|
| Ponds and Wetlands<br><br>(1) | Cleaning and removal debris after major storm events; (>2" rainfall).<br>Harvest vegetation when a 50 % reduction in the original open water surface area occurs.<br>Repair of embankment and side slopes<br>Repair of control structure. | Annual or As Needed |
| | Removal of accumulated sediment from foreays or sediment storage areas when 60% of the original volume has been reduced. | 5 year cycle |
| | Removal of accumulated sediment from main cells of pond once 50% of the original volume has been reduced. | 20 year cycle |
| Infiltration Trench<br><br>(1) | Mowing and maintenance of upland vegetated areas.<br>Sediment cleanout<br>Repair or replacing of stone aggregate<br>Maintenance of inlets and outlets. | Annual or As Needed |
| | Removal of accumulated sediment from main cells of pond once 50% of the original volume has been reduced. | 4 year cycle |
| Infiltration Basin<br><br>(2) | Cleaning and removal debris after major storm events; (>2" rainfall).<br>Mowing and maintenance of upland vegetated areas.<br>Sediment cleanout | Annual or As Needed |
| | Removal of accumulated sediment from main cells of pond once 50% of the original volume has been reduced. | 3 to 5 year cycle |
| Sand filters<br><br>(3) | Removal of trash and debris from control openings.<br>Repair of leaks from the sedimentation chamber or deterioration of structural components.<br>Removal of the top few inches of sand, and cultivation of the surface, when filter bed is clogged. | Annual or As Needed |
| | Clean out of accumulated sediment from filter bed chamber once depth exceeds approximately one-half (1/2) inch, or when the filter layer will no longer drawdown within 24 hours.<br>Clean out of accumulated sediment from sedimentation chamber once depth exceeds 12 inches. | 3 to 5 year cycle |
| Bioretention<br><br>(4) | Repair of erosion areas<br>Mulching of void areas<br>Removal and replacement of all dead and diseased vegetation<br>Watering of plant material | Bi-annual or as needed |
| | Removal of mulch and application of a new layer | Annual |
| Dry swales/ Grassed Channel/ Biofilter<br><br>(1) | Mowing and litter and debris removal<br>Stabilization of eroded side slopes and bottom<br>Nutrient and pesticide use management<br>Detaching swale bottom and removal of thatching<br>Discing or aeration of swale bottom | Annual or As Needed |
| | Scraping swale bottom, and removal of sediment to restore original cross section and infiltration rate<br>Seeding or sodding to restore ground cover (use proper erosion and sediment control) | 5 year cycle |
| Filter Strips<br><br>(5) | Mowing and litter debris removal<br>Nutrient and pesticide use management<br>Aeration of soil on the filter strip<br>Repair of eroded or sparse grass areas | Annual or As Needed |

1. Modified from Livingston, et. al (1997)
2. Modified from Livingston, et. al (1997), based on infiltration trench requirements
3. Modified from Claytor and Scheuler(1997)
4. Modified from ETA and Biohabitats (1993)
5. Modified from Livingston, et. al (1997) based on grass swale recommendations

(CWP, 1998, Costs and Benefits of Stormwater BMPs Final Report 9/`4/98, S 20)

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## Appendix E: Public Process

Educating the public about the project and inviting them to get involved are critical to its ultimate success. Members of the public are the "eyes" for identifying problem areas along the stream. They can provide the impetus for the restoration of the watershed, and influence upon other stakeholders to get involved and work cooperatively with the Restoration Team to find solutions that can work.

The goals of the public participation component of the project are to:

- Work with citizen groups and town leaders to identify which of the watershed qualities residents most value, and what they would like their watershed to "look like" in the future.
- Engage residents in a resource inventory of the Allen Brook watershed. This promotes a sense of ownership.
- Educate residents and town leaders about watershed processes, existing and future sources of pollution and the impacts their actions have on Allen Brook and its ecosystem.
- Develop a consensus of control strategies and decision-making strategies for management of the Allen Brook watershed.

The strategy to educate and involve as many members of the public as possible included using the press, public meetings and tours, and advertisements.

The Allen Brook Restoration Team used a variety of tools to reach out to the public, local officials, and stakeholders that live or do business in the Allen Brook watershed. A summary of the activities can be found in the main document. Below are the actual outreach tools and meeting minutes that describe how we raised public awareness and involvement in this project:

- Poster of the Allen Brook Restoration Project, Used in Presentations to the Public;
- Public Questionnaire, Used at Town Meeting and Available at Library, Town Hall;
- Project Announcement Included in the Town Annual Report, Used at Public Meetings;
- Article, Introducing the Allen Brook Restoration Project, 03/01;
- Meeting with the Williston Selectboard, 04/01;
- Article, Assessing the Allen Brook and Inviting the Public to Attend the River Walks, 06/01;
- Postcard, Mailed to Town Residents: Inviting the Public to the River Walks, Photos, 07/01;
- Letter Submitted to Williston Development Review Board Containing Recommendations on a Proposed Subdivision, 08/01;
- Letter from the Town of Williston, with Attachment, Inviting the Development Community to Attend a Meeting Regarding the Allen Brook Restoration Project, 09/01;
- Meeting with Williston Conservation Commission, 10/01;
- Second Meeting with the Williston Conservation Commission, 02/02;
- Article, Announcing Public Meeting with Homeowner Associations, 03/02;
- Article, Describing Homeowner Meeting, 04/02;
- Article, Describing Buffer Planting Conducted by the local Rotary Club, 05/02;
- Article, State Stormwater Rules and the Allen Brook Restoration Project, 05/02; and,
- Meeting with the Williston Planning Commission, 06/02.

**Poster of the Allen Brook Restoration Project**

# Allen Brook Restoration Project

## Goal

Develop a plan to improve and maintain the water quality and health of Allen Brook.

## Partners

Vermont Agency of Natural Resources (ANR)
United States Environmental Protection Agency (USEPA)
Town of Williston
Allen Brook Restoration Team

## Problem

Allen Brook's Water Quality is threatened because of land development, erosion and urban runoff. Pollutants include:

- Sediment
  - Reduces aquatic habitat for fish and other organisms
- Nutrients
  - Cause aquatic algal blooms and reduce fish habitat quality
- Toxic chemicals and metals
- Bacteria

*Eroding and slumping banks contribute sediment to the stream*

## Allen Brook Watershed

## Assessment Strategy

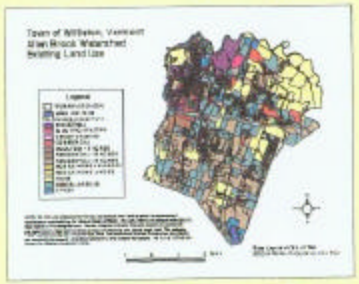
*Public Participation Component*

- Public Survey
- Watershed Awareness Tours
- Watershed Forum
- Site Planning Roundtable
- Community Mapping

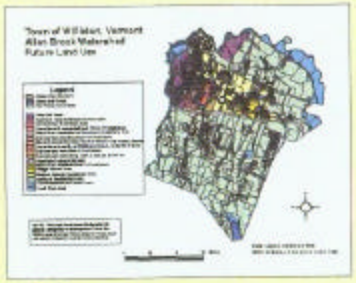
*Technical Component*

- Compile Existing Data
- Organize in Geographic Information System
- Field Assessments (stream and watershed)
- Simple Water Quality Modeling
- Restoration Activities

## Existing Land Use




## Future Land Use




*Land management decisions can significantly impact streams.*
*How and where development occurs can make all the difference!*

## Allen Brook Restoration Project Team Members

Lori Barg - Consulting Hydrogeologist
Kari Dolan - National Wildlife Federation
Chris Chadwick and Cindy Hendrie - Civil and Env. Engineering, UVM
Cindy Cook - Advanced Accord
Bob Kurt - USDA NRCS
Craig MacCrae - Aquifer Beach Ltd.

*Poster produced by Chris Chadwick, Department of Civil and Environmental Engineering, UVM March 2001*

## How Development Affects Streams

- More surface runoff
- Faster surface runoff
- Higher stream flow during storms
- Higher velocities, more energy
- Less infiltration
- Less groundwater recharge
- Lower stream flows during dry periods
- Wider channels

## Desired Outcomes/Results

- Achievable, realistic plan for improving and maintaining water quality in Allen Brook
- Community collaboration and education
- Community-based restoration
- Community-based monitoring
- Plan/process that satisfies EPA's requirements for water quality in Allen Brook

## We Need Your Help!

Your input is important. Please take a few minutes to fill out our survey or contact us with the answers to the below questions:

1) Where are the pollution problem areas in the Allen Brook Watershed?
2) What areas need to be cleaned up?
3) What areas in the Allen Brook Watershed would you like to see protected?
4) What issues should be addressed at public meetings about the Allen Brook cleanup?
5) Do you have any photos of what the river or Williston used to be like that you could share with us?
6) Would you like to join us on a river walk in late April, May or June?

Drop questionnaires in the box at town hall, the Dorothy Alling Memorial Library, or mail to:
Kari Dolan, 58 State Street, Montpelier, VT 05602

**Public Questionnaire, Used at Town Meeting and Available at Library, Town Hall:**

## ALLEN BROOK, MUDDY BROOK, SUCKER BROOK

These brooks flow through Williston. Two of them, Allen and Muddy Brooks, are damaged because of land development, erosion and urban runoff. They are polluted with sediment, nutrients, toxic chemicals, metals and bacteria.

We are a group of river and watershed experts, hired by the Vermont Agency of Natural Resources (ANR) who are working with the Town of Williston, ANR and the Environmental Protection Agency to address pollution in the Allen Brook watershed. During 2001, we will work with townspeople, landowners, business owners, developers and town officials to develop a plan to restore the water quality of Allen Brook. Federal law requires damaged waters to be cleaned up.

**We need your active participation in the restoration of this vital natural resource. We want to know what you most value about the watershed. Please write or call us, and let us know about:**

*a.) Pollution problem areas in the Allen Brook watershed*
*b.) Restoration opportunities*
*c.) Areas you would like to protect*
*d.) Concerns regarding this project's affect on you or your property.*

**By working with as many interested people as possible, we hope to develop a consensus on the restoration and management of the Allen Brook watershed.**

**We will be holding several public meetings, so that we can hear from as many people as possible, and so that we can share what we have learned about the watershed, existing and future sources of pollution, and the impacts we all have on water quality.**

**We look forward to hearing from you.**
***Lori Barg, Cindy Cook, Kari Dolan, Cully Hession, Bob Kort, & Craig Macrae***

**Allen Brook Restoration Project**
**Kari Dolan dolan@nwf.org**
**58 State Street**
**Montpelier, Vermont 05602**

*Your interest and participation in this effort will help make the communities of the Allen Brook Watershed healthier and more livable.*

**The lands within the Allen Brook watershed were largely converted from forests to agriculture. Now, the watersheds are experiencing development pressure. How the land and particularly the river banks are managed can have a big impact on the community of Williston and the health of these streams.**

**PLEASE TAKE A FEW MOMENTS TO FILL OUT THIS SURVEY !**
**PLEASE RETURN BY MAY 1, 2001**

**Where are there pollution problem areas in the Allen Brook watershed?**

**What areas need to be cleaned up?**

**What areas in the Allen Brook watershed would you like to see protected?**

**What issues should be addressed at public meetings about the Allen Brook cleanup?**

**Do you have photos of what the river or Williston used to be like that you could share with us?** (If so, please be sure to fill out the contact info below)

**Do you want to wander along the river with us for a day in late April, May or June?**

**Your Name:**
**Address:**
**Phone:**
**E-mail:**

**Announcement Included in the Town Annual Report, Used at Public Meetings:**

## *ALLEN BROOK POLLUTION CLEAN-UP PROGRESS REPORT*

In the fall of 2000, the Vermont Agency of Natural Resources (ANR) retained the services of a team of experts to develop the watershed restoration plan for the 14.5 square mile Allen Brook watershed, located in the town of Williston. The goal of the restoration plan is to restore Allen Brook to meet Vermont Water Quality Standards.

Office work and field assessments were completed during 2001 that characterize the biological, geomorphic, and riparian condition of Allen Brook; Field work included conducting a pollution prevention survey and identifying potential stream rehabilitation and candidate sites for remediation; Conducting public walks, meetings with Town personnel, and outreach events for the local community; and identifying opportunities to incorporate stormwater management into the Town Plan and ordinances.

The Town of Williston is experiencing rapid growth. In 1995, the Allen Brook watershed was approximately 50 percent agricultural, 25 percent forest, and 25 percent developed (Pease, 1997). Land use distribution in 1999, described in the 2000 Williston Comprehensive Plan, shows a marked change. Agriculture has decreased from 50 percent to 25 percent, and residential, commercial/industrial development has increased to 43 percent of the land use.

Actively eroding sites are found throughout the watershed from storm systems and via the tributaries. The 150 ft setback along the mainstem of Allen Brook and natural grade control in the watershed has helped protect the mainstem from incision. Recommendations will include 1) expanding the buffer to include all tributaries, ephemeral, intermittent and perennial and 2; developing a better surface water layer of all tributaries to effectively reduce the input of sediment via these pathways into Allen Brook.

The Williston Town Plan is designed to direct future growth to locations with adequate town services near its commercial areas (the Sewer Service Area), however, growth pressures outside this area have been significant. According to the 2000 Annual Growth and Development Report for the town of Williston, the target for new dwelling units outside the Sewer Service Area of 20 percent has been exceeded almost every year for the past 10 years.

This level of growth and the increase in impervious surface will change the hydrology of the watershed and contribute to further impairment of Allen Brook. The rapid growth requires that extra attention be paid to erosion and sediment control, stormwater management and maintenance and improved site design to reduce impervious area. These areas may be addressed through the development of ordinances and incentives to prevent further degradation of Allen Brook.

The Allen Brook team is interested in your input. We will be holding more public meetings and meetings with town officials throughout the year. Feel free to contact Kari Dolan, 58 State St, Montpelier, VT. 05602

Thank you very much. Sincerely, the project team:

Dr. Cully Hession, Kari Dolan, Lori Barg, Chris Cianfrani, Bob Kort

**Article, Introducing the Allen Brook Restoration Project:**

## GUEST COLUMN

# There's still time to save Allen Brook

March 8, 2001, *Williston Whistle*

**By Kari Dolan**

If you are driving, biking or walking around Williston, you may notice a stream flowing northwest. Meet Allen Brook — Williston's very own stream, running through the heart of the town and draining roughly 12 square miles of watershed.

Allen Brook gets its name from Ethan Allen, the Revolutionary War veteran who (with the Green Mountain boys) defended settlers living in Vermont.

Following the flow of Allen Brook is a great way to get to know the stream better. Start at the beautiful Mud Pond Conservation Area, where it flows north along South Road, then westward along Route 2.

The stream then cuts northwest of Taft Corners and passes under Route 2A and Industrial Avenue. You can see Allen Brook emptying into Muddy Brook along Poor Farm Road just before it empties into the Winooski River in South Burlington.

Like most of Vermont's rivers, Allen Brook was once clean. Floods spilled out into the floodplains, enriching the soil and preventing high waters from causing land

*continued on page 5*

erosion. The wetlands kept the water pure and provided habitat for a wide variety of birds, mammals, reptiles, fish and amphibians.

However, Allen Brook is damaged. Bank erosion is evident along the stream. The water quality in this brook drops as it flows through Williston. The Vermont Agency of Natural Resources (ANR) has identified Allen Brook as polluted and in need of restoration. Allen Brook's water quality problems include:

- Sediment, which reduces aquatic habitat for fish and other organisms, scours bridge abutments and river banks and makes streams more cloudy.
- Nutrients, which act like fertilizers to cause aquatic algae blooms that damage Lake Champlain.
- Toxic chemicals and metals from oils, grit and grease that are picked up by rainwater.
- Bacteria, an indicator of water-borne diseases.

How did the Allen Brook 1998, the population increased by 77 percent to 6,800.

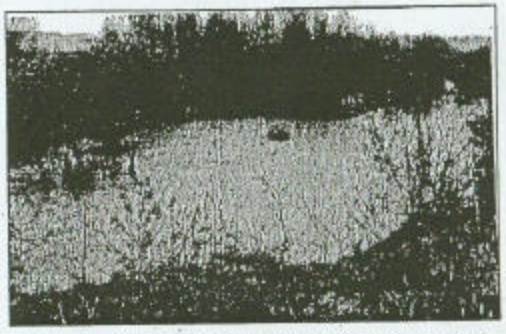
As land is converted from woods and fields to parking lots, roads, buildings and houses, rainwater and snowmelt can no longer infiltrate the ground. Instead, a greater volume of water runs off the hard surfaces, picking up contaminants and carrying them to the stream.

In addition, increased runoff during storms causes water to spill over the banks, and floods occur more frequently. More water running in the stream also causes more erosion, which damages both public and private property.

But there is still hope for Williston's stream. Last fall, we spotted a female moose near the brook's mouth. Otter are known to have played in its waters. Allen Brook is home to many species of fish, birds and two rare freshwater mussels. It is also close to Williston's schools, allowing town's character. The Williston Historical Society, since its formation in 1973, has worked hard to preserve the town's connection with its past. In 1980, much of Williston village was added to the National Register of Historic Places. Restoring Allen Brook, which flows through the very heart of Williston, presents an opportunity to preserve an important natural element of the town character.

We can reverse the damage and restore the town's brook with your help. The ANR has hired a team of river and watershed experts to work with residents, landowners, business owners, developers and town officials to develop a plan to restore the water quality of Allen Brook.

The team wants to hear from you. By working with as many interested people as possible, the team hopes to develop a community-embraced plan on the



*The Allen Brook runs through the heart of Williston and drains roughly 12 square miles of watershed. Contributed photo.*

restoration and management of the Allen Brook watershed.

Please take a few minutes and fill out the survey included in Williston's annual report. Copies of the survey are also available at Williston Town Hall and Dorothy Alling Memorial Library.

For more information about the project or how to get involved, contact: Kari Dolan, Allen Brook restoration team member at (802) 229-0650, or send e-mail to dolan@nwf.org. You can also contact Amy Cantor, Williston Conservation Commission liaison at 878-6704, or send e-mail to cantora@willistontown.com.

Your interest and participation in this effort will help make the communities of the Allen Brook watershed healthier and more livable. ■

*Kari Dolan is a water resources specialist for the National Wildlife Federation's northeast office and member of the Allen Brook restoration team.*

**Announcement, Meeting with the Williston Selectboard:**

WILLISTON SELECTBOARD MEETING
Thursday, April 26, 2001
Town Hall Meeting Room
7:00 PM

| *Times are approximate* | | |
|---|---|---|
| 7:00 | 1. | Call to Order |
| 7:05 | 2. | Minutes - February 22, 2001 |
| 7:10 | 3. | Board Interview/Appointments<br>An applicant for the Conservation Commission will be interviewed and the Board will consider making an appointment. Board will also consider making an appointment to the Board of Listers |
| 7:20 | 4. | Liquor License Applications - Bread and Beyond<br>Acting as the Local Liquor Control Board, review applications |
| 7:30 | 5. | Public Comment - General Issues |
| 7:40 | 6. | Allenbrook Watershed Study Update<br>Board will receive a progress report on the study of the Allenbrook Watershed |
| 8:00 | 7. | Meadowridge Sewer Connection Request<br>Review a request from the Meadowridge homeowners association to connect to the Town's sewer system |
| 8:30 | 8. | IBM Expansion<br>Consider adopting a resolution in support of the expansion plans of IBM |
| 9:00 | 9. | Business Round Table Forum<br>Receive an update on the planned forum |
| 9:10 | 10. | Sewer Allocation Requests<br>Review a sewer allocation request for the current fiscal year from Mansfield Investments to serve buildings to be constructed on lot #6 in the Mansfield Business Park |
| 9:20 | 11. | Request to Extend Transfer Station Hours<br>Review a request to extend the hours of the transfer station during Green Up Day, 2001 |
| 9:25 | 12. | Maple Tree Place Affordable Housing Grant Resolutions<br>Consider adopting the proposed resolutions concerning the grant agreement for the affordable housing at Maple Tree Place |
| 9:30 | 13. | Manager's Report |
| 9:40 | 14. | Other Business |
| 9:45 | 15. | Adjournment |

**Article, Assessing the Allen Brook and Inviting the Public to Attend the River Walks:**

# Team assesses ailing Allen Brook

June 7, 2001, *Williston Whistle*

*UVM faculty member Cully Hession checks out erosion at Allen Brook. (Photo by Jason Koornick)*

## Residents invited to tour stream with restoration group

**By Jason Koornick**

A team of environmental professionals and students waded along the muddy banks of Allen Brook in Williston earlier this week collecting data and making measurements.

The group was assessing the condition of Allen Brook as part of a state-funded effort to clean up the damaged stream.

The Allen Brook Restoration Team plans will eventually make recommendations to the town and the state on how the stream can be renewed and sustained for many years to come. Team members are currently taking the stream's vital signs, the first phase of the project.

The seven-member team of biologists, water specialists, conservationists, students and University of Vermont teachers was rating the stream based on 14 different variables including width, stability and biological data.

What they were finding was that Allen Brook suffers from erosion, iron staining, sediment collection and poor water quality — all signs that the stream is not as healthy as it once was.

Most of the damage has been caused by sediment collected through runoff. Water flows off of roofs and paved surfaces into Allen Brook, washing many foreign substances and contaminants into the streambed, where they accumulate and cause environmental damage. The increased volume of water causes the stream to overflow

*continued on page 25*

## Allen Brook

CONTINUED FROM PAGE 1

more frequently, eroding the banks and damaging public and private property.

"There are many areas here that are unstable," said project leader Lori Barg, pointing to a stream bank that was recently eroded. "You can also see that the whole river has dropped down."

An abandoned riverbed was more than 4 feet higher than the stream itself, suggesting that the stream has sunk into the field at an abnormal rate.

The group is concerned about the future of Allen Brook for a variety of reasons. They point out that the stream is an important part of the town's character. It runs north from Mud Pond though the village of Williston then passes under Route 2A and Industrial Avenue until it empties into Muddy Brook along Poor Farm Road. Running all the way across Williston, Allen Brook also provides a home for many types of wildlife.

"We have seen signs of muskrats, deer, beaver and lots of birds. There was even a moose sighting by the Allen Brook last fall," said Kari Dolan, a water resources specialist for the National Wildlife Federation.

Dolan emphasizes that the public's knowledge about the state of Allen Brook and their support for management actions is essential in preserving the natural resource.

"The public's involvement is very important," she said. "People have to know that the degradation is caused by urbanization upstream and we want to work with landowners so that the erosion doesn't eat away at their land."

Allen Brook was chosen for funding by the state Agency of Natural Resources because although the body of water is damaged, it can still be repaired using low-cost solutions. "Allen Brook is on the edge of urbanization, which can cause serious problems for the natural environment," said Tim Clear of the state Department of Environmental Conservation. "There is planning that can be done in the future to make it better."

Small steps can be taken by municipalities, private citizens and businesses to preserve the vitality of the town's streams. These can be as simple as draining a rainspout on a piece of land that can absorb water or as complex as implementing regulations that attempt to limit the amount of runoff from paved surfaces.

When the project is completed, the group plans to propose a number of low-cost solutions that will enhance the vitality of Allen Brook. This particular mission was undertaken so that the group can identify the problem areas and begin to address them. Although there has been a significant amount of data gathered about Allen Brook in the past — particularly about the biology of the area — the Allen Brook Restoration Team is looking at every variable to determine how the stream can be cleaned up. They want to make sure that its beauty and character can be enjoyed by many future generations.

Williston residents are invited to join the team on an educational and recreational walk along the stream.

"People can walk along the river, see the effects of runoff and see what they can do to help," said Dolan.

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*Walks along Allen Brook are scheduled for Wednesday, June 20 from 4 p.m. to 7 p.m. and on Saturday, June 23 from 8 a.m. to 11 am. Call Kari Dolan at (802) 229-0650 for directions and details.*

**Postcard, Mailed to Town Residents: Inviting the Public to the River Walks and Photos:**

THE ALLEN BROOK RESTORATION TEAM
INVITES YOU TO ATTEND
ONE OF THE TWO:

# Allen Brook RIVER WALKS

When: Wednesday, July 20th, 4-7pm OR
Saturday, July 23rd, 8-11am
Where: Meet us behind the Williston Town Hall
Contact: Kari Dolan, Allen Brook Restoration Team, 802/229-0650; or
Amy Cantor, Williston Conservation Commission, 802-878-6704

Come to a River Walk to learn about Williston's Allen Brook, its water quality and erosion problems, & restoration opportunities. Share your thoughts with the Restoration Team, who is working with the Vermont Agency of Natural Resources and the Town of Williston to assess the health of Allen Brook.

*Your interest and participation in this effort will help make the Williston community healthier and more livable.*

Lori Barg discussing the health of Allen Brook

Viewing an eroding tributary caused by hydrologic changes from stormwater runoff.

Another view of the same tributary.

Allen Brook cascades, Industrial Ave.

**Letter Submitted to Williston Development Review Board Containing Recommendations on a Proposed Subdivision:**

Town of Williston Development Review Board August 23, 2001
Town of Williston Offices
7900 Williston Road
Williston, VT 05495

Dear Members of the Williston Development Review Board:

We have been hired by the state of Vermont Agency of Natural Resources to develop the restoration plan for Allen Brook. Thank you for the opportunity to provide comments to the proposal for subdivision approval for a 50-lot subdivision on Beaudry Lane, submitted by Allen Brook Investments.

Allen Brook is impaired due to polluted runoff. The problem pollutants are chiefly sedimentation, pathogens, and nutrient pollution, with some indication of toxic contamination, due to the urban nature of the runoff.

As communities like Williston grow, the amount of impervious surfaces – roads, parking lots, sidewalks, and rooftops – grows. The amount of impervious cover is a concern because it prevents infiltration of water into the soil, forcing more water to move at higher speeds into watercourses. In addition, runoff picks up pollutants from the hard surfaces, such as dirt, litter, oil from cars, salts, and bacteria.

More stormwater runoff flowing at higher speeds can cause bank erosion and sedimentation. Sedimentation increases turbidity in the water column, greatly reducing the growth of beneficial aquatic plants. Sedimentation reduces aquatic habitat. Sedimentation also contributes to the nutrient problem, since phosphorus binds to sediment. Sediment is often a major problem at construction sites, if the disturbed land is left unprotected from wind and precipitation.

Since the subdivision is being proposed prior to the completion of our plan, we feel obligated to submit the following comments to you to provide guidance, to minimize problems associated with stormwater runoff, and to ensure that the town of Williston is on its way to restore the Allen Brook for its residents. We would like to see the following items as conditions to the approval of this subdivision:

- The development should not affect the integrity of the buffer. We recommend there be no encroachment into the buffer or buffer averaging, because it could potentially compromise the functions that the buffer ordinance attempts to protect, namely, protection of water quality, aquatic and terrestrial habitat, stream channel stability, flood control, and aesthetic and recreational values.

- The State of Vermont Agency of Natural Resources recently released a draft Riparian Buffer Procedure. The state buffer procedure makes no distinction between main channels and

unnamed streams or tributaries. Smaller streams are more vulnerable to changes in hydrology and erosion caused by the development. Therefore, to be consistent with the State procedure, the development, regardless if it drains into the mainstem of Allen Brook or its unnamed streams or tributaries, should comply with the town's 150-foot setback requirement.

- The need to minimize imperviousness is an important way to prevent stormwater runoff-related problems (as well as an opportunity for the developer to save money), without compromising safety. With respect to sidewalks, the development should: (a) have sidewalks on one side of a street, if the development plans to have sidewalks; and, (b) the sidewalk width should be no more than 3 to 4 feet wide, placed away from the street, and graded so that they drain to vegetation.

- Since the road network is a majority of the impervious cover in a watershed, revising the street width standards can help achieve stormwater management objectives while still allowing for expected traffic volumes and safety considerations. Several communities recommend street widths of 22 feet, which include parking on one side of the street. We would like to see: (a) that street widths are minimized; (b) curbing is avoided in order to allow precipitation to reach vegetation and infiltrate into the ground; and (c) all cul-de-sacs, if planned, must be designed with a smaller radius, ranging from 33 to 45 feet and have a pervious, vegetated island in the center of the turn (ideally with shrubs to prevent interference with visibility. The pervious island is to be designed to filter stormwater and enhances the attractiveness of the site.

- Driveway design is another opportunity to reduce impervious cover. We would like to see conditions placed on the permit that require driveways to: (a) have narrower widths (limited to 9 feet); (b) allow for multiple homes to share driveways; and, (c) have reduced lengths by minimizing the building setback from the road.

- Rooftops can also be designed to minimize stormwater-related problems. We recommend that rooftops be "disconnected," meaning that roof runoff will not flow, via rain gutters, onto driveways. The housing will be developed such that the rooftop runoff will be directed to vegetation and away from the driveway.

- Periodic maintenance, conducted according to a set schedule, is a vital yet often overlooked necessity for ensuring the continued performance of storm drainage systems. Therefore, explicitly stating the need to maintain stormwater controls by first the subdivider, to be continued by the homeowner, tenant=s association, or other responsible party, may increase the likelihood that maintenance will be continued. We recommend that the developer be required to maintain stormwater controls, until such time that the homeowner's association or other responsible party assumes the responsibility, to be established in writing.

- During construction, vegetation and topsoil are removed, bare soils are exposed to wind and precipitation, steep slopes may be cut, the natural contours and drainage patterns are altered, and riparian areas can be disturbed. To avoid the threat of erosion and sediment pollution problems during construction, we recommend that the developer provide, in writing, his or

her obligation to maintain erosion and sediment controls before, during, and after construction. This is necessary because many studies show that erosion and sediment controls do not work very well for many reasons, namely: (a) they were never installed in the first place; (b) they were not installed correctly; and (c) they were not maintained. Well maintained controls not only provide their intended environmental benefits, they ensure that the investment made to reduce erosion was well worth the cost. Williston needs to reduce sediment and erosion anyway, as part of the town's obligations under the EPA=s Phase II Stormwater Rules.

- The town should consider relaxing the setback requirements to give the Town greater flexibility to reduce total impervious areas. Minimizing setbacks from the road will reduce driveway length, thereby reducing impervious cover. Often, smaller setbacks are more consistent with Vermont's historical neighborhood character.

Thank you for your consideration.

Sincerely,

Kari Dolan, Allen Brook Restoration Project Outreach Coordinator

Cc: Scott Gustin, Williston Zoning Administrator
Michael Munson, Williston Planner
Richard McGuire, Williston Town Manager
Amy Cantor, Williston Conservation Commission Liaison
Neil Boydon, Williston Public Works Director
Allen Brook Restoration Team:
Lori Barg, Project Team Manager, Consulting Hydrogeologist
Dr. Cully Hession, Assistant Professor, Civil and Environmental Engineering, UVM
Bob Kort, Planning Engineer/Hydrologist, USDA Natural Resources Conservation Service
Chris Cianfrani, Doctoral Student, Civil and Environmental Engineering, University of Vermont
Jim Pease and Tim Clear, Vermont Agency of Natural Resources

**Letter from the Town of Williston, with Attachment, Inviting the Development Community to Attend a Meeting Regarding the Allen Brook Restoration Project:**

Dear engineers, developers, landowners, and others in the Williston development community:

The Town of Williston would like to invite you to attend a meeting to discuss the Allen Brook Restoration Project on September 12, 2001, at the Williston Town Hall at 7:00 PM.

Since the Allen Brook is designated as an "impaired water" on Vermont's Clean Water Act Section 303d list ("Impaired Waters List"), The Town of Williston, in conjunction with the Vermont Agency of Natural Resources ("ANR") and the U.S. Environmental Protection Agency ("EPA") is required to produce a plan to restore Allen Brook using pollution control actions. Such actions may be of interest to you. They include:

- Local stormwater regulations;
- "Better Site Design" standards; and,
- Riparian buffer initiative that is applied to all tributaries.

Some additional background information on the study is presented on the reverse side of this invitation.

The meeting on September 12 will begin with a presentation of the Allen Brook Restoration Study to date and a summary of the findings and conclusions. There will then be time for discussion where we welcome any questions or concerns you might have.

Please let us know if you can make this meeting. To RSVP, contact: Kari Dolan, Allen Brook Restoration Project Team Outreach Coordinator at 229-0650 **dolan@nwf.org** or Amy Cantor, Williston Conservation Commission Liaison at 878-6704 cantora@willistontown.com. If you are not able to attend this meeting but would like more information or be kept informed, please let Kari or Amy know.

Thank you for your attention to this matter. We look forward to meeting with you soon.

Sincerely,

Michael J. Munson, Ph.D., AICP
Williston Town Planner

**Attachment that Accompanied the Letter to the Development Community:**

## SOME BACKGROUND ON THE ALLEN BROOK RESTORATION STUDY

Allen and Muddy Brooks, both of which flow through the Town of Williston, are listed as impaired waters on Vermont's Clean Water Act Section 303d list ("Impaired Waters List"). The brooks are included on the Impaired Waters List because they fail to meet the state of Vermont's Water Quality Standards, which were established to protect public health and welfare. These standards identify the types of uses the particular water body should support (such as water supply, swimming, fishing) and the specific criteria necessary to protect those uses. Water quality standards also contain an "anti-degradation policy," which is intended to prevent any further degradation that would compromise existing uses of the water body.

The two brooks in Williston are listed as impaired due to excessive amounts of sediment from erosion, nutrient pollution, bacteria (an indicator of water-borne diseases), and toxic contaminants from stormwater runoff. The state's surveys of fish and macroinvertebrate populations, common indicators for detecting water pollution, demonstrate that the brooks do not currently meet Vermont Water Quality Standards.

The water quality problems stem from land-based activities and are common in an urbanizing landscape. Each development project adds more impervious cover, contributing to stormwater runoff, and thus making the current water quality conditions potentially worse. The growing amount of impervious cover produces greater volumes of water that runs off the land into the stream, picking up contaminants along the way. Increased runoff at greater velocities is causing significant bank erosion and increased flooding.

The Town of Williston, in conjunction with the Vermont Agency of Natural Resources ("ANR") and the U.S. Environmental Protection Agency ("EPA"), is required to produce a plan to restore Allen Brook using pollution control actions. These actions would likely be implemented town-wide, and include several in which you may be interested, such as:

- Local stormwater regulations;
- "Better Site Design" standards; and,
- Riparian buffer initiatives applied to all tributaries.

The first restoration plan will be carried out on Allen Brook, which is degraded but not so significantly that it would be difficult to clean it up. The steps necessary to restore Allen Brook today are doable, affordable, and have a high chance of bringing Allen Brook into compliance with the Vermont Water Quality Standards. ANR has retained the services of a team of experts who are assessing the condition of Allen Brook, involving the public in their work, and developing the restoration plan.

We wish to invite Williston's development community to participate in the restoration efforts for Allen Brook and the town planning process for the protection of these water resources. We hope that you can attend a meeting on September 12, 2001 at the Williston Town Hall at 7:00 PM. We plan to describe the project, present the preliminary results of the assessment. In addition, we wish to hear about any questions or concerns that you may have. We also welcome any ideas on how you can help in the restoration effort.

**Minutes, Williston Conservation Commission Meeting:** Approved 11/07/01

**Williston Conservation Commission**
**Minutes of October 17, 2001**

1. **Call to order**: 7:10AM
**Members present:** Mike Harris, Gary Hawley, Jean Kissner, Bill Skiff
**Members absent:** Richard Pritsky, Beth Wright, Carl Runge
**Staff present**: Amy Cantor
**Others Present**: Kari Dolan, Bob Kort, Allen Brook Consultants
**2. Approval of Minutes:** Mike moved to approve the minutes of October 3, 2001. Bill seconded. Passed unanimously.
**3. Update of Current Projects under Review:**
SUB-01-03 Page: The project was approved by the DRB

- SUB-02-02 Engisch: The WCC said getting this section of trail is key because there are a number of easements in the area. Only a small piece will still be needed to link a significant portion of trail.
- SUB-02-06 Village Associates: Mike said he spoke with the developer and they will include the streams on the plan. All proposed development appears to be outside the stream buffer.

**4. 2003 Budget:** Amy said that it is time to put in requests for the 2003 budget. The WCC said they would like to again try to increase staff time. They would like to be able to offer a position with more hours and with benefits in the hope of reducing the turnover in the position. Members will speak to Mike Munson and Neil Boyden about needs for increased time in their departments that could be part of the liaison position.
**5. Isham:** Isham is scheduled to go to the Selectboard for final approval on October 25. The closing can occur shortly after the approval is obtained. Amy will work on setting up a thank you celebration and gathering to take place after the closing.
**6. Mud Pond:** The management plan is being passed onto the Selectboard for their approval.
**7. Five Tree Hill:** Amy reported that Seth Coffey, WVPD, has finished blazing the boundaries. She also showed the WCC the signs, which arrived earlier in the week. She and Seth will be going out in early November to post trail and boundary signs. Gary reported that he had seen a group of Mountain Bikers entering the trail at Five Tree. He said he spoke to the group who seemed to be under the impression that it was now ok to bike there because of the ongoing negotiations. Gary told them that when the no biking signs are removed that will mean the trails are open and not before.
**8. Allen Brook Project:** Kari Dolan and Bob Kort, consultants on the Allen Brook Project, came to update the WCC on the project and answer questions. They explained that the project is looking at the condition of the stream and working with the state to create a TMDL plan for the stream. They said that the Town has asked for specific recommendations and ordinance language to assist in implementing changes. Kari said that they have gone through the existing Town Plan and zoning regulations and have suggested where changes can be made. These will be available to the Town shortly. Most of the changes are related to improving stormwater treatment and controlling erosion. They said the erosion control is especially important during construction and that existing state standards are not doing a good enough job. The WCC said they would support making these types of changes.
**9. Next Meeting: November 7, 2001**
**10. Adjourned: 9:10AM** ; minutes submitted by A. Cantor, Conservation Commission Liaison

**Minutes, Second Williston Conservation Commission Meeting:**

**Approved March 6, 2002**

**Williston Conservation Commission**
**Minutes of February 20, 2002**

1. **Call to order**: 7:00AM
**Members present:** Mike Harris, Gary Hawley, Jude Hersey, Jean Kissner, Carl Runge, Bill Skiff
**Members absent:** Richard Pritsky
**Staff present**: Amy Cantor
**Others Present**: Kari Dolan, Lori Barg, Bob Kort, Allen Brook Consultants (8:15AM).
**2. Approval of Minutes:** Carl moved to approve the minutes of January 16, 2002. Bill seconded. Passed unanimously.
**3. Update of Current Projects under Review:**

- SUB-02-10 Brownell Mountain Corp: Amy reported that final plans have not been submitted. Carl reported that he spoke with the owner and felt the siting of the project as they described it was fine. Since he will be out of town for several weeks he will put together findings which can be modified if submitted plans are different than expected.
- SUB-02-19 McMaster: Gary was not able to attend the meeting because he was ill. Amy will find out what happened with the project.
- SP-02-21 Wamsganz: An easement will be needed for the bike path.
- SP-02-22 Berlin City: Amy reviewed this project. It is a car display area. They are outside of the wetlands. Amy will check with Scott about the lot coverage.
- SP-02-23 D&D Enterprises: This project is being held up until a wetland delineation can be done.
- SP-02-24 Agway: An easement for the bike path will be needed.

