Technical Report No. 25

Urban Nonpoint Pollution Source Assessment of the Greater Burlington

Urban Stormwater Characterization Project

Lake Champlain Basin Program

Prepared by
James Pease, VT Dept. of
Environmental Conservation

for
Lake Champlain Basin Program

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Lake Champlain Basin Program
Grand Isle, Vermont

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This technical report is the twenty-fifth in a series of reports prepared under the Lake Champlain Basin Program. Those in print are listed below.

Lake Champlain Basin Program Technical Reports

1. *A Research and Monitoring Agenda for Lake Champlain.* Proceedings of a Workshop, December 17-19, 1991, Burlington, VT. Lake Champlain Research Consortium. May, 1992.

2. *Design and Initial Implementation of a Comprehensive Agricultural Monitoring and Evaluation Network for the Lake Champlain Basin.* NY-VT Strategic Core Group. February, 1993.

3. (A) *GIS Management Plan for the Lake Champlain Basin Program.* Vermont Center for Geographic Information, Inc., and Associates in Rural Development. March, 1993.

   (B) *Handbook of GIS Standards and Procedures for the Lake Champlain Basin Program.* Vermont Center for Geographic Information, Inc. March, 1993.

   (C) *GIS Data Inventory for the Lake Champlain Basin Program.* Vermont Center for Geographic Information, Inc. March, 1993.

4. (A) *Lake Champlain Economic Database Project. Executive Summary.* Holmes & Associates. March 1993.

   (B) *Socio-Economic Profile, Database, and Description of the Tourism Economy for the Lake Champlain Basin.* Holmes & Associates. March 1993

   B) *Socio-Economic Profile, Database, and Description of the Tourism Economy for the Lake Champlain Basin. Appendices.* Holmes & Associates. March 1993

   (C) *Potential Applications of Economic Instruments for Environmental Protection in the Lake Champlain Basin.* Anthony Artuso. March 1993.

   (D) *Conceptual Framework for Evaluation of Pollution Control Strategies and Water Quality Standards for Lake Champlain.* Anthony Artuso. March 1993.

5. *Lake Champlain Sediment Toxics Assessment Program. An Assessment of Sediment - Associated Contaminants in Lake Champlain - Phase 1.* Alan McIntosh, Editor, UVM School of Natural Resources. February 1994.

   Lake Champlain Sediment Toxics Assessment Program. An Assessment of Sediment - Associated Contaminants in Lake Champlain - Phase 1. Executive Summary. Alan McIntosh, Editor, UVM School of Natural Resources. February 1994.

6. *(A) Lake Champlain Nonpoint Source Pollution Assessment.* Lenore Budd, Associates in Rural Development Inc. and Donald Meals, UVM School of Natural Resources. February 1994.

   (B) Lake Champlain Nonpoint Source Pollution Assessment. Appendices A-J. Lenore Budd, Associates in Rural Development Inc. and Donald Meals, UVM School of Natural Resources. February 1994.

7. *Internal Phosphorus Loading Studies of St. Albans Bay. Executive Summary.* VT Dept of Environmental Conservation. March 1994.

   (A) *Dynamic Mass Balance Model of Internal Phosphorus Loading in St. Albans Bay, Lake Champlain.* Eric Smeltzer, Neil Kamman, Karen Hyde and John C. Drake. March 1994.

   (B) *History of Phosphorus Loading to St. Albans Bay, 1850 - 1990.* Karen Hyde, Neil Kamman and Eric Smeltzer. March 1994.

   (C) *Assessment of Sediment Phosphorus Distribution and Long-Term Recycling in St. Albans Bay, Lake Champlain.* Scott Martin, Youngstown State University. March 1994.

8. *Lake Champlain Wetlands Acquisition Study.* Jon Binhammer, VT Nature Conservancy. June 1994.

9. *A Study of the Feasibility of Restoring Lake Sturgeon to Lake Champlain.* Deborah A. Moreau and Donna L. Parrish, VT Cooperative Fish & Wildlife Research Unit, University of Vermont. June 1994.

10. *Population Biology and Management of Lake Champlain Walleye.* Kathleen L. Newbrough, Donna L. Parrish, and Matthew G. Mitro, Fish & Wildlife Research Unit, University of Vermont. June 1994.

11. (A) *Report on Institutional Arrangements for Watershed Management of the Lake Champlain Basin. Executive Summary.* Yellow Wood Associates, Inc. January 1995.

    (B) *Report on Institutional Arrangements for Watershed Management of the Lake Champlain Basin.* Yellow Wood Associates, Inc. January 1995.

    (C) *Report on Institutional Arrangements for Watershed Management of the Lake Champlain Basin. Appendices.* Yellow Wood Associates, Inc. January 1995.

12. (A) *Preliminary Economic Analysis of the Draft Plan for the Lake Champlain Basin Program. Executive Summary.* Holmes & Associates and Anthony Artuso. March 1995

    (B) *Preliminary Economic Analysis of the Draft Plan for the Lake Champlain Basin Program.* Holmes & Associates and Anthony Artuso. March 1995

13. *Patterns of Harvest and Consumption of Lake Champlain Fish and Angler Awareness of Health Advisories.* Nancy A. Connelly and Barbara A. Knuth. September 1995.

14. (A) *Preliminary Economic Analysis of the Draft Plan for the Lake Champlain Basin Program. Executive Summary - Part 2.* Holmes & Associates and Anthony Artuso. November 1995

    (B) *Preliminary Economic Analysis of the Draft Plan for the Lake Champlain Basin Program - Part 2.* Holmes & Associates and Anthony Artuso. November 1995

15. *Zebra Mussels and Their Impact on Historic Shipwrecks.* Lake Champlain Maritime Museum. January 1996.

16. *Background Technical Information for Opportunities for Action: An Evolving Plan for the Future of the Lake Champlain Basin.* Lake Champlain Basin Program. June 1996

17. (A) *Executive Summary. Economic Analysis of the Draft Final Plan for the Lake Champlain Management Conference.* Holmes & Associates and Anthony Artuso. July 1996

    (B) *Economic Analysis of the Draft Final Plan for the Lake Champlain Basin Management Conference.* Holmes & Associates and Anthony Artuso. July 1996

18. *Catalog of Digital Spatial Data for the Lake Champlain Basin* . Vermont Center for Geographic Information, Inc. September 1996.

19. *Hydrodynamic and Water Quality Modeling of Lake Champlain.* Applied Science Associates, Inc. July 1996.

20. *Understanding Phosphorus Cycling, Transport and Storage in Stream Ecosystems as a Basis for Phosphorus Management. Dr. James P.* Hoffmann, Dr. E. Alan Cassell, Dr. John C. Drake, Dr. Suzanne Levine, Mr. Donald W. Meals, Jr., Dr. Deane Wang. December 1996.

21. *Bioenergetics Modeling for Lake Trout and other Top Predators in Lake Champlain.* Dr. George W. LaBar and Dr. Donna L. Parrish. December 1996

22. *Characterization of On-Farm Phosphorus Budgets and Management in the Lake Champlain Basin.* Robert D. Allshouse, Everett D. Thomas, Charles J. Sniffen, Kristina Grimes, Carl Majewski - Miner Agricultural Research Institute. April 1997

23. (A) *Lake Champlain Sediment Toxics Assessment Program. An Assessment of Sediment - Associated Contaminants in Lake Champlain - Phase 11. Executive Summary.* Alan McIntosh, Mary Watzin and Erik Brown, UVM School of Natural Resources. October 1997

    (B) Lake Champlain Sediment Toxics Assessment Program. An Assessment of Sediment - Associated Contaminants in Lake Champlain - Phase 11. Alan McIntosh, Mary Watzin and Erik Brown, UVM School of Natural Resources. October 1997

24. *Development of Land Cover/Land Use Geographic Information System Data Layer for the Lake Champlain Basin and Vermont Northern Forest Lands Project Areas.* Dr. Thomas Millette. October 1997

25. *Urban Nonpoint Pollution Source Assessment of the Greater Burlington.* Urban Stormwater Characterization Project. James Pease, VT Dept. of Environmental Conservation. December 1997

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The estimates of pollutant loads provided in this report are presented here as planning estimates and any further use of these projections should be only done so in a careful and cautious manner.

Part 1: Table of Contents

Part 2: Individual Watershed Stormwater Assessments

The following watersheds have individual evaluations which are not included in this report but are available from the Vermont Department of Environmental Conservation, Water Quality Division.

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Introduction

Since 1992, the Vermont Department of Environmental Conservation (VTDEC) has been conducting studies, in cooperation with the United States Environmental Protection Agency (USEPA), the Lake Champlain Basin Program (LCBP), and the New York Department of Environmental Conservation (NYDEC), to characterize the input of pollutants into Lake Champlain. Activities from the initial phases (1992-93) were reported in **Mussel Monitoring for Toxic Contaminants in Tributaries to Lake Champlain** (Langdon, 1993), and **NPDES Effluent Characterization: Whole Effluent Toxicity and Priority Pollutants** (Quackenbush, 1993). During 1993-94, work focused on non-point urban sources of toxic pollutants. Monitoring activities were conducted in twelve predominantly urban watersheds with the objective of determining: 1) the cumulative effects of urban impacts to the biological communities of those streams; and 2) the potential of the streams to contribute toxic substances to Lake Champlain. Results have been reported in **Identifying Toxic Constituents of Urban Runoff from Developed Areas Within the Champlain Basin** (Quackenbush, 1995, DRAFT).

As a follow-up to the results reported in Quackenbush, 1995, VTDEC proposed to increase the detail of its evaluations within urban watersheds. A subset of these watersheds, along with several smaller drainages in the greater Burlington, Vermont area were selected for more intensive characterization (**Figure 1**). During the period 1994-1996, biological inventories, stream channel-riparian corridor evaluations, geographic information system (GIS) inventories and evaluations of urban best management practices (BMP), including pollutant loading reduction and cost estimates, were developed for each of these watersheds. All of the investigations have been coordinated within the context of three major goals: (1) restoration of the biological integrity of these streams, (2) reduction of phosphorus and toxic pollutant discharges to Lake Champlain and, (3) bacterial pollutant reduction to public recreation or drinking water source areas in Lake Champlain. The following report presents and discusses the findings of those activities. Part I of this report describes methodologies and discusses the overall findings. Part II consists of eight individual watershed stormwater management evaluations.

Background

The greater Burlington area (Burlington, Colchester, Essex, Essex Junction, Shelburne S.Burlington, Williston and Winooski) is experiencing rapid population growth. S. Burlington residential growth is occurring at twice the state rate of growth and Williston is growing at four times the state residential growth rate (Hopkins, 1995). Between July 1985 and June 1995, 284 residential subdivisions and 287 industrial or commercial site plans were approved by the Williston Planning Commission (Town of Williston, 1995). Six thousand new homes, condominiums and apartment complexes are expected to be built in this decade alone in Chittenden County. The county's population is expected to increase by 20,000 people to 150,000 by the year 2000. In addition, new highways at an estimated cost of 65 million dollars are expected to be built within the next 5 years in Chittenden County.

One result of this population growth is the loss of aquatic riparian habitat and the diversion of large amounts of storm water runoff from development into aquatic ecosystems. The VTDEC wetlands division has noted that the greatest loss of wetland habitat in the state has been in Chittenden County with a total loss of 65 acres during the period 1990-1995, almost three times the state average (305(b) Report, 1996). The cost of unplanned rapid growth and development is not acceptable to the public on the whole. According to the Center for Rural Studies at the University of Vermont, 70% of the county residents think that large scale urban sprawl should be discouraged and that this percentage has increased every year since 1990 (Sutowski, 1996).

Urban Runoff Study Watersheds

Figure 1

- Lake Champlain
- Lower Winooski River
- Allen Brook
- Bartlett Brook
- Centennial Brook
- Englesby Brook
- Indian Brook
- Morehouse Brook
- Muddy Brook
- Potash Brook
- Sunderland Brook
- City/Town Boundaries

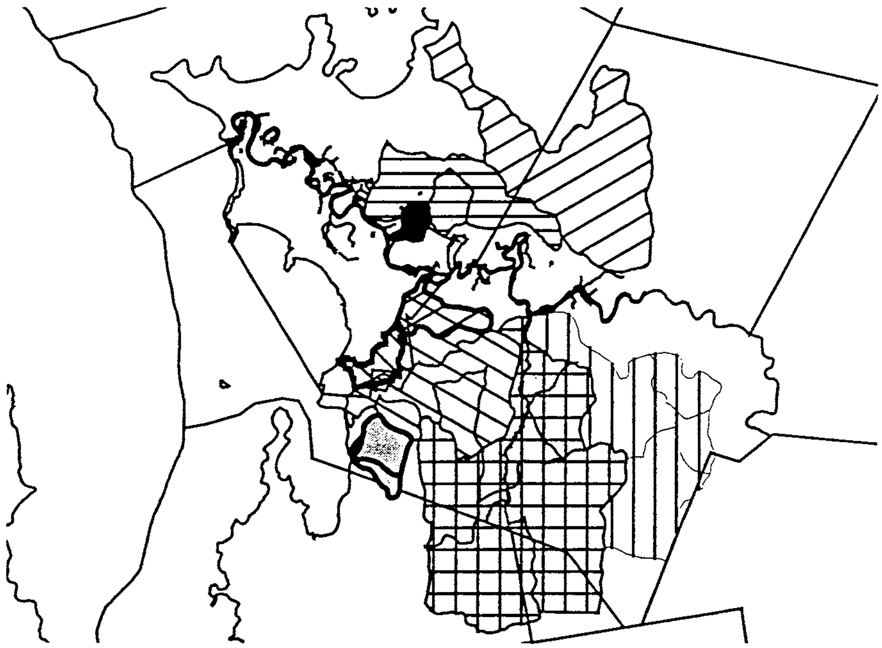
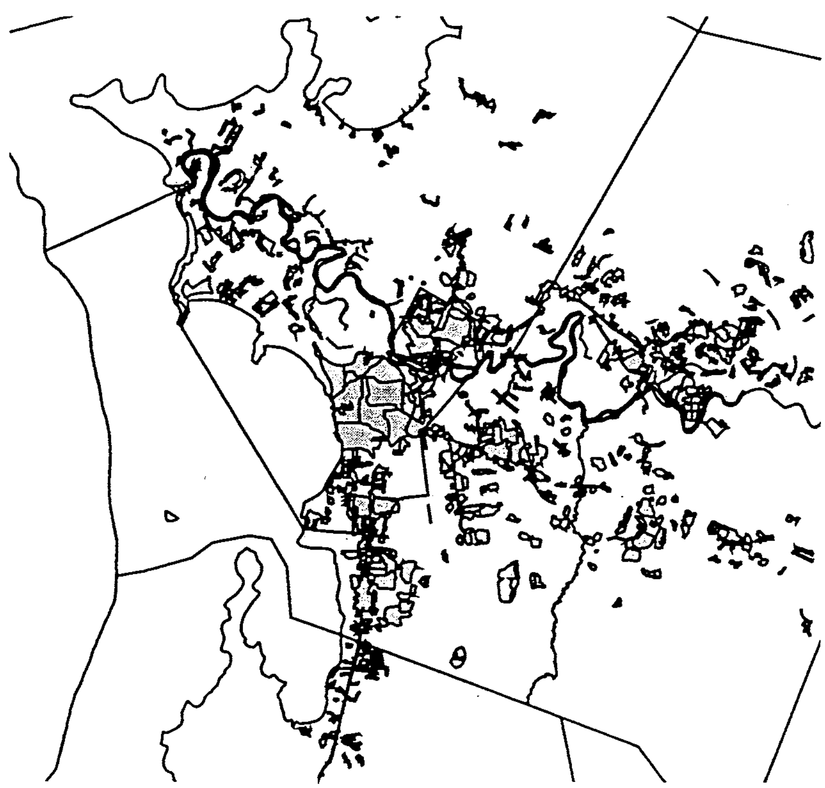


Figure 2

- Lake Champlain
- Lower Winooski River
- Stormwater Sewersheds
- City/Town Boundaries



Goals and Objectives:

For many reasons, including the control of cumulative development impacts on water quality, effective water quality management in urban areas requires the development of watershed management plans. A single development may have little or no impact on water quality but the cumulative effect of numerous impacts will degrade water quality (Morris, 1996). The overall goal of this project is to **generate specific assessment information for selected urban watersheds within the greater Burlington area that will assist local, regional and State planners in developing comprehensive watershed management plans, focusing on aquatic habitat restoration and pollutant loading reductions through stormwater management.**

In pursuit of this goal, the following objectives were addressed. These objectives correspond to the twelve steps identified by Livingston (Livingston, 1992) as required information for developing watershed management plans in urbanized areas:

1) Delineate and map watershed boundary and sub-basins within the watershed
2) Inventory and map natural stormwater conveyance and storage systems
3) Inventory and map man-made storm water conveyance and storage systems
4) Inventory pollution sources in the watershed
5) Inventory and map land use by sub-basin
6) Identify and map future land use by sub-basin
7) Inventory and map detailed soils by sub-basin
8) Establish a clear understanding of water resources in the watershed
9) Identify planned infrastructure improvements
10) Set resource management goals and objectives
11) Determine pollutant reduction needed to achieve water quality goals
12) Select appropriate management practices that can be used to achieve the goal

Methods

The methods used to address each of the twelve objectives listed above and the products of each methodology are described below.

(Step 1) Delineate and map watershed boundary and sub-basins within the watershed
(Step 2) Inventory and map natural stormwater conveyance and storage systems

A total of nine watersheds and two public beach drainages covering approximately 40,000 acres were inventoried (**Figure 1**). USGS 15 minute topographical maps were used to digitize all surface waters, watershed and subwatershed boundaries. Ponds and wetlands located during field checks and not found on topographical maps were added.

(Step 3) Inventory and map man-made storm water conveyance and storage systems
(Step 4) Inventory pollution sources in the watershed

1988 aerial orthophotographs (1:5000 scale) were used as the baseline information source for these two steps. In addition, 1992 NRCS aerial photographs were used to correct for any land use changes since 1988. Information was transferred from the orthophotographs to mylar overlays which were then digitized using an ARC-INFO GIS system. Data layers created are:

(1) **Stormwater Permit** - All VTDEC permitted stormwater discharges were located on topographical maps and converted to a GIS point coverage.

(2) **Stormwater Lines** - All currently mapped stormwater lines for each municipality were converted to a GIS coverage.

(3) **Storm Sewersheds** - All approximate drainage basins for individual stormwater drainage networks (**Figure 2**) were estimated from stormwater line configurations.

(4) **Nonpoint** - In each watershed, field surveys were carried out to inventory all existing potential sources of nonpoint source pollutants. Sites of concern included storm drain outfalls, overland drainage discharges, eroded stream banks, habitat encroachments, landfills, sites with visible oil/grease leachate or sewage, sites with high conductivity, etc. These sites were located on topographical maps and converted to a GIS point coverage.