**4. Liaison report:** Amy reported that she has been working on a grant for Sucker Brook
**5. Mud Pond Guide Printing:** Amy handed out copies of the new trail guide. She said she plans to have a box built for the trailhead similar to the one at Five Tree Hill.
**6. Cost of Growth Study:** The WCC discussed the Cost of Growth study. Members were concerned that the study did not adequately illustrate the school side of the issue. In particular when a new school is needed. Amy said she had spoken with Mike Munson about the study. He indicated that he has run several scenarios and the methods appear to work correctly.
**7. Five Tree Hill Trail Map:** The WCC looked at the Scout proposal to create a trail map for Five Tree Hill. Members agreed that it is a good project. Amy said she will work closely with the Scout to make sure we have a usable product. The focus will be on mapping the trails, not interpretation like the Mud Pond guide. Mike moved to accept the proposal from Steven Behun to create a trail guide for Five Tree Hill. Carl seconded. Passed unanimously.
**8. Telecommunication and Ridgeline Ordinance Updates:** Amy reported that both are still going through the process with the Selectboard.
**9. Ezerman Property:** There is nothing new on the project. Mike said he had sent an email recently inquiring how thing were going to Mike Mauss and Jacob Glaser, but has not had any response.
**10. Allen Brook Study:** Kari Dolan, Lori Barg and Bob Kort spoke to the WCC about the recommended changes to the Town Plan and Zoning and Subdivision regulations. They also said that the State will be sending letters out in April that they will be looking at existing stormwater

systems to make sure they match what was originally in the plans. In some cases these letters will go to homeowners associations. In an effort to educate the homeowner associations and give them an understanding of why this is happening the consultants would like to have a meeting for the associations. Jude said she would be interested in helping to organize this meeting and getting a list of associations together. The consultants also handed out some additional information on buffers and site design. Jean asked what are the most important things to tackle because the WCC had been given a lot of information. Kari listed four areas. 1. Improve the buffer ordinance. She said the tributary and intermittent streams are important for water quality. 2. Erosion Control. The State regulations are outdated. A large amount of sediment is released into streams during construction. 3. Adopt a stormwater management ordinance. Many stormwater systems are not affective if they are not maintained. 4. Adopt the draft 2002 Vermont stormwater regulations.

**11. Next Meeting: March 6, 2002**

**12. Adjourned: 9:00AM**

minutes submitted by Amy Cantor, Conservation Commission Liaison

**Article, Announcing Public Meeting with Homeowner Associations:**

March 21, 2002, Williston Whistle

# Allen Brook restoration meeting scheduled

Williston homeowners and their associations can learn about efforts to restore Allen Brook and Muddy Brook during a meeting at Town Hall on Monday, March 25 from 7 p.m. to 9 p.m.

The state of Vermont has identified the streams, which both flow through town, as polluted. The water quality problems are due to excessive amounts of sediment and bacteria (an indicator of water-borne diseases).

Also on the agenda is the state's stormwater program, which addresses water quality problems facing Vermont communities.

For more information, call Kari Dolan, Allen Brook Restoration Project coordinator, at (802) 229-0650 or send e-mail to dolan@nwf.org. Amy Cantor, Williston Conservation Commission liaison, also has information on the restoration efforts. She can be reached at 878-6704 or cantora@willistontown.com.

**Article, Describing Homeowner Meeting:**

April 18, 2002, Williston Whistle

# State may force stormwater costs on homeowners

## Some Williston subdivisions violate runoff regulations, pollute local streams

By Tom Gresham

Homeowners in subdivisions that fail to meet state stormwater runoff standards may have to pay for bringing their neighborhoods into compliance.

That surprising revelation was made during a recent meeting at Town Hall to discuss water quality problems associated with Allen Brook and efforts to clean up the stream. Attending the session were state and local officials and representatives of several Williston homeowners' associations.

The informational portion of the meeting regarding efforts to clean up Allen Brook inspired little controversy. However, when discussion turned to the prospect of homeowners being forced to foot the bill for stormwater improvements in their neighborhoods, tension filled the room.

Allen Brook qualifies as one of 26 stormwater-impaired watersheds in Vermont. Development near Allen Brook has led to increased stormwater runoff into the waterway.

Stormwater permits for many Williston developments have expired and some stormwater controls for those neighborhoods no longer meet state requirements. With the developers departed for other projects, the task of bringing those controls back up to code could fall on the individual homeowners.

"I think there's probably a lot of frustration for the homeowners," said Kari Dolan, outreach coordinator for the National Wildlife Federation's regional office. "The developers went in and created these developments. They went in front of town (boards) and agreed to put in the right stormwater controls, and they said they would be maintained.

"But after three years most stormwater ponds are ineffective. They have to be maintained. The developers built these places and left and the homeowners got caught holding the bag."

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## Stormwater

CONTINUED FROM PAGE 1

Bill Sheedy, a resident of the South Ridge neighborhood who attended the March 25 meeting, said it doesn't seem right to him that homeowners would be responsible for stormwater controls.

He asserted that a residential development in which the town owns the streets should not be considered the same thing as a condominium or commercial development, where an association or business owns the streets and other common facilities.

"Because of the fact that the deeds were turned over by the developers to the town, it seems to me the maintenance of the stormwater should stay with the town," Sheedy said. "I don't disagree with the need to control stormwater, but there are a lot of questions there."

The unwelcome news for homeowners came as the state attempts to clear the backlog of approximately 1,000 stormwater permits that have expired.

In order to receive a so-called "watershed improvement permit," a subdivision may have to comply with the original permit's requirements for stormwater discharges.

Unfortunately for homeowners, many stormwater control systems in subdivisions are now ineffective and need maintenance, according to Dolan. In a few rare instances, required stormwater controls were never put in place by the developer.

"Developers transfer the permit to the homeowners' associations," said Amy Cantor, a staff member for the Williston Conservation Commission. "Some bylaws say very clearly that the homeowners are responsible for stormwater discharges. Others are not so clear. That's why there are some homeowners who didn't realize there was this possibility."

Jim Pease of the state Stormwater Program said there are roughly 100 stormwater permits in Williston, most of them affecting either Allen Brook or Muddy Brook, both stormwater-impaired watersheds.

Allen Brook has been the focus of a pilot program for treating stormwater-polluted watersheds.

The study started last spring and should be finished in the fall, according to Pease. The March 25 meeting acted as an early explanation of the study and its potential effects.

Pease said there would be another meeting this summer in which all stormwater permit holders — residential and commercial — will be invited to attend. A public hearing on the general permit plan is tentatively set for the fall.

One potential solution to stormwater runoff in

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Williston is a townwide stormwater system. Residents would be billed for the service as they are for water and sewer service.

"It's something they do in larger municipalities," Pease said. "We are studying the possibility of having a stormwater plan with municipality-wide services. We're going to try to study it for a lot of towns in the state.

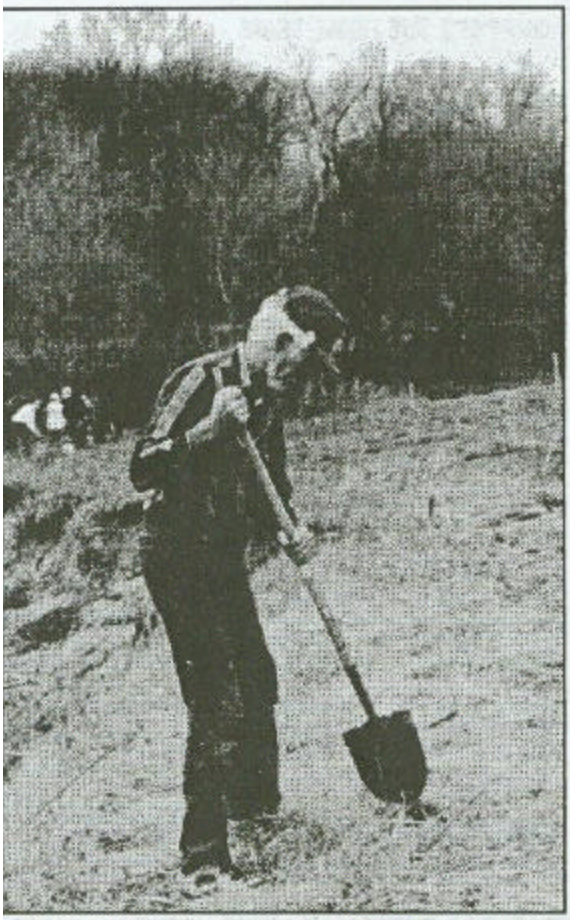
I think a lot of homeowners, given the legislative and maintenance headaches, would be willing to vote for a $36 annual fee or something like that. It's certainly a possibility in Williston."

Sheedy said that with the many questions around the stormwater issue, it was important that the town and its residents work to find a collaborative solution.

"I think it's important that we have a good, open discussion about this and that we move forward together," Sheedy said.

**Article, Describing Buffer Planting Conducted by the local Rotary Club:**





# Do-gooders

*Members of the Williston/ Richmond Rotary Club recently planted trees along Allen Brook in order to stabilize the stream's banks and prevent erosion. At left, Ken Stone readies a spot for planting. Below, Rotary Club President Bill Roberts (right) and another club member make sure a sapling is rooted. The Rotary Club, along with several Williston Federated Church members, also recently built a 32-foot ramp for a Williston couple that needed the structure to get in and out of their home. (Contributed photo)*

**Article, State Stormwater Rules and the Allen Brook Restoration Project:**



May 30, 2002, Williston Whistle

# Towns cope with flood of new stormwater rules

By Tom Gresham

Stormwater seems benign on the surface. When it rains or snows, stormwater seeps and flows. It often escapes notice.

However, in Chittenden County, stormwater appears poised to assume a position at the forefront of municipal concerns. The prospect of mandatory improvements in stormwater runoff has many town officials in the state's most populous region bracing for the burden that could soon rest on their community's shoulders.

"Oh, yeah, it could be very expensive," said Shelburne Town Manager Paul Bohne. "It could mean treating any amount of water before it runs into streams and waterways. We could be required to treat every drop of that. The task could be huge."

Charles Hafter, South Burlington's city manager, believes, "Our single biggest concern the next few years is going to be stormwater."

The state of Vermont has 126 surface water bodies on the 2000 list of impaired waters, according to a white paper issued by the Chittenden County Regional Planning Commission in March. Of the impaired waters, 25 receive their pollutants principally from stormwater runoff. Twelve of those waters are located in Chittenden County.

The high concentration in the county results from its relatively developed state as compared to the rest of Vermont.

Significant levels of development usually lead to: increased amounts of pollutants on ground surfaces, where they are vulnerable to being absorbed and transported by stormwater; increased impervious land coverage — e.g. streets, parking lots, sidewalks — which aids stormwater in its travels; and reduced vegetation and other pervious surfaces, which when present can help filter out pollutants before the stormwater reaches waterways.

"Stormwater is something that people have perceived as being free, but it's not," said Juli Beth Hoover, South Burlington's director of planning and zoning. "There are hidden costs — pollution, damage to property — that happen over time."

Many communities will face both federal and state mandates to improve stormwater runoff problems in the coming years. Eight Chittenden County municipalities (Burlington, Colchester, Essex, Essex Junction, Shelburne, South Burlington, Williston and Winooski) meet town size criteria set by the Environmental Protection Agency for the adminstration of stormwater requirements. The requirements were developed as a result of the federal Clean Water Act.

*Most people think of stormwater only when it floods roads. But water running off parking lots, building roofs and other areas also pollutes rivers and streams.*

### WILLISTON HOMEOWNERS FACE PROBLEM, TOO

The watershed improvement permits appear certain to cost municipalities with affected waterways, but homeowners and businesses could be hit as well.

The state has made it clear through a pilot program in Williston designed to clean up the Allen Brook that homeowners' associations will be bound to foot the bill for stormwater upgrades in their neighborhoods. During a March meeting, the state informed a collection of Williston homeowners of their possible financial responsibility. They did not hide their displeasure.

When developers construct a development, they earn a stormwater permit based on their promise to install facilities to control runoff. Often this means a holding pond. However, once the developers leave, the permits are transferred to the homeowners associations. Homeowners' groups become responsible for the upkeep of their stormwater facilities. Kari Dolan, an outreach coordinator for the National Wildlife Federation's Northeast office, points out that a stormwater pond must be maintained to remain efficient.

"I think there's probably a lot of frustration for the homeowners," said Dolan, who described the Williston meeting as "electric." "The developers went in and

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## Stormwater

CONTINUED FROM PAGE 12

created these developments. They went in front of town bodies and agreed to put in the right stormwater controls and they said they would be maintained.

"But after three years most stormwater ponds are ineffective. They have to be maintained. The developers built these places and left and the homeowners got caught holding the bag."

Homeowners' associations in other communities will surely face the same questions that have surfaced in Williston. However, Bohne notes that most homes and neighborhoods are not members of homeowners associations.

"Ultimately, (the towns are) probably going to be responsible for those," Bohne said.

### TOWNS SEEK COOPERATIVE SOLUTIONS

Further complicating matters is the fact that stormwater runoff for a single body of water can include sources from several municipalities. Bohne said that towns will have to cooperate in order to make progress in these bodies of water (such as Shelburne Bay).

Lutz believes that stormwater upgrades in urban areas will prove to be more expensive than those in suburban environments because of the limited space available in urban communities for stormwater improvements. He said open land offers possibilities for easy installation of stormwater ponds or other measures.

For example, Essex may have a simpler task than neighboring Essex Junction, a much more densely populated community (Essex: 323 residents per square mile; Essex Junction: 1,753 residents per square mile).

"I think it's pretty clear that the more built up the area, the harder it's going to be," Lutz said.

A possible long-term solution to stormwater runoff is the creation of either a regional stormwater utility, which would serve multiple communities, or a single municipal stormwater utility, which would serve a single community. The state and some individual communities are performing studies to examine the possibilities.

Pease believes a stormwater utility could prove to be an affordable stormwater option, whether the utility serves a region or a single community.

Hoover said South Burlington already possesses stormwater facilities capable of accomodating a utility. However, she does not believe that a regional utility encompassing most of Chittenden County has a very good chance of being realized.

Officials of the various municipalities agree that their time of reckoning on the stormwater issue is here.

"This is going to be a major issue for everbody," Lutz said. "Every once in a while, there's a big hot-button issue. Fifteen years ago, it was wastewater. Now it's

## Muddy Brook

CONTINUED FROM PAGE 3

the Environmental Board denied a request by the Friends of Muddy Brook Basin to further participate in the appeal process.

The Selectboard has until June 14 to decide whether it will continue to fight the development planned for the corner of Van Sicklen and Hinesburg roads.

The board was unable to make a decision at the special meeting on May 20 because member Ginny Lyons, also a state legislator, was not present. Also in attendance was the town's legal counsel and representatives from the Snyder Companies.

A special meeting to discuss the appeal is tentatively scheduled for the evening of June 6 at the Williston Town Hall.

**Minutes, Williston Planning Commission Meeting:**

**TOWN OF WILLISTON PLANNING COMMISSION**
**WILLISTON TOWN HALL**
**June 18, 2002**

**MEMBERS PRESENT:** Steve Bradish, Judy Sassorossi, Kevin Batson, Ted Kenney, Bob Bickford
**MEMBERS ABSENT:** Scott Luria, Sharon Gutwin
**OTHERS PRESENT:** Mike Munson, Dave Libby, Kari Dolan, Bob Court
**AGENDA:**
1. Approval of Minutes of May 21, 2002
2. Introduction of New Members
3. Public Hearing: Proposed Changes to the Industrial District
4. Meet with Kari Dolan and Team Studying Allen Brook
5. Discussion of Preparations for an AR District Display Table July 4
6. Other Business and Correspondence
7. Future Meetings
8. Adjournment

Chair Sassorossi called the meeting to order at 7:25 p.m.

**1. APPROVAL OF MINUTES OF MAY 21, 2002**

The approval of the minutes was deferred until a later meeting.

**2. INTRODUCTION OF NEW MEMBERS**

Mr. Munson introduced Steve Bradish, Kevin Batson, and Ted Kenney as new members of the Planning Commission. He explained that Scott Luria, the fourth new member, had a long standing commitment for tonight and was unable to be present for this meeting.

**3. PUBLIC HEARING: PROPOSED CHANGES TO THE INDUSTRIAL DISTRICT**

Chair Sassorossi opened the hearing at 7:30 p.m. by reading the warning.

Mr. Munson explained that the proposed changes were originated by IBM. They had wanted to subdivide a lot but the current regulations require a 15' setback with no structures. IBM wished to build connecting walkways between the subdivided lots and this would not be allowed under the current regulations because of the 15' setback. The best way to address this issue was to amend the zoning ordinance.

Mr. Munson noted that the industrial district had been divided into two parts. The northern district, consisting of IBM, would permit structures within the setbacks. Permitted uses in this district had also been changed.

Dave Libby, IBM representative, stated that he felt that the new setback requirements were excellent. However, IBM did have a few concerns.

Mr. Libby noted that one of these concerns was the fact that wholesale distribution was a conditional use. They occasionally had building equipment and/or spare parts that they might want to store for disposal. This could be perceived as wholesale distribution. Chair Sassorossi explained that conditional use does not deny the use, it means that IBM would have to obtain a conditional use permit from the DRB.

Mr. Libby stated that restaurants had been changed from permitted to conditional use and questioned if this would prohibit use of their corporate cafeteria by another company who might purchase or rent buildings on their property. Chair Sassorossi explained that they were trying to eliminate additional traffic to the site as a destination for shopping and dining. She felt that a

facility serving only the employees on the site would be permitted. Mr. Libby suggested a footnote to this effect.
Chair Sassorossi stated that the Planning Commission should consider corporate cafeteria as a separate category when they are revising the use table.
Mr. Libby stated that he was not concerned with outside storage, however, they might want to consolidate equipment from other lots for disposal on one lot. He was concerned that this would be prohibited the way the proposed amendment is written. Mr. Munson suggested handling this issue with a footnote that inside storage of equipment owned by the owner of the business was permitted.
There was no public input.
A **MOTION** was made by Ted Kenney, SECONDED by Kevin Batson, to close the public hearing.
**VOTING:** 5 ayes, motion carried.
The public hearing was closed at 7:53 p.m.
Chair Sassorossi stated she felt that they should address the corporate dining facilities in the use table particularly since this will not be an issue for IBM until after the use table revision is finished.
Mr. Munson noted that the Planning Commission wanted to prevent wholesale distribution in the district. However, leaving wholesale distribution as a conditional use would allow IBM to distribute their obsolete equipment. Chair Sassorossi agreed and noted that distribution of obsolete equipment by IBM could be handled administratively.
Mr. Munson stated that he felt that storage issue could be handled with a footnote stating "in the Industrial B District, inside storage of equipment from other lots is permitted if the equipment stored is owned by the owner of the business". Chair Sassorossi suggested that nearby lots be added.
Chair Sassorossi noted that the Planning Commission might want to think about shared parking in the other industrial district at a later meeting. For Industrial B, it could be treated the same as storage with a footnote.
A **MOTION** was made by Steve Bradish, SECONDED by Ted Kenney, that the proposed changes to the Industrial District be forwarded to the Selectboard with the changes made at this meeting and with the recommendation that they be approved.
**VOTING:** 5 ayes, motion carried.

**4. MEET WITH KARI DOLAN AND TEAM STUDYING ALLEN BROOK**

Kari Dolan explained that Allen Brook had been chosen as a pilot project for restoration of waterways with water quality problems in the State of Vermont and explained the project.
Ms. Dolan noted that they had prepared a report that identifies the problem areas in Allen Brook and made recommendations for Williston. In preparing the report, they had reviewed all of Williston's regulations including the stream buffer ordinance, Public Works specs, and the zoning ordinances. They also met with the Selectboard, the Conservation Commission, and homeowners associations as well as holding community meetings.
Mr. Munson stated that recommendations from the report could be incorporated into the zoning ordinances.
Ms. Dolan mentioned that there is a new manual from the State on how to design state of the art stormwater ponds.
Bob Court stated that the biggest problem with stormwater ponds in that they are not designed well and/or maintained.

Mr. Munson pointed out that in Phase 2 of the Water Quality Act, towns are required to prepare plans addressing six ways to correct water quality problems. These include such things as education of the public and construction site erosion control.
Ms. Dolan stated that construction erosion is one of the most important items to address. Mr. Court noted that if erosion is prevented then it will not be necessary to clean sediment from the ponds.
Mr. Munson mentioned that he felt education should be on a regional level.
Ms. Dolan commended the Planning Commission on their stream buffer ordinance as she felt it was a leader in the State. She urged the Commission to include all tributaries in the ordinance as they have impact on what is going into Allen Brook. At present, only named tributaries are included.
Mr. Bradish noted that all of the drainage from the village goes into Allen Brook and asked how this could be fixed. Mr. Court answered that there are some wetlands by the school to filter the drainage. They also addressed retrofitting in their recommendations. Chair Sassorossi said that this would be a good science project for the upper houses in the school.
Chair Sassorossi asked if subterranean systems would work for new developments as she wondered if soils could be created to make them work. Mr. Court noted that dry wells will work if soils are the right type. If the soils are tight, under drains and sand filters can be used.
Mr. Batson asked what the biggest problem will be. Ms. Dolan replied she felt the biggest problem was prioritizing and making recommendations for stormwater runoff and pollution prevention. Mr. Court stated he did not believe they could tell what the biggest problem will be as they are looking at this issue at the present time.
Mr. Munson mentioned that the study will be completed in the fall and the Town will reviewing the inclusion of recommendations in their ordinances in the next two-three years. He stated he hoped that the study team would be available to help in this process.

**5. DISCUSSION OF PREPARATIONS FOR AN AG/R DISTRICT DISPLAY TABLE JULY 4**

Mr. Munson stated that it was going to be difficult to staff a display all the time. They would have to develop a display that did not need to be staffed with perhaps a box for questionnaires.
Chair Sassorossi said she felt that a display on July 4 was a great idea, however, she felt that they were not able to do it this year. She suggested deferring until next year. The Commission was in agreement with this.

**6. <u>OTHER BUSINESS AND CORRESPONDENCE</u>**

Mr. Munson noted that there should be two citizen representative on the Pecor Property Future Development Study Committee. It had been suggested that Larry Jackson and Jay Pitrillo who had been applicants to the Planning Commission be appointed to this Committee.
Mr. Munson stated that letters had been sent to all the homeowners associations asking for volunteers to the Committee. The only volunteer they had received was Greg Dominque from Chelsea Commons.
Mr. Bradish said he felt that the two representatives should be people that are closely associated with the property.
A **MOTION** was made by Ted Kenney, SECONDED by Steve Bradish, to appoint Larry Jackson and Greg Dominque to the Pecor Property Future Development Study Committee.
**VOTING:** 5 ayes, motion carried.
Mr. Munson noted that the Selectboard is considering the ridgeline ordinance amendments and are making proposals for several minor changes. The Town attorney stated that these changes

will not require the ordinance to be sent back to the Planning Commission for another public hearing. However, the Planning Commission will need to comment on the changes and the Selectboard will have to hold a second public hearing.

**6. FUTURE MEETINGS**

The Commission agreed to hold an orientation session for the new members on either July 2 or July 16.

Mr. Munson reminded the Commission that they need to hold an annual reorganization meeting.

**7. ADJOURNMENT**

A **MOTION** was made by Steve Bradish, SECONDED by Kevin Batson, to adjourn the meeting.

**VOTING:** 5 ayes, motion carried.

The meeting was adjourned at 9:55 p.m.

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Minutes Submitted by Ann M. Gray

THESE MINUTES ARE SUBJECT TO CORRECTION BY THE PLANNING COMMISSION. CHANGES, IF ANY, WILL BE RECORDED IN MINUTES OF SUBSEQUENT MEETINGS OF THE COMMISSION.

## Appendix F: Recommendations for Changes to Local Ordinances

### i. Recommended Text for Williston

We evaluated the Town of Williston's local ordinances, specifically the: "(1) Conservation/Open Space and Watercourse Protection Overlay District" (to be referred to as the Buffer Ordinance); (2) 2000 Comprehensive Plan; (3) Subdivision Regulations; (4) Zoning Ordinance, Amended 2000; and, (5) Public Works Standards and Specification, 1997. We considered and tried to integrate the comments on draft recommendations that we had received at various public meetings. We offer the following observations and recommendations to enhance these ordinances. To assist in identifying our recommendations, we italicized our suggestions.

### 1.0 Conservation/Open Space and Watercourse Protection Overlay District (Buffer Ordinance)

<u>1.1 Identify other important values of buffers.</u>
Williston Zoning Ordinance, Article III, Section 3.11.1 Purpose
We recommend adding language to the second sentence of the stated purpose to read:
"It is the purpose of this district...to protect non-nuisance aquatic habitat, *to protect and maintain native vegetation in the riparian area, to provide tree canopy to shade streams, to stabilize streambanks, to reduce erosion, to protect, restore, and maintain the chemical, physical, and biological integrity of water resources,* and to promote the goals of pollution prevention, and the public health."

<u>1.2 Add definitions of a stream and buffer zone to the ordinance to match the State of Vermont's draft Riparian Buffer Procedure.</u>
Williston Zoning Ordinance, Article III, Section 2.3.11 D
The State of Vermont Agency of Natural Resources recently released a draft Riparian Buffer Procedure. To be consistent with the state buffer procedure, the Town's ordinance should include a definition of a stream and have all references to "unnamed streams or brook tributaries" be changed to state: "…top of bank of *streams that are unnamed or brook tributaries, …*" The state definition of a stream is as follows:
**Stream:** The full length and width, including the sediment bed and banks, of any moving watercourse, including creeks, brooks, rivers, branches, and kills. A stream has a channel, whether natural or artificial, that periodically or continuously contains moving water, has a defined bed, and has banks that serve to confine water at low to moderate flows. Typically streams support communities of plants and animals within the channel and the riparian corridor vegetation zone. Within the definition of stream are included intermittent and ephemeral streams. The following are offered to make this distinction: **Intermittent streams** have a defined channel and evidence of sediment transport (scour or deposition) but usually do not have surface water flow throughout the year and/or throughout the channel. Often the surface flow is reduced to a series of separated pools, with subsurface flow through riffle areas, for all or part of the year. **Intermittent streams** include ephemeral streams that have a defined channel with evidence of sediment transport. **Ephemeral streams** are streams that carry surface water during snowmelt or in response to precipitation events. Ephemeral streams may or may not have a defined channel and evidence of sediment transport. These watercourses are above the water table.

We recommend adopting the State's definition of riparian buffer zone, which is: "The width of land adjacent to streams or lakes between the top of the bank or top of slope or mean water level and the edge of other land uses. Riparian buffer zones are typically undisturbed areas, consisting of trees, shrubs, groundcover plants, duff layer, and a naturally vegetated uneven ground surface,

that protect the water body and adjacent riparian corridor ecosystem from the impact of these land uses."

1.3 Protect tributaries.
A. Conservation/Open Space Lands
Williston Zoning Ordinance, Article III, Section 2.3.11, D
Protecting the smaller streams that are unnamed or tributaries with an adequate buffer ordinance can be just as important as establishing one on the stream's main tributary. Often, the smaller streams are more vulnerable to hydrologic impacts related to increases in impervious cover. Moreover, activities that create instability at the tributary can contribute to water quality problems downstream on the main channel. Therefore, towns need to protect their tributaries in order to improve the health of the watershed. For example, Tables Two and Three in the report, *Watershed Improvement Plan and Recommendations for a TMDL for Sediment, Allen Brook*, list four tributaries that are unstable and in need of greater protection.

The amount of impervious cover is a concern because impervious cover prevents infiltration of water into the soil, forcing more water to move at higher speeds into watercourses, potentially causing erosion. In addition, runoff picks up pollutants from the hard surfaces, such as dirt, litter, oil from cars, salts, and bacteria. Greater runoff and less infiltration also result in less recharge of groundwater, which is essential for keeping streams flowing during dry weather.

The State of Vermont's draft Riparian Buffer Procedure applies to all streams. Therefore, we recommend applying the buffer ordinance fully to the streams that are unnamed or brook tributaries, which will be consistent with the State's draft riparian buffer procedure. Thus, D should read: "All lands within *100 ft* of the top of the bank of the *streams that are unnamed* or brook tributaries..."

1.4 Update town maps to show mainstem and tributary buffer protection.
Many participants at various public events concerning the Allen Brook restoration project asked for maps to show the applicability of the Town's buffer ordinance. Geographic Information Systems (GIS) maps, ideally at 1:5000 scale and based on ortho-photo data, are important tools to help residents, businesses, and the development community understand where the buffer ordinance applies. The Vermont Center for Geographic Information is in the process of developing surface water data layers at this scale throughout the state and may be a helpful resource for developing such maps.

1.5 Allow for flexibility in buffer width.
Williston Zoning Ordinance, Article III, Section 2.3.11, c, D
The ordinance should provide the opportunity to modify the size of buffer along specific stream or tributary reaches, to better incorporate the 100 year floodplain, steep slopes, presence of existing forested buffer, presence of natural, well vegetated drainage ways, or existence of adjacent wetlands or other critical areas. Wetlands need to be included here because they provide important functions, such as serving as filters to remove a variety of water borne pollutants. In addition, they help control stormwater events and mitigate floods. However, the trend in wetland loss in the county is significant. According the Agency of Natural Resources, 35 percent of Vermont's historic wetlands were destroyed by 1988. Chittenden County lost 65 acres of wetlands between 1990 and 1995 – three times the state average over that time period. We recommend adding to Part 1, Section 2.3.11, C, and D, pg. 2: "*Forested buffers could be extended beyond the 150 foot buffer to encompass the 100 year flood plain, with a minimum width of 25 ft beyond the edge of the floodplain. Such buffers could also be extended to include wetlands and 25 ft beyond the edge of the wetland*."

1.6 Remove parking lots from the list of permitted uses.
Williston Zoning Ordinance, Article III, Section 3.11.2, C, Permitted Uses
Parking lots should not be an acceptable use of the buffer, which would compromise the water quality filtering and shading functions of the buffer. In fact, the impacts from transportation-related impervious cover, parking lots and roads, can be quite significant when they are directly connected to the stormwater collection system. In addition, the runoff from roads and parking lots is more contaminated, carrying with it oil, grease, and anti-freeze from leaking cars, as well as heat, grit, and litter. We acknowledge that the ordinance requires that parking lots be at least 100 ft from named streams. However, we recommend removing parking lots from the list of permitted uses.

1.7 Provide some additional buffer protection from recreational paths.
Williston Zoning Ordinance, Article III, Section 3.11.2, D, Permitted Uses
Running a path next to the river can result in the removal of tree canopy, which is essential for stream shading and habitat functions of the stream and riparian area. Moreover, streams naturally meander laterally, which could compromise the integrity of path and become expensive to repair. Therefore, we recommend: "Recreation paths which are open to the public, and bridges associated with such paths, *provided that there is at the minimum of 25 ft between the recreational path and the top of bank to preserve the purpose of this watercourse protection overlay district, described above*."

1.8 Provide some specific practices for minimizing runoff from paved paths and parking areas.
Williston Zoning Ordinance, Article III, Section 3.11.6 A. 2 and 3, pg. 4
There should be some suggested practices to minimize runoff associated with paved paths (and parking areas). The 2001 Vermont Stormwater Management Manual Public Review Draft, beginning on page 4-6, contains guidance on how to ensure that the impervious surface of the path does not create a stormwater problem that would compromise the integrity of the buffer. We recommend adding to Section 3.11.6 A. 2.: "Pavement associated with public recreation paths...to minimize runoff into the adjacent watercourse, *using guidance contained in the 2001 Vermont Stormwater Management Manual Public Review Draft. Require practices to minimize runoff, such as, though not limited to: discouraging the use of curbing, using pervious materials, installing vegetated filter strips and directing flow into vegetation, and applying level spreaders. These techniques help to ensure that the runoff will enter the buffer as sheet flow (or less than 0.25 ft per second) to increase infiltration*."

If Williston eliminates parking as a permitted use, this section could be deleted. Otherwise, combine parking to Section 3.11.6 A. 2: "Pavement associated with public recreation paths *and parking areas*..."

1.9 Place additional protections regarding buffer crossings.
Williston Zoning Ordinance, Article III, Section 3.11.6 A. 9. c2
Breaks in the riparian buffer need to be minimized, in order to maximize the buffers ecological value for instream habitat, shading, and as a wildlife travel corridor. In addition, the impact of the stream crossing to channel functions could be minimized through application of techniques that leave a natural channel bottom. This technique includes the use of bridges and structural plate steel arches. We also recommend adding additional conditions for buffer crossings, such as: "*The crossing frequency – the number of District crossings within each subdivision – should be minimized and should not exceed one crossing for every 1000 ft of buffer. Crossings should be located on gently sloping terrain (less than 5 percent) where possible. Impact of the stream crossing should be minimized by installing, where feasible, bridges and open-bottom culverts.*" See, The Architecture of Urban Stream Buffers, pg. 4-5.

1.10 Discourage encroachment.
Williston Zoning Ordinance, Article III, Section 3.11.6 B
To be consistent with our recommendation to apply this ordinance to tributaries, this section should be modified to read: "Encroachment of the *100* foot tributary buffers.…" In addition, this section needs to reflect the position that encroachment is really an option for handling existing structures. We approve of the hardship clause under 3.11.6 B. 3, however, the ordinance should discourage the use of waivers for new developments and require that all new developments comply with the buffer ordinance. We recommend introducing the opportunity for encroachment with a statement that reads: "*The intent of encroachment is to allow for the presence of existing structures. Existing structures should not compromise the purpose of the ordinance*."

Encroachment is a particular threat during construction. Therefore, we recommend adding steps to prevent encroachment: "*(a) Construction plans must illustrate buffer limits, (b) the buffer location must be staked before construction begins, (c) silt or snow fences and signs preventing entry to the buffer must be used to limit disturbance during construction, and (d) contractors must become familiar with the location of the buffer*."

1.11 Remove the buffer averaging policy.
Williston Zoning Ordinance, Article III, Section 3.11.6 C. 1.b. Mitigation Plan for Encroachment
Buffer averaging is a technique that is used in limited circumstances, such as to accommodate an existing structure or to recover a "lost lot." The problem with buffer averaging is that it tends to compromise the very functions that a buffer ordinance is trying to protect, namely, protection of water quality, aquatic and terrestrial habitat, stream channel stability, flood control, and aesthetic and recreational values. Buffer averaging also provides the unfortunate incentive to develop a site prior to securing local permits. The unintended result could be a development with more land in the buffer zone, but of poor quality due to "holes" from structures located within the buffer zone. The State's draft Riparian Buffer Procedure does not allow for buffer averaging, and defines buffer zones to be: "undisturbed areas, consisting of trees, shrubs, groundcover plants, duff layer, and a naturally vegetated uneven ground surface, that protect the water body and adjacent riparian corridor ecosystem from the impact of these land uses." The intent of the state's procedure is to establish quality buffers – continuous, uninterrupted, well-functioning streamside zones. We recommend eliminating buffer averaging as an option.

1.12 Give special attention to water pollution hazards.
Williston Zoning Ordinance, Article III, Section 3.11
The Buffer Ordinance needs to include a section of water pollution hazards that need setbacks. We recommend a statement, "*Activities and landuses that are potential water pollution hazards must comply with the 150 foot setback from the watercourse. Activities that pose greater health risks, such as raised septic systems because of poorly drained soils, and solid waste landfills must comply with a 300 setback*."

## 2.0 2000 Williston Comprehensive Plan

The Allen Brook Restoration Team evaluated the 2000 Williston Comprehensive Plan. We offer the following recommendations to enhance the local management of stormwater runoff and water quality:

2.1 Specify streamside protection.
II. B. 1. Resource Conservation, pg. 8
Add the following to the third sentence: "Open and natural areas and cultural...woodlands, *riparian or streamside and shoreline areas, slopes and ridges, ...*"

II. B. 3. Development Distribution, pg. 8
Add the following to the first sentence: "The Town will support...by open land, *and away from environmentally sensitive land, such as flood plains, riparian and shoreline areas.*"

2.2 Specify stormwater management.
II. B. 13. Environmental Protection, pg. 11
Add the following sentence: "*The Town will also promote better stormwater management practices to protect watercourses and riparian areas from the impacts of growth*."

2.3 Bring in the concept of watershed and stormwater management.
IV. pg. 18, following A. Trends
The Town Plan should contain a watershed map, showing the major watersheds within the town and adjacent towns – Allen Brook, Muddy Brook, the Winooski River, and Sucker Brook. The section could also contain a map of the general soil types, describing how they affect drainage and erodibility potential. For example, the most erodable soils generally contain fine sands and silt. Clay and organic matter are more binding, and therefore, less susceptible to erosion. Combining information on the watershed, topography, vegetation, and soil type will help to identify environmentally sensitive areas, and sites that are vulnerable to erosion.

The section could describe the concept of imperviousness, showing how the percent imperviousness has changed over time. The section would then describe the objectives of local stormwater management, namely, (a) to improve water quality, (b) to enhance the character of Williston, (c) to reduce property loss through erosion, (d) the provide recreational benefits, and (e) the recover aquatic and riparian habitat conditions. Finally, the section would state that the Town will go about realizing those benefits by encouraging: stormwater retrofitting, pollution prevention, streamside buffer protection, and stream restoration opportunities.

2.4 Minimize imperviousness by having sidewalks on one side of the street instead of two.
IV. C. 3. (3rd paragraph) pg. 32
Sidewalks are important for enhancing a neighborhood's character, providing safe corridors for pedestrians, and encouraging pedestrian travel. However, the Town should look for opportunities to reduce imperviousness. One way is to eliminate redundant pavement by having sidewalks on one side of a street. We recommend that all references to providing sidewalks state that sidewalks should be provided on only one side of the street. Sidewalks are also discussed below under Section 3, *Town of Williston, Vermont Subdivision Regulations* and Section 5, *Town of Williston, Vermont Public Works Standards and Specifications*, below.

2.5 Include a general statement that roads should be designed and built to minimize adverse impacts to watercourses.
VI. C. 4. pg. 63
As stated in Recommendation #5 of the buffer ordinance, parking lots and roads can cause significant impacts to watercourses because they are typically connected directly to the stormwater collection system, and water, running off the road network, carries with it contaminants from leaking cars, sand, litter, and heat. Therefore, we recommend modifying the last paragraph to state: "In general, all roads should be designed...and minimizing adverse impacts on nearby properties, *neighborhoods, and watercourses*."

2.6 Include a reference to a stormwater utility as a possible initiative to achieve the Town's conservation goals.
XI. 9. pg. 99

The benefit of a local stormwater utility is to reduce the impact of stormwater runoff and flooding to watercourses and protect public health, primarily by: (1) efficiently addressing the inadequate management of stormwater that is threatening the health, safety, and welfare of the public; (2) providing regular maintenance and improvements to stormwater practices, ditches, and the local stormwater collection system; (3) raising funds through a fee system to implement actions to correct existing water quality problems and prevent future ones; and, (4) educating property owners and the general public about how they can reduce polluted runoff from their land. We recommend adding the establishment of a stormwater utility as another initiative for the Town to consider as a means to achieve its conservation goals.

The model ordinance listed in Appendix K called, Kitsap County Public Works Stormwater Management Ordinance, 1997, contains good information to consider when establishing a stormwater utility (http://www.kitsapgov.com/sswm/ordinance199.htm). Additional guidance can be found in a document entitled, "How to Create a Stormwater Utility," produced by Pioneer Valley Planning Commission in Massachusetts. You can find the document on their website: www.pvpc.org/library/html/library_envir.html. Also refer to the discussion in the Allen Brook Report entitled, **"How to Succeed in Pollution Prevention by Really Trying**," which describes an interesting alternative to a stormwater utility implemented by the Massachusetts town of Chicopee.

## 3.0 Town of Williston Subdivision Regulation

3.1 Include under maintenance of facilities a statement concerning the maintenance of stormwater controls.

Article IX, Section 950 pg. 28

Maintenance, conducted according to a set schedule, is a vital yet often overlooked necessity for ensuring the proper and prolonged performance of stormwater management systems. The importance of maintenance cannot be overstated. Today's stormwater practices, which typically store and treat runoff, are more complex than their runoff conveyance system predecessors. Regular maintenance can prevent failure of a facility to operate as designed, structural failure that creates a safety hazard, appearance issues, and more. Failure to provide adequate maintenance may even create worse conditions than if nothing had been constructed at all. Therefore, explicitly stating the need to maintain stormwater controls by first the subdivider, to be continued by the homeowner, tenant's association, or other responsible party, may increase the likelihood that maintenance will be continued. We recommend adding: "The subdivider shall be required to maintain all facilities, *including stormwater controls*, and provide for snow removal..." A good source for additional information about maintenance of stormwater systems is the Watershed Management Institute, 1997. "Operation, Maintenance, and Management of Stormwater Management Systems."

3.2 Reference erosion and sediment control measures and ordinance (if adopted), which are described below in the Town "Public Works Standards and Specification" , 1997.

Article X, Section 1010 E pg. 31

Provide a reference to the Town Public Works Standards document: Control measures shall follow the guidelines of the Vermont Handbook for Soil Erosion and Sediment Control on Construction Sites (VT Geological Survey, 1987), *and the Williston Public Works Standards and Specification*.

3.3 Provide a statement on the need to maintain erosion and sediment controls before, during, and after construction.

Article X, Section 1010 pg. 32

Many studies show that erosion and sediment controls do not work very well for many reasons, namely: (a) they were never installed in the first place; (b) they were not installed correctly; (c) they were not maintained. Well maintained controls not only provide their intended environmental benefits, they ensure that the investment made to reduce erosion was well worth the cost. Therefore, we recommend adding a section on the maintenance of erosion and sediment controls.

3.4 Include information for minimizing the runoff potential from the impervious cover of the cul-de-sac.

Article X, Section 1020 H. pg. 35

Cul-de-sacs are often designed with a large impervious surface and no capacity for stormwater runoff to enter vegetation. We recommend incorporating stormwater-related design considerations into this section: *To better manage stormwater from cul-de-sacs, they should be designed to feature: (a) a smaller radius, ranging from 33 to 45 ft; (b) the installation of a pervious island in the center of the turn and built below grade and without curbs or with curb breaks to allow water to flow into it. Applicants should also consider alternatives to cul-de-sacs that use less impervious cover, such as "T-shaped" turnarounds and looped roads.* A pervious island (such as a bioretention STP) provides stormwater infiltration and enhances the attractiveness of the site. Looped roads offer additional benefits, such as allowing for more building units and providing two exits which improves the performance of the road.

3.5 Allow for greater flexibility when installing sidewalks.

Article X, Section 1030 A pg. 36

A sidewalk is another type of impervious cover. The Center or Watershed Protection's publications, "Better Site Design: A Handbook for Changing Development Rules in Your Community" and "An Introduction to Better Site Design" state that the placement and width of sidewalks could be modified to reduce impervious cover without compromising travel and safety. Another reference is the article, *Skinny and One-sided Sidewalks: A Strategy for Not Paving Paradise*, Article 50 in the Practice of Watershed Protection, found at the Center's website: www.stormwatercenter.net. Improved sidewalk designs include: (a) having a sidewalk on one side of the street; (b) using narrower sidewalk widths; and, (c) placed away from the street and graded so that they drain to vegetation. We recommend a change to the language to allow greater flexibility: "Sidewalks or recreation paths *shall be required, with preference given to installing sidewalks on one side of the street,* in all zoning districts. We also recommend adding stormwater design criteria for sidewalks here or under the Town Public Works Standards document, which would recommend: *sidewalks be placed away from the street, and graded so that they drain to vegetation.* A Williston official commented that sidewalks 4 feet or less may actually discourage pedestrian use because they are not wide enough for two people to walk side-by-side. Requiring sidewalk widths of 3 to 4 feet is an appropriate step to minimize impervious cover. Nevertheless, due to this concern, we do not recommend reduction in sidewalk widths to four feet at this time.

3.6 Allow for greater flexibility regarding curbing.

Article X, Section 1030 B pg. 36

Discouraging the use of curbing and grading the sidewalks to direct rainwater to vegetation will help to increase infiltration. We recommend modifying the language here to read: *"In general, the use of curbing should be minimized in order to allow precipitation to reach vegetation and infiltrate into the ground. Where sidewalks are provided, allow for either breaks in curbing or other means, such as separation between road and sidewalk, to allow infiltration to occur".*

3.7 Add additional considerations to reduce the impact of stormwater runoff from other impervious surfaces, such as driveways and rooftops.
Article X Section 1020 pg. 32
Driveways can be better designed to reduce impervious cover by: (a) having narrower widths (limited to 9 ft); (b) allowing multiple homes to share driveways; and reducing the length by minimizing the building setback (see recommended changes to Williston's Zoning Ordinance, below). Moreover, runoff problems become exasperated when the runoff of impervious surfaces is "directly connected." Directly connected impervious cover means that roof runoff flows onto driveways, into streets, and ultimately into the stormwater conveyance system. Disconnecting runoff requires directing rooftop runoff to vegetation and away from the road network (driveway, sidewalk, and street). Making sure that runoff is disconnected will make a huge difference in preventing additional stormwater runoff-related water quality problems. We recommend including a statement that refers to these other opportunities to reduce stormwater runoff.

3.8 Address opportunities to minimize stormwater-related problems associated with parking lots.
Either in the subdivision regulations or the public works standards, the Town needs to incorporate stormwater controls at another important source: parking lots. Parking lots are another example of an impervious surface. Reducing the impervious surface coverage of parking requires: (a) decreasing parking ratio requirements below 3 spaces per 1,000 $ft^2$ as much as possible; (b) reducing the size of parking stalls to 9-by-18-ft, and 7.5-by-15 ft for compact stalls (which can reduce imperviousness associated with parking by 20-50 percent.); and (c) allowing for spillover parking where a pervious surface can be used.

Reducing the size of parking areas involve: (a) encouraging shared parking and paired parking (where daytime parking can be used for evening demand); (b) investigating shared parking before developing excess parking; (c) adopting parking standards based on average parking needs; and (d) constructing multi-story or below-ground parking facilities.

Parking lots for office complexes could be designed with vegetative borders to allow infiltration of the runoff. This design may be appropriate for office complexes, where less congestion and truck traffic would minimize the likelihood of contamination from petro-chemical products from leaking vehicles. However, large parking lots may pose the added risk of petro-chemical contamination. Preventing water quality problems due to parking lot runoff may require the installation of controls, such as dry and wet bio-filters. (Center for Watershed Protection, 1997).

## 4.0 Town of Williston Zoning Ordinance, Amended 2000

4.1 Be consistent with the recommended changes to the Buffer Ordinance to protect tributaries
Article II, Section 2.3.11 D pg. 8
See Recommendation #2 under the Buffer Ordinance, which describes our recommendation to protect streams that are unnamed and brook tributaries. This language should state: "All lands within *150 ft* of the top of the bank of the *streams that are unnamed* or brook tributaries..."

4.2 Relax setback requirements to give the Town greater flexibility to reduce total impervious areas.
Section 3.16 pg. 53
Modifying the shape, size, and layout of the residential lot can help reduce impervious cover. For example, the Town has a setback requirement for residential street of 35 ft. Minimizing this requirement will reduce driveway length, thereby reducing impervious cover. Often, smaller setbacks are more consistent with Vermont's historical neighborhood character.

**5.0 Public Works Standards and Specification, 1997**

5.1 Consider alternative permeable surfaces and location of sidewalks and recreation paths away from the existing road network and draining to vegetation.

Part I C.1.c. pg. I-9, and Appendix E – Highway Details.

The Town should encourage opportunities to minimize impervious cover and use pervious materials. We recommend changing the language to read: "Walks/paths 6 ft wide or less *may be* concrete and walks/paths more than 6 ft wide *may be* bituminous concrete. *To minimize impervious cover while maintaining the goal of improve pedestrian movement and safety, walks and paths should be placed away from the road network, graded so that they drain to vegetation, and possibly built with more pervious materials*."

5.2 Include a maintenance plan for testing and inspection requirements of storm drainage systems and reflect maintenance in the title of Section K.

Part II K 4 pg. II-6

As mentioned above, maintenance is essential for ensuring the continued adequacy of stormwater controls. We recommend adding a schedule for periodic maintenance to the checklist for determining the completion of a storm drainage system. We also recommend changing the title of Section K to read: "Testing, Inspection, and Maintenance Requirements."

5.3 Incorporate erosion and sediment control measures into the inspection of road construction.

Part II K 5 pg. II-7

Sedimentation in watercourses, due to erosion and unchecked runoff, is the leading water quality problem in Vermont and nationally. Sedimentation increases turbidity in the water column, greatly reducing the growth of beneficial aquatic plants. The high volume of stormwater runoff, carrying the sediment, can be abrasive to bridge infrastructure and streambanks. Sedimentation reduces spawning habitat, suffocates fish eggs, and smother bottom-dwelling organisms that are food sources for fish. Erosion and resultant off-site sedimentation becomes a major problem at construction sites, if the disturbed land is left unprotected from wind and precipitation.

The Town should take all steps necessary to reduce the vulnerability of erosion by wind and water. We recommend adding, *the installation of erosion and sediment control measures,* as an early phase in the road construction. We also recommend expanding the roadway general inspection checklist to state: seeding and erosion *controls (mulch or temporary vegetation)* for all areas that have *been cleared and graded but will not be constructed on for more than 14 days (7 days for steep slopes). Temporary seeding and mulching, as well as phased construction techniques to prevent the mass grading when only a small site is actively under development, are necessary erosion control measures.*

5.4 Emphasize erosion and *sediment* control.

Part II M pg. II-10

To emphasize the important objective of controlling erosion and sediment pollution during the construction process, we recommend modifying the agenda item for the pre-construction meeting with the town to state: "Erosion, *sediment*, and dust control measures."

5.5 Consider adopting an erosion and sediment control/grading ordinance or guidance.

Part V

As stated in Section A.1 of the Town's *Public Works Standards and Specification*, the control measures described in this part of the document are not intended to be a complete set of specifications. However, this part contains nothing at all on erosion and sediment control, even though it is entitled "Storm Drainage and Erosion Control Measures." The Town should consider including at least some basic information on this topic, including the rationale for utilizing these

control measures. Guidance contained in this part and in the technical appendices could be enhanced by containing a new ordinance for controlling erosion and sediment. This is particularly important, since studies show that construction is potentially the most damaging phase of development to stream stability and aquatic health. During construction, vegetation and topsoil are removed, bare soils are exposed to wind and precipitation, steep slopes may be cut, the natural contours and drainage patterns are altered, and riparian areas can be disturbed. Moreover, Williston must develop sediment and erosion control standards anyway, as part of the US. EPA's Phase II Stormwater Rules.

A good reference for erosion and sediment control and stormwater management, which contains sample ordinances, is the stormwater Manager's Resource Center, at www.stormwatercenter.net. This reference offers the following principles to help make any erosion and sediment control ordinance more effective: (a) a reference to technical manuals; (b) clear enforcement measures to ensure maintenance of erosion and sediment control measures; (c) flexibility to allow a process to change the plan in response to field conditions; (d) authority for inspectors from the town to inspect construction sites regularly; (e) incorporation of measures to protect natural resources such as wetlands and vegetative buffers; and, (f) guidelines in developing an approving an erosion and sediment control plan.

We recommend including erosion and sediment control guidance directly in Section A of the Town's *Public Works Standards and Specification*. The guidance would give the developer or designer of stormwater controls greater understanding of the Town's goals on stormwater management. If the Town decides to include the guidance in an alternative ordinance, Section A should refer to that ordinance.

5.6 Specify that streets need to be designed to minimize impervious cover, while maintaining safety objectives.
Part V
Since the road network is a majority of the impervious cover in a watershed, revising the street width standards can help achieve stormwater management objectives while still allowing for expected traffic volumes, parking needs, and safety considerations. The Center or Watershed Protection's, *A Better Site Design: A Handbook for Changing Development Rules in Your Community* (pg. 29) contains examples of modified street pavement widths. In addition, the Stormwater Center has information on road widths in "*Better Site Design Fact Sheet: Narrower Residential Streets*" (see www.stormwatercenter.net). Several communities use street widths of 22 to 26 ft, which include parking on one side of the street. We suggest modifying the specifications to include stormwater management considerations, such as: (a) recommended street design widths; (b) a statement to discourage street cul-de-sacs or modify them to reduce imperviousness and allow for greater stormwater infiltration (see discussion above); and, (c) a statement to discourage curbing and the use of vegetated open channels to allow for infiltration.

Another technique for minimizing impervious cover associated with the road network is to use alternative street layouts to maximize the number of homes per length of road. Developers may favor this approach to reduce costs. Homeowners could be attracted to the clustering of homes because of the larger amount of open space now available to them.

5.7 Enhance the specification for storm drainage and erosion control to incorporate stormwater management techniques.
Appendix D, pg. D-7
The details for erosion and sediment control need to provide better guidance. Any changes to include better guidance should also be reflected in Part V of the *Standards and Specifications*.

The current details promote the use of "hay bale sediment dams" or silt fence as site perimeter controls. Properly used, hay bales become one possible component of an erosion and sediment control plan, but must not be the only component. The use of haybales as a first choice contradicts the *"Vermont Handbook for Soil Erosion and Sediment Control on Construction Sites"*(VT Geological Survey, 1987), which states that "The hay bale dike is used where … no other practice is feasible…." Haybale or silt fence check dams are routinely installed across Vermont, despite the fact that neither practice should be used where there is a concentration of water in a channel or other drainageway. The Vermont handbook notes that haybales should not be used for this but fails to say the same for silt fence (the handbook is in need of updating). In addition to guidance for other structural practices, standards and specifications for nonstructural practices also needs to be provided (such as phased construction, temporary stabilization with seeding and/or mulching, etc.). Details from the "Vermont Handbook for Soil Erosion and Sediment Control on Construction Sites" and other more current erosion and sediment control documents could be incorporated by reference.

5.8 Enhance the detailed specifications for residential roads and trails to incorporate stormwater management techniques.

Appendix E

For example, the specifications show concrete curbing for most developments. It is best to manage stormwater on site by promoting infiltration. Grading should be done to: (a) direct sheet flow onto pervious surfaces, rather than concentrating flow into ditches or storm systems; and (b) generate diffuse sheetflow, rather than concentrated storm flow. Refer to the Vermont Stormwater Management Manual (CWP 2001) for design details.

5.9 Reference technical guidance for managing stormwater using Stormwater Treatment Practices (STP's).

We recommend providing additional guidance and reference materials for BMPs, such as: (a) erosion and sediment control; (b) infiltration; (c) retention basins; (d) extended detention basins; (e) filters; and (f) open channel STP's. The Public Works Specifications could reference the State of Vermont's enhanced stormwater program and its new (albeit draft) Vermont Stormwater Manual (Center for Watershed Protection, November, 2000). That manual contains standards for design and construction of stormwater management facilities and incentives to reduce collected stormwater volume through better site design and planning.

5.10 Promote additional "better site design practices" that rely on existing contours and natural vegetation to minimize stormwater runoff and protect natural resources including tillable soils.

The landscape with natural contours and vegetation work to slow down runoff and increase infiltration, thus avoiding the liability of having to collect and treat stormwater runoff. Allowing for natural contours with vegetation is much more effective at infiltration than lawns, where the contours were removed, and soil compacted.

5.11 Consider adopting channel protection design criteria for stormwater practices, which is an important inclusion in the State of Vermont's draft stormwater management handbook (Center for Watershed Protection, November 2000).

"The Vermont Stormwater Management Handbook, Technical Support Document" (Center for Watershed Protection. November, 2001), includes a "24-hour extended detention of the one-year storm" channel protection criteria (see, pp. 2-11-2-14). Recent studies conclude that controlling for such storms will protect downstream channels from erosion caused by development. Research has found that the traditional criteria – controlling for the "two-year, 24-hour storm event – frequently does not protect channels from erosion. In fact, studies indicate that such

controls may actually contribute to erosion, since banks are exposed to a longer duration of erosive events.

Alternatively, controlling for the one-year, 24 hour storm event, releases the runoff volumes gradually over the 24-hour period, thereby reducing erosive velocities. Therefore, we recommend that the Town adopt the channel protection criteria contained in the draft handbook.

5.12 Consider adding a section that allows for alternatives to culverts, such as prefabricated bridges.
Bridges are a better alternative than culverts because they better maintain the integrity of the natural channel. Bridges, as opposed to culverts, do not increase the velocity of streamflow (which could be erosive downstream), are more dependable in providing fish passage, and allow for the transport of sediment as well as flow. (Undersizing of culverts is a common problem, which interferes with the transport of sediment).

### ii. Reference List of Model Ordinances

The model ordinances referenced below can provide towns like Williston useful guidance on how to best manage future growth while protecting local water resources. The ordinances offer language and ideas for town officials to incorporate when constructing their own local ordinances. The Allen Brook Restoration Team has copies of these ordinances. Feel free to contact the Team, or you can get an electronic copy of these ordinances directly from the Center for Watershed Protection's Stormwater Center: http://www.stormwatercenter.net.

Buffer Protection
1. Rhode Island Ordinance, see: Rhode Island Ordinance
2. Stream Buffer and Open Space Zoning Model Ordinances from the Stormwater Center (the Center for Watershed Protection's clearinghouse of information for management of stormwater): www.stormwatercenter.net

Erosion and Sediment Control
1. City of Minneapolis Planning Department, 1996
2. Erosion and Sediment Control/Grading Model Ordinance: www.stormwatercenter.net (also attached)

Stormwater Management
1. Kitsap County Public Works Stormwater Management Ordinance, 1997: http://www.kitsapgov.com/sswm/ordinance199.htm
2. Albemarle County, VA Water Resources Management, "Stormwater Management/BMP Facilities Agreement
3. State of Colorado, Performance Bond Agreement
4. Post Construction Stormwater Management Model Ordinance: www.stormwatercenter.net
5. Golf Course Management Guidelines, Baltimore County, MD
6. "Enforcing Sediment Regulations in North Carolina," Center for Watershed Protection, Article #62: Technical Note #41 from Watershed Protection Techniques 1(3) 143-144.
7. Model Illicit Discharge and Connection Stormwater Ordinance

## Appendix G: Rapid Stream Assessment Methods

This section describes the methods used in conducting the rapid field assessments. A literature search and data review was completed to select parameters for the collection and analysis of field data. The final field forms integrate information from the sources listed below.

1. Rapid Geomorphic Assessment (Center for Watershed Protection et al., 1999).
2. Rapid Bioassessment Protocols (USEPA, 1999b; Fishenich and Allen, 2000).
3. Vermont Agency of Natural Resources Section Protocols (VT ANR- River Management Section, 2001).
4. Rapid Assessment of Channel Stability in Vicinity of Road Crossing (Johnson et al., 1999).
5. Fluvial Processes in Geomorphology (Leopold et al., 1964).
6. Schumm's Channel Evolution Model (Figure 1, Schumm, 1984).
7. Stream Management, Water Operations Technical Support Program (Fishenich and Allen, 2000).
8. Urban Stream Assessment Methods, developed by Pizzuto and Hession (Pizzuto et al., 2000).

The mainstem of Allen Brook was divided into 11 reaches for assessment purposes. Reaches were defined relative to road crossings or access points. They were not defined as "like reaches." In fact, within each reach the stream types were likely to vary substantially from bedrock controlled cascades to low-gradient riffle-pool systems. Thirty-five sites along the mainstem and headwater tributaries were assessed both quantitatively and qualitatively. Tributaries that appear as perennial streams on the USGS 7.5-minute topographic maps were walked. Features of special interest (such as beaver dams, stream crossings, etc.), which occurred between assessment locations were noted on aerial photos and logged on the Map Descriptions data sheet. Maps of the reaches, rapid assessments, and sampling locations for the map descriptions can be seen in figures in the final report. Field data were collected using a four-page field form, Map Description form, and Photo Log form (Also contained here in Appendix G). The field form was developed for this study and supplements the Phase II protocols outlined by ANR (ANR, 2001c). All assessments determined left bank/right bank by facing downstream. The appendix of the interim report for this study contains photos of all cross-sections.

### Floodplain Assessment

The floodplain assessment examines the condition of the floodplain, the streams access to it, and whether there have been any natural or anthropogenic encroachments.

### Streambank Assessment

The bank assessment includes physical descriptions of the bank materials, typical bank slopes, length and height of bank erosion, and type and amount vegetation present.

### Rapid Bioassessment Protocols

The U.S. Environmental Protection Agency (U.S. EPA) Rapid Bioassessment Protocols (RBP's) (USEPA, 1999b) are used to:

- Determine if a stream is supporting or not supporting aquatic life.
- Characterize the existence and severity of impairment.
- Help to identify sources and causes of impairment.
- Evaluate the effectiveness of control actions and restoration activities.
- Support use attainability studies and cumulative impact assessments.

The RBP's rely on an assessment of a reference condition that is either specific to the stream (usually in the upper watershed), or a regional reference. They contain 10 physical parameters

that can be measured along a scale of 0 (poor) to 20 (optimal). The total score for all parameters is summed and compared to a reference condition score. The results of the stability assessment can be used either as a total score, or can be divided into categories such as floodplain/channel alterations, sediment deposition, or bank erosion/slope failure.

The parameters used for Allen Brook are those outlined in the Phase II Protocols from the ANR (2001c). They include the following:

1. Epifaunal Substrate/Available Cover – habitat suitability for aquatic macroinvertebrates and fish (we also added the number of pieces of large woody debris (LWD)).
2a. Embeddedness (High Gradient Streams) – amount of surface area of cobbles, boulders, snags and other stream bottom structures covered with sand and silt (we modified the approach by measuring 10 cobbles in each assessed riffle).
2b. Pool Substrate Characterization (Low Gradient Streams) – type and variety of pool substrates.
3a. Velocity/Depth Regime (High Gradient Streams) – diversity of flow regimes and indicator of habitat diversity.
3b. Pool Variability (Low Gradient Streams) – overall mixture of pool types based on size and depth.
4. Sediment Deposition – accumulation of sediments on the streambed.
5. Channel Flow Status – degree to which the channel is filled with flow.
6. Channel Alteration – degree of channel alteration.
7a. Morphological Diversity/Frequency of Riffles (High Gradient Streams) – ratio of distance between riffles to stream depth.
7b. Channel Sinuosity (Low Gradient Streams) – ratio of channel length to valley length.
8. Bank Stability – condition of streambanks.
9. Vegetative Protection – percent of native vegetation in riparian zone and disruption.
10. Riparian Vegetative Zone Width – width of natural vegetation from stream through riparian zone.

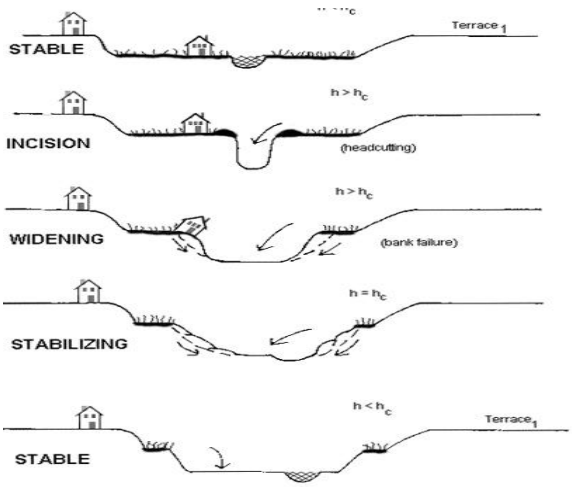
**Rapid Geomorphic Assessment**

The Vermont Rapid Geomorphic Assessment (RGA) (ANR, 2001) is a semi-quantitative assessment of a stream's stability designed to supplement the U.S. EPA's Rapid Bioassessment Protocols. The RGA assesses four methods of channel adjustment: widening, aggradation, degradation and change in plan form. The RGA scores can be used to classify the streams overall stability as well as identify the major mode of adjustment.

**Channel Evolution Model**

The Channel Evolution Model (CEM) (Schumm, 1984), shown in Figure 1, has five stages. In Stage 1, the river is stable. In Stage 2, the channel responds to increased runoff caused by changes in the watershed (for example, increased development, forest clearcutting)) by incising, or cutting down deeper into the bed. Incision or degradation is indicated by: (1) the presence of recent terraces which indicates loss of access to floodplain; (2) the presence of till in the bed; and, (3) nickpoints or headcuts. As the riverbed elevation lowers, the banks become steeper and more unstable and collapse, widening the river (Stage 3). During Stage 4, the banks continue to collapse until a stable slope is reached and the river widens, but at a lower elevation than it was during Stage 1. In Stage 5, the stream has the same dimensions (width and depth) as it did during Stage 1, but the river has created a new floodplain at a lower elevation. During the Rapid Geomorphic Assessment, reaches were categorized using one or two of the above stages of the CEM model.

**Figure 1: Channel Evolution Model**




**Bankfull and Cross-Sections**

Bankfull width was measured, using a tape strung level across the channel and bankfull indicators, including tops of bars, vegetation lines, breaks in slope, and lichen or moss lines. Measured cross-sections at a minimum went from top of bank to top of bank, and included all flood and cut-off chutes. Where applicable, the widths of active floodplains or abandoned terraces were measured using either a tape or rangefinder. Depths were measured at locations across the stream approximately every one ft and at the thalweg (point of greatest flow along the channel cross-section, which is usually at the deepest cross-section point) across the bankfull width. Beyond the bankfull width, measurements were taken at breaks in slope, changes in elevation and other physical features. Physical parameters measured include bankfull width, entrenchment ratios, width/depth ratios, and channel gradient (see next section).

**Water Surface Slope**

Water slope was measured with a hand level and two stadia rods. Slope was measured at similar features, for example, from top of riffle to top of riffle, or base of pool to base of pool. Distance was measured with a rangefinder or tape. Generally the slope was measured along a distance that ranged from 150-250 ft in length. Water surface slopes were taken by holding the bottom of the rod at the top of the water surface.

**Stream Classification**

Reaches of the stream were placed into the Rosgen (1996) and Montgomery and Buffington (1997) stream classification systems (see table below) primarily on the basis of slope and entrenchment ratio. Entrenchment ratio is calculated by dividing the flood-prone width by the bankfull width. These classification systems were developed for less disturbed systems and hence are difficult to use in an unstable system.

**Stream Classification**

| M-B Reach Type | Bed Form | Substrate | Valley | Gradient | Associated Rosgen Type and Gradient | W/D ratio* |
|---|---|---|---|---|---|---|
| Cascade | Tumbling jet and wake flow | Boulder | Narrowly confined | Steep >6.5% | A 4 – 10% | <12 (Rosgen) |
| Step-Pool | Steps and channel spanning pools | Boulder-cobble | Confined | Steep 3 – 6.5% | A, B | Steeper gradients = 17 2 – 4 % gradient = 21 |
| Plane-Bed | Run, riffle, and rapid | Cobble-Gravel | Confined or Unconfined | Mod.-High 1.5 – 3% | B 2 – 4% | 21 |
| Pool-Riffle | Undulating | Gravel-Cobble | Unconfined | Mod.-Low <1.5% | C <2% | 28 |
| Dune-Ripple | Ripples, dunes and anti-dunes | Sand | Unconfined | Low <1.5% | D, E <4%, <2% | Wide variation |

*Types based on a combination of Rosgen and Montgomery-Buffington Stream Types

**Bed Substrate Composition**
Bed substrate composition over the length of the reach was estimated using six categories: bedrock, boulder, cobble, gravel, sand/silt and clay. The largest particle observed on both the bed and bars was also noted.

**Erosion Processes**
The erosion processes considered were bed, toe, upper bank, piping, seeps and undercut banks. The length and height of mass failures was measured as well as the presence of nickpoints. The process was characterized as shear dominated or falling stage dominated based on the form and type of failure.

**Photo Documentation**
Each rapid and detailed assessment site was documented with four photographs. Standing at the cross-section location photos were taken looking upstream, downstream, towards the left bank and towards the right bank.

## Detailed Stream Assessment

Three sites along Allen Brook were permanently monumented for detailed assessment. Two of the sites are used by the DEC Biomonitoring Section (see figure in final report). Reach lengths were determined on site and were sized to include 3 riffle features, or 10-20 bankfull widths. The reach lengths were 150 to 400 feet long. Once the top and bottom points were chosen, the reach was flagged for a longitudinal profile and the cross-sections. The longitudinal profile and the cross-sections were surveyed using a laser level. The exact location of the top and bottom of the reach as well as the rebar markers on the permanent cross-sections were recorded using a Trimble ProXR GPS unit.

**Longtitudinal Profile**
For the longitudinal profile, water surface and thalweg (the portion of channel with majority of flow – often the deepest part of channel) elevations were recorded at feature locations such as top of pool (TP), deep point of pool (DPP), and top of riffle (TR) along the entire reach. Occasionally, intermediate riffle and pool points were surveyed, if the distance between features was too great. A tape was stretched along the thalweg for distance measurements.

**Cross-Sectional Survey**
Three cross-sections per reach were surveyed within riffle features. The survey team chose one cross-section per reach (the middle cross-section) as a permanent site to allow for future surveys to assess channel change over time. Steel rebar markers were driven into opposite sides of the flood plains to permanently mark its location.

Steel pins were placed perpendicular to the stream on opposite banks of the channel for each cross-section, approximately level. A measuring tape was attached to opposite pins, taught, with the zero point at the location of the left pin (on left bank, looking downstream). Beginning at the left pin (0' marker), elevations were measured at one to two foot intervals. In addition, elevations and horizontal distances were recorded for special features such as left and right top of bank, bankfull, left and right edge of bed, left and right water surface, thalweg, and any other significant features (e.g., islands, protruding rocks).

Four photographs were taken of the permanent cross-section (XS) in the following order:
- from left bank across the XS, standing over the left rebar.
- from right bank across the XS, standing over the right rebar.
- upstream, standing at center of stream and looking upstream at the XS.
- downstream, standing at center of stream and looking downstream at the XS.

**Streambed Material Characterization**
The composition of the channel substrate was characterized using a modified Wolman pebble count procedure (Wolman, 1954; Potyondy, 1994; Bevenger, 1995) at the three detailed reaches. Pebbles were chosen at random from the channel substrate in the riffle and pool sections along length of the reach. The "B axis" (the intermediate axis (width); neither the longest axis (length) nor the shortest axis (thickness)) of pebbles was measured. The reach feature (riffle or pool) was noted, and the sections tried to mimic the balance of pools, riffles and runs within the reach. For example, a reach with 30 percent riffles and 70 percent pools and runs would have 30 percent of the pebbles counted in riffle sections. A minimum of 200 pebbles was counted at each site. Ten "samples" were taken randomly at each of 20 transects across the channel by closing ones eyes and placing a finger on the channel bottom, sizing the first particle touched, and moving incrementally across the channel until ten samples have been taken across the channel. Particle size was measured using a Wentworth gravelometer.

**Embeddedness**
A process similar to that used for the rapid geomorphic assessment measured embeddedness for each detailed reach. We measured the amount of surface area of particles (gravel that was larger than golfball size, cobbles, and boulders) that was covered with sand and silt. We repeated that measurement for a total of 10 particles within each cross-section riffle along the reach (for a total of 30 samples per reach). Particles were categorized according to percentage of surface area covered: 0-25 percent, 25-50 percent, 50-75 percent, and 75-100 percent.