(5) **Impervious Surface Area (ISA)** - All impervious surfaces such as building footprints and paved surfaces not existing on any other database were digitized from sources as described above. Impervious surface area of roads was calculated from the roads GIS datalayer acquired from the Chittenden County Regional Planning Commission and information provided by the Vermont Agency of Transportation Laboratory. This layer was corrected for all existing or permitted development up to October 1, 1996.

(Step 5) Inventory and map land use by sub-basin
(Step 6) Identify and map future land use by sub-basin

Current (1995) and future land use layers were acquired from the Chittenden County Regional Planning Commission. Datum are presented as figures in Part 2 of this report.

(Step 7) Inventory and map detailed soils by sub-basin

The NRCS soils data layer was mapped for each subwatershed and is included in each watershed evaluation. Soils suitable for wetponds or wetlands and soils capable of significant erosion if exposed to surface water runoff were selected and mapped separately for each watershed.

These soil characteristics can overlap as, for example, with clays which provide excellent sites for ponds by retaining water but if eroded will release fine suspended sediments which will degrade water quality. Urbanization is known to have a greater detrimental effect on the hydrologic balance of watersheds with soils having high infiltration rates (A-B soils) than in watersheds consisting of silts and clays (C-D soils) which generally have low infiltration rates (USDA, 1986). The watersheds of this study are generally characterized as sandplain watersheds, the soils being predominantly A-B soils although subwatersheds vary and some may have little if any A-B soils.

(Step 8) Establish a clear understanding of water resources in the watershed

Riparian corridor habitat was assessed using the Riparian Corridor Evaluation Method (Petersen, 1992). Field surveys were conducted in each watershed and habitat evaluations were conducted at approximately 500 meter intervals. The stream channel substrate was sampled at a pool and a riffle in each interval. Sedimentation levels were assessed by analyzing the clay/silt/sand fraction with soil texture kits (Foth, 1970). Heavily eroded areas such as slumping and collapsed stream banks were assessed using the method by Henzel (Henzel, 1992).

Biological sampling of fish and macroinvertebrates was performed at a minimum of two sites per watershed (**Figure 3**). The sample locations were situated above and below stream reaches where significant stormwater runoff discharges occur. Stream flow, dissolved oxygen content and temperature were recorded on a weekly basis during the field season and are summarized (**Figures 6.1-6.2**). The data is presented over two years with a zero indicating the transition point.

All lands considered critical to ground and surface water quality and the aquatic ecosystem in each watershed were mapped using existing GIS data sources. Lands that fall into this category are wetlands, flood plains, steep slopes, and biological natural areas/natural heritage sites. These maps are attached to the individual watershed evaluations in Part 2 of this report. These lands should be protected from development as the minimum level of protection for these watersheds. In some, but not all watersheds, this protection already exists.

(Step 9) Identify planned infrastructure improvements

Future growth areas where planned infrastructure development is expected to occur are denoted as subregional growth centers (see Watershed Evaluations, Future Land Use Maps, code 7500). In general, municipalities do not plan stormwater infrastructure improvements unless it is required with sewage treatment plant upgrades. Stormwater is an orphan infrastructure in Vermont with no municipality levying a stormwater utility fee. Almost all of the urban areas receive routine catch basin cleaning but this is not necessarily true in the suburban municipalities. Stormwater lines are rarely if ever cleaned (Roy, personal communication). All of the municipal public works agencies have been notified of water quality concerns in their respective watersheds.

(Step 10) Set resource management goals and objectives

All of the water bodies in this study are classified as B waters and as such should be able to maintain or attain the **Class B** water quality standard. **Attaining and maintaining all beneficial values and uses associated with its classification**, including swimming, fishing, general recreation, aquatic habitat protection and drinking water quality with disinfection, should be the primary management goal in all of the evaluated watersheds.

Several of these streams discharge adjacent to public swimming areas and/or public drinking water supply intake pipes; **attaining swimming and drinking water quality** are priority goals for Bartlett, Englesby and Potash Brooks. A surface water source protection plan for the Shelburne Bay Watershed is currently being developed (Champlain Water District, 1995) and will include components of this report for the Bartlett and Potash Brook watersheds.

Protection of National Wetlands Inventory wetlands in Allen, Centennial, Indian, Muddy, Potash and Sunderland Brooks is a goal for these streams. Wetlands provide flood protection, protect water quality, recharge groundwater, stabilize shorelines and provide wildlife habitat.

High levels of phosphorus in Lake Champlain are causing eutrophication which inhibits recreational use and causes impairment of aquatic life. Targeting for reduction of phosphorus to improve water quality is being done on a watershed basis. It is has been shown that urban land use contributes the greatest amount of phosphorus per unit area of any land use to Lake Champlain. Significant reductions in phosphorus loading to the lake can be achieved by addressing urban nonpoint source controls (Budd and Meals, 1994). For these reasons, **phosphorus reduction in stormwater discharges** for all of the study streams and drainages is a priority management objective.

(Step 11) Determine pollutant reduction needed to achieve water quality goals

In order to accomplish this step, pollutant loads needed to be estimated in each watershed. Pollutant loads were estimated using the Simple Method pollutant export model (Schueler, 1987)[1]. This method is reasonably accurate and allowed for an assessment of over 550 stormwater sewer sheds (**Figure 2**). The method yields an annual load of pollutant by solving the equation:

$$\textbf{Annual Load} = [(P)\times(Pj)\times(Rv)/12]\times(C)\times(A)\times(2.72)$$

where,

P = rainfall depth over 1 year, calculated as the 40 year mean from the Burlington International Airport National Weather Service Station, which is equal to 32.67".

Pj = the fraction of rainfall events that produce runoff calculated as the percentage of 75 years of rainfall data (BIA-NWS) with rainfall greater than 0.2", which is equal to 0.72.

Rv = (.05) + (.009)×(Site Percent Imperviousness), Site Percent Imperviousness is calculated as the area of impervious surface in a storm sewershed divided by the total area of the storm sewershed. ARC-INFO was used to calculate this value.

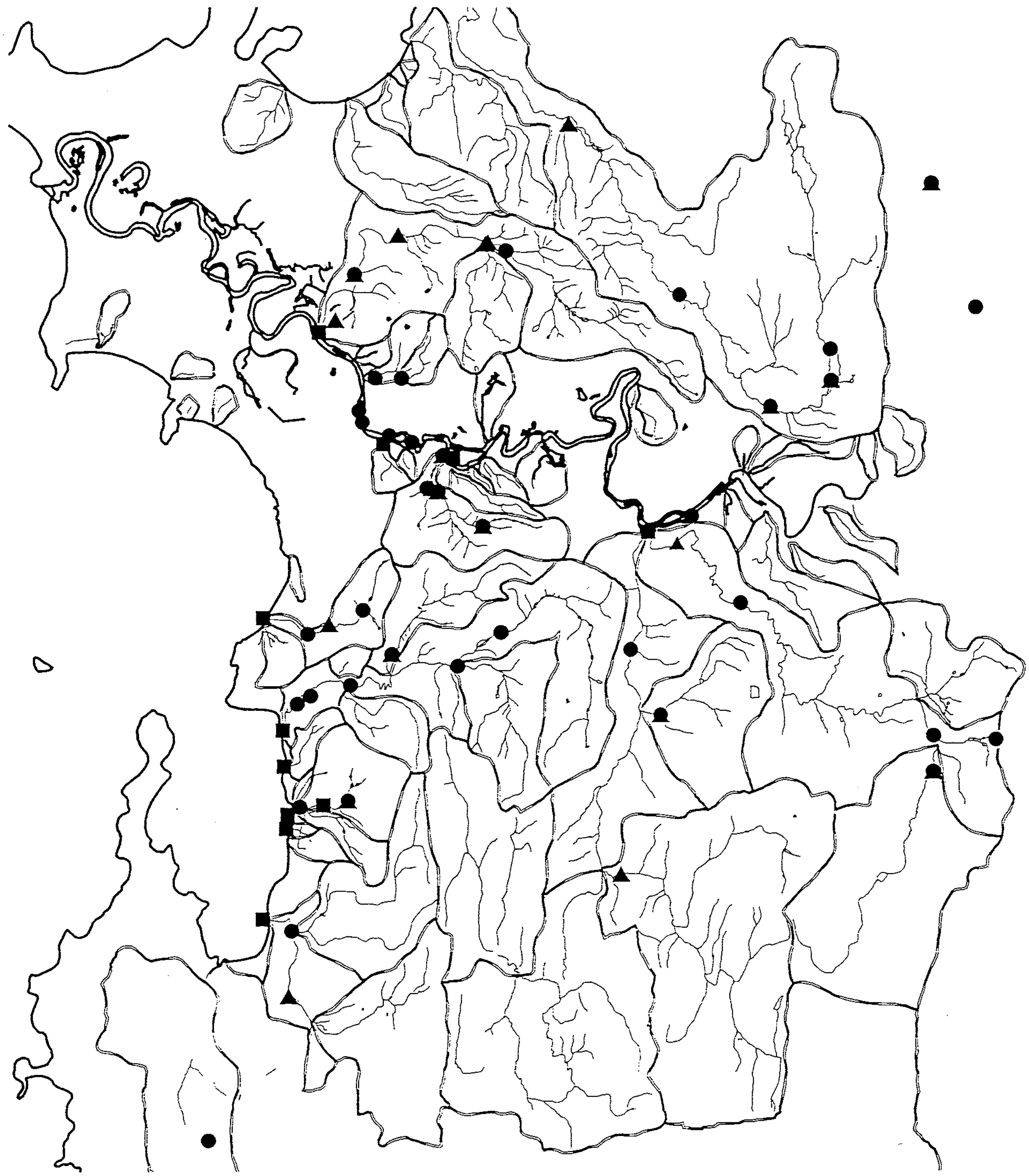
C = the flow weighted mean concentration of the pollutant (**Appendix 1**)

A = area of storm sewershed (acres)

[1] The Simple Method has been found to be accurate and somewhat conservative in estimating pollutant loads when applied to drainages not exceeding 640 acres. When compared to more complex models (ie. SWMM, HSPF) applied in the same drainages, the Simple Method estimated phosphorus load averaged slightly less than half the complex model estimate (Chandler, 1994).

The values presented in this report reflect the **low end estimate** for annual loadings, and more precisely, reflect annual loading estimates only from the sewersheds themselves rather than the entire watershed and its multiplicity of non-sewer related nonpoint sources. In addition a preliminary analysis of long term precipitation databases (Girton, 1997) suggests that a ten percent increase in the calculated loads presented would be a more accurate estimate of actual loadings. Since not all impervious surfaces are directly connected to storm drain networks it cannot be assumed that all precipitation that falls on a impervious surface becomes runoff

Monitoring Sites



- ■ Sediment Sample
- ▲ Fish Biomonitoring Station
- ● Macroinvertebrate Biomonitoring Station
- ● Macroinvertebrate Biomonitoring Station
- Watershed Boundary
- Lower Winooski River
- Streams
- Lake Champlain

Figure 3

and is discharged to surface waters. Therefore, the mapped impervious surface (MIA) and the effective impervious surface (EIA) are frequently not equal. For each watershed, the MIA has been adjusted to account for the connectedness of the basin based on Sutherland's EIA equations (Sutherland, 1995). Stormwater discharges permitted by VTDEC with treatment other than grass swales were considered for this study to be extremely disconnected with respect to the Sutherland equation. Treatment type is explained in **Appendix 4.**

Pollutant loadings for each identified sewershed were calculated for all parameters listed in **Appendix 1**. Total metals is the sum of the five most common metals in runoff (mercury, zinc, lead, copper and arsenic). Total PAH's is the sum of the four most common polyaromatic hydrocarbons (pyrene, chrysene, benzo-α-pyrene, and fluoranthene). TSS is total suspended solids. TP is total phosphorus. FC is Fecal coliform. PAH loadings are only calculated for storm sewers draining commercial or transportation lands. For each parameter, a literature survey was conducted and an average value was used, except for phosphorus where a high and a low value is also calculated. Storm sewers were then prioritized for pollutant loads. Sewers are listed (**Tables 1 and 2**) if they exceeded at least one of these criteria:

(1) TSS loadings greater than 4,536 kg/year (10,000 lbs/year)
(2) TP loadings greater than 6.8 kg/year (15 lbs/year)
(3) Total Metals loadings greater than 5.4 kg/year (12 lbs/year)
(4) Total PAH loadings greater than 36 kg/year (80 lbs/year)
(5) FC loadings greater than 500,000 col/year

Table 1 lists the highest pollutant loads in storm sewers which were in place prior to the initiation of the VTDEC stormwater permitting program and therefore are not required to be permitted under that program. **Table 2** lists the highest pollutant loads in storm sewers currently permitted by VTDEC. The results are presented in tabular format for each parameter and ordered by magnitude of loading for each watershed. Results are also presented in the individual watershed evaluations included in Part 2 of this report in both tabular and graphical format. In the Part 2 figures, total metals loading and total PAH loading are displayed with existing sediment concentrations as determined from previous studies (Quackenbush, 1995). Bacterial loadings are displayed where they are known to be at high levels as a result of other monitoring data. All known storm sewers in the greater Burlington area were included in this analysis whether or not they discharged to one of the nine watersheds. Some of the largest pollutant loads are not in the study watersheds but discharge directly to Lake Champlain or the Winooski River. These nonstudy discharges are discussed in **Targeting Areas to Achieve Water Quality Goals.**

(Step 12) Select appropriate management practices that can be used to achieve the goal

In Part 2 of this report an implementation strategy is presented for each study watershed. Each strategy includes recommendations for structural best management practices that will reduce total current pollutant loadings to each brook by 40-60%. Research indicates that properly designed and maintained BMP's can mitigate stormwater impacts on aquatic systems (Jones et. al., 1996) although there are limitations to maintaining the preexisting biological community, diversity and structure. Stream channel stabilization can also be mitigated with BMP implementation (Maxted and Shaver, 1996). Structural BMP's that best function to improve water quality are wetponds, wetlands and various types of infiltration systems (basins, trenches and galleries). The pollutant removal rates for these BMP's that are expected in New England are presented in **Table 3**. These rates were used to calculate the reduction options for the highest polluting sewer sheds (**Table 1, Table 2**). The pollutant reductions and a cost range for each option are presented in each table. Cost estimates are based on current USEPA cost figures (Griffin, 1993). Annualized costs are included in Part 2 of this report and are calculated for thirty years at five percent.

Achievement of any water quality goals will also require nonstructural source controls because of the nature of nonpoint urban runoff. Less intensive lawn care practices, proper disposal of household hazardous wastes, infiltration of roof top drainage, streambank restoration, are all practices that improve surface drainage water quality. A watershed wide education strategy that teaches residents about these and other practices is suggested in each stormwater evaluation.

Implementation of buffer or "filter strip" zoning is an important nonstructural strategy that should be implemented, where it is not already, in each of these developing watersheds. Monitoring data suggests that riparian buffers can mitigate cumulative stormwater impacts and restore water quality in urbanized streams (Little, 1977; May et.al.,1997; Maxted and Shaver, 1996). The existing zoning status for each study watershed is discussed in each stormwater evaluation and under **Watershed Protection**.

In several watersheds actual restoration of degraded biological communities may be necessary to restore aquatic health. This can involve the creation of pool and riffle habitat to enhance the existing stream channel. When this practice is linked to all of the above strategies it has a good chance of success.

In order for Class B water quality standards to be reached in these streams both structural and nonstructural controls must be implemented. Neither one alone can successfully accomplish this goal.

Table 3: Expected pollutant removal rates for selected BMP's (Griffin, 1993).

BMP	Total Metals	TSS	Total Phosphorus	Fecal Coliform
Wetpond	0.68	0.6	0.45	0.8
Wetland	0.55	0.7	0.45	0.8
Infiltration Basin	0.8	0.8	0.6	0.8

Discussion: Biology

In urbanized areas development covers over the smallest swales and rills in the landscape. These first order channels contribute significantly to the ability of the watershed to retain rainfall and snow melt rather than allowing it to run off quickly. As a result of this increased runoff, urbanization of a watershed also tends to increase the cross-sectional area of a stream channel (Dunne and Leopold, 1978). Increased stream velocities, more frequent flooding and the resulting scouring are the agents of stream channel enlargement. Measurement of stream cross-sectional areas in the greater Burlington area indicates a large number of streams with scoured channels (**Figure 4**). Sunderland Brook, Indian Brook and Allen Brook are the least impaired by stormwater runoff and show the least channel erosion and alteration.

Sedimentation, bank slumping and other forms of erosion are serious threats to aquatic life. All three become more prevalent as watershed imperviousness increases. Increasing stream velocities cause sediment scouring and deposition which smothers macroinvertebrates, blocks sunlight thereby

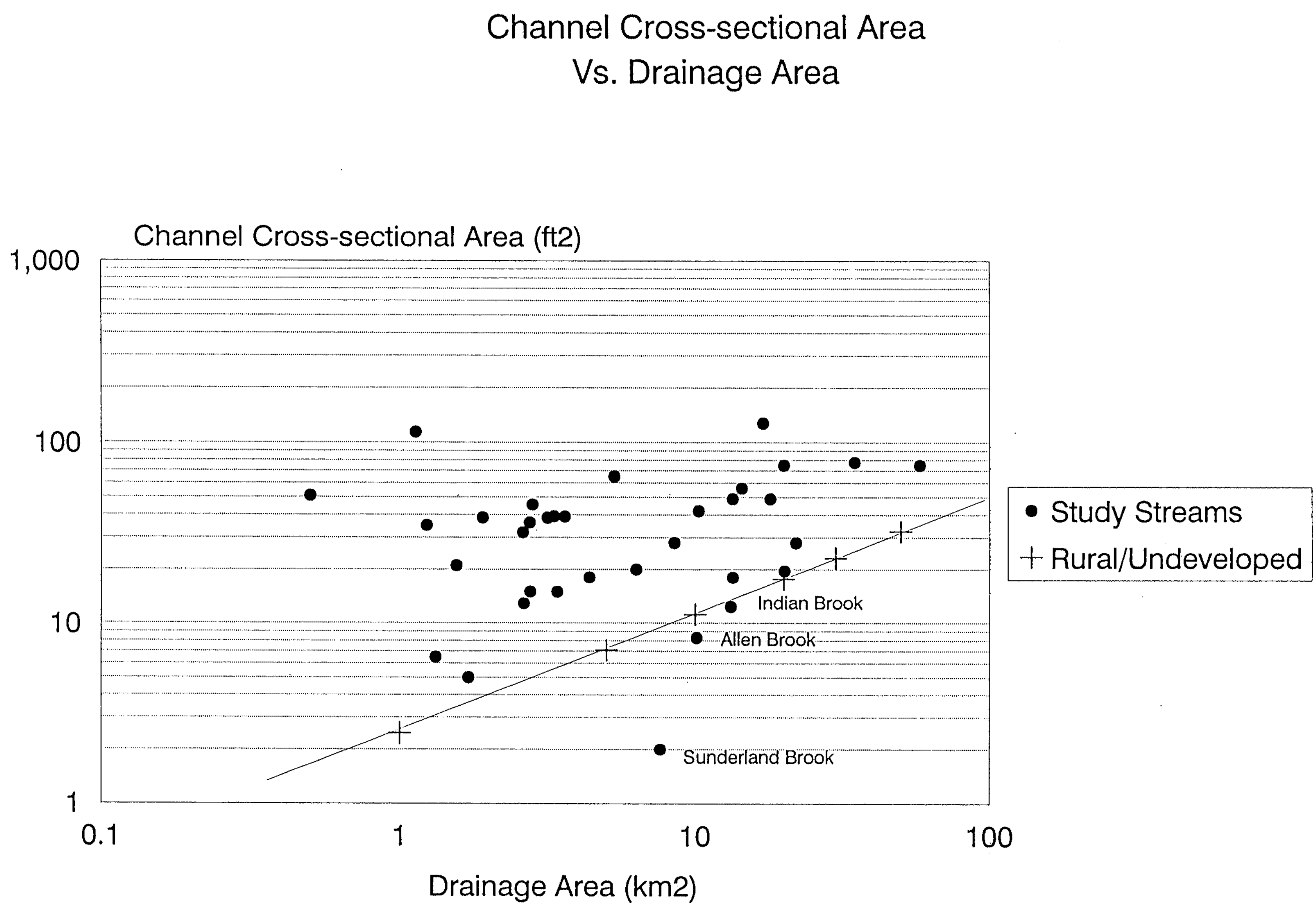

Channel Cross-sectional Area
Vs. Drainage Area
Channel Cross-sectional Area (ft2)
1,000
100
10
1
0.1
1
10
100
Drainage Area (km2)
Indian Brook
Allen Brook
Sunderland Brook
Study Streams
Rural/Undeveloped

Figure 4

Table 4: Biological integrity in the study area watersheds. Mean EPT richness is a measure of the number of pollution sensitive aquatic invertebrates[2]. Mean species richness is a measure of the total diversity of macroinvertebrates at the site. Density is a count of the total number of macroinvertebrates per unit area. The 3 metrics are combined to estimate the overall macroinvertebrate stream health. The fish community is assessed using a modified Index of Biotic Integrity, a multi-parameter index that evaluates overall fish community health.

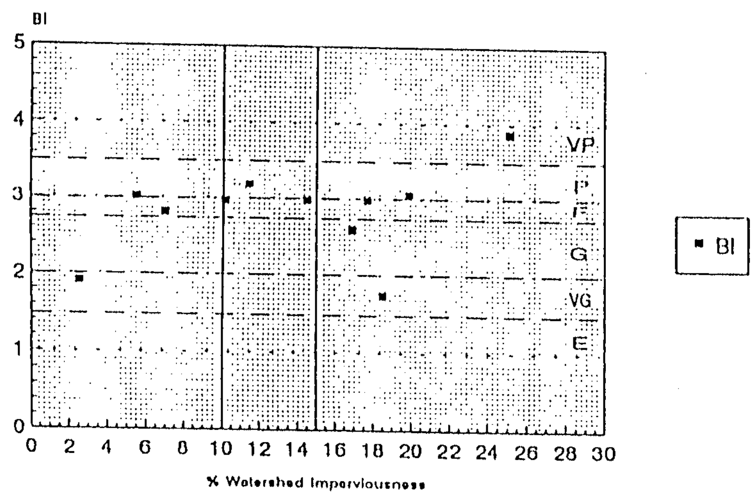
Stream/ % ISA	Site	Biotic Index[3] (0-5)	Mean EPT Richness	Mean Species Richness	Density	Macro. Commun. Assess.	Fish Commun. Assess.
Allen	**Above**	**1.91**	**19.5**	**44.5**	**1060**	**Good**	**Good-Exc**
% 5.5	Below	2.64	17.5	44	3010	Good	Poor
Bartlett	Above	2.83	6	28	1394	Poor	Fair
% 16.9	Below	2.58	3.5	27	263	Poor	Fair
Centennial	Above	4.07	3.5	15.5	1004	Poor	Good
% 25.1	Below	3.87	2	12.5	184	Poor	Fair
Englesby	Above	2.84	5	27	1691	Poor	NA
% 19.9	Below	3.09	2.3	18.8	305	Poor	Fair
Indian	**Above**	**2.36**	**19.5**	**45.5**	**1312**	**Good-Exc**	**Fair**
% 6.3	Below	2.93	12	32.5	816	Poor	Fair
Morehouse	Above	1.73	3.5	19	232	Poor	NA
% 13.6	Below	3.06	3.5	19.5	133	Poor	NA
Muddy	Above	NA	NA	NA	NA	NA	Fair-Good
% 3.9	Below	2.81	16	35.5	1898	Good	Poor
Potash	Above	2.42	15.3	35	1740	Good	Good
% 17.7	Below	2.9	10	30.5	788	Poor	Poor
Sunderland	Above	2.75	8.5	25.5	1638	Poor	Fair
% 11.4	Below	3.18	4	20.5	475	Poor	Fair

[2] EPT refers to Ephemeroptera (may flies), Plecoptera (stone flies) and Trichoptera (caddis flies), macroinvertebrate species indicative of clean water.
[3] Biotic Index (BI) is a measure of stream nutrient enrichment and overall stream health, a range of 0-5 is indicative of excellent to poor.

preventing algal growth and depresses functional feeding groups such as macroinvertebrate scrapers which consume diatoms and algae.

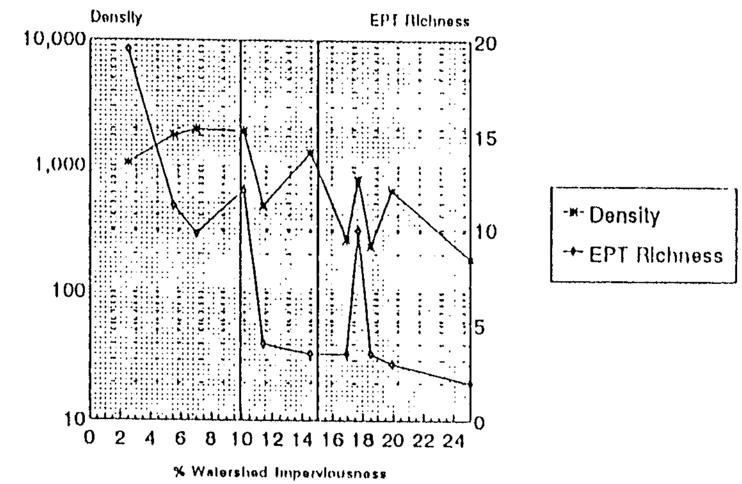
Embeddedness of the stream channel substrate, either in a riffle or a pool, is frequently an indication of habitat degradation. As embeddedness increases biological integrity decreases. Sand is a much more common constituent of stream channels in the Champlain Valley lowlands than in other

Impacts of Imperviousness on Stream Biology
Macroinvertebrates



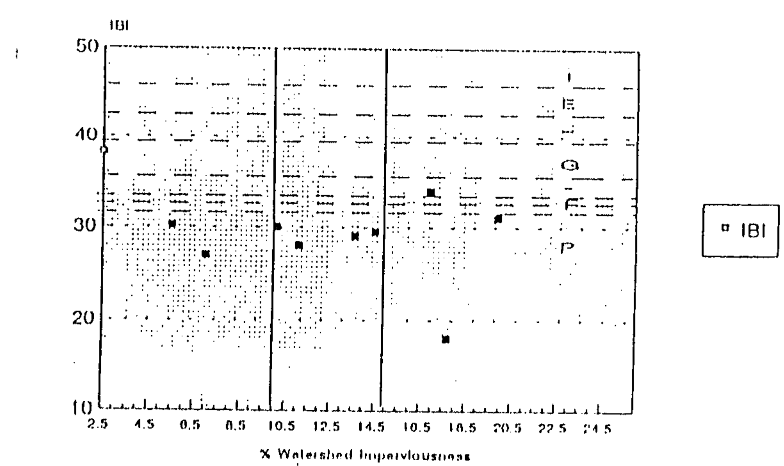
All Biometrics are mean values from ABN database

Impacts of Imperviousness on Stream Biology
Macroinvertebrates



All Biometrics are mean values from ABN database

Impacts of Imperviousness on Stream Biology
Fish



All biometrics are mean values from VTDEC ABN database

ABN is the Aquatic Biomonitoring Network managed by the Vermont Department of Environmental Conservation

BI is the Biotic Integrity value, a measure of nutrient enrichment and overall water quality

IBI is the Index of Biotic Integrity, an ecologically based index for the entire fish community

Figure 5

areas of the state where bedrock is closer to the surface. However, even in these streams where biological tolerance to a certain amount of sand exists, excessive levels will have a negative effect.

The effect of toxic metals in runoff, particularly zinc, has been previously investigated and documentation exists to show that untreated high volume stormwater discharges to small and medium sized receiving waters (50-250 km^2) are ecologically destructive to aquatic ecosystems (Metcalf and Eddy, 1983).

The impacts of impervious surfaces on stream water quality are also well documented; significant deterioration of in-stream aquatic communities is likely to occur when watershed imperviousness reaches 10-15% (Klein, 1979; Bannerman, 1993; Schueler, 1994). Current biological data from the Burlington area (**Table 4, Figure 5**) are consistent with the observation that increased impervious surface area negatively impacts the aquatic health of streams. Bartlett Brook, Centennial Brook, Englesby Brook, the Essex Junction subwatershed of Indian Brook, the Taft Corners subwatershed of Muddy Brook, and Potash Brook have all exceeded the fifteen percent imperviousness threshold. Sunderland Brook and Morehouse Brook are very close to this threshold. However, the biological monitoring data also indicates that ISA is not the only factor affecting biological health and that in some cases, high ISA does not result in highly impaired biota. The relationship between ISA and biological health is clear but most probably is complicated by the degree of connectedness within blocks of ISA and the existence of biological recovery zones (natural areas, protected riparian corridor) between blocks.

The two sites highlighted in **Table 4** are considered macroinvertebrate biological reference sites for the Lake Champlain lowlands (Fiske, personal communication). Only the Allen Brook site meets the existing criteria for Class B Water Quality status for both macroinvertebrates and fish. The Indian Brook site does not meet the fish criteria for Class B status (Langdon, personal communication) although the stream does meet Class B status downstream of this site. For each watershed evaluation (Part 2), the biotic index (BI) for macroinvertebrates, which is a measure of nutrient enrichment and overall stream health, and the biotic index for fish (IBI), which is a measure of overall habitat quality for nongame and game fish, are presented in conjunction with an assessment of stream riffle embeddedness and pool siltation. For each stream, a habitat assessment map is also presented that rates overall habitat health by measuring riparian corridor size and level of human impact.

Chemistry

Stormwater water chemistry is highly variable and has a broad range of impacts on its receiving water (Makepeace, 1995). The introduction of nutrients, large quantities of organic debris (trash) and fluctuating stream flows can cause significant depressions in dissolved oxygen levels as occurs in Englesby Brook. Healthy dissolved oxygen levels should range from 8-10 mg/l in riffle streams (Allen, Bartlett, Englesby, Morehouse and Muddy) and 7-10 mg/l in slower streams with wetlands (Centennial, Indian, Potash and Sunderland)(**Figure 6.1, Figure 6.2**).

Salt (NaCl) from winter street maintenance elevates stream conductivities to over twice the background level in the Burlington area. The Williston Rd.-Dorset St. storm sewer was found to have 518 mg/l of Na, 898 mg/l of Cl and a conductivity of 3180 uS/cm (VTDEC Laboratory, 1994) six times higher than an adjacent groundwater spring. High salt solutions can dissolve metals in urban streams (Kunkle, 1971) releasing them for biological uptake.

A high percentage of imperviousness in a watershed can contribute to thermal loading in the stream by heat transfer and by the absence of riparian vegetation shading. Both Potash and Centennial Brooks show a greater fluctuation in ambient stream temperature (Δ 12+°C) compared to the Allen Brook control (Δ 7°C)(**Figure 6.1, Figure 6.2**). Increased ambient stream temperature can cause greater biological uptake of copper and cadmium by both macroinvertebrates and fish (Morris, 1996). Bacterial colonies can also multiply rapidly (x 100-1000) in sediments as a result of thermal loading (Morris, 1996).

Table 1. Targeted Storm Sewer Treatment Options

Receiving Water	Sewershed Name	Map #	Existing Treatment	EIA%	Total Metals	Load (Kg) After <----BMP Reduction----> Pond BMP	Wetland BMP	I-Basin BMP	TP	TP Low	TP High	TP Kg/hct	Load (Kg) After <----BMP Reduction----> Pond BMP	Wetland BMP	I-Basin BMP
Bartlett	Bay Court	1	SF	15	11	4	5	2	14	7	25	0.63	8	8	6
Bartlett	Shelburne Road 1	1	DP/OS/CB/GS	47	43	14	19	9	56	25	97	1.65	31	31	22
Centennial	Staples Plaza 2	4	CB	100	9	3	4	2	11	5	19	3.29	6	6	4
Centennial	Airport Pkwy-White St	5	CB	15	10	3	4	2	12	6	21	0.64	7	7	5
Centennial	Williston Rd-Dorset St	4	CB	80	19	6	9	4	25	11	42	2.67	14	14	10
Englesby	Proctor St-Hadley St	2	CB	11	9	3	4	2	12	5	20	0.52	6	6	5
Englesby	Richardson Terrace	2	CB/CF	12	9	3	4	2	12	6	21	0.56	7	7	5
Englesby	Shelburne Rd-Outlet Mall	2	CB	61	24	8	11	5	31	14	54	2.07	17	17	12
Indian	Essex Junction H.S. 1	8	CB	71	4	1	2	1	6	3	10	2.37	3	3	2
Indian	Five Corners-North	8	CB	57	7	2	3	1	9	4	15	1.94	5	5	4
Lake Champ	Upper Shore Rd 1	14	CB	20	6	2	2	1	7	3	12	0.80	4	4	3
Lake Champ	Burlington H.S.	18	CB	41	6	2	3	1	7	3	13	1.44	4	4	3
Lake Champ	Holmes Road	1	CB/SB	35	6	2	3	1	8	4	14	1.26	4	4	3
Lake Champ	Austin Dr	13	CB	13	6	2	3	1	8	4	14	0.57	4	4	3
Lake Champ	Shelburne Road 2	1	CB	15	11	3	5	2	14	6	24	0.63	8	8	6
Morehouse	W.Spring St-Malletts Bay Ave	6	CB	32	22	7	10	4	28	13	48	1.17	15	15	11
Muddy	Engineers Dr	7	CB/CP	99	5	2	2	1	6	3	11	3.25	4	4	3
Muddy	Griswold Industrial Park	7	CB	89	19	6	8	4	24	11	42	2.96	13	13	10
Potash	Corporate Way 1	3	CB	58	7	2	3	1	9	4	16	1.97	5	5	4
Potash	Laurel Hill Dr.	16	CB	12	7	2	3	1	10	4	16	0.56	5	5	4
Potash	Williston Rd	3	CB	62	8	2	3	2	10	5	17	2.09	6	6	4
Potash	Mills Ave	3	CB	12	8	3	4	2	11	5	18	0.56	6	6	4
Potash	Shelburne Road 8	16	CB	70	8	3	4	2	11	5	19	2.34	6	6	4
Potash	Timber Lane	3	CB	27	9	3	4	2	11	5	19	1.01	6	6	4
Potash	Shelburne Road 7	16	CB	81	9	3	4	2	11	5	20	2.68	6	6	5
Potash	KMart	16	CB	81	11	3	5	2	14	6	24	2.69	8	8	6
Potash	Williston Rd 2	3	CB	68	12	4	6	2	16	7	28	2.28	9	9	6
Potash	Williston Rd-Pinetree	3	CB	16	14	4	6	3	18	8	31	0.66	10	10	7
Potash	San Remo Dr.	3	CB	85	19	6	9	4	25	11	43	2.81	14	14	10
Sunderland	Meadows Industrial Park 1	12	CB/DP/GS	40	8	2	3	2	10	5	17	1.42	6	6	4
Sunderland	Ames	9	CB	92	8	3	4	2	10	5	18	3.05	6	6	4
Sunderland	Pearl St-East	10	CB	86	9	3	4	2	12	6	21	2.85	7	7	5
Sunderland	Fort Ethan Allen 6	9	CB	92	22	7	10	4	28	13	49	3.04	16	16	11
Winooski	Pearl St 1	11	CB	33	4	1	2	1	6	3	10	1.19	3	3	2
Winooski	North Ave 2	19	CB	23	5	2	2	1	7	3	12	0.87	4	4	3
Winooski	Lower Main St	17	CB	74	7	2	3	1	9	4	15	2.47	5	5	3
Winooski	E.Allen St	17	CB	52	9	3	4	2	11	5	19	1.79	6	6	4
Winooski	Woolen Mill	17	CB	94	9	3	4	2	11	5	20	3.10	6	6	5
Winooski	Five Corners	15	CB	60	10	3	4	2	12	6	22	2.04	7	7	5
Winooski	Pearl St 2	11	CB	23	10	3	5	2	13	6	23	0.90	7	7	5
Winooski	Gazo Ave	19	CB	22	6	2	3	1	14	6	23	0.86	7	7	5
Winooski	Hiawatha Ave	15	CB	24	17	6	8	3	23	10	39	0.93	12	12	9
Winooski	S.Summit-South St	15	CB	19	18	6	8	4	23	10	39	0.75	13	13	9
Winooski	Upper Main St	17	CB	51	18	6	8	4	23	10	40	1.76	13	13	9
Winooski	Barlow St	17	CB/GS	46	18	6	8	4	24	11	41	1.60	13	13	9
Winooski	Hickock St-W.Allen St	17	CB	35	39	12	17	8	50	23	87	1.25	28	28	20
Winooski	Mid Main St-E.Spring St	17	CB	31	46	15	21	9	60	27	103	1.15	33	33	24
			Total Kg/yr		599	192	270	120	785	355	1352		431	431	313