## ALLEN BROOK STREAM GEOMETRY DATA SHEET

**ANR PHASE II PROTOCOL RESULTS**

| Reach Number | Site Number | Bankfull Width (ft) | BF Thalweg Depth (ft) | Mean Depth (ft) | Low Bank Height | Incision Ratio (Low Bank Height/ Dmax) | Entrenchment Ratio | Cross-Sectional Area (sq. Feet) | Water Surface Slope* % | Estimated Width of Flood Prone Area (ft) | Riparian Buffer Type/forest or grass/wetland | Width/ Depth Ratio | DA | Rosgen Stream Type: |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 25.3 | 4.1 | 3.30 | 1.50 | *0.37* | 2.4 | 83.9 | 0.6 | 61 | g | 7.7 | 14.5 | E5 |
| 1 | 2 | 33.9 | 2.5 | 1.50 | 2.90 | 1.16 | 2.7 | 52.3 | 0.1 | 92 | g | 22.6 | | C5 |
| 1 | 3 | 38.2 | 2.9 | 2.1 | 3.20 | 1.10 | 3.9 | 78.7 | 0.3 | 149 | g | 18.2 | 13.4 | C5 |
| ***M1*** | ***2.1*** | ***22.4*** | ***2.7*** | ***1.80*** | ***6.50*** | 2.41 | 2.7 | ***40.6*** | ***0.3*** | ***60*** | ***f/g*** | ***12.4*** | | E5 |
| ***M1*** | ***2.2*** | ***22.6*** | ***2.4*** | ***1.50*** | ***3.10*** | 1.29 | 2.2 | ***40.9*** | ***0.3*** | ***50*** | ***f/g*** | ***15.1*** | | C5 |
| ***M1*** | ***2.3*** | ***21.7*** | ***2.4*** | ***1.60*** | ***6.70*** | 2.79 | 2.3 | ***35.7*** | ***0.3*** | ***50*** | ***f/g*** | ***13.6*** | | C5 |
| *avg* | | *22.23* | *2.50* | *1.63* | | | 2.4 | *39.07* | *0.3* | *53* | *0.00* | *13.69* | | |
| 2 | 1 | 33.5 | 2.5 | 1.7 | 3.70 | 1.48 | 1.5 | 56.5 | 1.1 | 50 | f | 19.7 | | C3 |
| 2 | 2 | 34.2 | 3.1 | 1.7 | 3.40 | 1.10 | 2.9 | 58.1 | 2.0 | 100 | f | 20.1 | | BC3 |
| 2 | 3 | 42.5 | 3.6 | 1.8 | 3.60 | *1.00* | 2.4 | 76.7 | 0.7 | 100 | f | 23.6 | | C3 |
| **M3** | **0.1** | **24.6** | **1.8** | **1.10** | **4.10** | 2.28 | 1.6 | **28** | **1.4** | **40** | **f** | **22.4** | | B3 |
| **M3** | **0.2** | **24.8** | **1.2** | **0.90** | **3.30** | 2.75 | 1.3 | **22.5** | **1.4** | **31** | **f** | **27.6** | | F3 |
| **M3** | **0.3** | **28.7** | **1.5** | **1.00** | **2.80** | 1.87 | 1.1 | **28.6** | **1.4** | **33** | **f** | **28.7** | | F3 |
| *avg* | | *26.03* | *1.50* | *1.00* | | | 1.3 | *26.37* | *1.4* | *35* | *0.00* | *26.21* | | |
| 3 | 1R | 38.8 | 2.6 | 2.1 | | 0.00 | 2.3 | 80.3 | 1.3 | 89 | f | 18.5 | 9.8 | C3 |
| 3 | 1s | 40.3 | 2.9 | 2.30 | 4.30 | 1.48 | 2.2 | 92.1 | 1.3 | 90 | | 18.0 | | B3 |
| 3 | 2 | 31.4 | 1.8 | 1.2 | 1.70 | *0.94* | 1.9 | 36.8 | 0.2 | 60 | f | 27.0 | | B3 |
| 3 | 3 | 32.6 | 2.5 | 2.1 | 2.80 | 1.12 | 3.1 | 68.2 | 1.2 | 100 | f | 15.5 | | C3 |
| 4 | 1 | 28.7 | 2.4 | 1.8 | 4.20 | 1.75 | 1.7 | 52.1 | 0.2 | 50 | f | 15.9 | | B5 |
| 4 | 2 | 21.5 | 1.6 | 1.3 | 1.80 | 1.13 | 1.9 | 27.3 | 1.4 | 40 | f | 16.5 | | BC3 |
| 4 | 3 | 24 | 2.4 | 1.8 | 2.80 | 1.17 | 1.3 | 52.1 | 0.2 | 30 | f | 13.3 | | F3-5 |
| 5 | 1 | 12 | 1.2 | .8 | 2.00 | 1.67 | 1.7 | 9.7 | 1.5 | 20 | g | 15.0 | | B3 |
| 5 | 2 | 12.7 | 1.2 | .9 | 2.10 | 1.75 | 1.8 | 11.6 | 2.2 | 23 | g | 14.1 | | B4 |
| 6 | 1 | 16.7 | 1.6 | 1 | 3.70 | 2.31 | 1.6 | 17.5 | 0.2 | 26 | g | 16.7 | | G4 |
| 6 | 2 | 40.8 | 1.8 | 1 | 3.40 | 1.89 | 1.2 | 42.6 | 1.0 | 48 | f | 39.0 | | F3 |
| 6 | 3 | 23.7 | 1.7 | .8 | 2.70 | 1.59 | 1.9 | 19.1 | 1.4 | 45 | g | 29.6 | | BC3 |
| 6 | 4 | 20.3 | 2.4 | 1.7 | 4.70 | 1.96 | 2.4 | 34.8 | 1.0 | 49 | g | 11.9 | | E5 |
| 7 | 1 | 8.2 | 1.8 | 1.4 | 3.30 | 1.83 | 1.8 | 11.5 | 0.3 | 15 | g | 5.9 | | B5 |
| 7 | 2 | 10.8 | 1.3 | .9 | 2.30 | 1.77 | 1.3 | 9.9 | 1.2 | 14 | g | 12.0 | | F5 |
| 8 | 1 | 18.7 | 1.8 | 1 | 2.50 | 1.39 | 2.7 | 18.4 | 1.0 | 50 | f | 18.7 | | C4 |
| 8 | 2 | 9.7 | 1 | .6 | 2.60 | 2.60 | 4.1 | 5.8 | 0.4 | 40 | g | 16.2 | | C3 |
| **M9** | **0.1** | **14.3** | **1.3** | **0.90** | **1.50** | 1.15 | 2.0 | **13** | **3.0** | **29** | **f** | **15.9** | | |
| **M9** | **0.2** | **16.6** | **1.6** | **0.90** | **2.00** | 1.25 | 2.6 | **14.4** | **3.0** | **43** | **f** | **19.0** | | B3 |
| **M9** | **0.3** | **12.4** | **1** | **0.50** | **1.90** | 1.90 | 1.2 | **6.1** | **3.0** | **15** | **f** | **24.8** | | |
| *avg* | | *10.83* | *0.98* | *0.58* | | 0.00 | 2.0 | *8.38* | *2.3* | *22* | | *14.92* | | |
| 9 | 2 | 14.1 | 1.3 | 1 | 3.40 | 2.62 | 2.8 | 13.5 | 5.3 | 40 | f | 14.1 | | C5b |
| 10 | 1 | 14.8 | 2.5 | 1.2 | 4.40 | 1.76 | 2.6 | 17.5 | 0.1 | 38 | g | 12.3 | | E5 |
| 11 | 1 | 8.5 | 0.7 | .4 | 0.80 | 1.14 | 1.8 | 3.6 | 2.9 | 15 | f | 21.3 | | B3 |
| **Tributaries** | | | | | | | | | | | | | | |
| 5 | T2.1 | 3.1 | 1 | .8 | 1.70 | 1.70 | 32.0 | 2.5 | x | 99 | | 3.9 | | E6 |
| 5 | T3.1 | 7.5 | 0.8 | .6 | 4.30 | 5.38 | 2.0 | 4.2 | x | 15 | | 12.5 | | B4 |
| 7 | T6.1 | 6 | 1.3 | .7 | 2.40 | 1.85 | 11.6 | 4.5 | 0.4 | 70 | | 8.6 | | E5 |
| 7 | T6.2 | 2.9 | 1 | .9 | 3.00 | 3.00 | 1.4 | 2.5 | 0.6 | 4 | | 3.2 | | G5 |
| 7 | T6-1.1 | 6.3 | 1.1 | .3 | 1.20 | 1.09 | 2.4 | 2.1 | 3.7 | 15 | | 21.0 | | C5 |
| 7 | T6-2.1 | 2.8 | 0.6 | .3 | 2.00 | 3.33 | 2.1 | 0.9 | 1.3 | 6 | | 9.3 | | B5 |

* (bed slope on permanent cross-sections)

Permanent cross-sections in bold, M1, M3 and M9

**ANR PHASE II PROTOCOL RESULTS SHEET 5**

| REACH NUMBER | SITE NUMBER | 5.1 Bed Sediment Storage: | 5.2 Chute Cut-offs: | Channel Avulsions | 5.3 Steep Riffles or Head Cuts | Height of steep riffles | # Head Cuts | 5.4 Evidence of gravel mining or re-arranging: | 5.5 Channelized/ Straightened: | 5.6 Stream Ford or Animal Crossing: | EROSION PROCESSES | Length Mass Failure (feet) | Height Mass Failure (feet) | Shear Dominated Erosion | Falling Stage Dominated Erosion | Bank | Dominant Channel Adjustment Process | Channel Evolution Stage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | point | 0 | 0 | 0 | | | 0 | 0 | 0 | | | | | | | | 4 |
| 1 | 2 | point | 0 | 1 | 0 | | | 0 | 0 | 0 | upper bank | 20 | 7 | 0 | 0 | | A | 2 |
| 1 | 3 | mcb, point | 1 | 1 | 0 | | | 0 | 0 | 0 | none | | | 0 | 0 | | A | 1 |
| 2 | 1 | point | 1 | 0 | 0 | | | 0 | 0 | 0 | none | | | 0 | 0 | | CP | 1 |
| 2 | 2 | point | 1 | 1 | 0 | | | 0 | 0 | 0 | toe, upper bank | 180 | 14-20 | 0 | 1 | | A, CP | 5 |
| 2 | 3 | point | 1 | 1 | 1 | 1.25 | 1 | 0 | 0 | 0 | toe | | | 1 | 0 | | | 1 |
| 3 | 1 | none | 0 | 0 | 0 | | | 0 | 0 | 0 | none | | | 0 | 0 | | OW, D | 3 |
| 3 | 2 | point | 0 | 0 | 0 | | | 0 | 0 | 0 | undercut bank | 120 | 4 | 1 | 0 | right | A | 1 |
| 3 | 3 | mcb | 0 | 0 | 0 | | | 0 | 0 | 0 | mass failure | 30 | 6 | 0 | 0 | left | A | 4 |
| 4 | 1 | none | 0 | 0 | 0 | | | 0 | 0 | 0 | none | | | | | | A | 1 |
| 4 | 2 | mcb | 0 | 0 | 0 | | | 0 | 0 | 0 | none | | | 0 | 0 | | A | 1 |
| 4 | 3 | point | 0 | 0 | 0 | | | 0 | 0 | 0 | | | | 1 | | | OW | 4 |
| 5 | 1 | none | 1 | 1 | 0 | | | 0 | 0 | 0 | undercut bank | 15 | 2 | 1 | 0 | left | CP | 3 |
| 5 | 2 | diagonal | 0 | 0 | 0 | | | 0 | 0 | 0 | bed, undercut | | | | | | CP | 3 |
| 5 | T2.1 | none | 1 | 1 | 0 | | | 0 | 0 | 0 | none | | | | | | A | 1 |
| 5 | T3.1 | point | 0 | 0 | 0 | | | 0 | 0 | 0 | bed | 50 | 6 | | | left | D | 2-3 |
| 6 | 1 | mcb | 1 | 0 | 0 | | | 0 | 0 | 0 | none | | | | | | CP | 1-2 |
| 6 | 2 | mcb | 1 | 1 | 0 | | | 0 | 0 | 0 | ›er bank, mass fai | 60 | 20 | 0 | 1 | right | CP | 3 |
| 6 | 3 | none | 0 | 0 | 0 | | | 0 | 0 | 1 | none | | | | | | A | 3 |
| 6 | 4 | ehind LD jam | 0 | 0 | 1 | 1 | 3 | 0 | 0 | 0 | none | | | | | | CP | **2** |
| 7 | 1 | ncb, alternate | 0 | 0 | 0 | | | 0 | 0 | 0 | undercut bank | 60 | 3.5 | 1 | 0 | | D | 2 |
| 7 | 2 | alternate | 1 | 0 | 0 | | | 0 | 0 | 0 | undercut bank | | | 1 | 0 | | D,OW | 2-3 |
| 7 | T6.1 | alternate | 0 | 1 | 0 | | | 0 | 0 | 0 | undercut bank | | | 1 | 0 | | D | 2 |
| 7 | T6.2 | alternate | 1 | 0 | 0 | | | 0 | 0 | 0 | undercut bank | 40,30 | 2,2 | 1 | 0 | left, right | D | 2-3 |
| 7 | T6-1.1 | none | 0 | 0 | 0 | | | 0 | 0 | 0 | none | | | | | | D | 1 |
| 7 | T6-2.1 | alternate | 0 | 0 | 0 | | | 0 | 0 | 0 | undercut bank | 10 | 1 | | | left, right | D | 2 |
| 8 | 1 | mcb, point | 1 | 0 | 0 | | | 0 | 0 | 0 | 0 | | | | | | CP | 3 |
| 8 | 2 | point | 0 | 0 | 0 | | | 0 | 0 | 0 | undercut bank | 20 | | 1 | 0 | left | OW | 2-3 |
| 9 | 1 | alternate | 0 | 0 | 0 | | | 0 | 0 | 0 | none | | | | | | n/a | 1 |
| 10 | 1 | none | 0 | 0 | 0 | | | 0 | 0 | 0 | none | | | | | | none | 5 |
| 11 | 1 | none | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | none | | | | | | none | 1 |
| **CHOICES** | | none / mid-channel bars / point bars / diagonal bars / delta bars /alternate bars | Y/N | Y/N | Y/N | | | Y/N | Y/N | Y/N | None / Bed / Toe / Undercut Bank / Upper Bank / Piping / Seeps / Failure at contact | | | Y/N | Y/N | | Degradation (D) / Aggradation (A) / Over-Widened Channel (OW) / Change in Planform (CP) | Stable (1) / Incision (2) / Widening (3) / Stabilizing (4) / Stable (5) |

**ANR PHASE II PROTOCOL RESULTS SHEET 4**

| REACH NUMBER | SITE NUMBER | 4.1 Springs or Seeps: | 4.2 Adjacent Wetlands | 4.3 Historic Ice or Debris Jam Locations: | 4.4 Stormwater Outfalls: | 4.5 Flow regulations or withdrawals | 4.6 Culvert: | 4.7 Bridge or Channel Constriction |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1 | 2 | 0 | 0 | no info | 0 | 0 | 0 | 0 |
| 1 | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 2 | 1 | 0 | 1 | no info | 0 | 0 | 0 | 0 |
| 2 | 2 | 0 | 0 | no info | 0 | 0 | 0 | 0 |
| 2 | 3 | 0 | 1 | no info | 0 | 0 | 0 | 0 |
| 3 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| 3 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 4 | 2 | 0 | 1 | no info | 0 | 0 | 1 | 0 |
| 4 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | T2.1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 5 | T3.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 1 | 0 | 0 | no info | 0 | 0 | 0 | 0 |
| 6 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 6 | 3 | 0 | 0 | no info | 0 | 0 | 0 | 1 |
| 6 | 4 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 7 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 7 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7 | T6.1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 7 | T6.2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7 | T6-1.1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7 | T6-2.1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 8 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 8 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 9 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | |
| 11 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| **CHOICES** | | Y/N | Y/N | Y/N/No info | Y/N | Y/N | Y/N | Y/N |

## ANR PHASE II PROTOCOL RESULTS SHEET 3A

| REACH NUMBER | SITE NUMBER | 3.1 Left Stream Bank | Canopy: | Percentage covered: | Bank Erosion: | Length (ft) | Height (ft) | rip-rap/ gabion/ concrete/other/ none | Length (ft) | 3.1 Right Stream Bank | Canopy: | Percentage covered: | Bank Erosion: | Length (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | h | open | <25 | 1 | 60 | 4-8 | | | d,h | open | <25 | 0 | |
| 1 | 2 | d (few), h | open | <25 | 0 | | | tree revet | 20 | d (few), h | open | <25 | 0 | |
| 1 | 3 | d,h | closed | 50-75 | 1 | 200 | 2-3 | none | | d,h | open | 25-50 | 1 | 20 |
| 2 | 1 | d | closed | 75-100 | 0 | | | none | | d | closed | 75-100 | 1 | 20 |
| 2 | 2 | c,d | closed | 75-100 | 1 | 60 | 12-18 | none | | d | closed | 50-75 | 1 | 180 |
| 2 | 3 | d,s | open | 25-50 | 1 | 75 | 10 | none | | c,d | closed | 75-100 | 0 | |
| 3 | 1 | d,h | open | <25 | 0 | | | none | | d,h | open | 25-50 | 0 | |
| 3 | 2 | c,h | closed | 75-100 | 1 | 30 | 3 | none | | c,h | closed | 50-75 | 1 | 120 |
| 3 | 3 | d,h | closed | 75-100 | 1 | 30 | 6 | rip-rap | 90 | d,h | closed | 50-75 | 0 | |
| 4 | 1 | d | closed | 75-100 | 0 | | | | | s,h | open | <25 | 0 | |
| 4 | 2 | d | closed | 25-50 | 1 | 30 | 3 | none | | d,s | closed | 50-75 | 0 | |
| 4 | 3 | d | closed | 50-75 | 1 | 30 | 4 | | | d,h | open | 25-50 | 0 | |
| 5 | 1 | h | open | <25 | 1 | 10 | 1 | | | h | open | <25 | 0 | |
| 5 | 2 | d,h | open | <25 | 1 | 150 | 3 | | | d,h | open | <25 | 1 | 40 |
| 5 | T2.1 | h | open | <25 | 0 | | | | | h | open | <25 | 0 | |
| 5 | T3.1 | d,h | closed | 75-100 | 1 | 50 | 3-6 | | | d,h | closed | 75-100 | 1 | 10 |
| 6 | 1 | d,h | open | 25-50 | 0 | | | | | d,h | open | 25-50 | 0 | |
| 6 | 2 | c | closed | 75-100 | 0 | | | | | c,d | closed | 75-100 | 1 | 60 |
| 6 | 3 | h | open | <25 | 0 | | | | | d | closed | 75-100 | 0 | |
| 6 | 4 | s,h | open | 25-50 | 0 | | | | | h | open | <25 | 0 | |
| 7 | 1 | h | open | <25 | 1 | 60 | 3.5 | | | h | open | <25 | 1 | 60 |
| 7 | 2 | h | open | <25 | 1 | 35 | 1.5 | | | h | open | <25 | 1 | 30 |
| 7 | T6.1 | h | open | <25 | 1 | 20 | 3 | | | s,h | open | <25 | 1 | 6 |
| 7 | T6.2 | h | open | <25 | 1 | 40 | 2 | | | h | open | <25 | 1 | 30 |
| 7 | T6-1.1 | h | open | <25 | 0 | | | | | h | open | <25 | 0 | |
| 7 | T6-2.1 | h | open | <25 | 1 | 8 | 1 | | | h | open | <25 | 1 | 8-10 |
| 8 | 1 | d | closed | 75-100 | 0 | | | | | d | closed | 75-100 | 0 | |
| 8 | 2 | h | open | <25 | 1 | 20 | | | | d,h | open | <25 | 0 | |
| 9 | 1 | d | closed | 75-100 | 0 | | | | | d | closed | 75-100 | 0 | |
| 10 | 1 | p | open | <25 | 0 | | | | | p | open | <25 | 0 | |
| 11 | 1 | d,h | closed | 75-100 | 0 | | | | | d,h | closed | 75-100 | 0 | |
| **CHOICES** | | Coniferous trees (c) / deciduous trees (d) / shrubs (s) / herbaceous (h) / pasture-lawn (p) / meadow (m) / invasives (i) / bare (b) | Open / Closed | | Y/N | | | | | Coniferous trees (c) / deciduous trees (d) / shrubs (s) / herbaceous (h) / pasture-lawn (h) / meadow (m) / invasives (i) / bare (b) | Open / Closed | | Y/N | |

## ANR RESULTS SHEET 3B

| REACH NUMBER | SITE NUMBER | Height (ft) | rip-rap/gabion /concrete/ other/non e | Length (ft) | 3.2 Left Adjacent Land Use: | Left Buffer | Left Buffer Width | 3.2 Right Adjacent Land Use: | Right Buffer | Right Buffer Width | 3.3 Left Bank: Typical Bank Slope: | Right Bank: Typical Bank Slope: | 3.4 Lower Bank Texture: | Upper Bank Texture: |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | o | h | 10-40 | a | d,h | 50 | high | vert, undercut | fa | fa |
| 1 | 2 | | concrete, tree revet | 2, 20 | m | h | >100 | m | h | >100 | vert | vert | ca | fa |
| 1 | 3 | 2-3 | none | | f | d | >200 | r | d,h | 150 | medium | vert | ca | fa |
| 2 | 1 | 5 | none | | m | d | >150 | f | d | >150 | low | high | ca | ca/fa |
| 2 | 2 | 14 | none | | f | c,d | >200 | f | d | >200 | medium | medium | ɔulder in gra | ɔulder in gra |
| 2 | 3 | | asphalt | 50 | f,i | d,s | >60 | f | c,d | >100 | low | high | ablation till | ablation till |
| 3 | 1 | | none | | i | c,d | 100 | r | d | >200 | high | high | fa | fa |
| 3 | 2 | 4 | none | | f | c | >200 | r | c | 100 | medium | medium | ca | fa |
| 3 | 3 | | none | | m | d | 30 | f,r | d | 30 up 100 down | vert | vert | ca | fa |
| 4 | 1 | | | | f | | >100 | m | d,s | >100 | medium | medium | fa | fa |
| 4 | 2 | | | | c | d,s | 50 | r | d,s | >100 | high | high | fa | fa |
| 4 | 3 | | | | c | d | 50 | r | d | 100 | high | high | fa | fa |
| 5 | 1 | | none | | m | h | >300 | m | s,h | >300 | high | medium | ca | fa |
| 5 | 2 | 3 | | | f,m | c,h | >300 | f,m | d,h | >300 | high | high | fa | fa |
| 5 | T2.1 | | | | m | d,s,h | >500 | a | d,s,h | >400 | high | high | fa | fa |
| 5 | T3.1 | 6 | | | m | d | 30 | m | d,h | 20 | vert | high | ca | fa |
| 6 | 1 | | | | m | h | 30 | r | h | 40 | high | high | ca | fa |
| 6 | 2 | 20 | | | f | d | >100 | f | d | >100 | vert,undercu | vert | ca | ca |
| 6 | 3 | | | | a | d,h | 3-20 | m | d | 10 | low | low | ca | ca |
| 6 | 4 | | | | m | s,h | 50-100 | m | s,h | >100 | vert | vert | s | s |
| 7 | 1 | 3.5 | | | m | d | >200 | r | h | 100 | vert | vert | fa | fa |
| 7 | 2 | 1.5 | | | f,m | d,h | 300 | f,m | d,h | 400 | high | vert | ca | fa |
| 7 | T6.1 | 3 | | | f | s,h | 40 | r | d,s,h | 150 | high | high | fa | fa |
| 7 | T6.2 | 2 | | | f,m | d,h | >300 | f,m | d,h | >300 | high | high | fa | fa |
| 7 | T6-1.1 | | | | f | h | >400 | f | h | >400 | high | high | sc | sc |
| 7 | T6-2.1 | 1 | | | a | h | >200 | m | h | >100 | high | high | fa | fa |
| 8 | 1 | | | | c,r | d | 30-100 | r | d,h | 60-100 | vert, undercu | vert | ca | ca |
| 8 | 2 | | | | m | h | >100 | m | h | >100 | vert | vert | ca | ca |
| 9 | 1 | | | minor, from farms | d | d | 200 | a | d | 100 | medium | low | fa | ca |
| 10 | 1 | | | | a | h | 0 | a | h | 0 | low | low | t | t |
| 11 | 1 | | | | f | d,h | >100 | f | d,h | >100 | high | high | ca | ca |
| CHOICES | | | | | forest (f) / agricultural-crop or pasture (a) / meadow (m) / commercial (c) / industry (i) / residential (r) / other (o) | coniferous trees (c) / deciduous trees (d) / shrubs (s) / herbaceous (h) / invasives (i) | | forest (f) / agricultural-crop or pasture (a) / meadow (m) / commercial (c) / industry (i) / residential (r) / other (o) | coniferous trees (c) / deciduous trees (d) / shrubs (s) / herbaceous (h) / invasives (i) | | Low (3:1) / Medium (2:1) / High (1:1) / Vert / Undercut | Low (3:1) / Medium (2:1) / High (1:1) / Vert / Undercut | till (t) / coarse alluvial (ca) / fine alluvial (fa) / sand (s) / silt/clay (sc) / other (o) | till (t) / coarse alluvial (ca) / fine alluvial (fa) / sand (s) / silt/clay (sc) / other (o) |

**ANR PHASE II PROTOCOL RESULTS SHEET 2**

| REACH NUMBER | SITE NUMBER | 2.6 Sinuosity | 2.7 Stream Type: | Stream Type: | 2.8 Riffles/Steps: | 2.9 Riffle/Step Spacing (ft) | Pool Spacing: (ft) | D50 in riffle | 2.10 Percent Bed Substrate Composition (should add up to 100%): | Bedrock | Boulder (>10 in) | Cobble (2.5 - 10 in) | Gravel (0.1 - 2.5 in) | Sand / Silt (< 0.1 in) | Clay | CPOM | 2.11 Largest Particle on bed: (in) | Largest Particle on bar: (in) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | high | E5 | RD | runs only | n/a | n/a | 0.1 | 100 | 0 | 0 | 0.5 | 0.5 | 99 | 0 | 0 | 4 | <0.1 |
| 1 | 2 | high | C5 | RP | partial | 175 | 50 | 0.1 | 100 | 0 | 0 | 0 | 2 | 97 | 0 | 1 | 3 | 1 |
| 1 | 3 | high | C5 | RP | partial | 80 | 30-40 | 1 | 100 | 0 | 0 | 1 | 8 | 91 | 0 | 0 | 4 | 4 |
| 2 | 1 | moderate | C3 | RP | complete | 60 | 100 | 4 | 100 | 0 | 1 | 30 | 25 | 44 | 0 | 0 | 32 | 6 |
| 2 | 2 | low | BC3 | PB | complete | 70 | none | 3.5 | 100 | 0 | 10 | 80 | 10 | 0 | 0 | 0 | 32 | 18 |
| 2 | 3 | high | C3 | RP | complete | 120 | 100 | 3 | 100 | 0 | 5 | 60 | 30 | 5 | 0 | 0 | 24 | 1.5 |
| 3 | 1 | low | B3 | RP | complete | 75 | 664 | 6-8 | 100 | 0 | 10 | 80 | 5 | 5 | 0 | 0 | 36 | none |
| 3 | 2 | moderate | B3 | RP | complete | 120 | 120 | 2.5 | 100 | 0 | 5 | 32 | 32 | 31 | 0 | 0 | >10 | 5 |
| 3 | 3 | low | C3 | RP | complete | 60 | none | 2.5 | 100 | 0 | 2 | 57 | 1 | 40 | 0 | 0 | 24 | 2.5 |
| 4 | 1 | high | B5 | RD | runs only | >400 | none | <0.1 | 100 | 0 | 0 | 0.1 | 0 | 99.9 | 0 | 0 | 1 | n/a |
| 4 | 2 | high | BC3 | PB | complete | n/a | none | 2 | 100 | 0 | 5 | 70 | 20 | 5 | 0 | 0 | 145 | n/a |
| 4 | 3 | | F3-5 | RD | runs only | >300 | n/a | <0.1 | 100 | 0 | 1 | 4 | 15 | 80 | 0 | 0 | 10 | <0.1 |
| 5 | 1 | moderate | B3 | PB/RP | partial | 60 | none | 6 | 100 | 0 | 10 | 75 | 0 | 15 | 0 | 0 | 30 | 0 |
| 5 | 2 | high | B4 | RP | complete | >100 | 120 | 0.1 | 100 | 0 | 0 | 0 | 25 | 75 | 0 | 0 | 2.5 | n/a |
| 5 | T2.1 | low | E6 | PB | runs only | none | none | <0.1 | 100 | 0 | 0 | 2 | 0 | 98 | 0 | 0 | 3 | 0 |
| 5 | T3.1 | high | B4 | PB | partial/di | 20 | none | 0.01 | 100 | 0 | 0 | 0 | 50 | 50 | 0 | 0 | 6 | 2 |
| 6 | 1 | moderate | G4 | RP | runs | 100 | 80 | 0.6 | 100 | 0 | 0 | 3 | 82 | 15 | 0 | 0 | 8 | 2 |
| 6 | 2 | moderate | F3 | PB | rtial, transve | n/a | 150 | 1.5 | 100 | 0 | 5 | 30 | 60 | 5 | 0 | 0 | 40 | 9 |
| 6 | 3 | low | BC3 | PB | complete | 50 | 150 | 3 | 100 | 0 | 5 | 85 | 10 | 0 | 0 | 0 | 30 | n/a |
| 6 | 4 | high | E5 | RD | runs only | n/a | n/a | <0.1 | 100 | 0 | 0 | 1 | 0 | 99 | 0 | 0 | 1 | n/a |
| 7 | 1 | low | B5 | RD | runs only | n/a | n/a | <0.1 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0.1 | n/a |
| 7 | 2 | low | F5 | RP | rtial, transve | 30 | 30 | 0.5 | 100 | 0 | 0 | 0 | 5 | 95 | 0 | 0 | 1.5 | 1 |
| 7 | T6.1 | moderate | E5 | RD | partial | 30 | n/a | <0.1 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0.1 | n/a |
| 7 | T6.2 | high | G5 | RD | runs only | n/a | n/a | <0.1 | 100 | 0 | 0 | 0 | 0 | 90 | 10 | 0 | 0.1 | 0.1 |
| 7 | T6-1.1 | moderate | C5 | RD | runs only | n/a | n/a | <0.1 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0.1 | 0.1 |
| 7 | T6-2.1 | low | B5 | RD | partial | 20 | n/a | <0.1 | 100 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0.1 | n/a |
| 8 | 1 | high | C4 | RP | rtial, transve | 120 | 50 | 0.2 | 100 | 0 | 0 | 0 | 40 | 60 | 0 | 0 | 2.4 | 2.2 |
| 8 | 2 | high | C3 | RP | plete, transv | 20-80 | n/a | 2 | 100 | 0 | 1 | 60 | 38 | 1 | 0 | 0 | 14 | n/a |
| 9 | 1 | moderate | B3 | PB | partial | 30 | 40 | 4 | 100 | 0 | 20 | 60 | 10 | 10 | 0 | 0 | 36 | 6 |
| 10 | 1 | low | E5 | RD | runs only | n/a | n/a | <0.1 | 100 | 0 | 0 | 0 | 2 | 98 | 0 | 0 | <0.1 | n/a |
| 11 | 1 | low | B3 | SP, PB | complete | 40 | 40 | 1.5 | 100 | 0 | 10 | 60 | 30 | | 0 | 0 | 22 | n/a |
| **CHOICES** | | Low / Moderate / High / Oxbows | A B D 3 | G E 1 4 | F C 2 5 | Cascade (C) Step-Pool (SP) Plane Bed (PB) Riffle-Pool (RP) Ripple-Dune (RD) Braided (B) | complete / partial / runs only / transverse | | | | | | | | | | | |

## ANR PHASE II PROTOCOL RESULTS SHEET 1A

| REACH NUMBER | SITE NUMBER | Latitude | Longitude | Elevation | Site Length | 1.1 Alluvial Fan: | 1.2 Floodplain | 1.2 Flood Plain Encroachment | 1.3 Berms LB | 1.3 Berms RB | 1.4 Roads, Railroads LB | 1.4 Roads, Railroads RB | 1.5 Developments in Floodplain LB | 1.5 Developments in Floodplain RB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | 210 | 500 | 0 | i | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 1 | 2 | | | | 550 | 0 | i | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 3 | | | | 440 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1 | | | 210 | 450 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 | | | | 675 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 3 | | | 270 | 450 | 0 | i | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1 | | | | 664 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 2 | 44.45988 | 73.10541 | 420 | 320 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 3 | | | | 460 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 1 | | | 360 | 400 | 0 | i | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 4 | 2 | | | | 250 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 3 | | | 370 | 270 | 0 | i | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 1 | 44.44575 | 73.09998 | 406 | 108 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 2 | 44.44431 | 73.09364 | 405 | 210 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | T2.1 | 44.44464 | 73.10227 | | 40 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | T3.1 | 44.44621 | 73.09276 | 384 | 114 | 0 | i | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 1 | | | 390 | 250 | 0 | i | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 2 | | | 395 | 300 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 3 | | | | 250 | 0 | a | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 6 | 4 | | | 450 | 360 | 0 | i | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 1 | 44.54534 | 73.07023 | 517 | 78 | 0 | i | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 2 | 44.43969 | 73.06735 | 500 | 120 | 0 | i | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | T6.1 | 44.44541 | 73.07021 | 498 | 56 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | T6.2 | 44.44593 | 73.06736 | 512 | 86 | 0 | i | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | T6-1.1 | | | | 30 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | T6-2.1 | 44.44585 | 73.06595 | 514 | 40 | 0 | i | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1 | | | 480 | 300 | 0 | i | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 8 | 2 | | | | 200 | 0 | i | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 9 | 1 | 44.42698 | 73.06992 | 506 | 240 | 0 | a | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 1 | | | 630 | 630 | 0 | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 1 | | | 640 | 100 | 0 | i | a | 0 | 0 | 0 | 0 | 0 | 0 |
| **CHOICES** | | | | | | Y/N | active (a) / inactive (i) / unsure (u) / bedrock (b) | Y/N | Y/N | Y/N | Y/N | Y/N | Y/N | Y/N |

## ANR RESULTS SHEET 1B

| REACH NUMBER | SITE NUMBER | 1.6 Adjacent Slope: Left | 1.6 Adjacent Slope: Right | 1.7 Valley Type: | 1.8 Upstream Grade Controls | Distance to Grade Control (ft) | Grade Control Type | Fish Barrier | 1.8 Downstream Grade Controls | Distance to Grade Control (ft) | Grade Control Type | Fish Barrier |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 4 | 4 | BU | 0 | | | 0 | 0 | | | 0 |
| 1 | 2 | 4 | 4 | BU | 0 | | | | 0 | | | |
| 1 | 3 | 4 | 4 | BU | 1 | | dams | | 1 | | dams | |
| 2 | 1 | 4 | 4 | BU | 0 | | | | 0 | | | |
| 2 | 2 | 3 | 4 | BAT | 0 | | | 0 | 0 | | | 0 |
| 2 | 3 | 4 | 4 | BAT | 0 | | | 0 | 0 | | | 0 |
| 3 | 1 | 3 | 4 | SC | 0 | | | | 0 | | | 0 |
| 3 | 2 | 3 | 3 | BU | 0 | | | | 0 | | | |
| 3 | 3 | 2 | 4 | SC | 0 | | | | 0 | | | |
| 4 | 1 | 4 | 4 | BAT | 0 | | | 0 | 0 | | | 0 |
| 4 | 2 | 3 | 4 | BU | 0 | | | 0 | 0 | | | 0 |
| 4 | 3 | 1 | 4 | BAT | 0 | | | 0 | 0 | | | 0 |
| 5 | 1 | 3 | 3 | BU | 0 | | | 0 | 1 | 300 | stream culve | 0 |
| 5 | 2 | 3 | 3 | BU | 0 | | | 0 | 0 | | | 0 |
| 5 | T2.1 | 4 | 4 | BU | 1 | >100 | dams | 1 | 1 | 200 | culverts | 1 |
| 5 | T3.1 | 4 | 4 | BU | 0 | | | | 0 | | | |
| 6 | 1 | 4 | 4 | BU | 0 | | | 0 | 0 | | | 0 |
| 6 | 2 | 4 | 4 | BAT | 1 | top of reach | boulders | 0 | 0 | | | |
| 6 | 3 | 4 | 4 | BAT | 0 | | | 0 | 0 | | | 0 |
| 6 | 4 | 4 | 4 | BAT | 0 | | LWD, dams | 0 | 0 | | | 0 |
| 7 | 1 | 4 | 4 | BU | 1 | 30 | dams | 1 | 0 | | | |
| 7 | 2 | 4 | 4 | BU | 0 | | | | 0 | | | |
| 7 | T6.1 | 4 | 3 | BU | 0 | | | | 0 | | | |
| 7 | T6.2 | 4 | 4 | BU | 0 | | | | 0 | | | |
| 7 | T6-1.1 | 4 | 4 | BU | 0 | | | | 0 | | | |
| 7 | T6-2.1 | 4 | 4 | BU | 0 | | | | 0 | | | |
| 8 | 1 | 4 | 4 | BU | 0 | | | 0 | 0 | | | 0 |
| 8 | 2 | 4 | 4 | BU | 1 | 350 | ete bottom b | 1 | 0 | | | 0 |
| 9 | 1 | 3 | 4 | SC | 1 | 30 | oulders, LW | 0 | 1 | 30 | oulders, LW | 0 |
| 10 | 1 | 3 | 3 | BU | 0 | | | 0 | 0 | | | 0 |
| 11 | 1 | 4 | 4 | SC | 1 | 70 | stream culve | 1 | 0 | | | 0 |
| **CHOICES** | | x-steep (1) / steep (2) / mod.(3) / shallow (4) | x-steep (1) / steep (2) / mod.(3) / shallow (4) | NC/SC/NU/BU /BAT | Y/N | | Bedrock / Boulders / LWD / Dams / Weirs / in-stream culverts / concrete bottom bridges | Y/N/U | Y/N | | Bedrock / Boulders / LWD / Dams / Weirs / in-stream culverts / concrete bottom bridges | Y/N/U |

**ALLEN BROOK RAPID GEOMORPHIC ASSESSMENT RESULTS**

| Reach Number | Site Number | 9-1: Degree Of Channel Degradation (Incision) | 9-2: Degree Of Channel Aggradation | 9-3: Over-Widened Channel | 9-4: Changes In Planform | TOTAL SCORE | RATING (TOTAL SCORE /80) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 13 | 8 | 11 | 14 | **46** | 0.58 |
| 1 | 2 | 10 | 6 | 13 | 13 | **42** | 0.53 |
| 1 | 3 | 18 | 11 | 18 | 13 | **60** | 0.75 |
| 2 | 1 | 18 | 15 | 18 | 13 | **64** | 0.80 |
| 2 | 2 | 18 | 13 | 11 | 8 | **50** | 0.63 |
| 2 | 3 | 13 | 13 | 9 | 8 | **43** | 0.54 |
| 3 | 1 | 13 | 18 | 13 | 18 | **62** | 0.78 |
| 3 | 2 | 15 | 13 | 15 | 14 | **57** | 0.71 |
| 3 | 3 | 15 | 11 | 13 | 14 | **53** | 0.66 |
| 4 | 1 | 16 | 8 | 18 | 18 | **60** | 0.75 |
| 4 | 2 | 18 | 14 | 18 | 18 | **68** | 0.85 |
| 4 | 3 | 14 | 10 | 12 | 18 | **54** | 0.68 |
| 5 | 1 | 12 | 15 | 12 | 6 | **45** | 0.56 |
| 5 | 2 | 8 | 8 | 9 | 5 | **30** | 0.38 |
| 5 | T2.1 | 20 | 8 | 20 | 18 | **66** | 0.83 |
| 5 | T3.1 | 1 | 3 | 1 | 17 | **22** | 0.28 |
| 6 | 1 | 15 | 13 | 13 | 8 | **49** | 0.61 |
| 6 | 2 | 18 | 13 | 13 | 2 | **46** | 0.58 |
| 6 | 3 | 18 | 13 | 18 | 18 | **67** | 0.84 |
| 6 | 4 | 11 | 8 | 18 | 2 | **39** | 0.49 |
| 7 | 1 | 10 | 11 | 5 | 13 | **39** | 0.49 |
| 7 | 2 | 8 | 13 | 8 | 11 | **40** | 0.50 |
| 7 | T6.1 | 9 | 10 | 13 | 11 | **43** | 0.54 |
| 7 | T6.2 | 9 | 10 | 10 | 13 | **42** | 0.53 |
| 7 | T6-1.1 | 15 | 16 | 18 | 16 | **65** | 0.81 |
| 7 | T6-2.1 | 12 | 15 | 15 | 18 | **60** | 0.75 |
| 8 | 1 | 16 | 6 | 7 | 4 | **33** | 0.41 |
| 8 | 2 | 13 | 13 | 8 | 18 | **52** | 0.65 |
| 9 | 1 | 20 | 18 | 17 | 18 | **73** | 0.91 |
| 10 | 1 | 18 | 18 | 18 | 18 | **72** | 0.90 |
| 11 | 1 | 18 | 18 | 18 | 18 | **72** | 0.90 |
| | TOTAL | 14 | 12.3 | 13.7 | 13.4 | **54** | 0.67 |