Table 1. Targeted Storm Sewer Treatment Options

Receiving Water	Sewershed Name	Map #	TSS	Load (Kg) After <------BMP Reduction------> Pond BMP	Wetland BMP	I-Basin BMP	Fec.Col. x1000	Load (Kg) After <-----BMP Reduction-----> Pond BMP	Wetland BMP	I-Basin BMP
Bartlett	Bay Court	1	9185	3674	2756	2756	1470	294	294	294
Bartlett	Shelburne Road 1	1	35701	14280	10710	10710	5714	1143	1143	1143
Centennial	Staples Plaza 2	4	7115	2846	2134	2134	1139	228	228	228
Centennial	Airport Pkwy-White St	5	7923	3169	2377	2377	1268	254	254	254
Centennial	Williston Rd-Dorset St	4	15647	6259	4694	4694	2504	501	501	501
Englesby	Proctor St-Hadley St	2	7448	2979	2235	2235	1192	238	238	238
Englesby	Richardson Terrace	2	7754	3102	2326	2326	1241	248	248	248
Englesby	Shelburne Rd-Outlet Mall	2	19774	7910	5932	5932	3165	633	633	633
Indian	Essex Junction H.S. 1	8	3576	1430	1073	1073	572	114	114	114
Indian	Five Corners-North	8	5687	2275	1706	1706	910	182	182	182
Lake Champ	Upper Shore Rd 1	14	4567	1827	1370	1370	731	146	146	146
Lake Champ	Burlington H.S.	18	4756	1902	1427	1427	761	152	152	152
Lake Champ	Holmes Road	1	4981	1992	1494	1494	797	159	159	159
Lake Champ	Austin Dr	13	5117	2047	1535	1535	819	164	164	164
Lake Champ	Shelburne Road 2	1	8826	3531	2648	2648	1413	283	283	283
Morehouse	W.Spring St-Malletts Bay Ave	6	17817	7127	5345	5345	2852	570	570	570
Muddy	Engineers Dr	7	4049	1620	1215	1215	648	130	130	130
Muddy	Griswold Industrial Park	7	15478	6191	4644	4644	2477	495	495	495
Potash	Corporate Way 1	3	5988	2395	1797	1797	958	192	192	192
Potash	Laurel Hill Dr.	16	6050	2420	1815	1815	968	194	194	194
Potash	Williston Rd	3	6396	2558	1919	1919	1024	205	205	205
Potash	Mills Ave	3	6815	2726	2044	2044	1091	218	218	218
Potash	Shelburne Road 8	16	6896	2758	2069	2069	1104	221	221	221
Potash	Timber Lane	3	7112	2845	2134	2134	1138	228	228	228
Potash	Shelburne Road 7	16	7283	2913	2185	2185	1166	233	233	233
Potash	KMart	16	8875	3550	2662	2662	1420	284	284	284
Potash	Williston Rd 2	3	10312	4125	3094	3094	1651	330	330	330
Potash	Williston Rd-Pinetree	3	11584	4633	3475	3475	1854	371	371	371
Potash	San Remo Dr.	3	15728	6291	4718	4718	2517	503	503	503
Sunderland	Meadows Industrial Park 1	12	6395	2558	1919	1919	1024	205	205	205
Sunderland	Ames	9	6596	2638	1979	1979	1056	211	211	211
Sunderland	Pearl St-East	10	7834	3134	2350	2350	1254	251	251	251
Sunderland	Fort Ethan Allen 6	9	17958	7183	5387	5387	2874	575	575	575
Winooski	Pearl St 1	11	3643	1457	1093	1093	583	117	117	117
Winooski	North Ave 2	19	4359	1744	1308	1308	698	140	140	140
Winooski	Lower Main St	17	5553	2221	1666	1666	889	178	178	178
Winooski	E.Allen St	17	7106	2843	2132	2132	1137	227	227	227
Winooski	Woolen Mill	17	7281	2912	2184	2184	1165	233	233	233
Winooski	Five Corners	15	7927	3171	2378	2378	1269	254	254	254
Winooski	Pearl St 2	11	8414	3366	2524	2524	1347	269	269	269
Winooski	Gazo Ave	19	8662	3465	2599	1732	1386	277	277	277
Winooski	Hiawatha Ave	15	14355	5742	4307	4307	2298	460	460	460
Winooski	S.Summit-South St	15	14541	5816	4362	4362	2327	465	465	465
Winooski	Upper Main St	17	14713	5885	4414	4414	2355	471	471	471
Winooski	Barlow St	17	15062	6025	4518	4518	2411	482	482	482
Winooski	Hickock St-W.Allen St	17	31908	12763	9572	9572	5107	1021	1021	1021
Winooski	Mid Main St-E.Spring St	17	37881	15152	11364	11364	6063	1213	1213	1213
	Total Kg/yr		498629	199452	149590	148723				

Table 1. Targeted Storm Sewer Treatment Options

Receiving Water	Sewershed Name	Map #	Area Hectares	Wetpond Low Cost	Wetpond High Cost	Wetland Low Cost	Wetland High Cost	I-Basin Low Cost	I-Basin High Cost	Instream Treatment
Bartlett	Bay Court	1	22.9	$5,647.28	$112,945.60	$282,364.01	$4,517,824.19	$11,294.56	$67,767.36	NONE
Bartlett	Shelburne Road 1	1	34.0	$8,393.48	$167,869.61	$419,674.02	$6,714,784.36	$16,786.96	$100,721.77	NONE
Centennial	Staples Plaza 2	4	3.4	$840.24	$16,804.90	$42,012.24	$672,195.82	$1,680.49	$10,082.94	3 TEMP PONDS
Centennial	Airport Pkwy-White St	5	19.4	$4,792.89	$95,857.80	$239,644.50	$3,834,311.98	$9,585.78	$57,514.68	6 TEMP PONDS
Centennial	Williston Rd-Dorset St	4	9.2	$2,270.16	$45,403.23	$113,508.07	$1,816,129.06	$4,540.32	$27,241.94	2 TEMP PONDS
Englesby	Proctor St-Hadley St	2	22.5	$5,567.32	$111,346.37	$278,365.93	$4,453,854.94	$11,134.64	$66,807.82	NONE
Englesby	Richardson Terrace	2	21.7	$5,362.80	$107,256.03	$268,140.07	$4,290,241.13	$10,725.60	$64,353.62	NONE
Englesby	Shelburne Rd-Outlet Mall	2	15.0	$3,715.75	$74,315.03	$185,787.57	$2,972,601.14	$7,431.50	$44,589.02	NONE
Indian	Essex Junction H.S. 1	8	2.4	$585.24	$11,704.71	$29,261.78	$468,188.47	$1,170.47	$7,022.83	WETLDS/POND
Indian	Five Corners-North	8	4.6	$1,135.61	$22,712.14	$56,780.36	$908,485.69	$2,271.21	$13,627.29	WETLDS/POND
Lake Champ	Upper Shore Rd 1	14	9.0	$2,225.11	$44,502.11	$111,255.27	$1,780,084.28	$4,450.21	$26,701.26	NONE
Lake Champ	Burlington H.S.	18	5.2	$1,278.25	$25,565.07	$63,912.69	$1,022,602.99	$2,556.51	$15,339.04	1 TEMP POND
Lake Champ	Holmes Road	1	6.2	$1,528.03	$30,560.56	$76,401.39	$1,222,422.28	$3,056.06	$18,336.33	NONE
Lake Champ	Austin Dr	13	14.0	$3,467.84	$69,356.82	$173,392.05	$2,774,272.75	$6,935.68	$41,614.09	NONE
Lake Champ	Shelburne Road 2	1	22.1	$5,453.98	$109,079.68	$272,699.19	$4,363,187.03	$10,907.97	$65,447.81	NONE
Morehouse	W.Spring St-Malletts Bay Ave	6	23.9	$5,900.17	$118,003.49	$295,008.74	$4,720,139.78	$11,800.35	$70,802.10	NONE
Muddy	Engineers Dr	7	2.0	$483.01	$9,660.18	$24,150.44	$386,407.07	$966.02	$5,796.11	1 WETLAND
Muddy	Griswold Industrial Park	7	8.2	$2,030.08	$40,601.51	$101,503.76	$1,624,060.20	$4,060.15	$24,360.90	1 WETLAND
Potash	Corporate Way 1	3	4.8	$1,181.12	$23,622.42	$59,056.06	$944,896.96	$2,362.24	$14,173.45	NONE
Potash	Laurel Hill Dr.	16	16.9	$4,182.95	$83,659.07	$209,147.66	$3,346,362.62	$8,365.91	$50,195.44	NONE
Potash	Williston Rd	3	4.8	$1,184.84	$23,696.71	$59,241.78	$947,868.48	$2,369.67	$14,218.03	1 WETLAND
Potash	Mills Ave	3	19.2	$4,752.22	$95,044.35	$237,610.87	$3,801,773.85	$9,504.43	$57,026.61	WETLDS/POND
Potash	Shelburne Road 8	16	4.6	$1,141.33	$22,826.52	$57,066.30	$913,060.79	$2,282.65	$13,695.91	NONE
Potash	Timber Lane	3	11.1	$2,738.98	$54,779.60	$136,949.00	$2,191,183.96	$5,477.96	$32,867.76	1 WETLAND
Potash	Shelburne Road 7	16	4.3	$1,053.72	$21,074.44	$52,686.09	$842,977.50	$2,107.44	$12,644.66	NONE
Potash	KMart	16	5.2	$1,282.14	$25,642.75	$64,106.87	$1,025,709.93	$2,564.27	$15,385.65	NONE
Potash	Williston Rd 2	3	7.1	$1,758.47	$35,169.33	$87,923.32	$1,406,773.11	$3,516.93	$21,101.60	WETLDS/POND
Potash	Williston Rd-Pinetree	3	27.6	$6,829.69	$136,593.87	$341,484.66	$5,463,754.62	$13,659.39	$81,956.32	1 WETLAND
Potash	San Remo Dr.	3	8.8	$2,175.55	$43,510.93	$108,777.34	$1,740,437.38	$4,351.09	$26,106.56	NONE
Sunderland	Meadows Industrial Park 1	12	7.1	$1,744.61	$34,892.18	$87,230.45	$1,395,687.22	$3,489.22	$20,935.31	WETLDS/POND
Sunderland	Ames	9	3.4	$839.08	$16,781.55	$41,953.89	$671,262.17	$1,678.16	$10,068.93	WETLDS
Sunderland	Pearl St-East	10	4.3	$1,067.62	$21,352.35	$53,380.88	$854,094.03	$2,135.24	$12,811.41	WETLDS/POND
Sunderland	Fort Ethan Allen 6	9	9.3	$2,293.49	$45,869.71	$114,674.28	$1,834,788.47	$4,586.97	$27,521.83	WETLDS
Winooski	Pearl St 1	11	4.8	$1,189.47	$23,789.37	$59,473.42	$951,574.79	$2,378.94	$14,273.62	NONE
Winooski	North Ave 2	19	7.8	$1,934.17	$38,683.48	$96,708.70	$1,547,339.21	$3,868.35	$23,210.09	NONE
Winooski	Lower Main St	17	3.5	$874.05	$17,480.97	$43,702.41	$699,238.64	$1,748.10	$10,488.58	NONE
Winooski	E.Allen St	17	6.2	$1,537.63	$30,752.53	$76,881.33	$1,230,101.36	$3,075.25	$18,451.52	1 WETLAND
Winooski	Woolen Mill	17	3.7	$912.65	$18,253.00	$45,632.49	$730,119.81	$1,825.30	$10,951.80	NONE
Winooski	Five Corners	15	6.1	$1,509.19	$30,183.81	$75,459.52	$1,207,352.34	$3,018.38	$18,110.29	NONE
Winooski	Pearl St 2	11	14.7	$3,626.97	$72,539.32	$181,348.30	$2,901,572.74	$7,253.93	$43,523.59	NONE
Winooski	Gazo Ave	19	15.9	$3,930.00	$78,600.00	$176,500.00	$3,144,000.00	$7,860.00	$47,160.00	1 WETLAND
Winooski	Hiawatha Ave	15	24.1	$5,960.69	$119,213.89	$298,034.72	$4,768,555.57	$11,921.39	$71,528.33	WETLDS
Winooski	S.Summit-South St	15	30.3	$7,490.30	$149,806.01	$374,515.01	$5,992,240.23	$14,980.60	$89,883.60	NONE
Winooski	Upper Main St	17	13.1	$3,248.58	$64,971.54	$162,428.84	$2,598,861.40	$6,497.15	$38,982.92	1 WETLAND
Winooski	Barlow St	17	14.8	$3,661.66	$73,233.27	$183,083.19	$2,929,330.96	$7,323.33	$43,939.96	1 WETLAND
Winooski	Hickock St-W.Allen St	17	40.0	$9,881.66	$197,633.20	$494,083.00	$7,905,327.97	$19,763.32	$118,579.92	NONE
Winooski	Mid Main St-E.Spring St	17	51.8	$12,800.55	$256,011.07	$640,027.67	$10,240,442.74	$25,601.11	$153,606.64	1 WETLAND
	Total		605.2							

Table 2. Targeted Stormwater Permits

Recwater	ShedID	Treatment	EIA%	Total Metals	Load (Kg) After <----BMP Reduction----> Pond BMP	Wetland BMP	I-Basin BMP	TP	TP Low	TP High	Load (Kg) After <-----BMP Reduction-----> Pond BMP	Wetland BMP	I-Basin BMP
Burl-Main WW	M8-WWTP Subarea	VS	25	30	10	14	6	50	33	72	27	27	20
Burl-Main WW	M6-WWTP Subarea	VS	31	32	10	14	6	53	35	77	29	29	21
Burl-Main WW	M1-WWTP Subarea	VS	10	9	3	4	2	14	9	21	8	8	6
Burl-Main WW	M2-WWTP Subarea	VS	12	8	2	3	2	13	8	19	7	7	5
Burl-Main WW	M7-WWTP Subarea	VS	6	7	2	3	1	12	8	17	7	7	5
Burl-Main WW	M5-WWTP Subarea	VS	10	13	4	6	3	22	14	31	12	12	9
Burl-Main WW	M3-WWTP Subarea	VS	9	10	3	4	2	16	11	23	9	9	6
Burl-Main WW	M4-WWTP Subarea	VS	9	12	4	6	2	20	13	29	11	11	8
Centennial	UVM School of Medicine	CB/SB/WL	44	8	2	3	2	10	4	17	5	5	4
Englesby	Redstone Campus	DP/CB	35	7	2	3	1	10	4	17	5	5	4
Indian	Laing Farm Shopping Center	CB/SB/WL	55	5	2	2	1	11	6	21	6	6	4
Morehouse	Highland Industrial Park	CB/GS/RS	20	5	1	2	1	6	3	10	3	3	2
Muddy	Blair Park	SB/RR/GS/DP	9	5	2	2	1	7	3	11	4	4	3
Muddy	Tafts Corners Commer. Park 4	GS/SB/CB	11	7	2	3	1	9	4	15	5	5	4
Muddy	Tafts Corners Commer. Park 5	WL/GS/CB	37	14	5	6	3	19	8	32	10	10	7
Muddy	Maple Tree Place 1	DP/GS	19	5	2	2	1	7	3	12	4	4	3
Muddy	Burlington International Airport	CB	74	10	3	5	2	13	6	23	7	7	5
Muddy	Alling Industrial Park 1	CB/IG/SB	32	7	2	3	1	9	4	15	5	5	4
Potash	Oak Ridge-Butler Farm 2	GS	6	10	3	5	2	13	6	23	7	7	5
Potash	University Mall 1	CB/PP/GT/RS	95	25	8	11	5	32	14	55	18	18	13
Potash	University Mall 2	CB/PP/GT/RS	61	9	3	4	2	11	5	19	6	6	5
Potash	Lane Press-New England Telep.	DP/CB	35	9	3	4	2	12	5	21	7	7	5
Potash	Burlington Interntl. Airport 1	CB	54	5	1	2	1	6	3	10	3	3	2
Potash	Burlington Interntl. Airport 2	CB	21	5	1	2	1	6	3	10	3	3	2
Potash	Burlington Interntl. Airport 4	CB/LU	29	13	4	6	3	16	7	28	9	9	7
Winooski	UVM Main Campus	CB/TT	12	6	2	3	1	8	4	14	4	4	3
Winooski	Burlington Inter. Airport-Nort	CB/GS	74	11	3	5	2	14	6	24	8	8	6
Winooski	Air National Guard 2	GS/SB	79	10	3	4	2	12	6	22	7	7	5
Winooski	IBM Corp-Williston	CB	61	24	8	11	5	31	14	54	17	17	13
Winooski	IBM Corp-Essex 1	CB	88	9	3	4	2	11	5	19	6	6	4
Winooski	IBM Corp-Essex 2	CB	74	8	2	3	2	10	5	17	6	6	4
Winooski	IBM Corp-Essex 3	CB	65	7	2	3	1	10	4	17	5	5	4
Winooski	IBM Corp-Essex 4	CB	61	6	2	3	1	8	4	14	5	5	3
	Total Kg/yr			349	112	158	70	501	268	811	275	275	200

Table 2. Targeted Stormwater Permits

Receiving Water	Stormsewer Name	Permit #	TSS	Load (Kg) After <-----BMP Reduction----> Pond BMP	Wetland BMP	I-Basin BMP	Fec.Col. x1000	Load (Kg) After <------BMP Reduction----> Pond BMP	Wetland BMP	I-Basin BMP
Burl-Main WW	M8-WWTP Subarea	3-1247	29853	11941	8956	8956	7336	1467	1467	1467
Burl-Main WW	M6-WWTP Subarea	3-1247	31950	12780	9585	9585	7851	1570	1570	1570
Burl-Main WW	M1-WWTP Subarea	3-1247	8635	3454	2591	2591	2122	424	424	424
Burl-Main WW	M2-WWTP Subarea	3-1247	7688	3075	2306	2306	1889	378	378	378
Burl-Main WW	M7-WWTP Subarea	3-1247	7199	2879	2160	2160	1769	354	354	354
Burl-Main WW	M5-WWTP Subarea	3-1247	12905	5162	3872	3872	3171	634	634	634
Burl-Main WW	M3-WWTP Subarea	3-1247	9634	3854	2890	2890	2367	473	473	473
Burl-Main WW	M4-WWTP Subarea	3-1247	12146	4858	3644	3644	2985	597	597	597
Centennial	UVM School of Medicine	2-1109	6212	2485	1864	1864	994	199	199	199
Englesby	Redstone Campus	1-1055	6144	2458	1843	1843	983	197	197	197
Indian	Laing Farm Shopping Center	1-0775*	5029	2012	1509	1006	6066	1213	1213	1213
Morehouse	Highland Industrial Park	1-0910	3856	1542	1157	1157	617	123	123	123
Muddy	Blair Park	1-0453*	4172	1669	1252	1252	668	134	134	134
Muddy	Tafts Corners Commer. Park 4	1-0511*	5607	2243	1682	1682	897	179	179	179
Muddy	Tafts Corners Commer. Park 5	1-0511*	11899	4759	3570	3570	1904	381	381	381
Muddy	Maple Tree Place 1	1-0764	4366	1746	1310	1310	699	140	140	140
Muddy	Burlington International Airport	1-0839	8501	3400	2550	2550	1360	272	272	272
Muddy	Alling Industrial Park 1	1-0519*	5570	2228	1671	1671	892	178	178	178
Potash	Oak Ridge-Butler Farm 2	1-0464	8384	3354	2515	2515	1342	268	268	268
Potash	University Mall 1	1-0503	20353	8141	6106	6106	3258	652	652	652
Potash	University Mall 2	1-0503	7162	2865	2149	2149	1146	229	229	229
Potash	Lane Press-New England Telep.	1-0618*	7609	3044	2283	2283	1218	244	244	244
Potash	Burlington Interntl. Airport 1	1-0839*	3852	1541	1156	1156	617	123	123	123
Potash	Burlington Interntl. Airport 2	1-0839*	3747	1499	1124	1124	600	120	120	120
Potash	Burlington Interntl. Airport 4	1-0839*	10374	4150	3112	3112	1660	332	332	332
Winooski	UVM Main Campus	1-0973	5037	2015	1511	1511	806	161	161	161
Winooski	Burlington Inter. Airport-Nort	1-0839*	8900	3560	2670	2670	1424	285	285	285
Winooski	Air National Guard 2	2-0805*	7946	3178	2384	2384	1272	254	254	254
Winooski	IBM Corp-Williston	3-1295	19951	7981	5985	5985	3193	639	639	639
Winooski	IBM Corp-Essex 1	3-1295	7121	2849	2136	2136	1140	228	228	228
Winooski	IBM Corp-Essex 2	3-1295	6374	2549	1912	1912	1020	204	204	204
Winooski	IBM Corp-Essex 3	3-1295	6133	2453	1840	1840	982	196	196	196
Winooski	IBM Corp-Essex 4	3-1295	5235	2094	1571	1571	838	168	168	168
	Total Kg/yr		309547	123818	92864	92361				

*Denotes more than 1 permit in drainage

Table 2 . Targeted Stormwater Permits

Receiving Water	Stormsewer Name	Area Hectares	Wetpond Low Cost	Wetpond High Cost	Wetland Low Cost	Wetland High Cost	I-Basin Low Cost	I-Basin High Cost	Instream Treatment
Burl-Main WW	M8-WWTP Subarea	76.2	$18,837.90	$376,758.02	$941,895.04	$15,070,320.62	$37,675.80	$226,054.81	NONE
Burl-Main WW	M6-WWTP Subarea	68.6	$16,955.42	$339,108.48	$847,771.19	$13,564,339.03	$33,910.85	$203,465.09	NONE
Burl-Main WW	M1-WWTP Subarea	43.8	$10,835.10	$216,701.91	$541,754.77	$8,668,076.25	$21,670.19	$130,021.14	NONE
Burl-Main WW	M2-WWTP Subarea	33.3	$8,218.94	$164,378.88	$410,947.19	$6,575,155.06	$16,437.89	$98,627.33	NONE
Burl-Main WW	M7-WWTP Subarea	49.4	$12,199.83	$243,996.57	$609,991.43	$9,759,862.89	$24,399.66	$146,397.94	NONE
Burl-Main WW	M5-WWTP Subarea	64.6	$15,969.26	$319,385.20	$798,463.00	$12,775,408.03	$31,938.52	$191,631.12	NONE
Burl-Main WW	M3-WWTP Subarea	52.3	$12,914.31	$258,286.12	$645,715.30	$10,331,444.73	$25,828.61	$154,971.67	NONE
Burl-Main WW	M4-WWTP Subarea	66.8	$16,505.65	$330,112.95	$825,282.37	$13,204,517.94	$33,011.29	$198,067.77	NONE
Centennial	UVM School of Medicine	6.3	$1,566.69	$31,333.73	$78,334.33	$1,253,349.32	$3,133.37	$18,800.24	2 PONDS/WETLDS
Englesby	Redstone Campus	7.6	$1,868.02	$37,360.38	$93,400.95	$1,494,415.14	$3,736.04	$22,416.23	NONE
Indian	Laing Farm Shopping Center	6.4	$1,575.11	$31,502.20	$78,755.49	$1,260,087.83	$3,150.22	$18,901.32	POND/WETLAND
Morehouse	Highland Industrial Park	7.5	$1,855.14	$37,102.83	$92,757.07	$1,484,113.04	$3,710.28	$22,261.70	NONE
Muddy	Blair Park	14.6	$3,613.81	$72,276.21	$180,690.52	$2,891,048.26	$7,227.62	$43,365.72	WETLDS
Muddy	Tafts Corners Commer. Park 4	17.6	$4,339.38	$86,787.70	$216,969.24	$3,471,507.90	$8,678.77	$52,072.62	NONE
Muddy	Tafts Corners Commer. Park 5	14.1	$3,485.41	$69,708.29	$174,270.73	$2,788,331.75	$6,970.83	$41,824.98	NONE
Muddy	Burlington International Airport	5.4	$1,337.54	$26,750.80	$66,870.00	$1,070,032.00	$2,675.08	$16,050.50	NONE
Muddy	Maple Tree Place 1	9.1	$2,248.99	$44,979.80	$112,449.49	$1,799,191.83	$4,497.98	$26,987.88	NONE
Muddy	Alling Industrial Park 1	7.5	$1,865.12	$37,302.49	$93,256.22	$1,492,099.51	$3,730.25	$22,381.49	1 WETLAND
Potash	Oak Ridge-Butler Farm 2	35.4	$8,735.76	$174,715.22	$436,788.04	$6,988,608.72	$17,471.52	$104,829.13	WETLDS
Potash	University Mall 1	10.2	$2,516.36	$50,327.20	$125,818.01	$2,013,088.12	$5,032.72	$30,196.32	WETLDS
Potash	University Mall 2	5.4	$1,334.34	$26,686.71	$66,716.78	$1,067,468.44	$2,668.67	$16,012.03	WETLDS
Potash	Lane Press-New England Telep.	9.6	$2,364.42	$47,288.46	$118,221.14	$1,891,538.24	$4,728.85	$28,373.07	WETLDS
Potash	Burlington Interntl. Airport 1	3.3	$811.81	$16,236.28	$40,590.70	$649,451.15	$1,623.63	$9,741.77	WETLDS
Potash	Burlington Interntl. Airport 2	7.1	$1,759.31	$35,186.15	$87,965.38	$1,407,446.02	$3,518.62	$21,111.69	WETLDS
Potash	Burlington Interntl. Airport 4	15.3	$3,781.18	$75,623.67	$189,059.18	$3,024,946.80	$7,562.37	$45,374.20	WETLDS
Winooski	UVM Main Campus	14.1	$3,486.86	$69,737.16	$174,342.89	$2,789,486.20	$6,973.72	$41,842.29	1 POND
Winooski	Burlington Inter. Airport-Nort	5.7	$1,399.14	$27,982.73	$69,956.83	$1,119,309.23	$2,798.27	$16,789.64	NONE
Winooski	Air National Guard 2	4.7	$1,173.44	$23,468.76	$58,671.91	$938,750.49	$2,346.88	$14,081.26	NONE
Winooski	IBM Corp-Williston	15.0	$3,710.62	$74,212.48	$185,531.20	$2,968,499.28	$7,421.25	$44,527.49	NONE
Winooski	IBM Corp-Essex 1	3.8	$945.78	$18,915.55	$47,288.87	$756,621.98	$1,891.55	$11,349.33	NONE
Winooski	IBM Corp-Essex 2	4.1	$1,002.56	$20,051.26	$50,128.15	$802,050.42	$2,005.13	$12,030.76	NONE
Winooski	IBM Corp-Essex 3	4.4	$1,086.00	$21,719.99	$54,299.98	$868,799.65	$2,172.00	$13,031.99	NONE
Winooski	IBM Corp-Essex 4	4.0	$983.05	$19,661.00	$49,152.50	$786,440.03	$1,966.10	$11,796.60	NONE
	Total	687.8							

Targeting Areas to Achieve Water Quality Goals

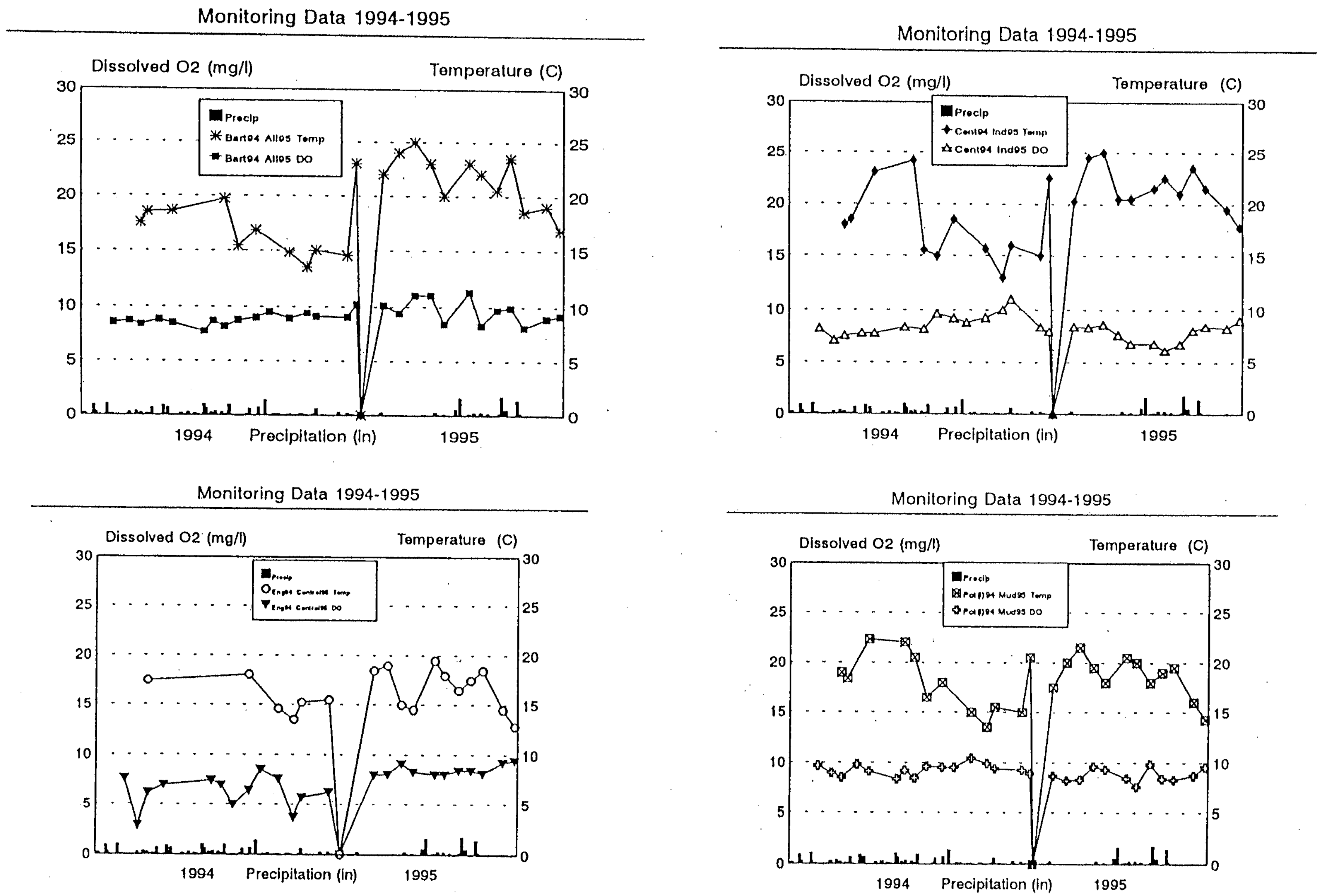
For each watershed, the storm sewers with the highest level of pollutants (TSS/TP/PAH/Metals/Bacti) are listed in **Tables 1 and 2**. Existing treatment structures are identified for each sewershed (see **Appendix 4** for an explanation of the treatment codes used). Except for permitted storm sewers which are in *italics*, a treatment listed for a sewershed does not necessarily mean the entire area is treated by that structure. Because some permitted discharges ranked high in pollutant level (**Table 2**) it is recommended that additional treatment be pursued for these sewersheds. To aid in selection of targets information about natural instream treatment of these discharges is included. The use of natural ponds and wetlands for stormwater treatment does have a detrimental effect on the aquatic ecosystems being used and is not encouraged (Hicks, 1996). Phosphorus areal loadings (kg/hct/yr) for each target are also calculated to aid in determining the most cost efficient sites for phosphorus reduction.

Each stormwater discharge identified in **Table 1** is linked with a map number. Map number refers to site specific maps for each targeted sewer shed. These maps show soil types suitable for infiltration structures (Adams and Duane Series) and wetland/wetpond sites (Covington, Enosburg, Livingston, Munson and Vergennes Series) and the availability of public lands or park lands (hatched) for locating these structures. In most cases specific locations for the potential siting of recommended stormwater treatment BMP'S are identified on these maps (**Appendix 5**).

Evaluations of targeted storm sewers are addressed for each watershed in the stormwater evaluations (Part 2). Because management goals and political boundaries differ between watersheds, a "blanket" management plan for the nine streams is impractical. In addition development built with VTDEC stormwater discharge permits generally requires less additional pollutant control than development built prior to the permit program. The amount of permitted development varies between watersheds with the highest amount in the newly developed subregional growth centers. Expensive structural retrofitting of stormwater controls may be necessary in the "older" watersheds to improve water quality whereas zoning changes and more stringent water quality discharge permits can protect the more recently developed watersheds.

Modification of existing permits (e.g. conversion of dry ponds to wet ponds) might also be explored where existing permits are found to have high pollutant loads. Retrofitting of storm sewers with structural controls may also be required under the proposed EPA Phase 2 stormwater management policy. Stormwater discharges that exceed the minimum conditions of the state stormwater statutes but preexist the statute exist in large numbers in some municipalities (Winooski, S. Burlington and Essex Junction).

Because phosphorus, metals, polyaromatic hydrocarbons and bacteria bind to suspended sediment particles, an overall discharge limit on total suspended solids has been recommended (USEPA, 1990) as the most practical way of controlling nonpoint stormwater discharges in urban areas. Targeting storm sewers for TSS controls and for bacteria should take into account distance to the watercourse as sediment will settle and form deposits and most pathogenic bacteria tend to die off rapidly at ambient temperature (Maas, 1985). Streams or sewersheds discharging directly to water bodies or highly connected through stormwater drains should be targeted first over those more distantly located or less directly connected (Griffin, 1993, Maas, 1985). Other factors important in targeting sites for structural BMP's are site soils, infiltration rate (based on soil type), slope, land use, zoning, and depth to bedrock. This report does not attempt to address all these concerns but does provide guidance for BMP site selection.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Dissolved O2 (mg/l)
Temperature (C)
Precip
Bart94 All95 Temp
Bart94 All95 DO
1994
Precipitation (in)
1995
Monitoring Data 1994-1995
Dissolved O2 (mg/l)
Temperature (C)
Precip
Cent94 Ind95 Temp
Cent94 Ind95 DO
1994
Precipitation (in)
1995
Monitoring Data 1994-1995
Dissolved O2 (mg/l)
Temperature (C)
1994
Precipitation (in)
1995
Monitoring Data 1994-1995
Dissolved O2 (mg/l)
Temperature (C)
Precip
1994
Precipitation (in)
1995

Figure 6.1

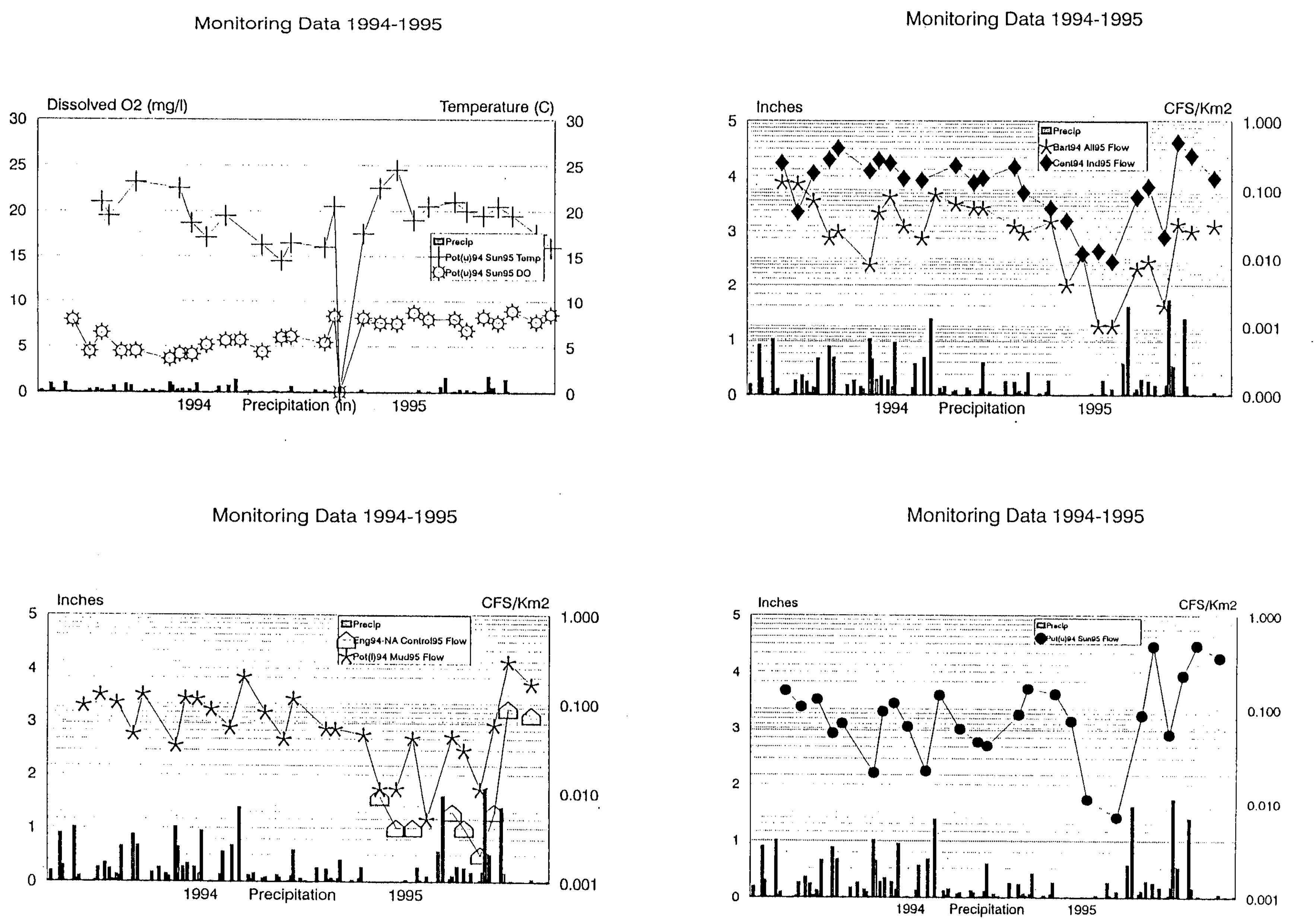

Monitoring Data 1994-1995
Dissolved O2 (mg/l)
Temperature (C)
Precip
Pot(u)94 Sun95 Temp
Pot(u)94 Sun95 DO
1994
Precipitation (in)
1995
Monitoring Data 1994-1995
Inches
CFS/Km2
Precip
Bart94 All95 Flow
Cent94 Ind95 Flow
1994
Precipitation
1995
Monitoring Data 1994-1995
Inches
CFS/Km2
Precip
Eng94-NA Control95 Flow
Pot(l)94 Mud95 Flow
1994
Precipitation
1995
Monitoring Data 1994-1995
Inches
CFS/Km2
Precip
Pot(u)94 Sun95 Flow
1994
Precipitation
1995

Figure 6.2

Appendix 2 lists all significant storm sewers discharging to the Burlington Barge Canal, Burlington Main WWTP, Gilbrook Reservoir, Lake Champlain, LaPlatte River, Munroe Brook, and the Winooski River and which are not located in the study watersheds (**Figures 8.1-2**). Pollutant loadings and maps are also provided or each of these sewersheds (**Table 1, 2; Appendix 5**). It is beyond the scope of this project to develop site-specific BMP recommendations for all of these sewersheds. However, because of their potential significance as pollution sources to Lake Champlain and for developing an overall phosphorus reduction strategy, it is recommended that more detailed evaluations of these sites be incorporated into future work plans. Included in this list of targeted sewersheds are the **highest** modeled pollutant loadings of all the sewersheds evaluated in the course of this project. The total estimated annual loading of TP and TSS from these nonstudy sewersheds is 708 kg/yr and 304,918 kg/yr respectively. In addition, these sewersheds discharge an estimated total of 3072 kg PAH's and 383 kg total metals on an annual basis to Lake Champlain.