# ALLEN BROOK TMDL QUANTITATIVE RESULTS

| Reach Number | Site Number | % Left Bank Eroded | % Right Bank Eroded | Total # pieces LWD | Total # pieces NLWD | # particles Embedded ness (0-25%) | # particles Embedded ness (25 - 50%) | # particles Embedded ness (50 - 75%) | # particles Embedded ness (75 - 100%) | Number of Mid-Channel Bars | Size of Mid-channel bars (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | | | | | | | |
| 1 | 2 | 5 | 5 | 32 | 0 | 2 | 0 | 1 | 0 | | |
| 1 | 3 | <1 | <1 | 55 | 0 | 5 | 3 | 2 | 0 | | |
| 2 | 1 | 1 | 1 | 33 | 0 | 6 | 4 | 0 | 0 | | |
| 2 | 2 | <1 | 25 | 48 | 7 | 5 | 3 | 2 | 0 | | |
| 2 | 3 | | | 18 | 1 | 4 | 3 | 3 | 0 | | |
| 3 | 1 | 10 | 0 | 28 | 0 | 6 | 4 | 0 | 0 | 0 | |
| 3 | 2 | 10 | 25 | 27 | 0 | 5 | 3 | 2 | 0 | | |
| 3 | 3 | 5 | 0 | 8 | 5 | 4 | 5 | 1 | 0 | | |
| 4 | 1 | <1 | <1 | 10 | 0 | | | | | | |
| 4 | 2 | 0 | <2 | 11 | 0 | 3 | 4 | 3 | 0 | | 4 x 6 |
| 4 | 3 | <1 | <1 | 45 | 0 | 0 | 4 | 6 | 0 | | |
| 5 | 1 | 20 | 0 | 1 | 0 | 8 | 2 | 0 | 0 | 0 | |
| 5 | 2 | 80 | 20 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 5 | T2.1 | 0 | 0 | 4 | 0 | 0 | 2 | 8 | 0 | 0 | |
| 5 | T3.1 | 50 | 20 | 1 | 0 | 0 | 3 | 1 | 6 | | |
| 6 | 1 | 0 | 0 | 16 | 1 | 5 | 5 | 0 | 0 | | |
| 6 | 2 | 10 | 0 | 32 | 0 | 2 | 6 | 2 | 0 | | |
| 6 | 3 | <1 | <1 | 2 | 0 | 0 | 5 | 5 | 0 | | |
| 6 | 4 | <1 | <1 | 126 | 0 | | | | | 0 | |
| 7 | 1 | 80 | 80 | 16 | 0 | | | | | | |
| 7 | 2 | 25 | 25 | 15 | 0 | | | | | 0 | |
| 7 | T6.1 | 30 | 15 | 10 | 0 | | | | | | |
| 7 | T6.2 | 50 | 30 | 7 | 1 | | | | | | |
| 7 | T6-1.1 | <5 | <5 | 5 | 0 | | | | | 0 | |
| 7 | T6-2.1 | 20 | 20 | 0 | 0 | | | | | | |
| 8 | 1 | <1 | <1 | 43 | 1 | | | | | 2 | |
| 8 | 2 | 10 | <1 | 13 | 0 | 2 | 7 | 1 | 0 | | |
| 9 | 1 | 0 | 0 | 25 | 0 | 6 | 3 | 1 | 0 | 0 | |
| 10 | 1 | 0 | 0 | | | | | | | | |
| 11 | 1 | 0 | 0 | 1 | 0 | 4 | 6 | 0 | 0 | | |

| | | Allen Brook-Comments |
|---|---|---|
| **Reach #** | **Site #** | |
| 1 | 2 | fairly stable, incised stream<br>lots of sss (soft sediment)<br>not enough cobble in riffle to get embeddness<br>tree revetments |
| 2 | 1 | multiple flood chutes upstream RB<br>large mcb upstream, well vegetated<br>nice stable reach, with good floodplain area<br>mcb's with large woody debris<br>vegetated mcb's downstream with flood chute, RB<br>iron staining |
| 2 | 2 | long 180 foot mass failure RB at upstream end of reach<br>large woody debris at downstream end of reach with channel avulsion<br>downstream/upstream end of reach has good floodplain area<br>lots of periphyton<br>about 50 years old filled in abandoned channel |
| 2 | 3 | mcb downstream with island and flood chute<br>large woody debris upstream<br>highly sinuous - scour at outside bends<br>delta in planform wetland used to be channel<br>black stripy fish<br>lots of filamentous algae and silt |
| 3 | 1 | no pools<br>straight<br>almost all riffle/run<br>fairly good riparian conditions<br>slick rocks |
| 3 | 2 | seems pretty stable<br>some indications of widening<br>lots of sediment from upstream<br>well vegetated bars |
| 3 | 3 | not downcutting<br>featureless wide channel, all run<br>lots of old sediment, not highly embedded |
| 4 | 1 | this area could be restored with alternate bars to create thalwag - narrow channel and move fine sediment<br>trib 1 has Brennan Woods and stormwater pond entering<br>bottom 100 feet trib rip rapped<br>bed at confluence - ephemeral channel reach<br>slow run - sand bed - 2-3 riffles between 4.1 and 4.2<br>lots of small fish<br>mussels on bed and bars |
| 4 | 2 | this is short-steep reach upstream of long homogenous run<br>T1 is ephemeral - did not do rapid<br>flow through wetland at mouth enter wetland at 18 inch culvert with 1 ft scour<br>culvert: 3.5 inches wide, 0.7 deep at upstream end of reach, LB, active stormwater gully |
| 4 | 3 | LB stormwater gully<br>rip rap from swale to inlet and down hill<br>except for 4.2 downstream of double culvert, this whole reach is lots of silt and sand - mostly runs<br>big mussels alive in bed |
| 5 | 1 | doesn't appear to be downcutting, is widening<br>good candidate for tree planting restoration<br>riffles, runs, no pools |
| 5 | 2 | good for fish, bad for bugs<br>unable to sample embeddness -- no cobble<br>lots of beaver dams<br>evidence of beaver everywhere, some clay lenses in bed substrate |
| 5 | T2.1 | no bars, small meadow stream<br>typical meadow<br>probably aggrading due to culvert downstream |
| 5 | T3.1 | inset floodlains beginning to form<br>just finished downcutting, about to start widening<br>buckthorn, exotic invasive plant along bank |
| 6 | 1 | culvert downstream end<br>3-4 small vmcb, 2-3 in. wide, up to 6 in. long<br>vegetated narrow channel<br>lots of small fish<br>1 nice overhanging bank with big tree |

| | | |
|---|---|---|
| Reach # 6 | Site # 2 | RB with mass failure at downstream end<br>over-widened<br>2 flood chute - RB<br>history of current and historic channel avulsions<br>about 3-4 channel avulsion in reach, 2 current<br>woody debris jam at base of reach with tires and drums<br>mass failure RB<br>forest is about 60-90 yards wide of large ~18" diameter maples<br>many gullies, ephemeral channels on RB<br>some steep transverse riffles |
| 6 | 3 | plane bed system with occasional step pool<br>minor agriculture on either side<br>narrow right bank but not actively farmed<br>14h x 12 (in.) culvert<br>VT rip rap (old car), upstream RB, end of reach |
| 6 | 4 | channel avulsions due to woody debris jams, possibly due to beaver activity<br>highly sinuous channel with change in planform<br>oil slick on surface<br>sss<br>no trees |
| 7 | 1 | beaver dam 2 ft high just upstream<br>not real good riffles<br>top of reach right at beaver dam<br>bottom just above confluence with trib |
| 7 | 2 | downstream of here all beaver dams and ponds<br>upstream some urbanization and widening<br>beaver dams serving as grade control, but not in upstream portion<br>some downcutting<br>looks okay |
| 7 | T6.1 | low gradient<br>LWD keeping it from downcutting too badly<br>appears to be downcutting due to urbanization<br>very fine sediments |
| 7 | T6-1.1 | channel very stable<br>little erosion<br>upstream stormwater pond outlet<br>stormwater pond is one we visited previously with small inlet and very big outlet pipe<br>looks like little actual "detention" in pond<br>upstream of pond drained splits and left branch is wide with nice substrate but very dry<br>need to figure out why it is dry |
| 7 | T6-2.1 | small stream<br>not really a gully<br>upstream evidence of stream split may have been filled in for agriculture<br>upstream appears to be channelized<br>stream goes into culver and under property to road<br>no real evidence of storm flows |
| 8 | 1 | many mcb and unvegetated point bars<br>steep bar faces<br>LWD throughout reach<br>bridge at downstream end with aggraded vmcb under bridge<br>bridge out of planform alignment<br>bad odor<br>stream appears over-widened |
| 8 | 2 | concrete culvert 8' x 8' x 120 (ft.)<br>24" wide scour pool<br>2.5' wide scour downstream end of I-89 culvert<br>bankful LB - alluvium exposed<br>channel incised<br>widening, slumping<br>town road culvert 10'H x 9.5'W x 100'L with riprap at downstream end |
| 9 | 1 | doesn't seem to be doing anything, except where widening there is LWD<br>very stable<br>very good<br>appears that farmers may have dumped rocks or other debris over the edge (some gas cans, antifreeze)<br>some large LWD<br>grade control from boulders spaced along stream |
| 10 | 1 | grass channel may have been straightened at some point, pastured but not much<br>Cows pastured at night and some weekends (hardly a cow patty in site)<br>lots of frogs and turtles |
| 11 | 1 | stable steep reach above mud pond |

**ALLEN BROOK RAPID HABITAT ASSESSMENT RESULTS**

| Reach Number | Site Number | 8. Bank Stability (left bank) | 8. Bank Stability (right bank) | 9. Vegetative Protection (left bank) | 9. Vegetative Protection (right bank) | 10. Riparian Vegetative Zone Width (left bank) | 10. Riparian Vegetative Zone Width (right bank) | 1. Epifaunal Substrate/ Available Cover | 2.a Embedded-ness | 2.b Embed ded-ness | 3.a Velocity/ Depth Regime | 3.b Velocity/ Depth Regime | 4. Sediment Deposition | 5. Channel Flow Status | 6. Channel Alteration | 7.a Frequency of Riffles/ Steps (or bends) | 7.a Frequency of Riffles/ Steps (or bends) | Total Score | Ranking = Total Score/200 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 4 | 8 | 4 | 7 | 1 | 5 | 7 | | 8 | | 13 | 8 | 18 | 13 | | 13 | **109** | **0.55** |
| 1 | 2 | 8 | 8 | 7 | 7 | 7 | 9 | 8 | 16 | | 11 | | 6 | 11 | 18 | 13 | | **129** | **0.65** |
| 1 | 3 | 9 | 9 | 9 | 9 | 10 | 9 | 18 | 16 | | 18 | | 13 | 18 | 18 | 18 | | **174** | **0.87** |
| 2 | 1 | 9 | 9 | 9 | 9 | 9 | 9 | 18 | 16 | | 18 | | 15 | 18 | 18 | 18 | | **175** | **0.88** |
| 2 | 2 | 7 | 5 | 9 | 9 | 9 | 9 | 14 | 15 | | 13 | | 8 | 6 | 18 | 13 | | **135** | **0.68** |
| 2 | 3 | 6 | 9 | 9 | 7 | 7 | 9 | 12 | 13 | | 11 | | 9 | 14 | 18 | 10 | | **134** | **0.67** |
| 3 | 1 | 7 | 8 | 8 | 8 | 8 | 9 | 15 | 17 | | 13 | | 18 | 13 | 17 | 13 | | **154** | **0.77** |
| 3 | 2 | 7 | 6 | 10 | 10 | 10 | 6 | 16 | 17 | | 15 | | 11 | 18 | 18 | 14 | | **158** | **0.79** |
| 3 | 3 | 6 | 9 | 9 | 9 | 8 | 6 | 13 | 13 | | 10 | | 13 | 17 | 18 | 7 | | **138** | **0.69** |
| 4 | 1 | 9 | 9 | 9 | 7 | 9 | 9 | 8 | 1 | | 1 | | 3 | 18 | 18 | 1 | | **102** | **0.51** |
| 4 | 2 | 9 | 9 | 9 | 9 | 7 | 8 | 13 | 13 | | 14 | | 13 | 18 | 18 | 18 | | **158** | **0.79** |
| 4 | 3 | 7 | 7 | 9 | 9 | 7 | 8 | 13 | 10 | | 1 | | 8 | 18 | 18 | 1 | | **116** | **0.58** |
| 5 | 1 | 7 | 9 | 8 | 8 | 10 | 10 | 14 | 18 | | 10 | | 14 | 18 | 19 | 13 | | **158** | **0.79** |
| 5 | 2 | 1 | 5 | 2 | 3 | 9 | 9 | 13 | 4 | | 14.5 | | 4 | 15 | 18 | 9 | | **106.5** | **0.53** |
| 5 | T2.1 | 10 | 10 | 10 | 10 | 10 | 10 | 11 | 9 | | 7 | | 4 | 19 | 18 | 7 | | **135** | **0.68** |
| 5 | T3.1 | 1 | 2 | 8 | 8 | 9 | 9 | 9 | 5 | | 1 | | 4 | 5 | 18 | 2 | | **81** | **0.41** |
| 6 | 1 | 9 | 9 | 7 | 7 | 8 | 8 | 13 | 15 | | 11 | | 11 | 13 | 18 | 11 | | **140** | **0.70** |
| 6 | 2 | 9 | 7 | 9 | 9 | 9 | 9 | 18 | 13 | | 11 | | 8 | 8 | 18 | 13 | | **141** | **0.71** |
| 6 | 3 | 9 | 9 | 9 | 9 | 4 | 4 | 13 | 11 | | 18 | | 18 | 18 | 18 | 18 | | **158** | **0.79** |
| 6 | 4 | 9 | 9 | 7 | 7 | 9 | 9 | 13 | | 8 | | 13 | 6 | 18 | 18 | | 13 | **139** | **0.70** |
| 7 | 1 | 2 | 2 | 7 | 7 | 9 | 9 | 10 | | 9 | | 10 | 5 | 14 | 18 | | 8 | **110** | **0.55** |
| 7 | 2 | 5 | 5 | 9 | 9 | 9 | 9 | 10 | | 8 | | 10 | 10 | 8 | 18 | | 10 | **120** | **0.60** |
| 7 | T6.1 | 6 | 8 | 8 | 8 | 9 | 9 | 8 | | 11 | | 10 | 8 | 13 | 16 | | 13 | **127** | **0.64** |
| 7 | T6.2 | 4 | 4 | 9 | 9 | 10 | 10 | 5 | | 8 | | 3 | 8 | 13 | 18 | | 15 | **116** | **0.58** |
| 7 | T6-1.1 | 8 | 8 | 8 | 8 | 10 | 10 | 3 | | 8 | | 5 | 13 | 13 | 18 | | 13 | **125** | **0.63** |
| 7 | T6-2.1 | 7 | 7 | 10 | 10 | 10 | 10 | 3 | | 8 | | 1 | 2 | 7 | 18 | | 6 | **99** | **0.50** |
| 8 | 1 | 9 | 9 | 9 | 9 | 6 | 8 | 11 | | | 11 | | 1 | 8 | 18 | 12 | | **111** | **0.56** |
| 8 | 2 | 7 | 9 | 7 | 7 | 9 | 9 | 13 | 15 | | 13 | | 13 | 18 | 18 | 13 | | **151** | **0.76** |
| 9 | 1 | 10 | 10 | 10 | 10 | 9 | 7 | 20 | 17 | | 15 | | 15 | 15 | 20 | 18 | | **166** | **0.83** |
| 10 | 1 | 9 | 9 | 8 | 8 | 7 | 7 | 13 | | 18 | | 18 | 18 | 18 | 18 | 3 | 6 | **160** | **0.80** |
| 11 | 1 | 9 | 9 | 9 | 9 | 9 | 9 | 18 | 15 | | 18 | | 18 | 18 | 18 | 18 | | **177** | **0.89** |

## Cross Section

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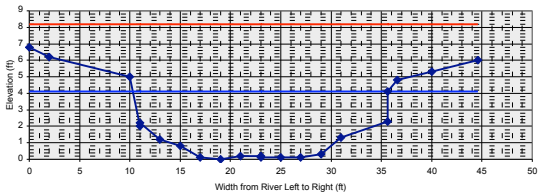
M1.1 Allen Brook




section: M1.1
stream: Allen Brook
watershed:
location:
description:
height of instrument (ft): 6.80

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| | 0 | 0 | 6.8 |
| | 2 | 0.6 | 6.2 |
| TB | 10 | 1.8 | 5 |
| | 11 | 4.8 | 2 |
| EW | 11 | 4.6 | 2.2 |
| | 13 | 5.6 | 1.2 |
| | 15 | 6 | 0.8 |
| | 17 | 6.7 | 0.1 |
| | 19 | 6.8 | 0 |
| | 21 | 6.6 | 0.2 |
| | 23 | 6.6 | 0.2 |
| | 23 | 6.7 | 0.1 |
| | 25 | 6.7 | 0.1 |
| | 27 | 6.7 | 0.1 |
| | 29 | 6.5 | 0.3 |
| | 31 | 5.5 | 1.3 |
| EW | 35.6 | 4.5 | 2.3 |
| RBF | 35.6 | 2.7 | 4.1 |
| break inslop | 36.6 | 2 | 4.8 |
| | 40 | 1.5 | 5.3 |
| flat after tha | 44.6 | 0.8 | 6 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2.7 | 1.8 | 51 | 0.5835249 | 0.020 |
| 4.1 | 5 | | | |

dimensions

| | | | |
|---|---|---|---|
| 83.9 | x-section area | 3.3 | d mean |
| 25.3 | width | 29.7 | wet P |
| 4.1 | d max | 2.8 | hyd radi |
| 5.0 | bank ht | 8 | w/d ratio |
| 61 | W flood prone area | 2.4 | ent ratio |

hydraulics

| | |
|---|---|
| 11.34 | velocity (ft/sec) |
| 951.3 | discharge rate, Q (cfs) |
| 1.03 | shear stress ((lbs/ft sq) |
| 0.73 | shear velocity (ft/sec) |
| 0.46 | stream power (lbs/ft/sec) |
| 15.6 | friction factor u/u* |
| 76 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

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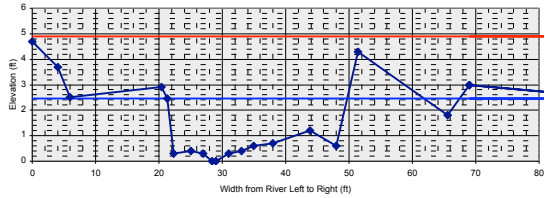
M1.2 Allen Brook




section: M1.2
stream: Allen Brook
watershed:
location:
description:
height of instrument (ft): 4.70

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 4.7 |
| | 4 | 1 | 3.7 |
| | 6 | 2.2 | 2.5 |
| LTB | 20.4 | 1.8 | 2.9 |
| LBF | 21.3 | 2.25 | 2.45 |
| LEW | 22.3 | 4.4 | 0.3 |
| BD | 25 | 4.3 | 0.4 |
| BD | 27 | 4.4 | 0.3 |
| TW | 28.4 | 4.7 | 0 |
| BD | 29 | 4.7 | 0 |
| BD | 31 | 4.4 | 0.3 |
| BD | 33 | 4.3 | 0.4 |
| REW | 34.9 | 4.1 | 0.6 |
| point bar | 38 | 4 | 0.7 |
| PB | 43.8 | 3.5 | 1.2 |
| REV | 48 | 4.1 | 0.6 |
| RTB | 51.4 | 0.4 | 4.3 |
| | 65.6 | 2.9 | 1.8 |
| | 69 | 1.7 | 3 |
| height of ab | 86 | 2.1 | 2.6 |
| | 69 | 1.7 | 3 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2.25 | 1.8 | 52 | 0.3 | 0.020 |
| 2.45 | 2.9 | | | |

dimensions

| | | | |
|---|---|---|---|
| 52.3 | x-section area | 1.5 | d mean |
| 33.9 | width | 36.4 | wet P |
| 2.5 | d max | 1.4 | hyd radi |
| 2.9 | bank ht | 22 | w/d ratio |
| 92 | W flood prone area | 2.7 | ent ratio |

hydraulics

| | |
|---|---|
| 5.18 | velocity (ft/sec) |
| 270.9 | discharge rate, Q (cfs) |
| 0.27 | shear stress ((lbs/ft sq) |
| 0.37 | shear velocity (ft/sec) |
| 0.04 | stream power (lbs/ft/sec) |
| 13.9 | friction factor u/u* |
| 15 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

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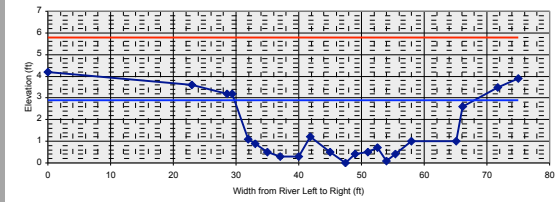
M1.3 Allen Brook




section: M1.3
stream: Allen Brook
watershed:
location:
description:
height of instrument (ft): 4.20

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 4.2 |
| G | 23 | 0.6 | 3.6 |
| LTB | 28.6 | 1 | 3.2 |
| LBF | 29.4 | 1 | 3.2 |
| TOE | 31.9 | 3.1 | 1.1 |
| LEW | 33.1 | 3.3 | 0.9 |
| BD | 35 | 3.7 | 0.5 |
| TW | 37 | 3.9 | 0.3 |
| BD | 40 | 3.9 | 0.3 |
| TBAR | 41.8 | 3 | 1.2 |
| BD | 45 | 3.7 | 0.5 |
| TW2 | 47.4 | 4.2 | 0 |
| BD | 49 | 3.8 | 0.4 |
| BD | 51 | 3.7 | 0.5 |
| TBAR | 52.5 | 3.5 | 0.7 |
| BD | 54 | 4.1 | 0.1 |
| REW | 55.4 | 3.8 | 0.4 |
| bar | 58 | 3.2 | 1 |
| RTOE | 65.1 | 3.2 | 1 |
| RBF/RTB | 66.1 | 1.6 | 2.6 |
| GD | 71.7 | 0.7 | 3.5 |
| RP | 75 | 0.3 | 3.9 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 1.3 | 1 | 149 | 0.6252033 | 0.030 |
| 2.9 | 3.2 | | | |

dimensions

| | | | |
|---|---|---|---|
| 78.7 | x-section area | 2.1 | d mean |
| 38.2 | width | 40.5 | wet P |
| 2.9 | d max | 1.9 | hyd radi |
| 3.2 | bank ht | 19 | w/d ratio |
| 149 | W flood prone area | 3.9 | ent ratio |

hydraulics

| | |
|---|---|
| 4.40 | velocity (ft/sec) |
| 346.3 | discharge rate, Q (cfs) |
| 0.39 | shear stress ((lbs/ft sq) |
| 0.45 | shear velocity (ft/sec) |
| 0.05 | stream power (lbs/ft/sec) |
| 9.8 | friction factor u/u* |
| 24 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| 33 | measured $D_{84}$(mm) | | |
| 19.0 | relative roughness | 10.1 | fric. factor |
| 0.029 | Manning's n from channel material | | |

## Cross Section

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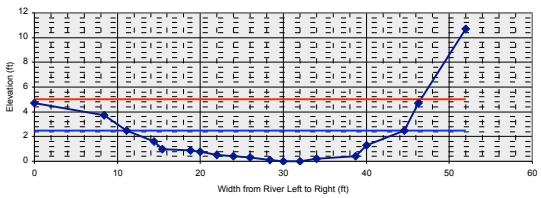
M2.1 Allen Brook




section: M2.1
stream: Allen Brook
watershed:
location: upstream farm bridge
description:
height of instrument (ft): 4.70

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| B | 0 | 0 | 4.7 |
| | 8.4 | 1 | 3.7 |
| BF | 11.1 | 2.2 | 2.5 |
| break inslop | 14.4 | 3.1 | 1.6 |
| TOE | 15.4 | 3.7 | 1 |
| EW | 18.8 | 3.8 | 0.9 |
| B | 20 | 3.9 | 0.8 |
| B | 22 | 4.2 | 0.5 |
| B | 24 | 4.3 | 0.4 |
| B | 26 | 4.4 | 0.3 |
| TW | 28.4 | 4.6 | 0.1 |
| TW | 30 | 4.7 | 0 |
| B | 32 | 4.7 | 0 |
| B | 34 | 4.5 | 0.2 |
| EW | 38.7 | 4.3 | 0.4 |
| TB | 40 | 3.4 | 1.3 |
| BF | 44.6 | 2.2 | 2.5 |
| RP | 46.3 | 0 | 4.7 |
| TB | 52 | -6 | 10.7 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2.2 | 1 | 50 | 1.1428571 | 0.040 |
| 2.5 | 3.7 | | | |

dimensions

| | | | |
|---|---|---|---|
| 56.5 | x-section area | 1.7 | d mean |
| 33.5 | width | 34.3 | wet P |
| 2.5 | d max | 1.6 | hyd radi |
| 3.7 | bank ht | 20 | w/d ratio |
| 50 | W flood prone area | 1.5 | ent ratio |

hydraulics

| | |
|---|---|
| 5.54 | velocity (ft/sec) |
| 313.3 | discharge rate, Q (cfs) |
| 1.18 | shear stress ((lbs/ft sq) |
| 0.78 | shear velocity (ft/sec) |
| 0.19 | stream power (lbs/ft/sec) |
| 7.1 | friction factor u/u* |
| 99 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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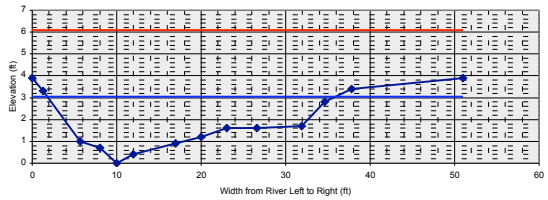
M2.2 Allen Brook




section: M2.2
stream: Allen Brook
watershed:
location: steep LB - FPA RB 1/3 up
description:
height of instrument (ft): 3.90

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 3.9 |
| BF | 1.3 | 0.6 | 3.3 |
| EW | 5.7 | 2.9 | 1 |
| BF | 8 | 3.2 | 0.7 |
| TW | 10 | 3.9 | 0 |
| BF | 12 | 3.5 | 0.4 |
| BF | 17 | 3 | 0.9 |
| BF | 20 | 2.7 | 1.2 |
| BF | 23 | 2.3 | 1.6 |
| EW | 26.6 | 2.3 | 1.6 |
| TOE | 31.9 | 2.2 | 1.7 |
| BF | 34.6 | 1.1 | 2.8 |
| TB | 37.8 | 0.5 | 3.4 |
| RP | 51 | 0 | 3.9 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 0.85 | 0.5 | 100 | 1.9904498 | 0.040 |
| 3.05 | 3.4 | | | |

dimensions

| | | | |
|---|---|---|---|
| 58.1 | x-section area | 1.7 | d mean |
| 34.2 | width | 35.1 | wet P |
| 3.1 | d max | 1.7 | hyd radi |
| 3.4 | bank ht | 20 | w/d ratio |
| 100 | W flood prone area | 2.9 | ent ratio |

hydraulics

| | |
|---|---|
| 7.33 | velocity (ft/sec) |
| 425.7 | discharge rate, Q (cfs) |
| 2.05 | shear stress ((lbs/ft sq) |
| 1.03 | shear velocity (ft/sec) |
| 0.44 | stream power (lbs/ft/sec) |
| 7.1 | friction factor u/u* |
| 295 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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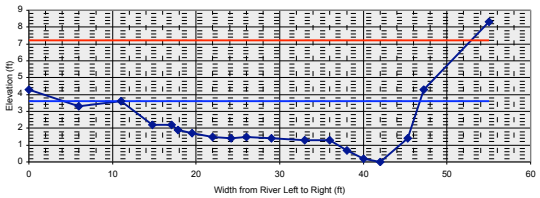
M2.3 Allen Brook




section: M2.3
stream: Allen Brook
watershed:
location: downstream of industrial ave - about 1000 ft
description:
height of instrument (ft): 4.30

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 4.3 |
| G | 6 | 1 | 3.3 |
| TB/BF | 11 | 0.7 | 3.6 |
| TOE | 14.8 | 2.1 | 2.2 |
| G | 17.1 | 2.1 | 2.2 |
| | 17.8 | 2.4 | 1.9 |
| EW | 19.5 | 2.6 | 1.7 |
| B | 22 | 2.8 | 1.5 |
| TW | 24.2 | 2.9 | 1.4 |
| B | 26 | 2.8 | 1.5 |
| B | 29 | 2.9 | 1.4 |
| B | 33 | 3 | 1.3 |
| POOL | 36 | 3 | 1.3 |
| POOL | 38 | 3.6 | 0.7 |
| POOL | 40 | 4.1 | 0.2 |
| POOL | 42 | 4.3 | 0 |
| EW | 45.3 | 2.9 | 1.4 |
| RP | 47.2 | 0 | 4.3 |
| BANK | 55 | -4 | 8.3 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 0.7 | 0.7 | 100 | 0.7317073 | 0.040 |
| 3.6 | 3.6 | | | |

dimensions

| | | | |
|---|---|---|---|
| 76.7 | x-section area | 1.8 | d mean |
| 42.5 | width | 44.5 | wet P |
| 3.6 | d max | 1.7 | hyd radi |
| 3.6 | bank ht | 24 | w/d ratio |
| 100 | W flood prone area | 2.4 | ent ratio |

hydraulics

| | |
|---|---|
| 4.56 | velocity (ft/sec) |
| 349.8 | discharge rate, Q (cfs) |
| 0.79 | shear stress ((lbs/ft sq) |
| 0.64 | shear velocity (ft/sec) |
| 0.08 | stream power (lbs/ft/sec) |
| 7.2 | friction factor u/u* |
| 51 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| 33 | measured $D_{84}$(mm) | | |
| 16.6 | relative roughness | 9.8 | fric. factor |
| 0.029 | Manning's n from channel material | | |

## Cross Section

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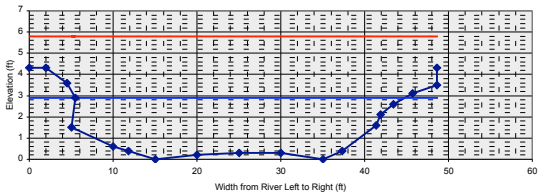
M3.1 Allen Brook




section: M3.1
stream: Allen Brook
watershed:
location: upstream of chiropractors aways
description:
height of instrument (ft): 4.30

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 4.3 |
| G | 2 | 0 | 4.3 |
| G | 4.5 | 0.7 | 3.6 |
| LBF | 5.5 | 1.4 | 2.9 |
| undercut ba | 5 | 2.8 | 1.5 |
| G | 10 | 3.7 | 0.6 |
| LEW | 11.8 | 3.9 | 0.4 |
| BD | 15 | 4.3 | 0 |
| TH | 20 | 4.1 | 0.2 |
| BD | 25 | 4 | 0.3 |
| BD | 30 | 4 | 0.3 |
| BD | 35 | 4.3 | 0 |
| REW | 37.3 | 3.9 | 0.4 |
| G | 41.4 | 2.7 | 1.6 |
| G | 41.9 | 2.2 | 2.1 |
| RBF | 43.4 | 1.7 | 2.6 |
| G | 45.7 | 1.2 | 3.1 |
| G | 48.6 | 0.8 | 3.5 |
| RP | 48.6 | 0 | 4.3 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 1.4 | 0 | 90 | 1.7711864 | 0.050 |
| 2.9 | 4.3 | | | |

dimensions

| | | | |
|---|---|---|---|
| 92.1 | x-section area | 2.3 | d mean |
| 40.3 | width | 41.9 | wet P |
| 2.9 | d max | 2.2 | hyd radi |
| 4.3 | bank ht | 18 | w/d ratio |
| 90 | W flood prone area | 2.2 | ent ratio |

hydraulics

| | |
|---|---|
| 5.66 | velocity (ft/sec) |
| 521.6 | discharge rate, Q (cfs) |
| 1.74 | shear stress ((lbs/ft sq) |
| 0.95 | shear velocity (ft/sec) |
| 0.25 | stream power (lbs/ft/sec) |
| 6.0 | friction factor u/u* |
| 214 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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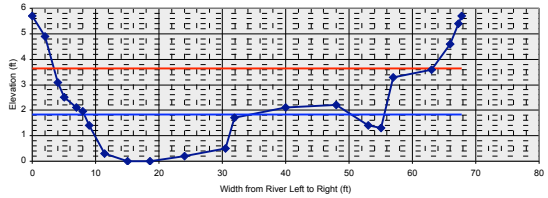
M3.2 Allen Brook




section: M3.2
stream: Allen Brook
watershed:
location: right near stormwater pond of Meadow something
description:
height of instrument (ft): 5.70

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 5.7 |
| G | 2 | 0.8 | 4.9 |
| G | 4 | 2.6 | 3.1 |
| G | 5 | 3.2 | 2.5 |
| G | 7 | 3.6 | 2.1 |
| LBF | 8 | 3.75 | 1.95 |
| G | 9 | 4.3 | 1.4 |
| LEW | 11.4 | 5.4 | 0.3 |
| BD | 15 | 5.7 | 0 |
| TW | 18.6 | 5.7 | 0 |
| BD | 24 | 5.5 | 0.2 |
| REW | 30.5 | 5.2 | 0.5 |
| RBF/TB | 31.9 | 4 | 1.7 |
| G | 40 | 3.6 | 2.1 |
| G | 48 | 3.5 | 2.2 |
| G | 53 | 4.3 | 1.4 |
| G | 55 | 4.4 | 1.3 |
| G | 57 | 2.4 | 3.3 |
| G | 63 | 2.1 | 3.6 |
| G | 66 | 1.1 | 4.6 |
| G | 67.3 | 0.3 | 5.4 |
| RP | 67.8 | 0 | 5.7 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 3.875 | 4 | 50 | 0.2083333 | 0.040 |
| 1.825 | 1.7 | | | |

dimensions

| | | | |
|---|---|---|---|
| 36.8 | x-section area | 1.2 | d mean |
| 31.4 | width | 32.5 | wet P |
| 1.8 | d max | 1.1 | hyd radi |
| 1.7 | bank ht | 27 | w/d ratio |
| 60 | W flood prone area | 1.9 | ent ratio |

hydraulics

| | |
|---|---|
| 1.85 | velocity (ft/sec) |
| 68.0 | discharge rate, Q (cfs) |
| 0.15 | shear stress ((lbs/ft sq) |
| 0.28 | shear velocity (ft/sec) |
| 0.01 | stream power (lbs/ft/sec) |
| 6.7 | friction factor u/u* |
| 9 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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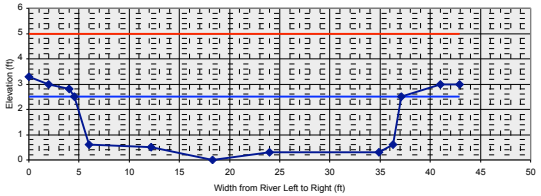
M3.3 Allen Brook




section: M3.3
stream: Allen Brook
watershed:
location: right near Brennan Woods
description:
height of instrument (ft): 3.30

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 3.3 |
| G | 2 | 0.3 | 3 |
| LTB | 4 | 0.5 | 2.8 |
| LBF | 4.5 | 0.8 | 2.5 |
| G | 6 | 2.7 | 0.6 |
| LEW | 12.2 | 2.8 | 0.5 |
| TW | 18.3 | 3.3 | 0 |
| BD | 24 | 3 | 0.3 |
| REW | 34.9 | 3 | 0.3 |
| G | 36.3 | 2.7 | 0.6 |
| RBF | 37.1 | 0.8 | 2.5 |
| G | 41 | 0.3 | 3 |
| RP | 42.9 | 0.3 | 3 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 0.8 | 0.5 | 100 | 1.75 | 0.040 |
| 2.5 | 2.8 | | | |

dimensions

| | | | |
|---|---|---|---|
| 68.2 | x-section area | 2.1 | d mean |
| 32.6 | width | 34.8 | wet P |
| 2.5 | d max | 2.0 | hyd radi |
| 2.8 | bank ht | 16 | w/d ratio |
| 100 | W flood prone area | 3.1 | ent ratio |

hydraulics

| | |
|---|---|
| 6.50 | velocity (ft/sec) |
| 443.7 | discharge rate, Q (cfs) |
| 1.53 | shear stress ((lbs/ft sq) |
| 0.89 | shear velocity (ft/sec) |
| 0.30 | stream power (lbs/ft/sec) |
| 7.3 | friction factor u/u* |
| 166 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| 33 | measured $D_{84}$(mm) | | |
| 19.3 | relative roughness | 10.2 | fric. factor |
| 0.029 | Manning's n from channel material | | |

## Cross Section

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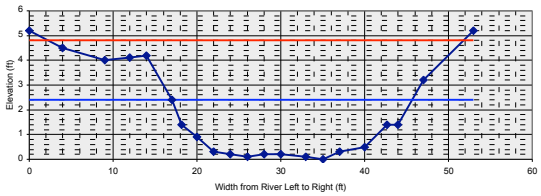
M4.1 Allen Brook




section: M4.1
stream: Allen Brook
watershed:
location: above confluence with Brennan Woods stormwater trib
description:
height of instrument (ft): 5.20