Stormwater Management Policy Considerations

Stormwater management policy should consider the following points in terms of stormwater management in urbanizing areas:

(1) Stormwater runoff regulations should be applied more strictly in Vermont's urban/suburban areas than in less densely developed areas. Degradation of water quality from nonpoint source pollution is usually not great unless multiple sites exist in a watershed. Larger cities and towns with highly developed watersheds and large amounts of impervious surface require intensive stormwater controls for water quantity and water quality management. This study encompassed eight municipalities with a total population of 108,112 people. National Pollutant Discharge Elimination System (NPDES) stormwater permits, issued under EPA's Phase 2 stormwater guidance, could be required in order to prevent further urban sprawl from increasing an already high level of urban nonpoint source pollution to Lake Champlain. If a permit system were implemented, a logical first step would be to utilize the NPDES "watershed" approach (USEPA, 1997) for watersheds (Potash, Bartlett, and Englesby Brooks) directly impacting drinking water source protection areas (Outer Burlington Harbor, Shelburne Bay).

(2) Municipalities will eventually need to institute a stormwater utility or a stormwater management plan (Burlington has considered a utility, S. Burlington has instituted the Bartlett Brook Stormwater Overlay District). A utility would provide important financial resources for siting, construction and maintenance of stormwater BMP's.

(3) Research by the EPA has shown that land uses involved with petroleum distribution, vehicle maintenance, vehicle parking and commercial quick services (quick marts, convenience stores, etc.) all have high levels of metals and hydrocarbons in their surface water runoff. Fuel service areas and convenience stores can be exceptionally high sources of these pollutants. The recommended BMP for these developments is a site specific sand filter, vortex separator or multi-chamber type treatment device. Current research favors the sand filter as the most effective BMP for these pollutants (Schueler, 1994).

(4) Detention basins should be designed to handle multiple storm types. With two or three outlets located in a stormwater detention basin smaller design storms can be handled for water quality purposes. The loss in flood control effectiveness is relatively small (Whipple, 1983). Research has shown that a 36 hour detention time will remove 60% of the total suspended solids. The presence of a wet pool within the detention basin will have the greatest pollutant trap efficiency of all stormwater controls.

(5) Stormwater management policy should encourage the "open stream concept" (Tourbier, 1994). As municipalities grow, new development should maintain open streams which favor wildlife and water quality rather than more expensive traditional curb-catch basin-pipe systems. This encourages good aesthetic values, stormwater reuse, open space planning, recreation and higher property values. Incorporation of stormwater controls into a green space or landscaping design of a development is preferable to last minute designs by consultants to meet permit conditions.

(6) Stormwater structures should not be placed in the 100-year flood plain.

(7) Maintenance requirements should be enforced at least once every three years. Research has shown that facilities that are not maintained or monitored are likely to become ineffective over time (Lindsey, 1992).

All of these recommendations particularly apply to the designated subregional growth centers of Taft Corners, the Butler Corners-Laing Farm region of Essex, Shelburne Road in Shelburne and South Burlington, Colchester Avenue from Winooski to Essex Junction and from Exit 16 north to Malletts Bay.

Phosphorus Loading from Urban Runoff

Phosphorus loading to Lake Champlain from urban/developed lands has been addressed in part by several previous studies. Three studies of Shelburne Bay estimated loadings for the Potash Brook watershed based on flow and phosphorus monitoring data (Little, 1976; Henson and Gruendling, 1977; Smeltzer, 1988). Little estimated the annual load to be 510 kg/yr, Henson and Gruendling estimated the load to be 743 kg/yr.

A predictive relationship between phosphorus loading and percent watershed imperviousness was developed by the New York Department of Environmental Conservation at Lake George, NY as part of the National Urban Runoff Project (Sutherland, 1983). Using the NYDEC method, and the current level of watershed imperviousness the predicted phosphorus load for all nine streams is 1771.3 kg/yr (1.7 metric tons/yr). The predicted stormwater contribution from this study for the same nine streams is 1246.6 kg/yr with a range of 564-2150 kg/yr (.6-2.1 metric tons/yr). Using the NYDEC equation, an overall increase in impervious surface of 20% in all watersheds results in a 110% increase in phosphorus load **(Table 5)**.

The total estimated phosphorus load to all surface waters by this study for all 563 storm sewers is 2469 kg/yr (2.47 metric tons/yr). Using the low and high event mean phosphorus concentrations yields a range of 1.12-4.05 metric tons/yr. Budd and Meals (Budd and Meals, 1994) reported an estimate of the phosphorus contribution from the greater Burlington - Muddy Brook - Malletts Bay - Lower Winooski (estimated) NRCS hydrologic unit areas as 13.8 metric tons/yr. The total acreage of these hydrologic units is approximately 592 km^2. This study estimated phosphorus loading from storm sewersheds with a total area of 27 km^2. These two analyses differ because only a small fraction of the total urban land use area is serviced by storm sewer systems, approximately 5%. The estimated phosphorus concentration per km^2 for the 563 storm sewersheds of this study is more than 3x as high as the estimated phosphorus concentration per km^2 for urban land found by Budd and Meals. Budd and Meals viewed all land use classified as urban as functionally equivalent. However the stormwater drainage networks concentrate and direct pollutants and realistically offer the best locations for effective structural and nonstructural pollutant controls.

Upgrades in urban area sewage treatment efficiency, for phosphorus removal, has increasingly shifted the phosphorus source load from point to nonpoint sources. In Shelburne Bay, in 1976, the estimated phosphorus contribution from nonpoint sources was 40% of the total load (Little, 1976); in

1988 this estimate was revised to 78% (Smeltzer, 1988). In the Burlington-Main WWTP subareas (a combined storm and sanitary system) stormwater treatment by vortex separation removes most sediment, as well as metals and PAH's attached to the sediment. Bacteria is also removed but total phosphorus is not significantly reduced (Roy, personal communication).

Nonstructural nonpoint source controls in addition to structural controls recommended by this report could address phosphorus runoff from all developed lands in the greater Burlington area. Examples of controls are riparian buffer zoning, information/education campaigns for low input residential and commercial lawns, increased street sweeping practices, and a ban on quick-release lawn and garden fertilizer.

Table 5: Comparative phosphorus loading estimates: using the Lake George watershed imperviousness model (Sutherland, 1983) and the Simple Method used by this project.

			▸-----Lake George Method		---------Simple Method-◂		
Stream	Water Shed km^2	ISA%	kg/p/yr	+10% ISA kg/p/yr	+20% ISA kg/p/yr	Storms kg/p/yr (low)	Storms kg/p/yr (high)
Allen	29.33	5.5	250.2	546.1	620.7	30.1	114.7
Bartlett	3.79	16.9	72.5	88.8	99.5	44.6	170.1
Centennial	3.7	25.1	84.8	95.8	104	54.3	206.9
Englesby	2.2	19.9	46	53.8	59.3	38.4	146.1
Indian	30.59	6.3	330.9	585.4	713.9	38.1	144.9
Morehouse	1.36	13.6	23.2	30.2	34.6	21.2	80.8
Muddy	54.19	3.9	216	942.8	1213	71.2	271.2
Potash	19.27	17.7	372.4	454.6	508.6	190.3	724.7
Sunderland	13.62	11.4	217.3	293	339	76.3	290.7
Total	158.05	-------	1771.3	3090.5	3692.6	564.5	2150

Stormwater and Public Swimming Areas

Public beach closures due to high Fecal Coliform counts (>200 col/100 ml) is a recurrent problem at public beaches in the Burlington area. Completion of the Burlington Main WWTP upgrade in 1994 appeared to solve the problem in Burlington harbor only to be followed in 1995 by the largest number of beach closures in the last 10 years (**Figure 7**). Monitoring data for Potash Brook over the last 23 years (see Part 2, Potash Brook Stormwater Management Evaluation) clearly exhibits a cause and effect relationship between rainfall and bacteria counts. In Englesby Brook surface water runoff has been found to have bacteria counts as high as 11,000 col/100 ml (Clapp, 1995). Monitoring data collected for the City of S. Burlington suggests that beaver can be a source of Fecal coliform, Fecal streptococci, Giardia and Cryptosporidium (Nelson, 1990). Although beaver have been identified as a source of bacteria their presence near public beaches has only been documented in Potash Brook, the

Burlington Barge Canal and the north drainage of North Beach. The beaver were removed in the lower Potash Brook watershed in 1994. Removal of the animals in Potash Brook apparently did not solve the problem as beach closures continued to occur in 1995.

Summer seasons characterized by low rainfall (<10") result in more beach closures than wet (>10") summers **(Figure 7)**. Prolonged dry spells allow time for pollutant buildup on impervious surfaces (Cassell, 1994). These high bacti levels in conjunction with the short time of concentration from the impervious surface to the beach result in more frequent closures. In wet summers the frequency of smaller storm events (.2-1") is greater **(Figure 7)** and therefore a more frequent rinsing of impervious surfaces occurs and pollutant buildup is prevented. All of the beach watersheds behave similarly in this regard; immediately upstream of each are large blocks of impervious surface.

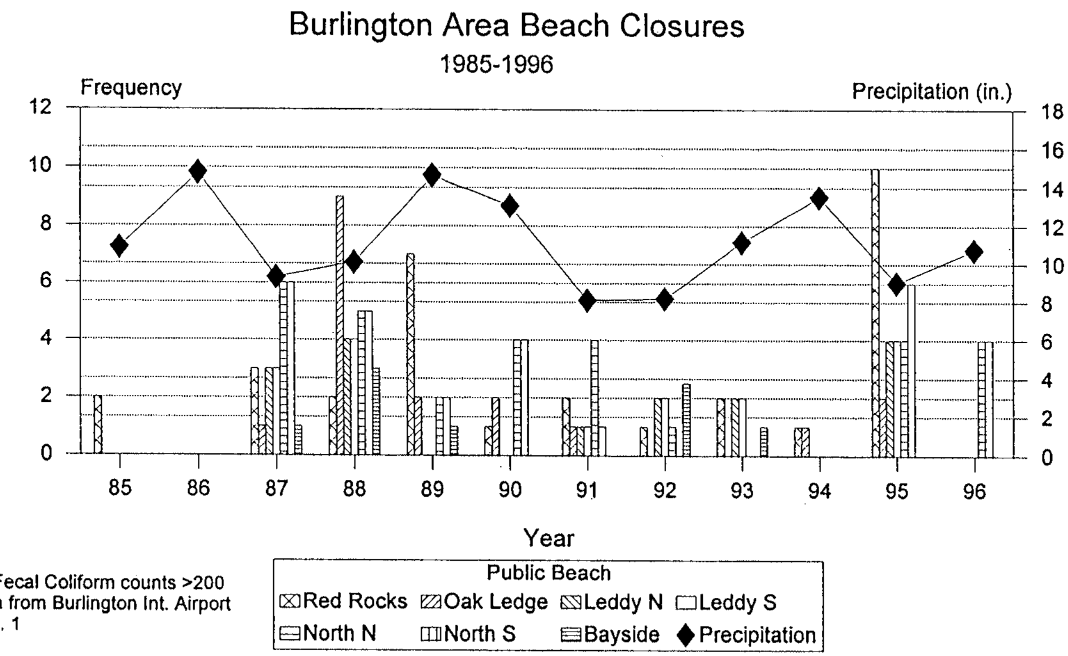
The watershed of Potash Brook is much larger than most of the other beach drainages and as a result responds to large precipitation events somewhat differently. In wet seasons large storms (>1.5") can cause a flushing of an entire watershed and a subsequent release of bacteria, as less of the runoff is retained, as occurred in the Potash Brook watershed in 1989. In water saturated soils bacteria as well as other pollutants can move into the stream by saturation overland flow (Kunkle, 1970) from areas such as the large wetlands and beaver ponds located in the brook's upper watershed.

Because of their proximity to public bathing beaches or public water supplies, a number of sewersheds were targeted specifically for bacteria reduction **(Appendix 3, Figure 8.3)**. Although significant progress has been made in the cleanup of combined sewer overflows in the greater Burlington area, bacterial contamination problems persist. Malletts Bay is currently suffering from chronic septic tank leakage to the bay as well as increasing urban runoff from new development. The siting of stormwater discharge pipes near swimming areas has led to numerous public and private beach closures. A greater risk of illness is associated with swimming near (0-100 yds) flowing storm drains (Haile, 1995). Many private homes, private beaches and several public beaches bordering Shelburne Bay, Burlington Harbor, Appletree Bay and Malletts Bay are exposed to this increased risk due to untreated stormwater discharges. A strategy for bacteria reduction for Oakledge-Blanchard and Redrocks Public Beaches is part of the overall TSS reduction strategy for Englesby and Potash Brooks respectively. The reduction strategy for North Beach targets the Burlington High School storm sewer (map 18). The reduction strategy for Leddy Beach targets the Upper Shore Rd. 1 storm sewer (map 14) and the Birchwood Parkway storm sewer.

Toxins in Stormwater

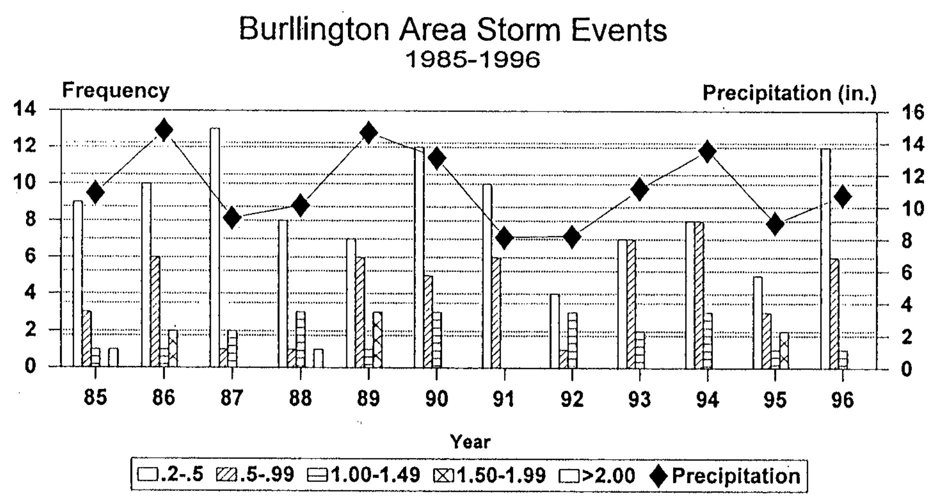
A diversity of metals, hydrocarbons and pesticides have been found in runoff in the greater Burlington area. Control of toxins in urban runoff has been advocated as part of a lake wide toxic reduction strategy (McIntosh, Watzin and Brown, 1997). A strategy to reduce, where possible, the public's dependence on toxic chemicals, has been in practice for several years in Burlington (Eisenman, 1994). Two toxic hot spots discovered during the first half of the Urban Runoff Characterization Study (Quackenbush, 1995) were investigated in this study. The toxins were silver in Englesby Brook and polyaromatic hydrocarbons in Bartlett Brook.

Silver was traced back from the mouth in a series of sediment samples with increasing concentrations to the Shelburne Road-Outlet Mall storm drain. Sediment concentrations ranged from 4.72 mg/kg at the mouth to 35.0 mg/kg at a depositional area below the outfall pipe. A series of samples in the storm and sewer lines isolated a catch basin in the Sherwin Williams Shopping Center at 370 Shelburne Road. Further sampling in the storm drain system of the shopping center revealed a sediment concentration of 333 mg/kg in one catch basin. A photo laboratory in the shopping center permitted an analysis of its treated film processing machine effluent. The liquid effluent had a silver



Frequency Fecal Coliform counts >200
Rainfall data from Burlington Int. Airport
June 1-Sept. 1

Year	%Closed	Sampling Effort
1985	1%	2/175
1986	0%	0/188
1987	12%	23/189
1988	16%	32/200
1989	7%	4/201
1990	5%	11/203
1991	3%	7/188
1992	3%	5/188
1993	3%	6/190
1994	1%	2/145
1995	20%	30/148



Rainfall data from Burlington Int. Airport
June 1-Sept.1

Figure 7

concentration of $>100\ \mu g/l$. At this time it is believed that the developer of the shopping center connected several floor drains of the building including the photo laboratory to the municipal storm system rather than the sewer system. Dye tests have been inconclusive. The shopping center was previously found to be discharging sewage to Englesby Brook through another illicit connection that has since been corrected.

The Bartlett Brook PAH sediment levels found ranged from $997\mu g/kg$ at the mouth of the middle fork to 6812 $\mu g/kg$ in a runoff ditch from Shelburne Road. The north fork had a level of 2280 $\mu g/kg$ at the mouth and increased to 8894 $\mu g/kg$ and 12249 $\mu g/kg$ at two stormwater outfalls. This stream receives a large amount of stormwater from the Shelburne Road 1,2 storm sewers. The south fork which receives some runoff from Shelburne Road had a level at the storm drain outfall of 388 $\mu g/kg$ in the sediment. Sediment samples collected in two adjacent smaller drainages highly impaired by Shelburne Road runoff had levels of 1043 and 1774 $\mu g/kg$ at the stream mouths. It is believed that Shelburne Road with its concentration of auto dealerships, service stations, traffic and other commercial development is a significant source of PAH loading to Bartlett Brook. The high levels in the middle and north forks are probably derived from the large auto dealerships immediately adjacent to the stream which do not have stormwater controls, and from Shelburne Road runoff.

The storm drain system on Shelburne Road will be reconstructed in 1999 and the opportunity to provide water quality controls to remediate these urban runoff problems exist. This opportunity to protect Bartlett Brook, Shelburne Bay and the Champlain Water District public water supply should not be missed.