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 5.2 |
| G | 4 | 0.7 | 4.5 |
| G | 9 | 1.2 | 4 |
| G | 12 | 1.1 | 4.1 |
| TB | 14 | 1 | 4.2 |
| BF | 17 | 2.8 | 2.4 |
| EW | 18.2 | 3.8 | 1.4 |
| B | 20 | 4.3 | 0.9 |
| B | 22 | 4.9 | 0.3 |
| B | 24 | 5 | 0.2 |
| B | 26 | 5.1 | 0.1 |
| B | 28 | 5 | 0.2 |
| B | 30 | 5 | 0.2 |
| B | 33 | 5.1 | 0.1 |
| B | 35 | 5.2 | 0 |
| B | 37 | 4.9 | 0.3 |
| B | 40 | 4.7 | 0.5 |
| EW | 42.7 | 3.8 | 1.4 |
| BF | 44 | 3.8 | 1.4 |
| G | 47 | 2 | 3.2 |
| RP | 53 | 0 | 5.2 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2.8 | 4 | 50 | 0.1550388 | 0.020 |
| 2.4 | 4.2 | | | |

dimensions

| | | | |
|---|---|---|---|
| 52.1 | x-section area | 1.8 | d mean |
| 28.7 | width | 29.6 | wet P |
| 2.4 | d max | 1.8 | hyd radi |
| 4.2 | bank ht | 16 | w/d ratio |
| 50 | W flood prone area | 1.7 | ent ratio |

hydraulics

| | |
|---|---|
| 4.26 | velocity (ft/sec) |
| 222.3 | discharge rate, Q (cfs) |
| 0.17 | shear stress ((lbs/ft sq) |
| 0.30 | shear velocity (ft/sec) |
| 0.03 | stream power (lbs/ft/sec) |
| 14.4 | friction factor u/u* |
| 10 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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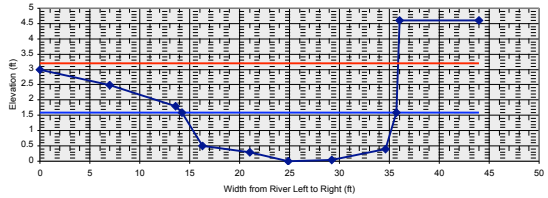
M4.2 Allen Brook




section: M4.2
stream: Allen Brook
watershed:
location: end of Allen Brook Lane - u/s Bob Slator, Journal up, light construction
description:
height of instrument (ft): 3.00

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 3 |
| TN | 7 | 0.5 | 2.5 |
| BF | 13.6 | 1.2 | 1.8 |
| EW | 14.2 | 1.4 | 1.6 |
| B | 16.3 | 2.5 | 0.5 |
| TW | 21 | 2.7 | 0.3 |
| B | 24.9 | 3 | 0 |
| EW | 29.2 | 2.95 | 0.05 |
| BF | 34.6 | 2.6 | 0.4 |
| FP | 35.7 | 1.4 | 1.6 |
| FP | 36 | -1.6 | 4.6 |
| FP | 44 | -1.6 | 4.6 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 1.4 | 1.7 | 40 | 1.3888889 | 0.030 |
| 1.6 | 1.8 | | | |

dimensions

| | | | |
|---|---|---|---|
| 27.3 | x-section area | 1.3 | d mean |
| 21.5 | width | 22.3 | wet P |
| 1.6 | d max | 1.2 | hyd radi |
| 1.8 | bank ht | 17 | w/d ratio |
| 40 | W flood prone area | 1.9 | ent ratio |

hydraulics

| | |
|---|---|
| 6.68 | velocity (ft/sec) |
| 182.4 | discharge rate, Q (cfs) |
| 1.06 | shear stress ((lbs/ft sq) |
| 0.74 | shear velocity (ft/sec) |
| 0.33 | stream power (lbs/ft/sec) |
| 9.0 | friction factor u/u* |
| 81 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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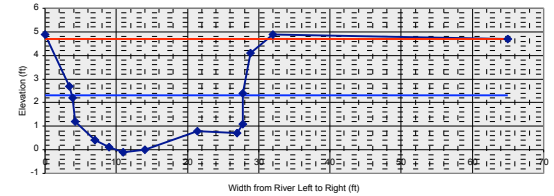
M4.3 Allen Brook




section: M4.3
stream: Allen Brook
watershed:
location: upstream road by shopping center
description:
height of instrument (ft): 4.90

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 4.9 |
| TB | 3.4 | 2.2 | 2.7 |
| BF | 3.9 | 2.7 | 2.2 |
| EW | 4.2 | 3.7 | 1.2 |
| BF | 7 | 4.5 | 0.4 |
| BF | 9 | 4.8 | 0.1 |
| BF | 11 | 5 | -0.1 |
| BF | 14 | 4.9 | 0 |
| EW | 21.4 | 4.1 | 0.8 |
| bar | 27 | 4.2 | 0.7 |
| TOE | 27.8 | 3.8 | 1.1 |
| BF | 27.8 | 2.5 | 2.4 |
| TB | 28.8 | 0.8 | 4.1 |
| RP | 32 | 0 | 4.9 |
| FP | 65 | 0.2 | 4.7 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2.6 | 2.2 | 30 | 0.4724568 | 0.020 |
| 2.3 | 2.7 | | | |

dimensions

| | | | |
|---|---|---|---|
| 44.0 | x-section area | 1.8 | d mean |
| 24.0 | width | 26.3 | wet P |
| 2.4 | d max | 1.7 | hyd radi |
| 2.8 | bank ht | 13 | w/d ratio |
| 30 | W flood prone area | 1.3 | ent ratio |

hydraulics

| | |
|---|---|
| 3.68 | velocity (ft/sec) |
| 162.0 | discharge rate, Q (cfs) |
| 0.13 | shear stress ((lbs/ft sq) |
| 0.26 | shear velocity (ft/sec) |
| 0.02 | stream power (lbs/ft/sec) |
| 14.3 | friction factor u/u* |
| 8 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| 33 | measured $D_{84}$(mm) | | |
| 16.9 | relative roughness | 9.8 | fric. factor |
| 0.029 | Manning's n from channel material | | |

## Cross Section

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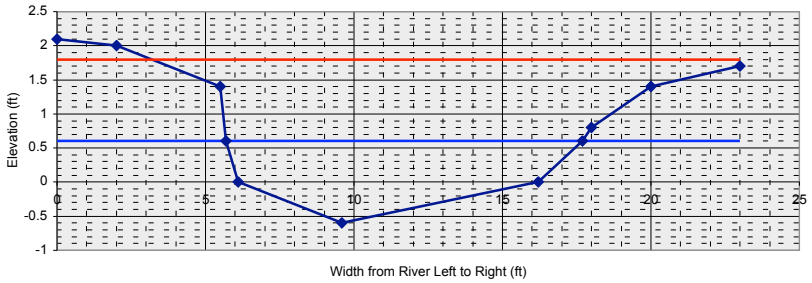
M5.1 Allen Brook




| | |
|---|---|
| section: | M5.1 |
| stream: | Allen Brook |
| watershed: | |
| location: | just upstream of Tafts Farms development |
| description: | |
| height of instrument (ft): | 2.10 |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 2.1 |
| G | 2 | 0.1 | 2 |
| LTB | 5.5 | 0.7 | 1.4 |
| LBF | 5.7 | 1.5 | 0.6 |
| LEW | 6.1 | 2.1 | 0 |
| TW | 9.6 | 2.7 | -0.6 |
| REW | 16.2 | 2.1 | 0 |
| RBF | 17.7 | 1.5 | 0.6 |
| RTB | 18 | 1.3 | 0.8 |
| G | 20 | 0.7 | 1.4 |
| RP | 23 | 0.4 | 1.7 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 1.5 | 0.7 | 20 | 4.41176471 | 0.050 |
| 0.6 | 1.4 | | | |

| dimensions | | | |
|---|---|---|---|
| 9.7 | x-section area | 0.8 | d mean |
| 12.0 | width | 12.5 | wet P |
| 1.2 | d max | 0.8 | hyd radi |
| 2.0 | bank ht | 15 | w/d ratio |
| 20 | W flood prone area | 1.7 | ent ratio |

| hydraulics | |
|---|---|
| 5.26 | velocity (ft/sec) |
| 50.8 | discharge rate, Q (cfs) |
| 2.12 | shear stress ((lbs/ft sq) |
| 1.05 | shear velocity (ft/sec) |
| 0.93 | stream power (lbs/ft/sec) |
| 5.0 | friction factor u/u* |
| 315 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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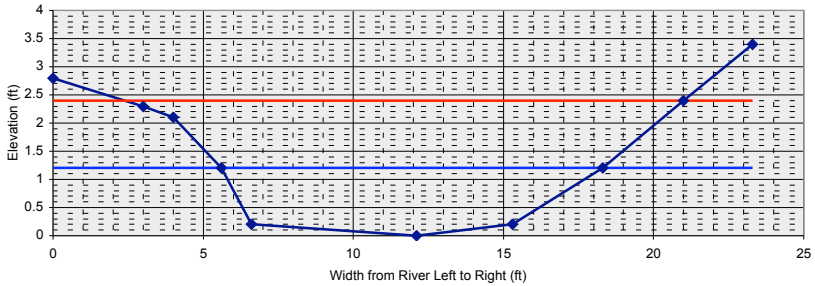
M5.2 Allen Brook




| | |
|---|---|
| section: | M5.2 |
| stream: | Allen Brook |
| watershed: | |
| location: | |
| description: | |
| height of instrument (ft): | 3.40 |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0.6 | 2.8 |
| G | 3 | 1.1 | 2.3 |
| LTB | 4 | 1.3 | 2.1 |
| LBF | 5.6 | 2.2 | 1.2 |
| LEW | 6.6 | 3.2 | 0.2 |
| TW | 12.1 | 3.4 | 0 |
| REW | 15.3 | 3.2 | 0.2 |
| RBF | 18.3 | 2.2 | 1.2 |
| G | 21 | 1 | 2.4 |
| RTB | 23.3 | 0 | 3.4 |

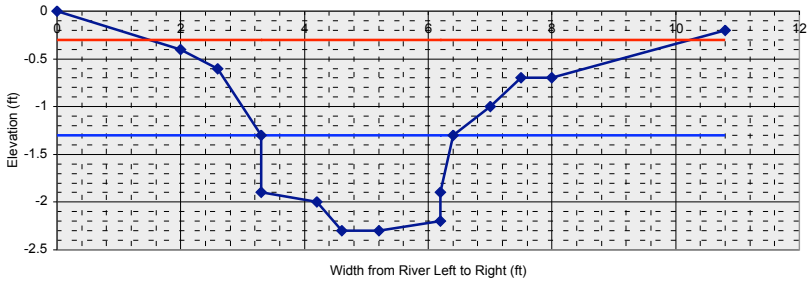
| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2.2 | 1.3 | 23 | 2.17948718 | 0.020 |
| 1.2 | 2.1 | | | |

| dimensions | | | |
|---|---|---|---|
| 11.6 | x-section area | 0.9 | d mean |
| 12.7 | width | 13.3 | wet P |
| 1.2 | d max | 0.9 | hyd radi |
| 2.1 | bank ht | 14 | w/d ratio |
| 23 | W flood prone area | 1.8 | ent ratio |

| hydraulics | |
|---|---|
| 10.01 | velocity (ft/sec) |
| 115.8 | discharge rate, Q (cfs) |
| 1.18 | shear stress ((lbs/ft sq) |
| 0.78 | shear velocity (ft/sec) |
| 0.93 | stream power (lbs/ft/sec) |
| 12.8 | friction factor u/u* |
| 101 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

M5 T2.1 Allen Brook




| | |
|---|---|
| section: | M5 T2.1 |
| stream: | Allen Brook |
| watershed: | |
| location: | right by 2 |
| description: | |
| height of instrument (ft): | |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 0 |
| G | 2 | 0.4 | -0.4 |
| LTB | 2.6 | 0.6 | -0.6 |
| LBF | 3.3 | 1.3 | -1.3 |
| LEW | 3.3 | 1.9 | -1.9 |
| BD | 4.2 | 2 | -2 |
| BD | 4.6 | 2.3 | -2.3 |
| TW | 5.2 | 2.3 | -2.3 |
| G | 6.2 | 2.2 | -2.2 |
| REW | 6.2 | 1.9 | -1.9 |
| RBF | 6.4 | 1.3 | -1.3 |
| RTB | 7 | 1 | -1 |
| G | 7.5 | 0.7 | -0.7 |
| G | 8 | 0.7 | -0.7 |
| RP | 10.8 | 0.2 | -0.2 |
| 1 | | | |

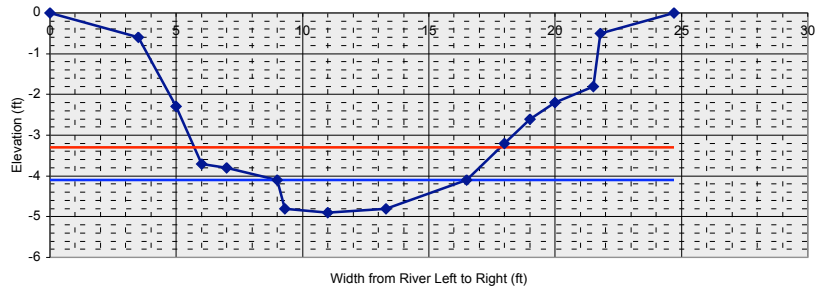
| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 1.3 | 0.6 | 9 | | 0.020 |
| -1.3 | -0.6 | | | |

| dimensions | | | |
|---|---|---|---|
| 2.5 | x-section area | 0.8 | d mean |
| 3.1 | width | 4.5 | wet P |
| 1.0 | d max | 0.6 | hyd radi |
| 1.7 | bank ht | 4 | w/d ratio |
| 9 | W flood prone area | 2.9 | ent ratio |

| hydraulics | |
|---|---|
| 0.00 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.00 | stream power (lbs/ft/sec) |
| 0.0 | friction factor u/u* |
| 0 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

M5 T3.1 Allen Brook




| | |
|---|---|
| section: | M5 T3.1 |
| stream: | Allen Brook |
| watershed: | |
| location: | up main trib |
| description: | |
| height of instrument (ft): | |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 0 |
| LTB | 3.5 | 0.6 | -0.6 |
| G | 5 | 2.3 | -2.3 |
| G | 6 | 3.7 | -3.7 |
| G | 7 | 3.8 | -3.8 |
| LBF | 9 | 4.1 | -4.1 |
| LEW | 9.3 | 4.8 | -4.8 |
| TW | 11 | 4.9 | -4.9 |
| REW | 13.3 | 4.8 | -4.8 |
| RBF | 16.5 | 4.1 | -4.1 |
| G | 18 | 3.2 | -3.2 |
| G | 19 | 2.6 | -2.6 |
| G | 20 | 2.2 | -2.2 |
| G | 21.5 | 1.8 | -1.8 |
| RTB | 21.8 | 0.5 | -0.5 |
| RP | 24.7 | 0 | 0 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 4.1 | 0.6 | 14 | 0.64935065 | 0.020 |
| -4.1 | -0.6 | | | |

| dimensions | | | |
|---|---|---|---|
| 4.2 | x-section area | 0.6 | d mean |
| 7.5 | width | 8.0 | wet P |
| 0.8 | d max | 0.5 | hyd radi |
| 4.3 | bank ht | 13 | w/d ratio |
| 14 | W flood prone area | 1.9 | ent ratio |

| hydraulics | |
|---|---|
| 3.90 | velocity (ft/sec) |
| 16.5 | discharge rate, Q (cfs) |
| 0.21 | shear stress ((lbs/ft sq) |
| 0.33 | shear velocity (ft/sec) |
| 0.11 | stream power (lbs/ft/sec) |
| 11.8 | friction factor u/u* |
| 12 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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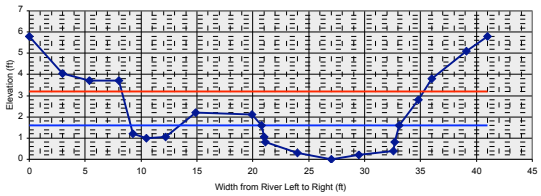
M6.1 Allen Brook




section: M6.1
stream: Allen Brook
watershed:
location: upstream Southridge (??) development
description:
height of instrument (ft): 5.80

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 5.8 |
| gully | 3 | 1.75 | 4.05 |
| gully | 5.4 | 2.1 | 3.7 |
| TB | 8 | 2.1 | 3.7 |
| flood chute | 9.3 | 4.6 | 1.2 |
| EW - FC | 10.5 | 4.8 | 1 |
| EW - FC | 12.2 | 4.75 | 1.05 |
| VBAR | 14.9 | 3.6 | 2.2 |
| VBAR | 19.9 | 3.7 | 2.1 |
| BF | 20.8 | 4.2 | 1.6 |
| EW - FC | 21 | 4.75 | 1.05 |
| B | 21.1 | 5 | 0.8 |
| B | 24 | 5.5 | 0.3 |
| B | 27 | 5.8 | 0 |
| B | 29.5 | 5.6 | 0.2 |
| B | 32.6 | 5.4 | 0.4 |
| EW | 32.7 | 5 | 0.8 |
| BF | 33.1 | 4.2 | 1.6 |
| break inslop | 34.8 | 3 | 2.8 |
| G | 36 | 2 | 3.8 |
| G | 39.1 | 0.7 | 5.1 |
| RP | 41 | 0 | 5.8 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 4.2 | 2.1 | 26 | 0.1626016 | 0.030 |
| 1.6 | 3.7 | | | |

dimensions

| | | | |
|---|---|---|---|
| 17.5 | x-section area | 1.0 | d mean |
| 16.7 | width | 18.5 | wet P |
| 1.6 | d max | 0.9 | hyd radi |
| 3.7 | bank ht | 16 | w/d ratio |
| 26 | W flood prone area | 1.6 | ent ratio |

hydraulics

| | |
|---|---|
| 1.93 | velocity (ft/sec) |
| 33.8 | discharge rate, Q (cfs) |
| 0.10 | shear stress ((lbs/ft sq) |
| 0.22 | shear velocity (ft/sec) |
| 0.01 | stream power (lbs/ft/sec) |
| 8.7 | friction factor u/u* |
| 6 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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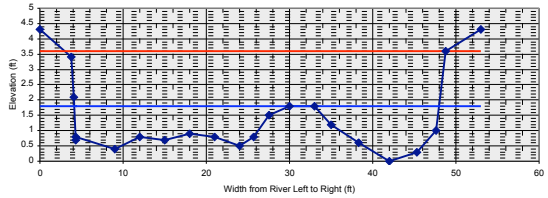
M6.2 Allen Brook




section: M6.2
stream: Allen Brook
watershed:
location: downstream old stage road
description:
height of instrument (ft): 4.30

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 4.3 |
| TB | 3.8 | 0.9 | 3.4 |
| BF | 4.1 | 2.2 | 2.1 |
| BF | 4.3 | 3.6 | 0.7 |
| EW | 4.31 | 3.5 | 0.8 |
| TW | 9 | 3.9 | 0.4 |
| B | 12 | 3.5 | 0.8 |
| B | 15 | 3.6 | 0.7 |
| bar | 18 | 3.4 | 0.9 |
| B | 21 | 3.5 | 0.8 |
| B - pool | 24 | 3.8 | 0.5 |
| EW | 25.7 | 3.5 | 0.8 |
| VMCB/BF | 27.5 | 2.8 | 1.5 |
| VMCB/BF | 30 | 2.5 | 1.8 |
| VMCB/BF | 33 | 2.5 | 1.8 |
| | 35 | 3.1 | 1.2 |
| EW - FC | 38.3 | 3.7 | 0.6 |
| FCB | 42 | 4.3 | 0 |
| EW - FC | 45.3 | 4 | 0.3 |
| TOE | 47.6 | 3.3 | 1 |
| TB | 48.8 | 0.7 | 3.6 |
| RP | 53 | 0 | 4.3 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2.5 | 0.9 | 45 | 1.0539298 | 0.030 |
| 1.8 | 3.4 | | | |

dimensions

| | | | |
|---|---|---|---|
| 42.6 | x-section area | 1.0 | d mean |
| 40.8 | width | 42.9 | wet P |
| 1.8 | d max | 1.0 | hyd radi |
| 3.4 | bank ht | 39 | w/d ratio |
| 48 | W flood prone area | 1.2 | ent ratio |

hydraulics

| | |
|---|---|
| 5.09 | velocity (ft/sec) |
| 216.9 | discharge rate, Q (cfs) |
| 0.66 | shear stress ((lbs/ft sq) |
| 0.58 | shear velocity (ft/sec) |
| 0.08 | stream power (lbs/ft/sec) |
| 8.7 | friction factor u/u* |
| 42 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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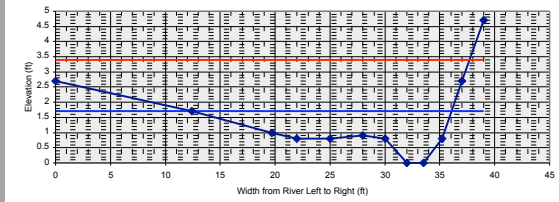
M6.3 Allen Brook




section: M6.3
stream: Allen Brook
watershed:
location: upstream old stage road
description:
height of instrument (ft): 2.70

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 2.7 |
| EV/BF | 12.4 | 1 | 1.7 |
| EW | 19.7 | 1.7 | 1 |
| BD | 22 | 1.9 | 0.8 |
| TW | 25 | 1.9 | 0.8 |
| BD | 28 | 1.8 | 0.9 |
| BD | 30 | 1.9 | 0.8 |
| Pool | 32 | 2.7 | 0 |
| Pool | 33.5 | 2.7 | 0 |
| EW | 35.2 | 1.9 | 0.8 |
| RP | 37 | 0 | 2.7 |
| RTB | 39 | -2 | 4.7 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 1 | 0 | 45 | 1.4497254 | 0.040 |
| 1.7 | 2.7 | | | |

dimensions

| | | | |
|---|---|---|---|
| 19.1 | x-section area | 0.8 | d mean |
| 23.7 | width | 24.4 | wet P |
| 1.7 | d max | 0.8 | hyd radi |
| 2.7 | bank ht | 29 | w/d ratio |
| 45 | W flood prone area | 1.9 | ent ratio |

hydraulics

| | |
|---|---|
| 3.80 | velocity (ft/sec) |
| 72.5 | discharge rate, Q (cfs) |
| 0.71 | shear stress ((lbs/ft sq) |
| 0.60 | shear velocity (ft/sec) |
| 0.11 | stream power (lbs/ft/sec) |
| 6.3 | friction factor u/u* |
| 45 | threshold grain size (mm) |

check from channel material

| | | | |
|---|---|---|---|
| 33 | measured $D_{84}$(mm) | | |
| 7.5 | relative roughness | 7.8 | fric. factor |
| 0.032 | Manning's n from channel material | | |

## Cross Section

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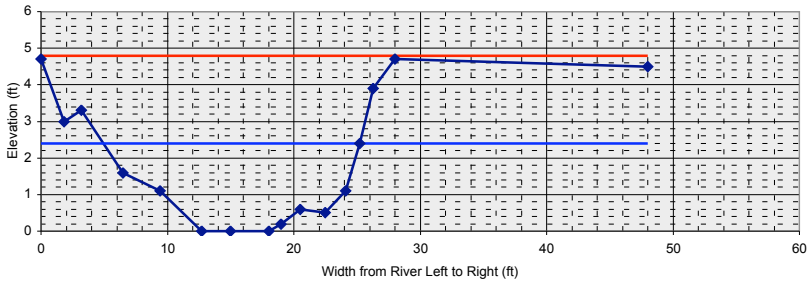
M6.4 Allen Brook




| | |
|---|---|
| section: | M6.4 |
| stream: | Allen Brook |
| watershed: | |
| location: | upstream bike bridge, E. of old stage road |
| description: | |
| height of instrument (ft): | 4.70 |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| RP | 0 | 0 | 4.7 |
| G | 1.8 | 1.7 | 3 |
| | 3.2 | 1.4 | 3.3 |
| EW | 6.5 | 3.1 | 1.6 |
| B | 9.4 | 3.6 | 1.1 |
| B | 12.7 | 4.7 | 0 |
| B | 15 | 4.7 | 0 |
| B | 18 | 4.7 | 0 |
| B | 19 | 4.5 | 0.2 |
| B | 20.5 | 4.1 | 0.6 |
| B | 22.5 | 4.2 | 0.5 |
| EW | 24.1 | 3.6 | 1.1 |
| BF | 25.2 | 2.3 | 2.4 |
| G | 26.3 | 0.8 | 3.9 |
| RP | 28 | 0 | 4.7 |
| FP | 48 | 0.2 | 4.5 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2.3 | 0 | 49 | 1.4 | 0.020 |
| 2.4 | 4.7 | | | |

| dimensions | | | |
|---|---|---|---|
| 34.8 | x-section area | 1.7 | d mean |
| 20.3 | width | 21.5 | wet P |
| 2.4 | d max | 1.6 | hyd radi |
| 4.7 | bank ht | 12 | w/d ratio |
| 49 | W flood prone area | 2.4 | ent ratio |

| hydraulics | |
|---|---|
| 12.13 | velocity (ft/sec) |
| 421.7 | discharge rate, Q (cfs) |
| 1.42 | shear stress ((lbs/ft sq) |
| 0.85 | shear velocity (ft/sec) |
| 0.85 | stream power (lbs/ft/sec) |
| 14.2 | friction factor u/u* |
| 143 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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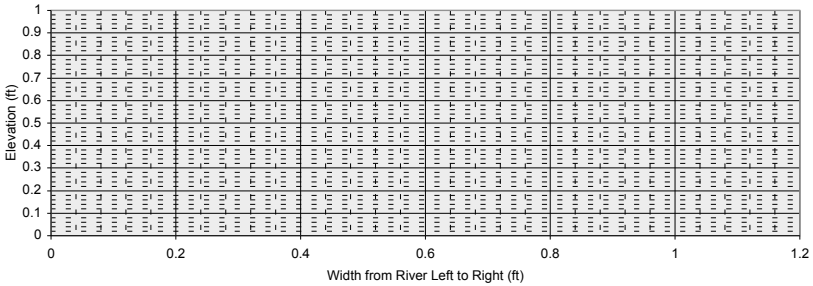


| | |
|---|---|
| section: | |
| stream: | |
| watershed: | INTENTIONALLY LEFT BLANK |
| location: | |
| description: | |
| height of instrument (ft): | |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| | | | | |
| 0 | --- | | | |

| dimensions | | | |
|---|---|---|---|
| 0.0 | x-section area | 0.0 | d mean |
| 0.0 | width | 0.0 | wet P |
| 0.0 | d max | 0.0 | hyd radi |
| 0.0 | bank ht | 0 | w/d ratio |
| 0 | W flood prone area | 0.0 | ent ratio |

| hydraulics | |
|---|---|
| 0.00 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.00 | stream power (lbs/ft/sec) |
| 0.0 | friction factor u/u* |
| 0 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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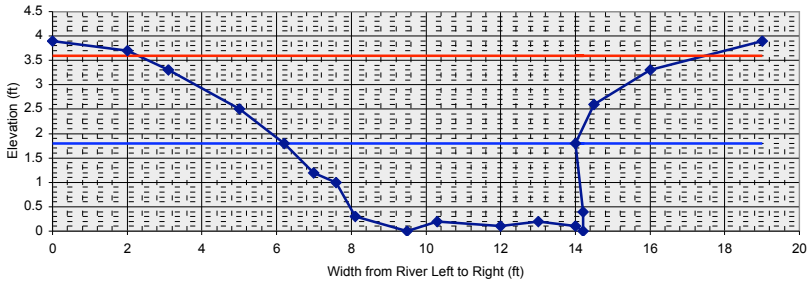
M7.1 Allen Brook




| | |
|---|---|
| section: | M7.1 |
| stream: | Allen Brook |
| watershed: | |
| location: | just above confluence of main and trib |
| description: | |
| height of instrument (ft): | 3.90 |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 3.9 |
| G | 2 | 0.2 | 3.7 |
| LTB | 3.1 | 0.6 | 3.3 |
| G | 5 | 1.4 | 2.5 |
| LBF | 6.2 | 2.1 | 1.8 |
| G | 7 | 2.7 | 1.2 |
| G | 7.6 | 2.9 | 1 |
| LEW | 8.1 | 3.6 | 0.3 |
| BD | 9.5 | 3.9 | 0 |
| BD | 10.3 | 3.7 | 0.2 |
| BD | 12 | 3.8 | 0.1 |
| BD | 13 | 3.7 | 0.2 |
| TW | 14 | 3.8 | 0.1 |
| G | 14.2 | 3.9 | 0 |
| RWS | 14.2 | 3.5 | 0.4 |
| RBF | 14 | 2.1 | 1.8 |
| RTB | 14.5 | 1.3 | 2.6 |
| G | 16 | 0.6 | 3.3 |
| RP | 19 | 0 | 3.9 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2.1 | 0.6 | 15 | 0.32258065 | 0.020 |
| 1.8 | 3.3 | | | |

| dimensions | | | |
|---|---|---|---|
| 11.5 | x-section area | 1.4 | d mean |
| 8.2 | width | 10.5 | wet P |
| 1.8 | d max | 1.1 | hyd radi |
| 3.3 | bank ht | 6 | w/d ratio |
| 15 | W flood prone area | 1.8 | ent ratio |

| hydraulics | |
|---|---|
| 4.49 | velocity (ft/sec) |
| 51.6 | discharge rate, Q (cfs) |
| 0.22 | shear stress ((lbs/ft sq) |
| 0.34 | shear velocity (ft/sec) |
| 0.12 | stream power (lbs/ft/sec) |
| 13.3 | friction factor u/u* |
| 13 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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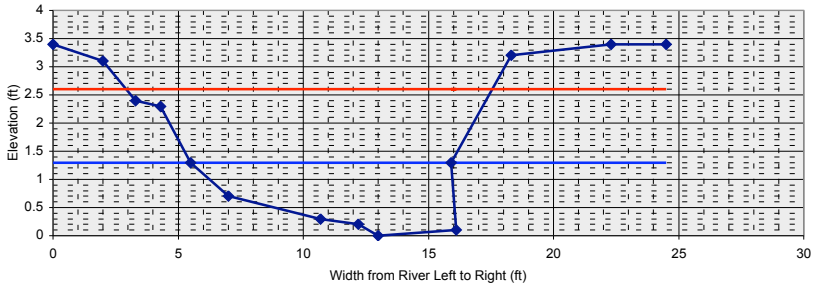
M7.2 Allen Brook




| | |
|---|---|
| section: | M7.2 |
| stream: | Allen Brook |
| watershed: | |
| location: | about 100 to 200 ft downstream of road |
| description: | |
| height of instrument (ft): | 3.60 |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| | 0 | 0.2 | 3.4 |
| | 2 | 0.5 | 3.1 |
| | 3.3 | 1.2 | 2.4 |
| | 4.3 | 1.3 | 2.3 |
| | 5.5 | 2.3 | 1.3 |
| | 7 | 2.9 | 0.7 |
| | 10.7 | 3.3 | 0.3 |
| | 12.2 | 3.4 | 0.2 |
| | 13 | 3.6 | 0 |
| | 16.1 | 3.5 | 0.1 |
| | 15.9 | 2.3 | 1.3 |
| | 18.3 | 0.4 | 3.2 |
| | 22.3 | 0.2 | 3.4 |
| | 24.5 | 0.2 | 3.4 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2.3 | 1.3 | 14 | 1.2 | 0.030 |
| 1.3 | 2.3 | | | |

| dimensions | | | |
|---|---|---|---|
| 9.9 | x-section area | 0.9 | d mean |
| 10.8 | width | 12.0 | wet P |
| 1.3 | d max | 0.8 | hyd radi |
| 2.3 | bank ht | 12 | w/d ratio |
| 14 | W flood prone area | 1.3 | ent ratio |

| hydraulics | |
|---|---|
| 4.79 | velocity (ft/sec) |
| 47.6 | discharge rate, Q (cfs) |
| 0.62 | shear stress ((lbs/ft sq) |
| 0.57 | shear velocity (ft/sec) |
| 0.28 | stream power (lbs/ft/sec) |
| 8.5 | friction factor u/u* |
| 39 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 1 | measured $D_{84}$(mm) | | |
| 561.0 | relative roughness | 18.5 | fric. factor |
| 0.014 | Manning's n from channel material | | |

## Cross Section

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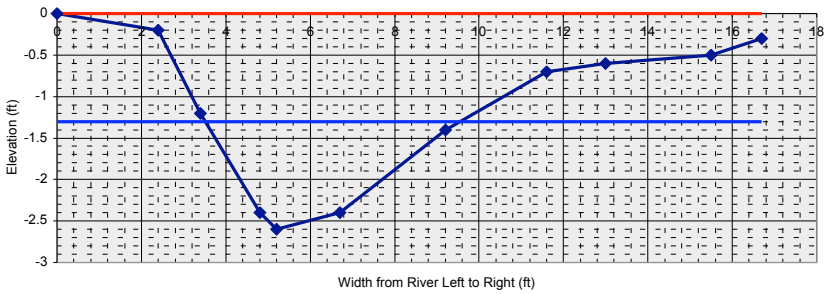
M7 T6.1 Allen Brook




| | |
|---|---|
| section: | M7 T6.1 |
| stream: | Allen Brook |
| watershed: | |
| location: | upstream of trib confluence with main |
| description: | |
| height of instrument (ft): | |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 0 |
| LTB | 2.4 | 0.2 | -0.2 |
| LBF | 3.4 | 1.2 | -1.2 |
| LEW | 4.8 | 2.4 | -2.4 |
| BD | 5.2 | 2.6 | -2.6 |
| REW | 6.7 | 2.4 | -2.4 |
| RBF | 9.2 | 1.4 | -1.4 |
| RTB | 11.6 | 0.7 | -0.7 |
| G | 13 | 0.6 | -0.6 |
| G | 15.5 | 0.5 | -0.5 |
| RP | 16.7 | 0.3 | -0.3 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 1.3 | 0.2 | 20 | 0.35 | 0.020 |
| -1.3 | -0.2 | | | |

| dimensions | | | |
|---|---|---|---|
| 4.5 | x-section area | 0.7 | d mean |
| 6.0 | width | 6.7 | wet P |
| 1.3 | d max | 0.7 | hyd radi |
| 2.4 | bank ht | 8 | w/d ratio |
| 20 | W flood prone area | 3.3 | ent ratio |

| hydraulics | |
|---|---|
| 3.37 | velocity (ft/sec) |
| 15.2 | discharge rate, Q (cfs) |
| 0.15 | shear stress ((lbs/ft sq) |
| 0.28 | shear velocity (ft/sec) |
| 0.08 | stream power (lbs/ft/sec) |
| 12.3 | friction factor u/u* |
| 9 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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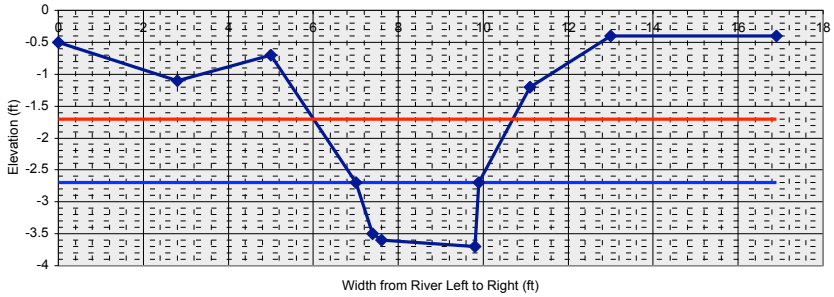
M7 T6.2 Allen Brook




| | |
|---|---|
| section: | M7 T6.2 |
| stream: | Allen Brook |
| watershed: | |
| location: | downstream of T6-2 and upstream of T6-1 |
| description: | |
| height of instrument (ft): | |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| | 0 | 0.5 | -0.5 |
| | 2.8 | 1.1 | -1.1 |
| | 5 | 0.7 | -0.7 |
| | 7 | 2.7 | -2.7 |
| | 7.4 | 3.5 | -3.5 |
| | 7.6 | 3.6 | -3.6 |
| | 9.8 | 3.7 | -3.7 |
| | 9.9 | 2.7 | -2.7 |
| | 11.1 | 1.2 | -1.2 |
| | 13 | 0.4 | -0.4 |
| | 16.9 | 0.4 | -0.4 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2.7 | 0.7 | 5 | 0.5813953 | 0.030 |
| -2.7 | -0.7 | | | |

| dimensions | | | |
|---|---|---|---|
| 2.5 | x-section area | 0.9 | d mean |
| 2.9 | width | 4.3 | wet P |
| 1.0 | d max | 0.6 | hyd radi |
| 3.0 | bank ht | 3 | w/d ratio |
| 5 | W flood prone area | 1.7 | ent ratio |

| hydraulics | |
|---|---|
| 2.60 | velocity (ft/sec) |
| 6.4 | discharge rate, Q (cfs) |
| 0.21 | shear stress ((lbs/ft sq) |
| 0.33 | shear velocity (ft/sec) |
| 0.19 | stream power (lbs/ft/sec) |
| 8.0 | friction factor u/u* |
| 12 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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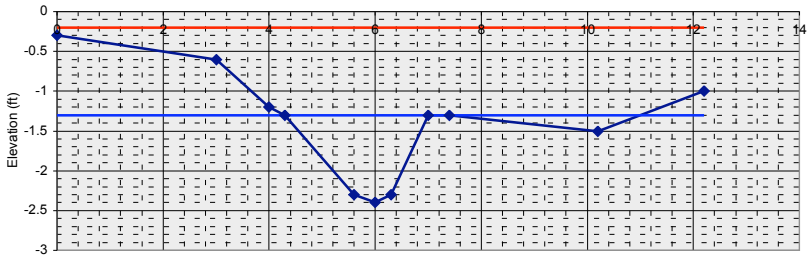
M7 T6-1.1 Allen Brook




| | |
|---|---|
| section: | M7 T6-1.1 |
| stream: | Allen Brook |
| watershed: | |
| location: | |
| description: | |
| height of instrument (ft): | |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0.3 | -0.3 |
| G | 3 | 0.6 | -0.6 |
| LTB | 4 | 1.2 | -1.2 |
| LBF | 4.3 | 1.3 | -1.3 |
| LEW | 5.6 | 2.3 | -2.3 |
| TW | 6 | 2.4 | -2.4 |
| REW | 6.3 | 2.3 | -2.3 |
| RBF | 7 | 1.3 | -1.3 |
| RTB | 7.4 | 1.3 | -1.3 |
| G | 10.2 | 1.5 | -1.5 |
| RP | 12.2 | 1 | -1 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 1.3 | 1.2 | 15 | 3.66666667 | 0.020 |
| -1.3 | -1.2 | | | |