Watershed Protection

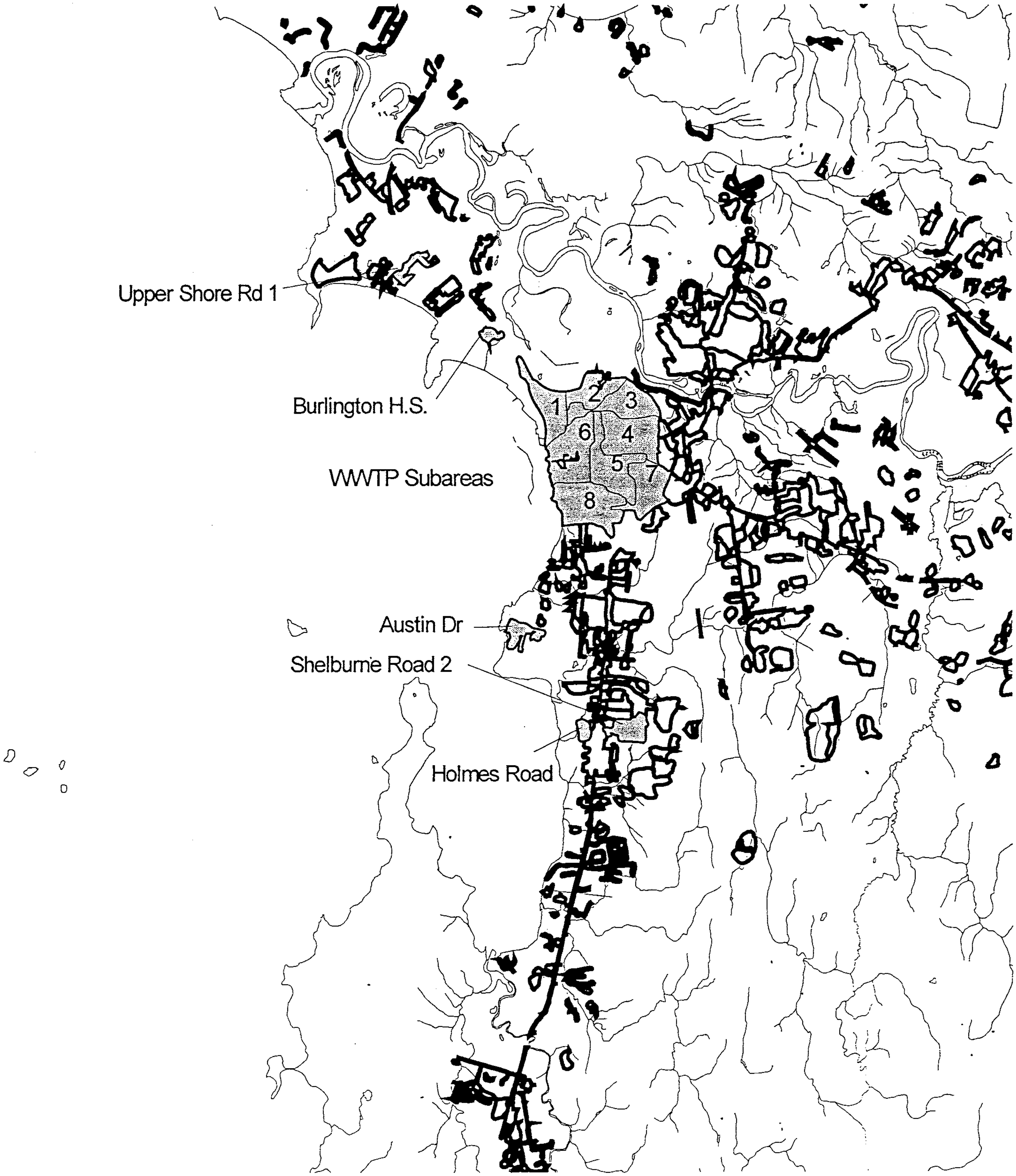
Only two of the watersheds in this study currently have adequate zoning to provide a minimum level of water quality protection **(Figure 9)**. Minimum protection is defined as a 50-100' buffer zone on either side of the stream.

In the rapidly developing areas of the Chesapeake Bay watershed these buffer zones are called Stream Valley Parks. These parks provide flood protection, wildlife habitat and recreation uses as well as water quality protection. By the very nature of the greater Burlington sand plain topography many of the study watersheds have protection; the dissected drainage pattern and steep slopes preclude development. However as land values rise development will spread into these open lands. As the buffer is lost runoff velocities and volumes will become greater and artificial hardening of the stream channel will become necessary as is occurring in Englesby and Bartlett Brooks. With channel hardening biological integrity of the stream is lost and the stream becomes a conduit for wastewater and an open nonpoint sewer.

Buffer protection provides an economical and effective way to clean water by allowing nature to clean the water itself. Buffers can be created by zoning, through land acquisition for parks, or by managing existing public rights-of-way. The Winooski Valley Park District has buffer lands along the Winooski and should be encouraged to expand into the Lower Winooski tributaries and other waterways of Chittenden County. Buffer zones do not guarantee clean water but provide a minimum level of water quality protection.

New development with stricter water quality permits and retrofitting of some older developments (the least cost effective water quality control) will have to occur in order to maintain Class B water quality standards in these streams.

Figure 8.1: Targeted Storm Sewers-
Lake Champlain Direct



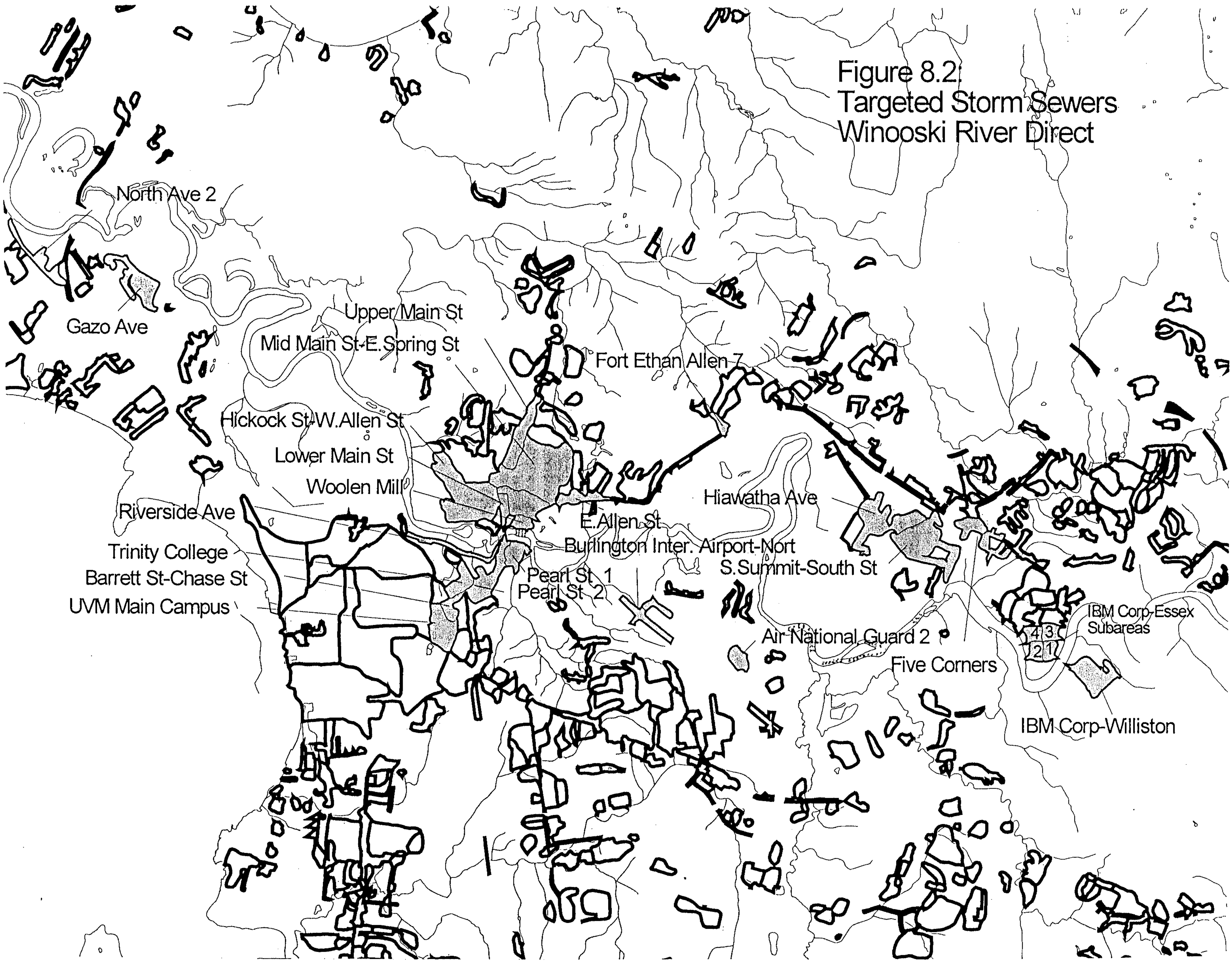
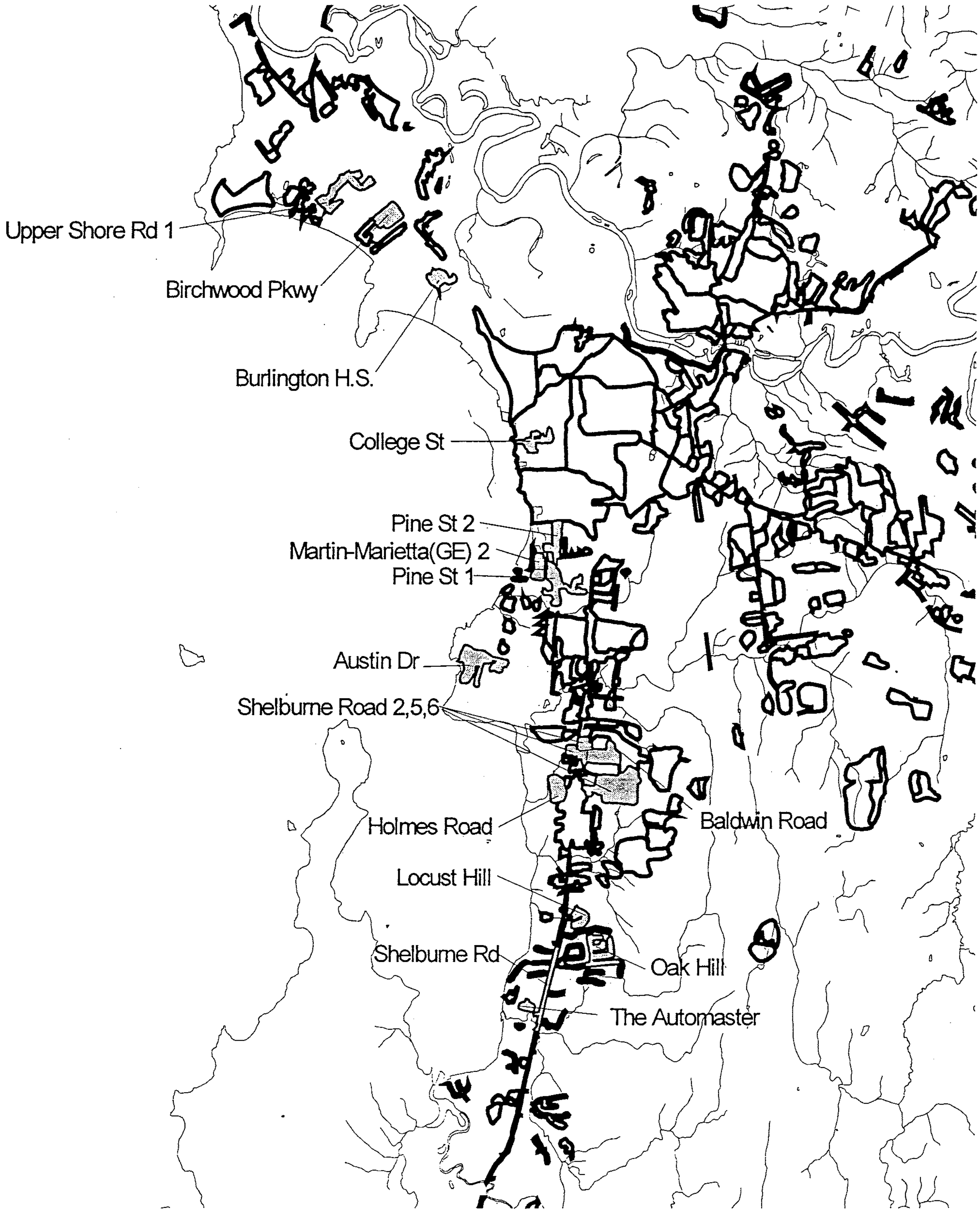


Figure 8.2:
Targeted Storm Sewers
Winooski River Direct
North Ave 2
Gazo Ave
Upper Main St
Mid Main St-E.Spring St
Fort Ethan Allen 7
Hickock St-W.Allen St
Lower Main St
Woolen Mill
Riverside Ave
Hiawatha Ave
E.Allen St
Trinity College
Burlington Inter. Airport-Nort
Barrett St-Chase St
S.Summit-South St
Pearl St 1
Pearl St 2
UVM Main Campus
IBM Corp-Essex
Subareas
4 3
2 1
Air National Guard 2
Five Corners
IBM Corp-Williston

Figure 8.3: Targeted Storm Sewers-Bacteria Reduction



Current Watershed Protection Status

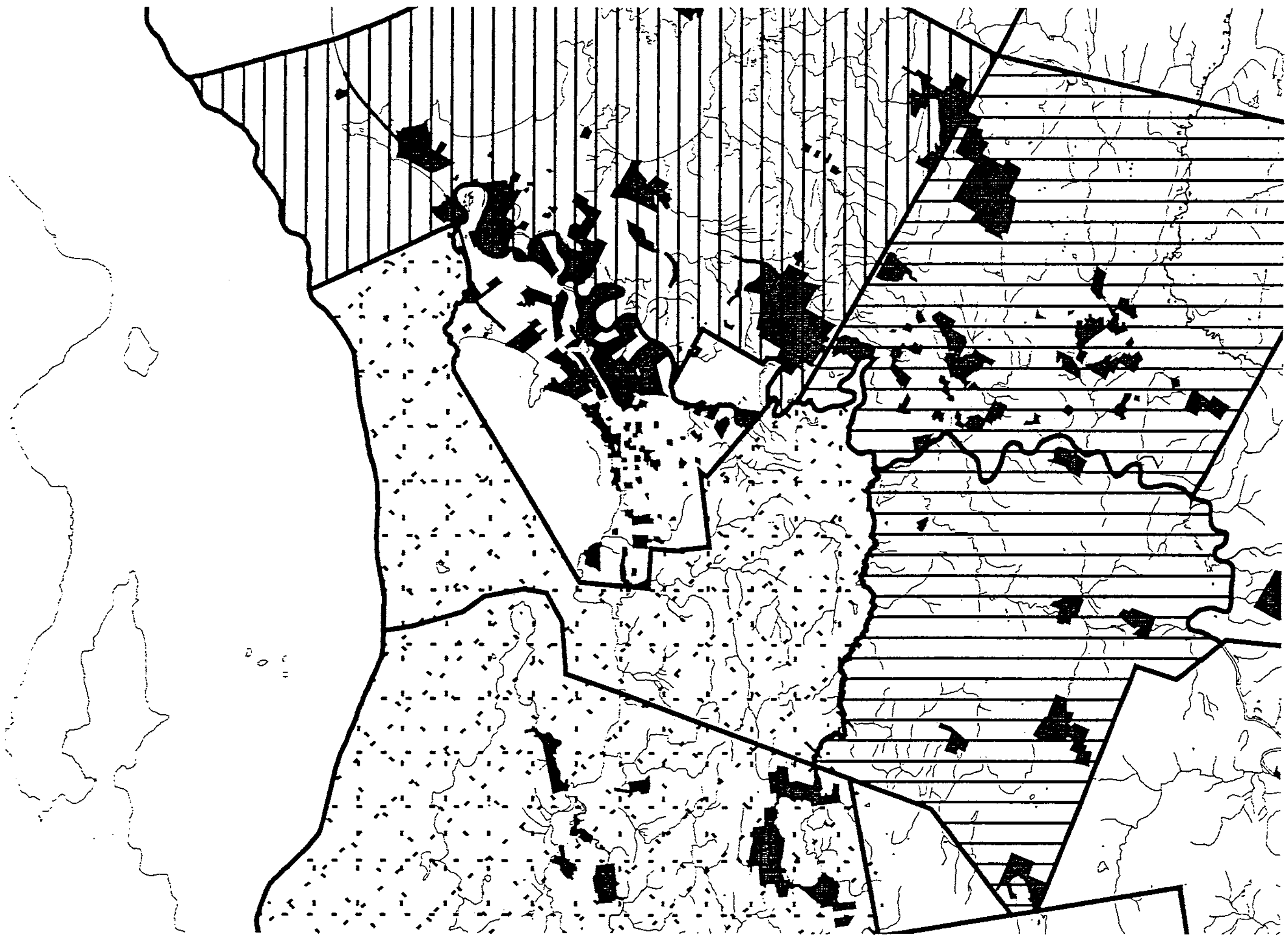


Figure 9

Streams/Rivers
Burlington
Colchester
Essex
Shelburne
S. Burlington
Williston
Winooski
Public Lands
Towns

Burlington - no water quality zoning
Colchester - floodplain zoning
Essex - incomplete water quality zoning
Shelburne - water quality zoning
S. Burlington - water quality zoning
Williston - incomplete water quality zoning
Winooski - no water quality zoning

Significant Findings:

1. Virtually all of the watersheds evaluated by this project are impaired and do not fully support the designated values and uses of the Vermont Water Quality Standards.

2. Biological and aquatic habitat impairment is significant in all watersheds evaluated.

3. Many of the stream channels have been altered by high stream flow volumes and velocities as evidenced by increased channel cross-sectional area/drainage area ratios. Such alterations impair aquatic habitat and streambank stability.

4. Aquatic habitat impairment due to sedimentation is evident in many of the project streams. It is likely that much of the biological impairment observed is a result of habitat degradation caused by excessive sedimentation, erosion and high velocity flows.

5. Many of the streams evaluated support high quality riparian habitat throughout much of their length.

6. Impervious surface area in the project watersheds ranges from 3.5 percent in Muddy Brook to 25 percent in Centennial Brook.

7. Full implementation of the recommendations of this project (**Table 1, Table 2**) could result in a conservative annual reduction of pollutants discharged to the project watersheds of: Total Suspended Solids - 540,000 kg/yr (54 metric tons); Total Phosphorus - 644 kg/yr; Total Metals - 640 kg/yr.

8. Annualized (30 yr/5%) capital costs for reductions in annual phosphorus and sediment loading range from $12 - $1705/kg phosphorus and $0.02 - $1.88/kg total suspended solids.