| dimensions | | | |
|---|---|---|---|
| 2.1 | x-section area | 0.3 | d mean |
| 6.3 | width | 7.2 | wet P |
| 1.1 | d max | 0.3 | hyd radi |
| 1.2 | bank ht | 19 | w/d ratio |
| 15 | W flood prone area | 2.4 | ent ratio |

| hydraulics | |
|---|---|
| 6.24 | velocity (ft/sec) |
| 13.1 | discharge rate, Q (cfs) |
| 0.66 | shear stress ((lbs/ft sq) |
| 0.58 | shear velocity (ft/sec) |
| 0.66 | stream power (lbs/ft/sec) |
| 10.7 | friction factor u/u* |
| 42 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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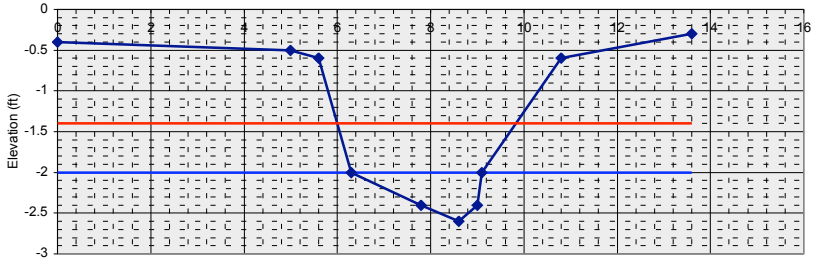
M7 T6-2.1 Allen Brook




| | |
|---|---|
| section: | M7 T6-2.1 |
| stream: | Allen Brook |
| watershed: | |
| location: | just above confluence about 100 ft |
| description: | |
| height of instrument (ft): | |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0.4 | -0.4 |
| G | 5 | 0.5 | -0.5 |
| LTB | 5.6 | 0.6 | -0.6 |
| LBF | 6.3 | 2 | -2 |
| LEW | 7.8 | 2.4 | -2.4 |
| TW | 8.6 | 2.6 | -2.6 |
| REW | 9 | 2.4 | -2.4 |
| RBF | 9.1 | 2 | -2 |
| RTB | 10.8 | 0.6 | -0.6 |
| RP | 13.6 | 0.3 | -0.3 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2 | 0.6 | 6 | 1.25 | 0.020 |
| -2 | -0.6 | | | |

| dimensions | | | |
|---|---|---|---|
| 0.9 | x-section area | 0.3 | d mean |
| 2.8 | width | 3.2 | wet P |
| 0.6 | d max | 0.3 | hyd radi |
| 2.0 | bank ht | 9 | w/d ratio |
| 6 | W flood prone area | 2.1 | ent ratio |

| hydraulics | |
|---|---|
| 3.60 | velocity (ft/sec) |
| 3.3 | discharge rate, Q (cfs) |
| 0.22 | shear stress ((lbs/ft sq) |
| 0.34 | shear velocity (ft/sec) |
| 0.28 | stream power (lbs/ft/sec) |
| 10.6 | friction factor u/u* |
| 13 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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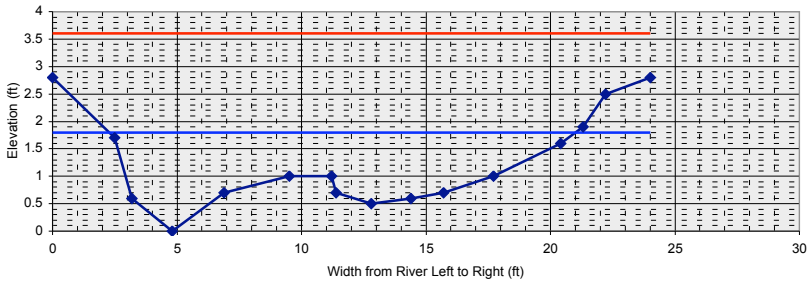
M8.1 Allen Brook




| | |
|---|---|
| section: | M8.1 |
| stream: | Allen Brook |
| watershed: | |
| location: | upstream mountain view road |
| description: | |
| height of instrument (ft): | 2.80 |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0 | 2.8 |
| BF | 2.5 | 1.1 | 1.7 |
| EW - FC | 3.2 | 2.2 | 0.6 |
| FC | 4.8 | 2.8 | 0 |
| EW | 6.9 | 2.1 | 0.7 |
| MCB | 9.5 | 1.8 | 1 |
| MCB | 11.2 | 1.8 | 1 |
| EW | 11.4 | 2.1 | 0.7 |
| B | 12.8 | 2.3 | 0.5 |
| B | 14.4 | 2.2 | 0.6 |
| EW | 15.7 | 2.1 | 0.7 |
| BAR | 17.7 | 1.8 | 1 |
| BAR | 20.4 | 1.2 | 1.6 |
| BF | 21.3 | 0.9 | 1.9 |
| TB | 22.2 | 0.3 | 2.5 |
| G | 24 | 0 | 2.8 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 1 | 0.3 | 50 | 0.52631579 | 0.030 |
| 1.8 | 2.5 | | | |

| dimensions | | | |
|---|---|---|---|
| 18.4 | x-section area | 1.0 | d mean |
| 18.7 | width | 19.9 | wet P |
| 1.8 | d max | 0.9 | hyd radi |
| 2.5 | bank ht | 19 | w/d ratio |
| 50 | W flood prone area | 2.7 | ent ratio |

| hydraulics | |
|---|---|
| 3.41 | velocity (ft/sec) |
| 62.9 | discharge rate, Q (cfs) |
| 0.30 | shear stress ((lbs/ft sq) |
| 0.40 | shear velocity (ft/sec) |
| 0.06 | stream power (lbs/ft/sec) |
| 8.6 | friction factor u/u* |
| 18 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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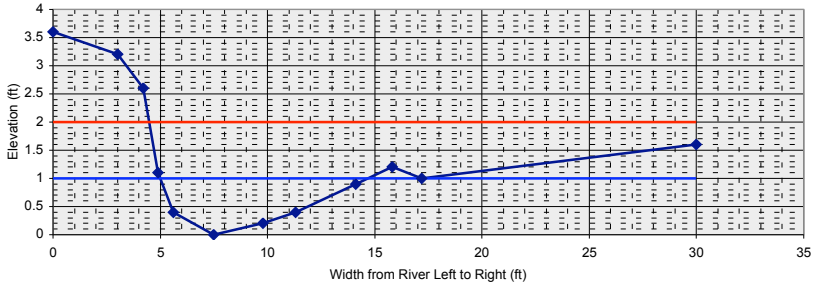
M8.2 Allen Brook




| | |
|---|---|
| section: | M8.2 |
| stream: | Allen Brook |
| watershed: | |
| location: | 350 ft (direct measure D) 5 I89 - N |
| description: | |
| height of instrument (ft): | 3.60 |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LB | 0 | 0 | 3.6 |
| G | 3 | 0.4 | 3.2 |
| TB | 4.2 | 1 | 2.6 |
| BF | 4.9 | 2.5 | 1.1 |
| EW | 5.6 | 3.2 | 0.4 |
| TW | 7.5 | 3.6 | 0 |
| BF | 9.8 | 3.4 | 0.2 |
| EW | 11.3 | 3.2 | 0.4 |
| BAR/BF | 14.1 | 2.7 | 0.9 |
| G | 15.8 | 2.4 | 1.2 |
| G | 17.2 | 2.6 | 1 |
| G | 30 | 2 | 1.6 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 2.6 | 1 | 40 | 0.42857143 | 0.030 |
| 1 | 2.6 | | | |

| dimensions | | | |
|---|---|---|---|
| 5.8 | x-section area | 0.6 | d mean |
| 9.7 | width | 10.0 | wet P |
| 1.0 | d max | 0.6 | hyd radi |
| 2.6 | bank ht | 16 | w/d ratio |
| 40 | W flood prone area | 4.1 | ent ratio |

| hydraulics | |
|---|---|
| 2.26 | velocity (ft/sec) |
| 13.2 | discharge rate, Q (cfs) |
| 0.16 | shear stress ((lbs/ft sq) |
| 0.28 | shear velocity (ft/sec) |
| 0.04 | stream power (lbs/ft/sec) |
| 8.0 | friction factor u/u* |
| 9 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

**Cross Section**

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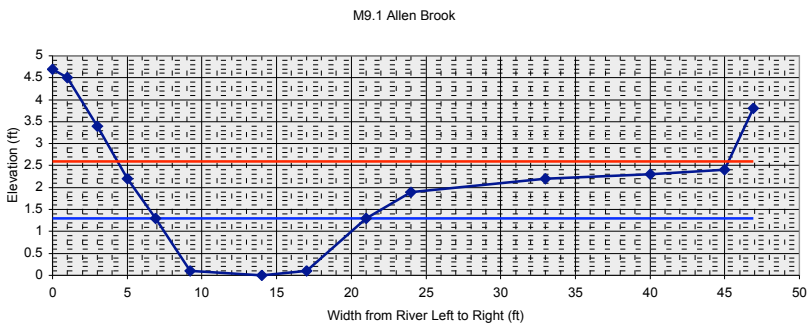


| | |
|---|---|
| section: | M9.1 |
| stream: | Allen Brook |
| watershed: | |
| location: | just upstream where hemlock forest ends, before ag |
| description: | |
| height of instrument (ft): | 5.10 |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0.4 | 4.7 |
| G | 1 | 0.6 | 4.5 |
| LTB | 3 | 1.7 | 3.4 |
| G | 5 | 2.9 | 2.2 |
| LBF | 6.9 | 3.8 | 1.3 |
| LEW | 9.2 | 5 | 0.1 |
| TW | 14 | 5.1 | 0 |
| REW | 17 | 5 | 0.1 |
| RBF | 21 | 3.8 | 1.3 |
| RTB | 24 | 3.2 | 1.9 |
| G | 33 | 2.9 | 2.2 |
| G | 40 | 2.8 | 2.3 |
| G | 45 | 2.7 | 2.4 |
| RP | 46.9 | 1.3 | 3.8 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 3.8 | 1.7 | 40 | 5.2 | 0.040 |
| 1.3 | 3.4 | | | |

| dimensions | | | |
|---|---|---|---|
| 13.5 | x-section area | 1.0 | d mean |
| 14.1 | width | 14.6 | wet P |
| 1.3 | d max | 0.9 | hyd radi |
| 3.4 | bank ht | 15 | w/d ratio |
| 40 | W flood prone area | 2.8 | ent ratio |

| hydraulics | |
|---|---|
| 8.07 | velocity (ft/sec) |
| 109.1 | discharge rate, Q (cfs) |
| 3.01 | shear stress ((lbs/ft sq) |
| 1.25 | shear velocity (ft/sec) |
| 1.72 | stream power (lbs/ft/sec) |
| 6.5 | friction factor u/u* |
| 623 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

**Cross Section**

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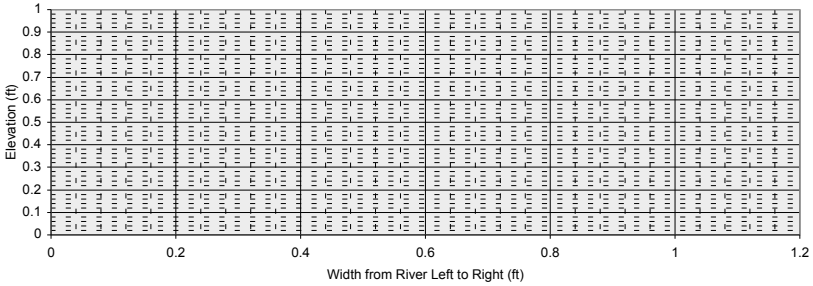


| | |
|---|---|
| section: | INTENTIONALLY LEFT BLANK |
| stream: | |
| watershed: | |
| location: | |
| description: | |
| height of instrument (ft): | |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| | | | | |
| 0 | --- | | | |

| dimensions | | | |
|---|---|---|---|
| 0.0 | x-section area | 0.0 | d mean |
| 0.0 | width | 0.0 | wet P |
| 0.0 | d max | 0.0 | hyd radi |
| 0.0 | bank ht | 0 | w/d ratio |
| 0 | W flood prone area | 0.0 | ent ratio |

| hydraulics | |
|---|---|
| 0.00 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.00 | stream power (lbs/ft/sec) |
| 0.0 | friction factor u/u* |
| 0 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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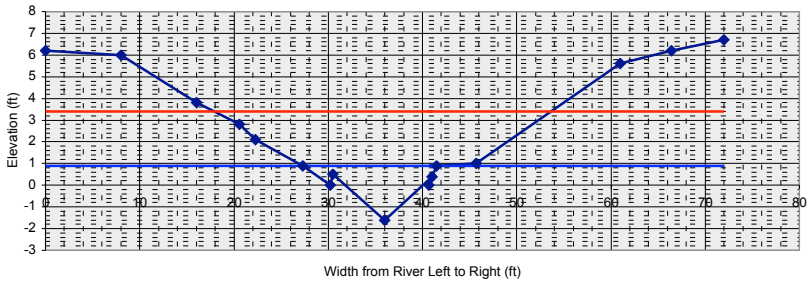
M10.1 Allen Brook




| | |
|---|---|
| section: | M10.1 |
| stream: | Allen Brook |
| watershed: | |
| location: | Siple Farm upstream of farm bridge |
| description: | |
| height of instrument (ft): | 6.70 |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LP | 0 | 0.5 | 6.2 |
| G | 8 | 0.7 | 6 |
| G | 16 | 2.9 | 3.8 |
| TB | 20.6 | 3.9 | 2.8 |
| TOE | 22.3 | 4.6 | 2.1 |
| E.VEG | 27.3 | 5.8 | 0.9 |
| B | 30.2 | 6.7 | 0 |
| EW | 30.5 | 6.2 | 0.5 |
| TW | 36 | 8.3 | -1.6 |
| EW | 41 | 6.3 | 0.4 |
| B | 40.7 | 6.7 | 0 |
| TB | 41.5 | 5.8 | 0.9 |
| NBF | 45.7 | 5.7 | 1 |
| break inslop | 61 | 1.1 | 5.6 |
| G | 66.4 | 0.5 | 6.2 |
| RP | 72 | 0 | 6.7 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 5.8 | 3.9 | 38 | 0.06666667 | 0.020 |
| 0.9 | 2.8 | | | |

| dimensions | | | |
|---|---|---|---|
| 17.5 | x-section area | 1.2 | d mean |
| 14.8 | width | 16.6 | wet P |
| 2.5 | d max | 1.1 | hyd radi |
| 4.4 | bank ht | 12 | w/d ratio |
| 38 | W flood prone area | 2.6 | ent ratio |

| hydraulics | |
|---|---|
| 1.99 | velocity (ft/sec) |
| 34.9 | discharge rate, Q (cfs) |
| 0.04 | shear stress ((lbs/ft sq) |
| 0.15 | shear velocity (ft/sec) |
| 0.01 | stream power (lbs/ft/sec) |
| 13.2 | friction factor u/u* |
| 3 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

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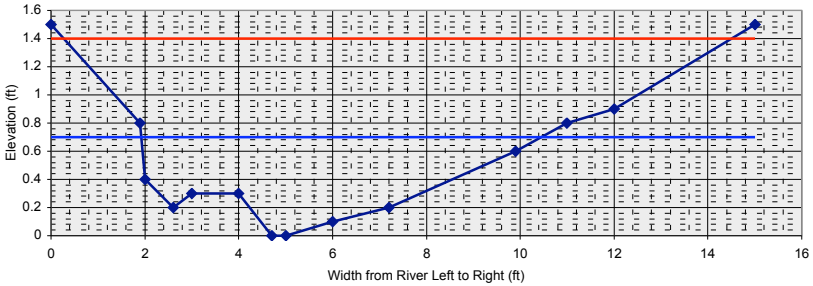
Allen Brook




| | |
|---|---|
| section: | M11.1 |
| stream: | Allen Brook |
| watershed: | |
| location: | driveway xing upstream Mud Pond |
| description: | |
| height of instrument (ft): | 1.50 |

| notes | distance (ft) | FS (ft) | elevation |
|---|---|---|---|
| LB | 0 | 0 | 1.5 |
| BF | 1.9 | 0.7 | 0.8 |
| TOE | 2 | 1.1 | 0.4 |
| EWB | 2.6 | 1.3 | 0.2 |
| B | 3 | 1.2 | 0.3 |
| B | 4 | 1.2 | 0.3 |
| TW | 4.7 | 1.5 | 0 |
| B | 5 | 1.5 | 0 |
| B | 6 | 1.4 | 0.1 |
| EWB | 7.2 | 1.3 | 0.2 |
| BF | 9.9 | 0.9 | 0.6 |
| G | 11 | 0.7 | 0.8 |
| G | 12 | 0.6 | 0.9 |
| RP | 15 | 0 | 1.5 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 0.8 | 0.7 | 15 | 2.88888889 | 0.030 |
| 0.7 | 0.8 | | | |

| dimensions | | | |
|---|---|---|---|
| 3.6 | x-section area | 0.4 | d mean |
| 8.5 | width | 8.9 | wet P |
| 0.7 | d max | 0.4 | hyd radi |
| 0.8 | bank ht | 20 | w/d ratio |
| 15 | W flood prone area | 1.8 | ent ratio |

| hydraulics | |
|---|---|
| 4.58 | velocity (ft/sec) |
| 16.4 | discharge rate, Q (cfs) |
| 0.72 | shear stress ((lbs/ft sq) |
| 0.61 | shear velocity (ft/sec) |
| 0.39 | stream power (lbs/ft/sec) |
| 7.5 | friction factor u/u* |
| 46 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| | measured $D_{84}$(mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Appendix H: Monitoring Plan for Allen Brook, Williston, Vermont

### H.1. Introduction

Changes in hydrology associated with land use change in the Allen Brook watershed have led to a loss of a stable morphology combined with a loss of bank vegetation, sedimentation, loss of aquatic habitat, change in water temperatures and increased hazards during flood events. These factors combine to deteriorate the biological, recreational, natural resource and aesthetic values of the watershed.

EPA states:
*Each storm water permit should include coordinated and cost-effective monitoring program to gather necessary information to determine the extent to which the permit provides for attainment of applicable water quality standards and to determine the appropriate conditions or limitations for subsequent permits. Such a monitoring program may include, ambient monitoring, receiving water assessment, discharge monitoring (as needed), or a combination of monitoring procedures designed to gather necessary information….*

*Under the Clean Water Act (CWA) and NPDES regulations, permitting authorities may employ a variety of conditions and limitations in storm water permits, including best management practices, performance objectives, narrative conditions, monitoring triggers, action levels (e.g., monitoring benchmarks, toxicity reduction evaluation action levels), etc….*

*Uses may be impacted by both water quality and water quantity. Depending on site-specific considerations, some of the water quality impacts of storm water discharges may be more related to the physical effects (e.g., stream bank erosion, streambed scouring, extreme temperature variations, sediment smothering) than the type and amount of pollutants present in the discharge.*

*For most dischargers, storm water monitoring can be conducted for two basic reasons: (1) to identify if problems are present, either in the receiving water or in the discharge, and to characterize the cause(s) of such problems; and (2) to assess the effectiveness of storm water controls in reducing contaminants and making improvements in water quality."*
(-EPA, 1996, Questions and Answers Regarding Implementation of an Interim Permitting Approach for Water Quality Based Effluent Limitations in Storm Water Permits 61FR 57425).

### H.2 Monitoring Report

The monitoring report shall:

A. Include discussions about the condition of the stream. The monitoring data will be compared to results obtained during the 2001 field season for the RGA and RHA.
B. Discuss the condition and geometry of permanent cross sections and whether or not changes have been observed in cross section geometry or lateral migration of the channel. The report shall include particle size distributions for each permanent cross section, Comparisons shall be made between assessments from different years. The cross-sectional data will be entered in a spreadsheet and compared to previous years. The spreadsheet designed by Mecklenburg (1999) and adapted by the VT ANR (2002) should be used to enter cross-sectional data. The parameters listed below shall be analyzed.
C. Assess changes in slopes of individual reaches. Changes in the slope of a reach serves as an indicator of bedload transport, change in stream power, active degradation, changes in planform, or other signs of instability.
D. Place the streams reaches within Schumm's Channel Evolution Model.

E. Include results and conclusions of fish surveys including population estimates and species types and abundance.
F. Assess the need for additional monitoring on the basis of new development projects in the watershed.
G. Include water quality data collected as part of any on-going WQ monitoring project, for example: stormwater, indirect or direct discharges, pesticide monitoring, golf course, NPDES monitoring or other study will be compared.
H. Include photos of the monumented and rapid assessment sites. A compass reading in the direction of the photo is sometimes helpful to obtain reproducible photographs from one year to the next. The photos and maps from the initial (2001) assessment should be carried in the field to use for site comparison. This will help to ensure replicability of sites from year to year. Four photos of each site, upstream, downstream, right bank and left bank should be taken.

The results of these and any other assessment methods will be presented in an easy to compare format for the period of record. Data collected in the field for each of the categories of monitoring will be evaluated using basic statistics, simple numerical comparisons, and graphical and photographic representations. Relationships between various channel parameters will also be evaluated using geomorphic channel classification principles.

If re-vegetation or re-planting has been undertaken, than the report shall detail the condition of riparian vegetation and include an assessment of whether or not vegetative success has been achieved. Vegetative success shall be defined as 30% cover by non-invasive species after one full growing season, 60% cover after two full growing seasons, and 75% cover after three full growing seasons. The report shall include recommendations for remedial plantings, if required to achieve vegetative success. Remedial plantings shall occur in areas of deficient cover, as determined in consultation with the State and Federal resource agencies.

**H.3 Proposed Projects/New construction/Updating Plan**

*"In the proposed rule, TMDL's are defined as follows:*

> ***"…written plans and analyses established to ensure that the waterbody will attain and maintain water quality standards (as defined in 1-1140 CFR 131) including consideration of reasonably foreseeable increases in pollutant loads…."***

*The proposed language: " including…foreseeable increases in pollutant loads" fundamentally changes the way that TMDL's are written. With this addition, a community is faced not only with removing existing pollutants, but with the additional task of ensuring that new development does not cause additional degradation or increase in pollutant loads."* (CWP, Guidance for Developing TMDL's in Urban Watersheds, June 2000).

It is recommended that the monitoring plan be updated regularly, or a maximum of every 5-7 years. As changes occur throughout the watershed additional monitoring may be called for. **Changes in the monitoring plan are likely to be required for any project that requires a stormwater permit under the Vermont Stormwater Management Manual.**

The Vermont Stormwater Management Manual *standards "apply to any construction activity that results in the creation of at least 5,000 feet of impervious cover and an on-site impervious cover percentage of greater than or equal to 8%, or the creation of at least one acre (43,560 square feet) of impervious cover on a site."* ANR, Feb. 2001 Management of Stormwater Runoff in Vermont.

New projects will be required to do initial monitoring including the RGA, RHA, CEM, biological

monitoring and stream geometry and substrate. This will provide a baseline for post-construction comparisons of the physical and biological systems.

### H.4 Erosion and Sediment Control

*"The rate of erosion on construction sites for highways, houses and shopping centers across the nation is about ten times greater than on agricultural land, 200 times greater than on pasture land, and 2000 or more times greater than on forest land."-1982 Vermont Handbook For Soil Erosion and Sediment Control On Construction Sites, Vermont Geological Survey, Special Publication No. 3.*

US EPA Phase II regulations will by March 2003 require that all construction activities which will disturb over 1 acre to obtain an NPDES permit from the DEC. Implementation of Erosion and Sediment Control Best Management Practices (Appendix A) and monitoring and enforceable maintenance agreements according to recommendations by the Watershed Management Institute and the Center for Watershed Protection are strongly recommended prior to this time.

### H.5 Phosphorus Monitoring

Allen Brook is located in the Champlain basin. Permit conditions, or other plans for restoring Lake Champlain may require phosphorus monitoring. A 1999 study of phosphorus movement (Meals, 1999) into Lake Champlain found that urban areas are a disproportionate source of the problem. Phosphorus monitoring may include algal monitoring as well as water quality sampling during storm events.

**Table H-1- Phosphorus loading in Champlain Basin**

| Land Use | Percent of Champlain basin in Land Use type | % Phosphorus | Phosphorus loading per land type |
|---|---|---|---|
| **Urban** | 5.5 | 37 | 6.7 |
| **Agriculture** | 17 | 56 | 3.3 |
| **Forest** | 66 | 7 | 0.1 |

### H.6 Quality Control

Quality control will primarily be achieved through replication and random sampling of rapid assessment sites in addition to monumented cross-sections. Replication is also achieved by established photo monitoring stations on both sides of the channel. Data will be plotted and analyzed within one week of field monitoring. Results will be compared to previous years data and unexpected variations or trends will be identified. Photo-monitoring also provides a tool for checking the validity of the monitoring results (Van Horn, M. and K. Van Horn. 1996. Quantitative Photomonitoring for Restoration Projects. Restoration & Management Notes. 14:1.).

Quality control of the geomorphic data will be achieved through the use of benchmarks and verification of the channel position relative to previous years data. Data will be plotted and analyzed within 3 months of the field monitoring.

## Appendix I: Watershed Modeling – SWAT-Impervious Cover

### 1.0 Background

The Soil and Water Assessment Tool (Srinivasan and Arnold 1994; Neitsch et al. 2001; SWAT - http://www.brc.tamus.edu/swat/) was chosen to model watershed level processes including annual average sediment loads and instream sediment concentrations for Allen Brook. This model is physically based and relies on actual data for the watershed (soils, topography, landuse, weather, etc.) as opposed to developed regression equations. It is a continuous model providing average annual estimates. It is not suitable for modeling single events.

SWAT can be run using an ArcView GIS (ESRI, Redland, CA) interface. Data layers readily available for most watersheds in the US can be incorporated into the model. It also provides the user the opportunity to input a variety of very specific parameters (mostly agricultural practices) if they are available, but can use default values if this information is not available.

### 2.0 Inputs

Three basic data layers provide the majority of information required for running SWAT. Digital elevation models (DEM) provide the topography information required for delineating watersheds and stream networks. For Allen Brook, the DEM grid had a 30 m pixel size. Landuse information is also required. The 1992 Landsat Thematic Mapper landuse grid (30 m pixel size) was used as the base landuse information. Updates were made to this data layer using 1999 digital orthophotos and ground-truthing. Soils data was obtained from the STATSGO soil database (USDA NRCS).

Climate information is also required. SWAT uses a weather generating model to create daily precipitation, air temperature, wind speed and solar radiation from monthly averages for given weather stations throughout the US. Information for Allen Brook was generated using Burlington weather data.

### 3.0 Model Processes

SWAT uses the DEM and user specified parameters to divide the watershed into subwatersheds. Model results are summed for each subwatershed. Allen Brook was divided into 25 subwatersheds. Each subwatershed is further divided into individual hydrologic response units based on landuse and soil combinations.

SWAT uses a water balance approach in estimating the movement of water and sediment throughout the watershed. It divides the hydrologic cycle into a land phase and a water phase. The land phase water balance is calculated using weather data, soil temperature, hydrologic processes (infiltration, evapotranspiration, etc.) and surface runoff (volume computed using the NRCS curve number method and peak rate computed using a modification of the rational method). Erosion for the land phase is calculated using the Modified Universal Soil Loss Equation (MUSLE).

SWAT uses the information generated in the land phase of the water balance to route water and sediment loads through the stream system. Flow in the stream system is modeled using a Muskingum routing method. Sediment is routed, taking into consideration two main processes –

deposition and degradation. The peak channel velocity determines which of these processes is occurring and how sediment is transported within a stream reach.

**4.0 Outputs**

SWAT can produce a variety of outputs on a watershed, subwatershed, hydrologic response unit, or reach basis. These outputs include: precipitation, potential evapotranspiration, actual evapotranspiration, water yield, and sediment yield. For Allen Brook, the subwatershed basis seemed the most appropriate. Ten years of data was generated and averaged to produce annual average results for sediment loads for each subwatershed. These results are presented in the main body of the report.

## References

Neitsch, S.L., J.G. Arnold, J.R. Kiniry, J.R. Williams. 2001. *Soil and Water Assessment Tool: Theoretical Documentation, Version 2000*. Grassland, Soil and Water Research Laboratory, Agricultural Research Service, Temple, TX.

Srinivasan, R. and J.G. Arnold. 1994. *Integration of a Basin-Scale Water Quality Model with GIS*. Water Resources Bulletin 30(3):453-462.

**Impervious Cover for Allen Brook Watershed (completed February 2003)**

**Description:**
This data layer contains the impervious cover for the Allen Brook watershed in ArcView shapefile format. The watershed boundary was determined by digitizing from USGS 1:24000 topographical maps and from the watershed boundary generated using the Soil and Water Assessment Tool (SWAT) Modeling software. Impervious cover in some areas is digitized beyond the watershed boundary.

Impervious cover was heads up digitized from digital orthophotos* using an on screen scale of 1:1000. Impervious cover includes: roads (paved and unpaved), driveways, sidewalks, roofs, swimming pools, parking lots. No effort is made to distinguish the different types within the data set (i.e. there are no attributes within the data layer).

*Information on Digitial Orthophotos from the Vermont Department of Taxes – Vermont Mapping Program
(http://www.state.vt.us/tax/Vermont%20Ortho%20Program.htm#Products)
Digital Orthophotography Quadrangles (DOQ), defined as raster image of the stereo pair of aerial photographs mathematically and optically corrected to eliminate distortion and to meet national map accuracy standards, but still have the readability of an aerial photograph. Each DOQ is a 64-mb file with a 1/2-meter pixel resolution. In Rutland and Windsor counties, the file format is a .LAN extension. Addison, Franklin, Grand Isle, Lamoille, and Washington are available are in a .BIP extension. Orange, Caledonia, Orleans, Essex, Chittenden, Windham and Bennington are available in a GeoTiff (.tif) extention. Two additional files are also available; i.e00 (interior data for the DOQ, i.e. River and mountain names), e.e00 (exterior data around the sheet edge, i.e. scale bars, sheet name and number, coordinate values, etc.). Also on the CD-ROM is the world file, which ties the digital image to a specific location on the surface of the earth. If you copy the DOQ to your hard dive, you must also copy the world file for the same image, for the images to match other DOQs or GIS data layers. NOTE all Vermont DOQs are in NAD83, in Vermont State Plane Coordinates System, Meters.

**Map Projection:**
Vermont State Plane Coordinate System
Meters
NAD 83
GRS 80

**Contact information:**
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## Appendix J

1. **Table J-1: Allen Brook Watershed Stormwater Retrofit Inventory**
2. **Figure J-1: Hydrologic Soil Groups A & B in Allen Brook Watershed**
3. **Figure J-2: Highly Erodible Soils in Allen Brook Watershed**
4. **Figures J-3 to J-14: Allen Brook Retrofit Inventory Photographs**
5. **Allen Brook Stormwater Retrofit Reconnaissance Inventory form**
6. **Allen Brook Pollution Prevention Survey forms**

## Table J-1: Allen Brook Watershed Stormwater Retrofit Inventory

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| **Allen Brook School** | 1-1230-1 | GS, OF, DB | 5.3 | 15.1 | Some swale erosion<br>Roadside erosion | Pursue grants for STP education -demonstration site<br>Bioretention | 3 |
| | 1-1230-2 | GS, OF | 0.6+ | 4.3 | Good GS vegetation height<br>School expansion impacts GS | Evaluate impact of expansion on SWM | 3 |
| **Avenue B** | none | Infiltrate | | | Highly erodible soils (end of road)<br>HSG A | Evaluate need for pretreatment before infiltration<br>Source controls | 4 |
| **Avenue C** | none | Infiltrate | | | SD outfalls into old sandpit at end of road<br>Some erosion but it never leaves site (highly erodible soils at end road)<br>HSG A | Evaluate need for pretreatment before infiltration<br>Engineered infiltration STPs will eventually be needed<br>Source controls | 4 |
| **Brennan Woods** | 1-1272-2 | CB,DB, GS, OF | 16.1 | 153.2 | No GS / OF visible<br>Some silting in of basin<br>DB not designed for total IC<br>Some HES and HSG A/B | Remove accumulated sediments<br>Modify outlet structure<br>Size DB for total IC<br>Rooftop runoff infiltration for HSG A | 2 |
| **Catamount Golf Club** | No permit required | GS, OF | | | No treatment<br>Originally permitted as 1-1092-1, 2, 3 | Treatment of runoff from impervious cover | 3 |
| **Chatham Woods** | 1-1517-1 | OF, GS, CB, DB | 3.7 | 23.5 | Not built<br>Designed to 2002 standards | none | 5 |
| | 1-1517-2 | OF, GS, CB, DB | 1.3 | 4.4 | Not built | none | 5 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| | | | | | Designed to 2002 standards | | |
| **Commons at Williston** | 1-1052-1 | CB, GS, OF, DB | 2.7 | 23.1 | DB outlet pipe partially blocked with debris | Modify OS<br>Remove accumulated sediments<br>Stop dumping of landscaping debris in GS / DB | 3 |
| | 1-1052-2 | OF | 0.1 | 9.0 | | none | 4 |
| **Coyote Run** | 1-1507-1 | CB, EDB | 4.4 | 23.8 | Pond in tributary floodplain<br>SD enters DB 6 ft. from OS<br>OS pipe direct to tributary<br>Yard debris dumped in DB | Modify to reduce short circuiting (even though OS and SD outfall appear to be located as per plans) | 2 |
| | 1-1507-2 | CB, EDB | 2.2 | 7.5 | Not built<br>Receiving tributary has erosion problems | Design to 2002 standards | 2 |
| | 1-1507-3 | OF, GS | 0.9 | 3.6 | Not built<br>Receiving tributary has erosion problems | Design to 2002 standards | 2 |
| | 1-1507-4 | OF, GS | 0.6 | 2.3 | Not built<br>Receiving tributary has erosion problems | Design to 2002 standards | 2 |
| **Foxwood Circle / Cadieux Ln**. | none | OF, GS | | | Adjacent to AB<br>HSG B | Bioretention (preferred) or enhance vegetation for OF, GS | 4 |
| **Golf Links** | 2-1180-1 | CB, WP | 1.5 | 47.8 | IC roads only<br>Shallow wet pool, cat-tails, pretreatment WP<br>Some HSG B | Size for total IC<br>Remove accumulated sediments<br>Modify outlet structure | 2 |
| | 2-1180-2 | CB, WP | 1.8 | 28 | IC roads only | Size for total IC | 2 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| | | | | | Shallow wet pool, cat-tails<br>Some HSG B | Remove accumulated sediments<br>Modify outlet structure<br>Reduce short circuiting<br>Utilize second basin for pretreatment | |
| **Heritage Meadows** | 1-1258-1 | CB, DB, GS | 5.0 | 42.0 | Little storage volume<br>No GS constructed<br>No WQ treatment | Enlarge DB and modify OS and/or provide other treatment<br>Provide DB maintenance access | 2 |
| **Hideaway Lane** (Country Crossings) | 2-0911 | CB, OF, GS | 1.4 | 4.6 | GS vegetation short<br>HSG A/B | GS vegetation height & type | 4 |
| **Hurricane Lane** | 1-0530-1 | DB | | | Small gravel bottom basin | Modify OS | 3 |
| | 1-0754-1 | OF, GS, SB | 0.5 | 1.3 | Sediment tanks<br>Road swale – wet, erosion<br>Erosion below culvert under Hurricane Lane<br>Culvert outfall includes flow from other parcels | Check/maintain tanks<br>Wet swale<br>CDs / streambank stabilization below Hurricane Lane culvert | 3 |
| | 1-0763-1 | DB | | | Includes 1-1301-1 runoff<br>DB short circuiting | Modify OS<br>Baffle to eliminate short circuiting<br>CDs / streambank stabilization below Hurricane Lane culvert | 2 |
| | 1-1078-1 | CB, OF, DB | 1.8 | 2.5 | OS in bank, gravel covered<br>Short circuiting<br>Erosion downstream of outfall<br>Some erosion at inflow RR | Retrofit OS<br>Baffle to eliminate short circuiting<br>Check dams / RR below outfall | 2 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| | | | | | | Repair RR entry swale | |
| | 1-1078-2 | OF, GS | 0.8 | 3.1 | Eroded swale<br>No treatment<br>Erosion downstream of outfall | Dry swale or bioretention<br>Check dams / RR below outfall | 3 |
| | 1-1205-1 | DB | 1.1 | 2.6 | OS in bank, gravel covered<br>Short circuiting | Modify OS<br>Baffle to eliminate short circuiting | 2 |
| | 1-1245-1 | OF, DB | 3.6 | 9.6 | Basin looks good<br>Some erosion downstream of basin outfall | Check dams below outfall and existing RR | 3 |
| | 1-1301-1 | GS, CB | 3.0 | 7.1 | Flows to 1-0763 DB<br>Entry drive to GS along road<br>GS wet / erosion | Wet swale | 3 |
| | 2-1172-2 | DB | | | OS in bank, gravel covered,<br>SWM for access road | Modify OS | 3 |
| **Immaculate Heart of Mary** | none | CB, OF | | | Some runoff over steep bank to AB tributary – no treatment | Pursue grants for STP<br>Bioretention / filtration | 4 |
| **Korner Kwik Stop** | none | CB | | | Runoff to wetland<br>Some runoff from roads, offsite, and church also to wetland | Hotspot: install filtering STP or manufactured treatment device<br>OS for wetland outlet culvert<br>Evaluate SWM for intersection | 2 |
| **Lamplite Acres** | none | CB | | | No curb & gutter<br>CB in grass. Not many CBs<br>HSG A part of subdivision | none | 5 |
| **LeFebvre Lane** (Allen | 2-0954-1 | OF, GS, DB | | | No curb & gutter<br>DB not located | Evaluate need for DB modification | 5 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| Brk Meadow) | | | | | HSG A/B | | |
| **Maple Road** | none | CB | | | No treatment<br>HSG A/B | Infiltration of rooftop runoff | 4 |
| **Martell Hill** | none | GS | | | Some highly erodible soils<br>Steep slope | Check dams | 4 |
| **Meadow Brook** | none | CB | | | No treatment<br>Erosion below SD outfall<br>HSG B | WQ treatment<br>Stabilize drainage channel | 4 |
| **Meadow Ridge** | 2-1107 | CB, GS, OF, DB | 11.1 | 204 | DB not constructed<br>GS not constructed as designed<br>No treatment<br>Impacts on adjacent property<br>Some HES | Build DB to 2002 standards<br>Checkdams for GS | 1 |
| | 2-0646-1 | GS | 2.5 | 94 | Short vegetation<br>WQ treatment questionable | Build GS to 2002 standards | 3 |
| **Meadow Run** | 2-1190-1 | OF, GS | 1.8 | 5.0 | No GS<br>Channel with vegetation<br>Limited WQ treatment | Open channel treatment system | 3 |
| | 2-1190-2 | CB, GS | 0.4 | 3.0 | No treatment with GS – RR bottom ditch on steep slope<br>HSG B | Grass channel or dry swale | 4 |
| | 2-1190-3 | CB, OF, GS | 1.7 | 5.5 | No treatment with GS<br>Gully erosion below outfall<br>Some HSG A | Stabilize gully<br>Infiltration, bioretention, or manufactured treatment device | 2 |
| | 2-1190-4 | CB, OF | 1.1 | 3.4 | Not constructed as designed<br>Connected to SD 2-1190-3 | Include drainage area and IC in design for SD 2-1190-3 | 3 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| Forest Run | 2-1190-A | CB, DB | 1.6 | | Some HSG A<br>Cattails<br>Sediment deposition<br>HSG B | Remove accumulated sediments<br>Modify outlet structure<br>Rooftop runoff infiltration if feasible | 3 |
| | 2-1190-B | CB, GS | 1.4 | | Discharges into wetland<br>Ditch drains wetland to AB<br>No GS or WQ treatment<br>HSG B | Install outlet structure<br>Construct embankment<br>Rooftop runoff infiltration if feasible | 3 |
| **Mountain View Manor** | none | GS | | | One section of swale replaced with pipe | Do not pipe any more sections of swale | 5 |
| **N. Brownell Ave at Indust. Dr.** | none | | | | Auto body shop<br>Construction company yard<br>HSG A | Evaluate need for pretreatment before infiltration | 3 |
| **O'Brien Ct.** | none | CB | | | End of cul-de-sac has no SD<br>Small DA | none | 5 |
| **Old Stage Estates** | 2-1146-1 | CB, GS | 0.4 | 2.1 | CB drain to GS<br>GS retrofitted with inlets | Evaluate effectiveness of modified system (WQ, etc.) | 3 |
| | 2-1146-2 | OF, DB | 1.1 | 11.9 | Basin partially silted in<br>OS orfice buried in sediment<br>No WQ treatment | Remove accumulated sediments<br>Modify outlet structure<br>Repair embankment | 2 |
| | 2-1146-3 | OF, DB | 0.3 | 11.0 | Basin partially silted in<br>OS orfice buried in sediment<br>Embankment breached<br>No WQ treatment | Remove accumulated sediments<br>Modify outlet structure<br>Repair embankment | 2 |
| **Oneida Acres** | none | CB, GS | | | Mix of curb & gutter, GS | Check dams in GS | 4 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| | | | | | Steep slope for some GS<br>Gully erosion<br>Some highly erodible soils<br>HSG A/B | Gully stabilization | |
| | none | CB | | | Includes some Industrial Ave runoff (CB)<br>Outfall at AB<br>HSG A/B | Little room for STP<br>Manufactured treatment device | 4 |
| **Onion River** | none | CB | | | No treatment<br>Ditch erosion – River Cove Road.<br>Not all drainage from Onion River development.<br>HSG B | Stabilize ditch<br>Install check dams | 3 |
| **Pinecrest Circle** | none | OF | | | No storm drain or catch basins.<br>HSG A | None | 5 |
| **Pinecrest Village** | 1-1047-1 | CB, OF, GS | 4.4 | 35.1 | Not all IC treated<br>Some OF lengths too short | Filtering system or manufactured treatment device | 3 |
| **Pleasant Acres** | 2-0231-1 | GS, CB, | 2.2 | 9.9 | No curbs<br>Permit only includes road IC<br>GS behind houses / by road | Evaluate/treat runoff from non-road IC | 3 |
| | none | CB | | | Not treated as new phase of permitted development<br>Curb and gutter<br>No treatment | Filtering system or manufactured treatment device | 2 |
| **Roadside** | none | none | | | No treatment | Infiltrate roof runoff | 4 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| **Marine** | | | | | HSG A/B<br>Erosion at end of parking lot | Further stabilize bank at end of lot.<br>Filtering STP | |
| **Rossignol Park** | none | CB | | | SW infiltrates in sandy soils<br>No designed infiltration structures<br>HSG A | Evaluate need for pretreatment before infiltration | 4 |
| **South Ridge** | 1-0664-1 | CB, DB | 2.9 | 10 | Some silting in of basin<br>No manhole lid for OS<br>Room for enlargement | Remove accumulated sediments<br>Modify outlet structure<br>Enlarge if necessary | 1 |
| | 1-0664-2 | CB, DB | 6.5 | 41.4 | Some silting in of basin<br>OS orfice buried in sediment<br>Cattails in basin<br>Room for enlargement | Remove accumulated sediments<br>Modify outlet structure<br>Enlarge if necessary | 1 |
| | 1-0664-3 | CB, GS | 0.1 | 0.5 | Not as designed (no GS)<br>Tied into SD for DB1-0664-1 | Check sizing of DB 1-0664-1 for added drainage area | 2 |
| | 1-0664-4 | CB, GS | 1.1 | 10.9 | No GS treatment<br>Flows into drainage channel | Divert to DB2 for treatment or create DB above Metcalf Road | 1 |
| | 1-0664-5 | CB, DB | 2.5 | 12.6 | Basin totally silted in<br>OS orfice buried in sediment<br>Embankment breached<br>Little room for enlargement<br>HSG B | Remove accumulated sediments<br>Modify outlet structure<br>Repair embankment | 1 |
| | 1-0664-6 | CB, DB | 1.6 | 6.1 | Silting in of basin<br>OS discharge directly to AB<br>Room for enlargement | Remove accumulated sediments<br>Modify outlet structure<br>Enlarge if necessary | 1 |
| **Taft's Farm** | | | | | | | |
| Lots E / F | 1-0513-9 | CB, OF | 0.2 | 1.1 | Vegetation too short | Increase vegetation height | 4 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| | | | | | | Plant warm season grasses | |
| Lots C / D | 1-0513-10 | CB, GS, OF | 1.3 | 3.7 | Severe gully erosion at SD outfall<br>Marginal WQ treatment | Stabilize gully<br>Plunge pool at outfall<br>Biofiltration or dry swale | 1 |
| | 1-0513-11 | CB, OF, GS | 4.5 | 10.6 | Connects to SD for 1-1275-2 | Confirm DB sized to include all flows directed to it | 1 |
| Lot F | 1-1519-1 | OF, DB | 0.9 | 1.8 | Not built<br>Designed to 1997 standards<br>Flows to S/N 1-0513-9 | Design / build to 2002 standards<br>Use bioretention instead of OF for one parking area | 1 |
| Townhouses | 1-0513-13 | CB, GS, DB | 0.7 | 2.4 | Little treatment | Modify outlet structure | 1 |
| Townhouses | 1-0513-14 | OF, DB | 0.8 | 1.5 | Not constructed as designed<br>Two OS – design has one<br>Storage volume low | Enlarge DB<br>Modify OS | 1 |
| Townhouses | 1-0513-15 | OF, GS, DB | 1.2 | 4 | Cattails<br>Sediment accumulation | Remove accumulated sediments<br>Modify outlet structure | 1 |
| Townhouses | 1-0513-16 | OF, GS, DB | 1.0 | 1.4 | Manhole grate OS | Modify OS | 1 |
| Townhouse/IR | 1-0513-17 | CB, OF, GS | 1.1 | 4.2 | Swale vegetation short<br>A little swale erosion | Vegetation repair / enhancement<br>Check dams or dry swale | 2 |
| Lot G | 1-0513-A | OF, DB | 0.8 | 2.4 | Cattails<br>Erosion at outfall<br>Accumulated sediments DB | Stabilize outfall<br>Remove accumulated sediments<br>Modify outlet structure | 2 |
| Lot H | 1-0513-B | CB, OF, GS | | | Gully erosion at outfall<br>Little treatment | Stabilize outfall – plunge pool & rip rap<br>Raingarden | 1 |
| Lot H | 1-0513-C | OF | | | Short OF treatment length<br>Very short vegetation<br>No treatment | Bioretention or other filtering STP | 1 |
| Lot H | 1-0513-D | none | | | Gully erosion at steep bank<br>No treatment | Stabilize bank<br>Filtering STP | 1 |
| Lot H | 1-0513-E | CB, OF, GS, DB | | | Some gully erosion<br>Clogged OS | Stabilize eroded areas<br>Remove accumulated sediments | 1 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| | | | | | Cattails | Modify outlet structure | |
| Lot H | A-E | | 2.4 | | IC total for S/N A-E | | |
| Indian Ridge | | | | | | | |
| | 1-1217-3 | CB, GS, DB | 6.1 | 16.6 | Not much treatment | Remove accumulated sediments<br>Modify outlet structure | 1 |
| | 1-1217-4 | CB, OF | 0.7 | 2.1 | No treatment<br>Gully erosion<br>SD outfall covered by RR | Stabilize gully<br>Install manufactured treatment device or filtering system | 1 |
| | 1-1217-6 | CB, DB | 1.5 | 3.9 | No outlet structure<br>Short circuiting<br>Sediment accumulation<br>No treatment | Remove sediment<br>Construct outlet structure<br>Eliminate short circuiting | 1 |
| | 1-1217-A | OF, GS | 0.4 | 1.4 | Drainage from back of lots (old S/N 005) | Evaluate effectiveness and modify as needed | 4 |
| | 1-1217-B | OF, GS | | | Drainage from back of lots (old S/N 012) | Evaluate effectiveness and modify as needed | 4 |
| Taft Farm Village Center | 1-1275-1 | CB, GS, DB (south) | 0.8 | 1.4 | Shopping center – hot spot | Modify basin outlet<br>Add curb stops on south side<br>Vegetation on south side | 1 |
| | 1-1275-2 | CB, OF, DB (north) | 3.8 | 11.8 | Shopping center plus senior housing and S/N 11 runoff<br>OF useless for parking lot<br>Shopping center – hot spot | Bioretention - parking lot median<br>Modify basin outlet | 1 |
| | 1-1275-3 | OF | 0.2 | 5.0 | Flow concentrates in spots<br>Erosion on steep slope<br>No treatment | Treatment prior to slope.<br>Filtering STP. | 2 |
| | 1-1275-A | OF | | | Flow into existing wetland<br>Haybale dike<br>Little treatment | Bioretention | 1 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| **Turtle Crossing** | 1-0792-1 | CB, OF, GS | 1.2 | 10.1 | No SW (GS, OF) treatment<br>GS is eroding channel<br>Very close to AB<br>Some HSG A/B & HES | Infiltration for rooftops<br>Install manufactured treatment device or filtering system for roads<br>Rip rap outfall channel | 2 |
| **Turtle Pond** | 2-1191-1 | GS, OF, WP | 1.1 | 12.0 | No curbs<br>Nice looking | None | 5 |
| **VT 287 (Circ)** | 1-1557-1 | CB, GS, OF, EDB | | | Not built<br>Some HES<br>Supercedes 1-0788 | Construct wet pond instead of dry basin | 3 |
| **VT I-89 Welcome** | 1-1401-1 | CB, GS, OF, DB | 4.1 | 14.2 | Trees on pond embankment<br>GS by northbound lane has some erosion beginning | Transplant tress on embankment<br>Reinforce turf in center of GS | 4 |
| **Vermont Rt 2** | none | CB, OF, ditches | | | Eroding ditches<br>No WQ treatment | Stabilize ditches after clean out<br>Improve ditch design<br>Install dry swales, wet swales & grass channels | 3 |
| **Village Grove** | none | CB | | | No treatment<br>HSG A most of subdivision | Infiltration for rooftops<br>DB upstream of culvert below subdivision (will also provide added treatment for Williston Elementary School) | 3 |
| **Whitcomb Industrial** | | | | | All sites granted a discharge permit waiver based on no | All infiltration sites should include proper pretreatment (as | |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| **Park**<br>(Avenue D) | | | | | collection & discharge of SW from the site need to *verify compliance with waiver:* STPs exist (built as designed, properly maintained, and operational) & that there is no offsite discharge.<br>All sites are HSG A. | per 2002 standards) due to very high soil infiltration rates.<br>Adequate SW treatment should be provided for all lots and roadways.<br>Septic systems should be 100 feet from infiltration STPs. | |
| Roads & open space | 2-0260-1 | CB, GS, RR | 0.4 | 7.0 | Severe gully erosion at SD outfall<br>HSG A<br>RR less than permit required | Verify installation & maintenance needs of "leach line trench"<br>Plunge pool and RR channel below outfall<br>Evaluate GS effectiveness | 1 |
| Roads & open space | 2-0260-2 | CB, GS | 0.6 | 4.0 | Erosion below outfall<br>Flows into off-site wetland<br>No treatment<br>HSG A | Verify installation & maintenance needs of "leach line trench"<br>Evaluate GS effectiveness | 1 |
| Roads & open space | 2-0260-3 | CB, GS, DB | 1.2 | 16.0 | No DB found<br>Significant erosion below outfall<br>Little treatment of discharged stormwater<br>HSG A | Verify installation & maintenance needs of "leach line trench"<br>On-site infiltration<br>Check dams / RR below outfall<br>Evaluate GS effectiveness | 1 |
| Lot 1 | Probably not required | ------- | | | No treatment found<br>HSG A<br>Some HES | On-site infiltration | 1 |
| Lot 2 | Not required | French drain, gravel parking area, CB | | | French drain not found<br>Gravel parking areas do not infiltrate stormwater<br>HSG A<br>Some HES | On-site infiltration | 1 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| Lot 3 | Not required | French drain, gravel parking area, CB | | | Gravel parking areas do not infiltrate stormwater<br>Parking lot runoff flows into road CB and 2-0260-2<br>French drain not found<br>HSG A<br>Some HES | On-site infiltration | 1 |
| Lot 4 | 1-1077-1 | GS, OF | | | Erosion below outfall<br>Flows into off-site wetland<br>Connects to 2-0260-2 SD above outfall<br>HSG A<br>Some HES | Retrofit grate to create OS for DB/infiltration basin<br>Evaluate GS effectiveness | 2 |
| Lot 4 | 1-1077-2 | CB, OF, RR | 1.8 | 6.4 | No treatment<br>A little erosion below RR<br>Drains into off-site wetland<br>HSG A<br>Some HES | Stabilize outfall<br>Onsite infiltration of rooftop runoff | 1 |
| Lots 4 | 1-1077-A | RR | | | No treatment<br>Erosion below outfall<br>Likely includes some runoff from lots 5 & 6<br>HSG A | On-site infiltration<br>Check dams | 1 |
| Lots 5 & 6 | Probably not required | ------ | | | No treatment found<br>HSG A<br>Some HES | On-site infiltration | 1 |
| Lot 7 | Not required | OF, stone lined French drain, CB, DW, gravel parking area | | | Gravel parking area on plans is paved<br>Gravel parking areas do not infiltrate stormwater<br>Only one of two dry wells on | Verify CB goes to DW<br>On-site infiltration | 1 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| | | | | | plans found<br>French drains not found<br>HSG A | | |
| Lot 7C | No permit for point of discharge | CB, OF | | | CB as OS for OF<br>CB and possible infiltration area appears to be in septic replacement area<br>HSG A | Infiltration basin<br>(modify CB) if suitable site | 2 |
| Lot 7D | No permit for point of discharge | CB | | | No treatment<br>Significant erosion below outfall<br>HSG A | Filtration<br>Check dams | 1 |
| Lot 7E | No permit for point of discharge | CB | | | No treatment<br>A little erosion below outfall<br>HSG A | Filtration<br>RR below outfall | 2 |
| Lot 7F | No permit for point of discharge | CB | | | CB at loading dock<br>Some erosion at outfall<br>Flows into off-site wetland<br>HSG A | On-site infiltration<br>RR at outfall | 2 |
| Lot 8 | Not required | OF, French drain, DW | | | French drains not found<br>Dry well not found unless the one on Lot 7 is sized for both lots<br>HSG A | On-site infiltration | 1 |
| Lot 9 | Not required | OF, French drain | | | French drains not found<br>HSG A | On-site infiltration | 1 |
| Lot 10 | Not required | OF, French drain, | | | French drains not found<br>CB found – does it go to a DW?<br>HSG A | On-site infiltration | 1 |
| Lot 11 | Not | French drain | | | French drains not found | On-site infiltration | 1 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| | required | | | | Erosion in road ditch<br>Infiltration basin for parking lot addition<br>Runoff via CB and ditch to 2-0260-3<br>Some runoff into ditch adjacent to parking area – possible infiltration<br>HSG A | | |
| Lot 12 | Not required | French drain | | | French drains not found<br>HSG A | On-site infiltration | 1 |
| Lot 13 | Not required | Two dry wells<br>CB feed DW | | | Two of three CB for DW not constructed<br>HSG A | Verify DW construction<br>On-site infiltration | 1 |
| Lot 14 | Not required | OF, GS | | | GS not constructed<br>Some infiltration possible in open space<br>Some runoff to off-site parking lot<br>HSG A | On-site infiltration | 1 |
| Lot 15 | Not required | OF, gravel parking area | | | Gravel parking areas do not infiltrate stormwater<br>HSG A | Verify OF is providing infiltration<br>Provide additional on-site infiltration as needed | 1 |
| Lot 16 | Probably not required | Gravel parking area | | | No treatment found<br>Gravel parking areas do not infiltrate stormwater<br>HSG A | On-site infiltration | 1 |
| Lot 17 | Probably not required | ----- | | | Slope erosion from flows<br>Erosion in road ditch<br>Flows to GS to CB to 2-0260-3 | On-site infiltration | 1 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| Lot 18 | Probably not required | CB | | | HSG A<br>Flows to parking lot CB to 2-0260-3 | On-site infiltration | 1 |
| Lot 19 | Not required | Gravel parking area | | | HSG A<br>No treatment found<br>Gravel parking areas do not infiltrate stormwater | On-site infiltration | 1 |
| Lot 20 | Not required | OF, gravel parking area | | | HSG A<br>Stormwater to CB to 2-0260-2<br>Gravel parking areas do not infiltrate stormwater | On-site infiltration | 1 |
| Lot 1-2 WIP Ext. | 1-1493-1 | DB | | | HSG A<br>Under construction<br>HSG A | Verify design accommodates flows from other lots and/or stop flows from other lots | 2 |
| Lot 1-2 WIP Ext. | 1-1493-2 | OF | | | Under construction<br>HSG A | Verify design accommodates flows from other lots and/or stop flows from other lots | 2 |
| Lot 1-2 WIP Ext. | 1-1493-3 | OF | | | Under construction<br>HSG A | Verify design accommodates flows from other lots and/or stop flows from other lots | 2 |
| **Whitney Hill Homestead** | 1-0963-1 | CB, OF, DB | 1.9 | 17.0 | Rock lining for some GS | Modify DB outlet structure | 3 |
| **Williston Chiropractic Center** | none | OF | | | Grassed area from building and parking area to Allen Brook<br>HSG B | Create buffer area by AB | 4 |
| **Williston Country Club** | none | none | | | Stone lined drainage channel leading to culvert under North | Modify channel for WQ<br>Treatment of runoff from | 3 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| | | | | | WillistonRoad<br>Considerable HSG A/B | impervious cover<br>Infiltration where feasible | |
| **Williston Elementary School** | 1-0932-1 | CB, GS, DB | 2.4 | 7.1 | CB in grass & pavement<br>Offsite flow bypasses DB<br>Cattails | Treat runoff from roof of addition that drains north – wet swale or filtration | 2 |
| | 1-0932-2 | CB, GS, DB | 3.0 | 19.7 | Runoff in swale behind school not treated<br>Erosion in swale. Cattails | Stabilize swale<br>Bioretention / filtration for non-addition runoff | 2 |
| **Williston Federated Church** | none | CB, OF | | | Some runoff to CB to behind Korner Kwik Stop<br>Some OF to AB | Pursue grants for STP<br>Bioretention / filtration behind parking lot | 4 |
| **Williston Hills** | | | | | | | |
| Hillside Drive | none | CB | | | Culvert outfall for CB/SD<br>Severe gully erosion<br>Highly erodible soils<br>Sediment deposits at AB<br>HSG B | Stabilize SD outfall<br>ED wet basin | 1 |
| Sundown Drive | none | curb & gutter | | | Gully erosion at end road<br>Highly erodible soils<br>HSG B | Stabilize bank at end of road<br>Disperse runoff into yards | 3 |
| Sundown Drive | none | none | | | Gully erosion behind houses north side Sundown<br>Highly erodible soils<br>HSG B | Check dams<br>Channel stabilization | 3 |
| **Williston Town Offices** | none | CB, OF | | | Some rooftop direct to SD<br>Most runoff to CBs | Pursue grants for STP demonstration site | 3 |

| SITE | VTDEC PERMIT | SW TREATMENT | IC | DA | CURRENT CONDITION | RECOMMENDED RETROFIT | RANK |
|---|---|---|---|---|---|---|---|
| | | | | | Some runoff OF to CB | SW filtering system<br>Offline DB below Old Stage Road culvert | |
| **Williston Town Roads** | none | CB, OF, ditches | | | Eroding ditches<br>No WQ treatment | Stabilize ditches after clean out<br>Improve ditch design<br>Install dry swales, wet swales & grass channels | 3 |
| **Wintersport Lane** | none | CB, OF | | | SW infiltrates in sandy soils<br>No designed infiltration structures<br>Some HSG A<br>1-0094 (not a SW permit) for building infiltration | Evaluate need for pretreatment before infiltration | 4 |

**ABBREVIATIONS:**

AB – Allen Brook
CB – catch basin
CD – check dam
DA – drainage area (acres)
DB – detention basin
EDB – extended detention basin
GS – grass swale
HES – highly erodible soils
HSG A – NRCS hydrologic soil group A
HSG B – NRCS hydrologic soil group B
IC – impervious cover
OF – "overland flow across vegetated terrain"
OS – outlet structure
RANK – priority ranking
MH – manhole
RR – rip rap
SD – storm drain
S/N –VTDEC permit discharge point
STP – stormwater treatment practice
SW – stormwater
SWM – stormwater management
WP – wet pond
WQ – water quality

**PRIORITY:**

1 –Highest priority retrofit (significant contributor due to proximity to AB, size of development (IC), high traffic volume, poor or nonexistent treatment, etc.)
2 – High priority retrofit (lack of STP; deficient design, construction, and/or maintenance; significant offsite impacts)
3 – Retrofit recommended
4 – Low priority retrofit (pretty good treatment already; small DA, high cost for treatment gained, etc.)
5 – No retrofit recommended at this time

| **SUMMARY: Stormwater Treatment Retrofit Ranking** | | | | | |
|---|---|---|---|---|---|
| Priority Rank | **1** | **2** | **3** | **4** | **5** |
| Number of Retrofits | 48 | 30 | 29 | 21 | 8 |

**NOTES:**

Table contains an entry for each discharge point of a permitted site plus any additional locations found in the field. Non-permitted location entries are for significant discharge points found in the field.

"SW TREATMENT" is as per permit requirements or as seen in field for non-permitted sites.

CERTAIN CHRONIC PROBLEMS SITE CONDITIONS needing attention that were found to be common at most every site were generally not listed in the table under current condition or recommended retrofit:
OF – This commonly applied permit condition was found to typically be ineffective due to concentrated flow, poor vegetative cover (sparse and/or short), steep slope and/or erosion. Each site with OF as part of its SW treatment needs to evaluate its effectiveness and provide an alternative treatment if necessary.
GS - This commonly applied permit condition was often found to be ineffective due to short vegetation height, steep slope, and/or erosion, resulting in detention time too short to provide adequate treatment. Each site with GS as part of its SW treatment needs to evaluate its effectiveness and provide an alternative treatment if necessary.
Areas adjacent to roadways and parking lots often had no or poor vegetative cover and rutting and/or erosion from vehicular traffic.

“Modify OS” in Retrofit column – DB should be designed to standards in the 2002 Vermont SWM manual.

Vegetation based STPs as primary treatment measure is not preferred due to Vermont’s cold climate considerations.

Inadequate STPs have recommended replacement or modifications.

HYDROLOGIC GROUP A & B soil group sites should investigate SW infiltration feasibility. Not all B soils have an infiltration rate suitable for infiltration STPs. On-site testing needed for all potential infiltration sites.

IC for certain older permits is for roads only (or roads and high density housing) and should be revised to include all impervious cover.
IC listed is from VTDEC permit unless better data was available
.

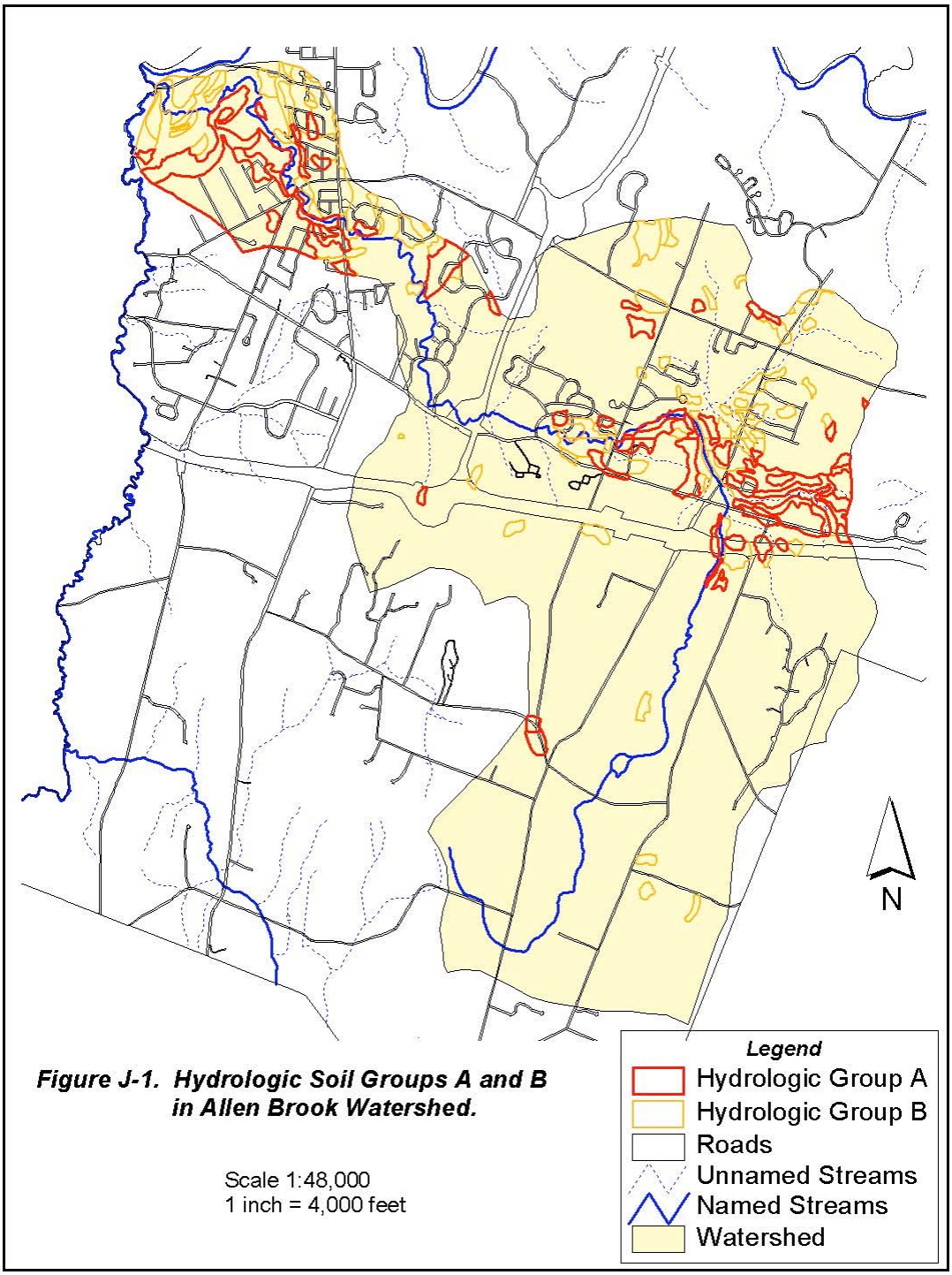


***Figure J-1. Hydrologic Soil Groups A and B in Allen Brook Watershed.***

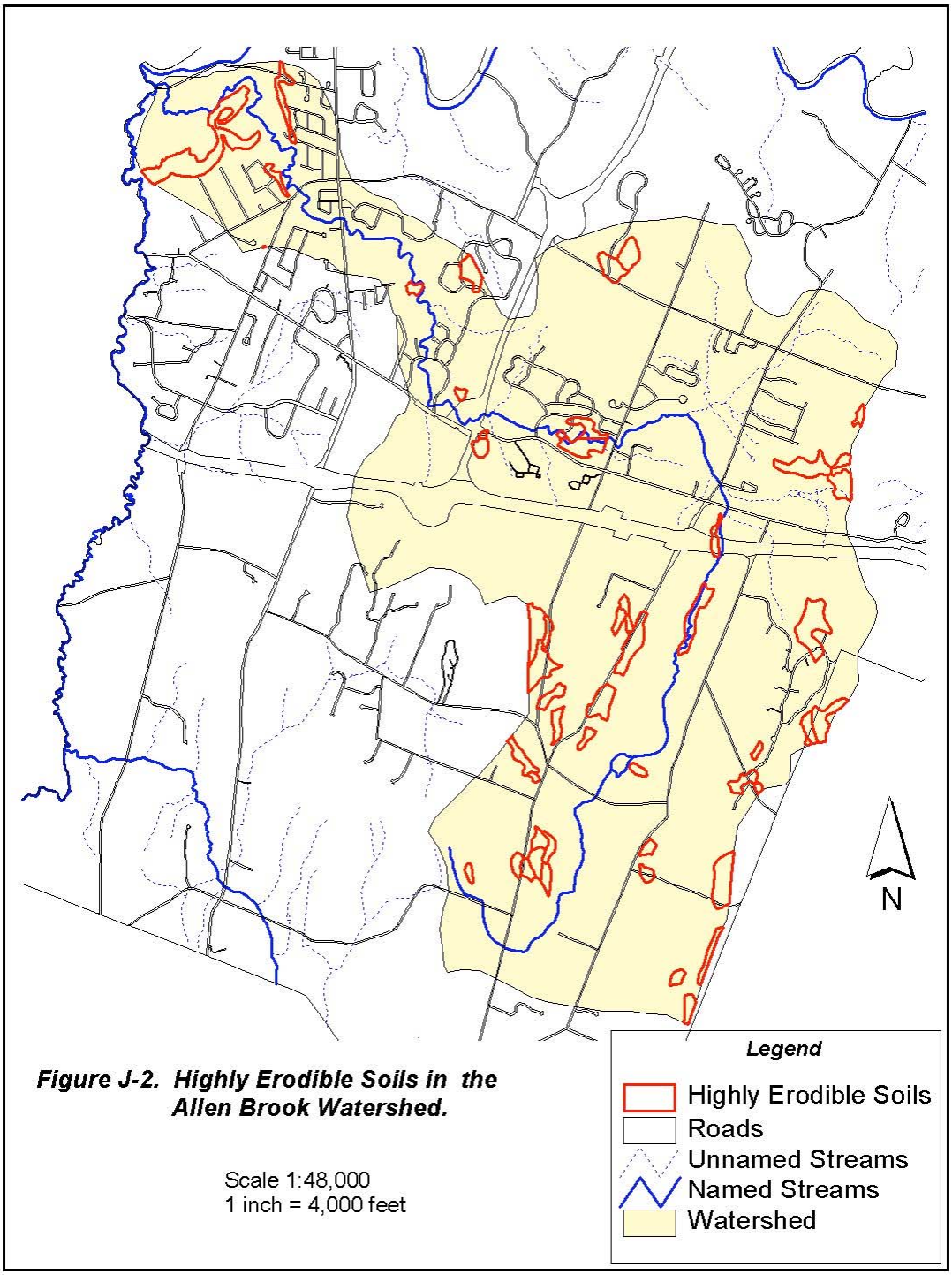


***Figure J-2. Highly Erodible Soils in the Allen Brook Watershed.***

**Figures J-3 & J-4: Detention Ponds**

**Figures J-5 & J-6: Detention Ponds Needing Maintenance**

**Figures J-7 & J-8: Gully Erosion at Storm Drain Outfalls**

**Figures J-9 & J-10: Eroding Swales**

**Figures J-1 & J-12: Poor Vegetative Cover**

**Figure J-13: Poor Vegetative Cover / Erosion**

**Figure J-14: Old Construction Site Silt Fence**

# Allen Brook Stormwater Retrofit Reconnaissance Inventory

**Site name:**

1. **Site number:**
2. **Type of site:**
3. **Vermont DEC permit number and year of issue:**
4. **Location:**
5. **Map:**
6. **Existing structure / treatment description:**

   **Type(s):**

   **Design criteria:**

   **Date of construction:**

   **Onsite conditions / issues:**

# Allen Brook Stormwater Retrofit Reconnaissance Inventory

**Offsite conditions / issues:**

7. **Preliminary assessment of most likely retrofit** (quality, quantity, both, or none)**:**

8. **Retrofit issues**

9. **Priority of retrofit:**

10. **Drainage area (ac):** **(permit)** **(stormsewer)** **(TMDL)**

11. **Impervious cover (ac):** **(permit)** **(stormsewer)** **(TMDL)**

12. **Approximate imperviousness (%): MIA** **EIA** **(permit)**

    **MIA** **EIA** **(stormsewer)**

    **MIA** **EIA** **(TMDL)**

13. **Date of field survey:**

14. **Photo numbers:**

15. **Additional notes and/or sketch information:**

# Allen Brook Site Pollution Prevention Opportunity Survey
# Commercial/Industrial/Retail Sites

Site No. _____ Photo Nos. _____

Name of Business: _____

Type of Business:

_ Vehicle Maintenance Operation
_ Commercial
_ Office
_ Industrial
_ Other _____

Address:
_____
_____

Owner: _____ RCRA/NPDES Permit? _
Phone No. _____

Approximate Area (acres): _____ On-site Stormwater Treatment?
Parking Area (acres): _____ _____

Evidence of Pollutant Sources:

_ Outside Material Storage
_ Dumpster spillage
_ Leakage from Vehicles
_ Above ground tanks
_ Vehicle Washing
_ Steam cleaning
_ Floor Drains connected to storm drain system
_ Uncovered vehicle fueling
_ Loading docks
_ Outside vehicle maintenance (including wrecked vehicles)
_ Trash/Debris
_ Intensive Landscaping
_ Erosion or bare surfaces.
_ Other sources of possible pollution
_ Inadequate BMP Maintenance

Evidence of pollutants leaving the site and entering Allen Brook (describe): _____
_____
_____

Recommendations for correcting problem: _____
_____
_____

Additional comments on the site: _____
_____
_____

# Allen Brook Site Pollution Prevention Opportunity Survey
# Residential and Institutional Areas

Area No. _____ Photo Nos. _____
(i.e., limits of survey area by street name or block)

Condition of Storm Drain Inlets & Catchbasins:
_____
_____

Are Storm Drains Stenciled? (Y) (N)

Pervious Area Condition (needless turf, exposed soils, etc.)
_____
_____
_____

Residential Lawns (condition, lawn clipping dumping evidence, overuse of fertilizer/pesticides):
_____
_____
_____

Vacant Areas (dumping, erosion, etc.)
_____
_____
_____

Opportunities for Reforestation/Revegetation (Location and Approximate Area):
_____
_____
_____

Other Opportunities for Pollution Prevention:

_ Downspout Disconnection
_ Pet Waste Disposal Areas
_ Signage Opportunities (buffer, wetland, bacteria, etc)
_ Turf Conversion to Landscaping or Xeriscaping
_ Other _____

Additional Comments and Recommendations for Correcting Problems:
_____
_____
_____

| Allen Brook<br>Pollution Prevention Survey<br>April 26 2001 | | | | |
|---|---|---|---|---|
| **Road, Reach # Or Name** | **Brief Description** | **Gutters Disconnected** | **Problem *** | **Opportunity** |
| Hickory Hill | Older Development | mostly | | community composting |
| Meadow Run | New Development | direct connection to storm system | | carwash on pervious area, education |
| Chelsea Commons | New Development | direct connection to storm system | | reduce width of roads, size of drives, disconnect impervious |
| Blair Park/Fletcher Allen | Commercial | connected | | sink parking islands for biofilters, remove cuts in curbs for stormwater onto pervious surface |
| Exxon Near Corner Of Rt 2 And 2a | Gas Station | connected | storm drain broken, some overland flow thru gas station; disconnect, incorporate WQ | |
| Taft Farm Village Center | Commercial | both | high flow outlet for storm pond appears higher than swale, stream nutrient enriched below beaver dam, Allen Brook needs riparian buffer. | parking lot has some flow into bio-filters; |
| Taft Farms | Newer Development | most roofs disconnected | streets need to be swept earlier in year | |
| South Ridge | Newer Development | 1/2 connected | clean streets sooner | |
| Commons | New Development | almost all lower circle connected, upper circle direct into storm drain | | short drives, curbs |
| Old Stage Estates | Older Development | minimal connection | | Maintain swales |
| Turtle Pond | Older Development | minimal connection | | Good example |
| Williston Country Club | Golf Course | NA | | Reduce agrichemical use, increase IPM, incorporate golf course BMP's |
| Golf Links | New Development | some | short-circuited storm pond | |
| Marty's Golf Course | Golf Course | NA | | Same as Williston Country Club |

NOTE: All connected impervious areas can be disconnected. Except for Old Stage Estates, almost all developments use stormwater ponds.