9. The eighteen highest non WWTP stormwater discharges are estimated to contribute a total of 527 kg of phosphorus per year. Implementation of BMP'S at these sites could reduce phosphorus loading by 120 - 455 kg/year. These values should be considered as the minimum discharge loads presently occurring.

10. An individual or institution responsible for coordinating activities and resources related to watershed planning and implementation issues is critical to efficient watershed management in multi-jurisdictional settings.

Recommendations:

The following recommendations, derived from the findings of this project, are made as technical suggestions that, if implemented, have a high likelihood of positively influencing water quality goals for the study watersheds. They are not intended to replace the development of fully comprehensive watershed management plans.

1. The most significant recommendation that can be made here is for the establishment of a watershed planning process that will be able to incorporate the findings of this evaluation into comprehensive watershed management plans. Such a plan would institutionalize stormwater and watershed management policies across political boundaries. Such a plan would also necessarily address the implementation issues such as prioritization and financing (Schueler, 1996).

2. Watershed Restoration - Aquatic biota and habitat are impaired in all of the study watersheds. It is likely that measures to minimize the release of sediments and suspended solids will result in improved habitat and biological integrity. Therefore:

- Additional feasibility studies for BMP implementation recommendations for targeted sewersheds, prioritized by estimated Total Suspended Solids loading, should be initiated.

- Efforts to reduce discharges from significant sources of nonpoint sediment, such as eroding or unstable banks identified by this or other evaluations, should be pursued. Opportunities to implement stream and riparian habitat restoration and improvement activities should be fully explored. Programs such as the Youth Conservation Corps, the USFWS Partnership program, and citizen watershed groups are likely resources for implementing watershed restoration activities. Cooperative efforts between landowners and various State, private, and Federal agencies should be encouraged and coordinated.

3. Coordination - Resources should be allocated to provide for coordination of activities, including the acquisition of implementation resources, related to urban watershed management. VTDEC and USEPA are currently funding a limited service position to provide this function. If multi-jurisdictional urban watershed management is to be effective in the future, this function must be maintained, ideally through institutionalized regional planning.

4. Monitoring - Continued monitoring of watershed conditions should be conducted in all of the study watersheds. BMP implementation effectiveness should be monitored. While VTDEC plans to maintain a minimal level of biological monitoring at many of the sites previously monitored, its resources are limited. Monitoring issues should be developed through the watershed planning process that should evolve at the regional or local level (Brown, 1996).

5. Education - A watershed management educational strategy should be developed and implemented for the project area watersheds. Generalized materials related to watershed protection are available from various private and governmental organizations. The educational strategy should, among other things, address the means by which residents of the watershed will be exposed to the appropriate educational materials and information (Fisher, 1992; Drinkwin, 1995).

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Appendix 1
Flow Weighted Mean Concentrations
Used to Calculate Pollutant Loadings

Parameter	Concentration	Units	Reference
Arsenic	0.0044	mg/l	Olsenholler,1991
Benzo-alpha-pyrene*	0.61	mg/l	Olsenholler,1991
Chrysene*	0.77	mg/l	Olsenholler,1991
Copper	0.056	mg/l	USEPA,1983
Fecal Coliform	26500	col/100ml	USEPA,1983
Fluoranthene*	1.4	mg/l	Olsenholler,1991
Lead	0.0145	mg/l	Schueler,1987
Mercury	0.0002	mg/l	Olsenholler,1991
Pyrene*	1.13	mg/l	Olsenholler,1991
Total Kjedahl Nitrogen	1.5	mg/l	Schueler,1987
Total Phosphorus	0.574	mg/l	USEPA,1983
Total Phosphorus (high)	0.99	mg/l	USEPA,1983
Total Phosphorus (low)	0.26	mg/l	Schueler,1987
Total Suspended Solids	365	mg/l	USEPA,1983
Zinc	0.1782	mg/l	USEPA,1983

*Polyaromatic hydrocarbons calculated only for commercial and transportation land uses.

Appendix 2. Significant Stormwater Discharges in Non-Study Watersheds (including Burlington Barge Canal, Burlington Main WWTP, Gilbrook Reservoir, Lake Champlain, LaPlatte River, Munroe Brook and the Winooski River): Discharges are targeted based on estimated exceedence of annual loading thresholds for: suspended solids (4,536 kg/year); total phosphorus (6.8 kg/year); total metals (5.4 kg/year); total PAHs (36 kg/year); fecal coliform (500,000 colonies/yr). Existing treatment structures are indicated. *Italics indicate stormwater discharges with VTDEC permits.* EIA% is the percent surface area as effective impervious surface area. Loadings are calculated from the means of ranges in export coefficients taken from the literature.

Recwater	**Storm sewershed**	**Treatment (Appendix 4)**	**EIA%**	**Loading kg/yr**
		Highest Total Suspended Solids		
Barge Canal	Pine St 1	CB	32.7	5384
Gilbrook	St. Micheals College	CB/SB/DW	16.6	6630
Gilbrook	Lapointe Ave	CB	37.2	5239
Gilbrook	Roger St	CB	41.7	5072
Lake Champ	Shelburne Road 2	CB	14.6	8826
Lake Champ	Austin Dr	CB	12.8	5117
Lake Champ	Holmes Road	CB/SB	35.1	4981
Lake Champ	Burlington H.S.	CB	40.8	4756
Lake Champ	Upper Shore Rd. 1	CB	20.0	4567
Winooski	Mid Main St-E.Spring St	CB	31.3	37881
Winooski	Hickock St-W.Allen St	CB	34.7	31908
Winooski	*IBM Corp-Williston*	*CB*	61.5	19951
Winooski	Barlow St	CB/GS	45.7	15062
Winooski	Upper Main St	CB	50.9	14713
Winooski	S.Summit-South St	CB	18.6	14541
Winooski	Hiawatha Ave	CB	24.5	14355
Winooski	*Burlington Inter. Airport-Nort*	*CB/GS*	73.7	8900
Winooski	Gazo Ave	CB	21.9	8662
Winooski	Pearl St 2	CB	23.4	8414
Winooski	*Air National Guard 2*	*GS/SB*	78.9	7946
Winooski	Five Corners	CB	59.9	7927
Winooski	Woolen Mill	CB	93.9	7281
Winooski	*IBM Corp-Essex 1*	*CB*	88.3	7121
Winooski	E.Allen St	CB	52.1	7106
Winooski	*IBM Corp-Essex 2*	*CB*	73.7	6374
Winooski	*IBM Corp-Essex 3*	CB	64.8	6133
Winooski	Lower Main St	CB	73.6	5553
Winooski	*IBM Corp-Essex 4*	CB	60.8	5235
Winooski	*UVM Main Campus*	CB/TT	12.5	5037
Winooski	Barrett St-Chase St	CB	27.8	4803
Winooski	Trinity College	CB	25.4	4770
Winooski	Riverside Ave	CB	47.9	4713

Appendix 2. (cont)

Recwater	**Storm sewershed**	**Treatment (Appendix 4)**	**EIA%**	**TP kg/yr**	**Loading kg/hct/yr**
		Highest Total Phosphorus			
Barge Canal	Pine St 1			9	1.19
Burl-Main	*WWM6-WWTP Subarea*	*VS*	30.5	53	1.12
Burl-Main	*WWM8-WWTP Subarea*	*VS*	24.8	50	0.94
Burl-Main	*WWM5-WWTP Subarea*	*VS*	9.9	22	0.48
Burl-Main	*WWM4-WWTP Subarea*	*VS*	8.5	20	0.44
Burl-Main	*WWM3-WWTP Subarea*	*VS*	8.7	16	0.44
Burl-Main	*WWM1-WWTP Subarea*	*VS*	9.7	14	0.47
Burl-Main	*WWM2-WWTP Subarea*	*VS*	12.3	13	0.56
Burl-Main	*WWM7-WWTP Subarea*	*VS*	5.7	12	0.35
Gilbrook	St. Micheal's College			10	0.69
Gilbrook	Lapointe Ave			8	1.33
Gilbrook	Roger St			8	1.47
Lake Champ	Shelburne Road 2			14	2.30
Lake Champ	Austin Dr			8	0.57
Lake Champ	Holmes Road			8	1.26
Lake Champ	Burlington H.S.			7	1.44
Lake Champ	Upper Shore Rd. 1			7	0.80
Lake Champ	College St	CB	38.1	7	1.36
Lake Champ	Shelburne Road 5	CB	58.8	7	1.95
Lake Champ	Shelburne Road 6	CB	74.8	7	3.14
Winooski	Mid Main St-E.Spring St			60	1.15
Winooski	Hickock St-W.Allen St			50	1.25
Winooski	*IBM Corp-Williston*			31	2.09
Winooski	Barlow St			24	1.60
Winooski	Upper Main St			23	1.76
Winooski	S.Summit-South St			23	0.75
Winooski	Hiawatha Ave			23	0.93
Winooski	*Burlington Inter. Airport-North*			14	1.86
Winooski	Gazo Ave			14	0.86
Winooski	Pearl St 2			13	0.90
Winooski	*Air National Guard 2*			12	2.63
Winooski	Five Corners			12	2.04
Winooski	Woolen Mill			11	1.80
Winooski	*IBM Corp-Essex 1*			11	2.92
Winooski	E.Allen St			11	1.79
Winooski	*IBM Corp-Essex 2*			10	2.47
Winooski	*IBM Corp-Essex 3*			10	2.19
Winooski	Lower Main St			9	2.47
Winooski	Barrett St-Chase St			9	1.04
Winooski	*IBM Corp-Essex 4*			8	2.07
Winooski	*UVM Main Campus*			8	0.56
Winooski	Trinity College			8	0.96
Winooski	Riverside Ave			7	1.66
Winooski	North Ave 2	CB	22.5	7	0.87

Appendix 2. (cont)

Recwater	Storm sewershed	Treatment (Appendix 4)	EIA%	Loading kg/yr
		Highest Total PAH (Commercial Landuses Only)		
Barge Canal	Pine St 1			58
Barge Canal	Pine St 2	CB	29.0	42
Gilbrook	St. Micheals College			71
Lake Champ	Shelburne Road 2			95
Lake Champ	Burlington H.S.			51
Lake Champ	College St			47
Lake Champ	Shelburne Road 5			46
Lake Champ	Shelburne Road 6			46
LaPlatte Riv	Shelburne Shopping Center			41
Munroe	Shelburne Road			43
Winooski	Mid Main St-E.Spring St			406
Winooski	Hickock St-W.Allen St			342
Winooski	*IBM Corp-Williston*			214
Winooski	Barlow St			161
Winooski	Upper Main St			158
Winooski	*Burlington Inter. Airport-Nort*			95
Winooski	Gazo Ave			93
Winooski	Pearl St 2			90
Winooski	*Air National Guard 2*			85
Winooski	Five Corners			85
Winooski	Woolen Mill			78
Winooski	*IBM Corp-Essex 1*			76
Winooski	E.Allen St			76
Winooski	*IBM Corp-Essex 2*			68
Winooski	*IBM Corp-Essex 3*			66
Winooski	Lower Main St			59
Winooski	*IBM Corp-Essex 4*			56
Winooski	*UVM Main Campus*			54
Winooski	Trinity College			51
Winooski	Riverside Ave			50
Winooski	North Ave 2			47
Winooski	Fort Ethan Allen 7	CB		39
Winooski	Pearl St 1	CB		39

Appendix 2. (cont)

Recwater	Storm sewershed	Treatment (Appendix 4)	EIA%	Loading kg/yr
		Highest Total Metals		
Barge Canal	Pine St 1			7
Barge Canal	Pine St 2			5
Gilbrook	St. Micheal's College			8
Gilbrook	Lapointe Ave			6
Gilbrook	Roger St			6
Lake Champ	Shelburne Road 2			11
Lake Champ	Austin Dr			6
Lake Champ	Holmes Road			6
Lake Champ	Burlington H.S.			6
Lake Champ	Upper Shore Rd. 1			6
Winooski	Mid Main St-E.Spring St			46
Winooski	Hickock St-W.Allen St			39
Winooski	*IBM Corp-Williston*			24
Winooski	Barlow St			18
Winooski	Upper Main St			18
Winooski	S.Summit-South St			18
Winooski	Hiawatha Ave			17
Winooski	Burlington Inter. Airport-Nort			11
Winooski	Pearl St 2			10
Winooski	*Air National Guard 2*			10
Winooski	Five Corners			10
Winooski	Woolen Mill			9
Winooski	*IBM Corp-Essex 1*			9
Winooski	E.Allen St			9
Winooski	*IBM Corp-Essex 2*			8
Winooski	*IBM Corp-Essex 3*			7
Winooski	Lower Main St			7
Winooski	*IBM Corp-Essex 4*			6
Winooski	*UVM Main Campus*			6
Winooski	Gazo Ave			6
Winooski	Barrett St-Chase St			6
Winooski	Trinity College			6
Winooski	Riverside Ave			6

Appendix 3. Significant Stormwater Discharges Near Public Swimming Beaches or Recreational Swimming Areas. Stormwater discharges to study watersheds near beaches or recreational areas are not included. Discharges are targeted based on estimated exceedance of annual loading thresholds for fecal coliform (500,000 colonies/yr). Existing treatment structures are indicated. *Italics indicate stormwater discharges with VTDEC permits.* EIA% is the percent surface area as effective impervious surface area. Loadings are calculated from the means of ranges in export coefficients taken from the literature.

Recwater	Storm sewershed	Treatment (Appendix 4)	EIA%	Beach Rec Area	Loading Cols/yr
		Highest Total Fecal Coliform (Colonies/year)			
Barge Canal	Pine St 1	CB	32.7	1	8.6×10^5
Barge Canal	Pine St 2	CB	29.0	1	6.3×10^5
Barge Canal	Martin-Marietta(GE) 2	CB	88.1	1	5.7×10^5
Lake Champ	Shelburne Road 2	CB	14.6	2/3	1.4×10^6
Lake Champ	Austin Dr	CB	12.8	4/8	8.1×10^5
Lake Champ	Holmes Road	CB	35.1	3	7.9×10^5
Lake Champ	Locust Hill	IG/GS	49.9	3	7.9×10^5
Lake Champ	Burlington H.S.	CB	40.8	5	7.6×10^5
Lake Champ	Upper Shore Rd. 1	CB	20.0	6/7	7.3×10^5
Lake Champ	College St	CB	38.1	1	6.9×10^5
Lake Champ	Shelburne Road 5	CB	58.8	2/3	6.9×10^5
Lake Champ	Shelburne Road 6	CB	74.8	2/3	6.9×10^5
Lake Champ	Birchwood Pkwy	CB	21.4	6	6.2×10^5
Lake Champ	Baldwin Road	CB	17.5	2/3	6.0×10^5
Lake Champ	The Automaster	CB/GS	74.5	3	5.4×10^5
Munroe	Shelburne Road	CB	42.8	3	7.9×10^5
Munroe	Oak Hill	CB	15.6	3	5.2×10^5

Beach/Recreational Area

1 - Burlington Waterfront
2 - Red Rocks Beach
3 - Shelburne Bay Recreation Area
4 - Oak Ledge Park
5 - North Beach
6 - Leddy Beach
7 - Crescent Beach (private)
8 - Southcove Beach (private)

Appendix 4
Stormwater Structure Key

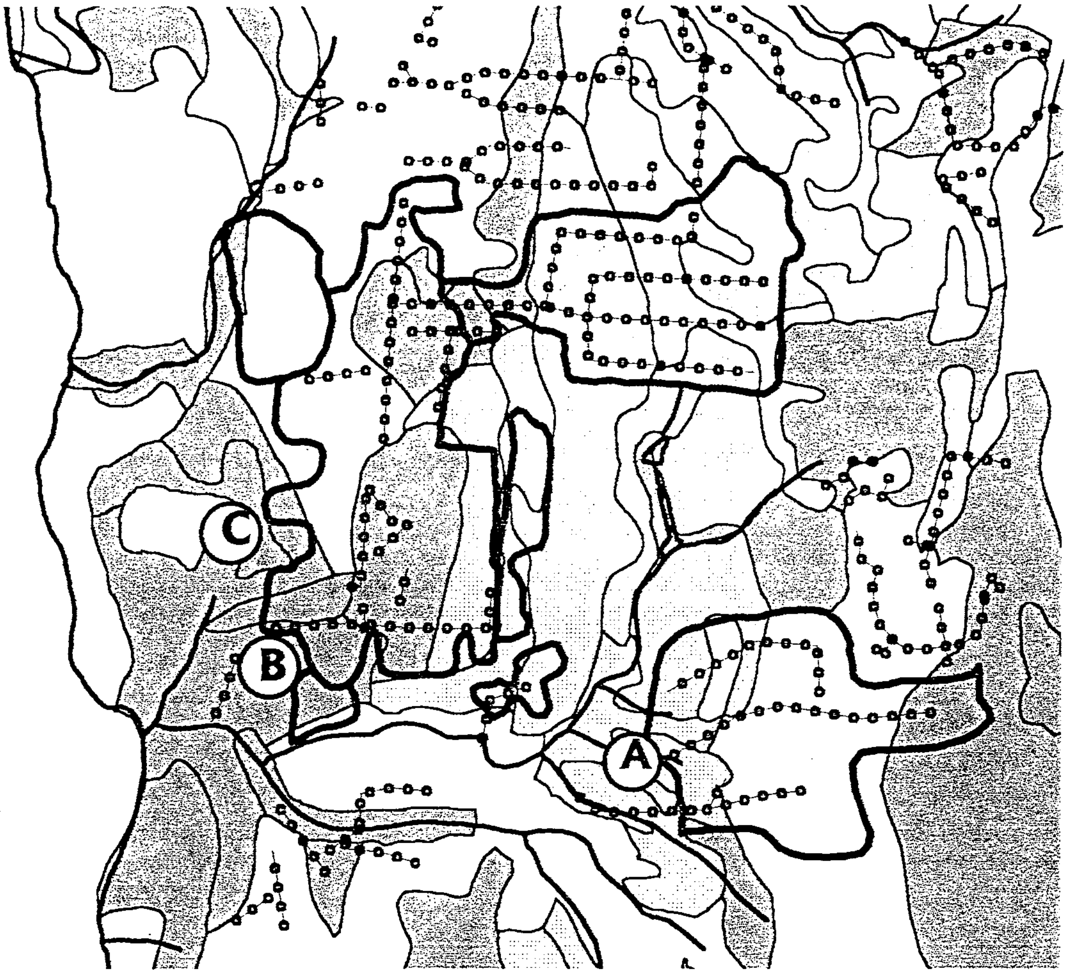
Structure Type	Code
Buffer Strip (25' Min.)	BS
Catch Basin	CB
Compost Filter	CF
Combination DP-SB	CP
Control structure	CS
Deep Sump	DS
Dry Well	DW
Extended Detention Pond	DP
Grass Swale	GS
Grease Trap	GT
Infiltration Gallery	IG
Inline Particle Separator	IPL
Leach Field	LF
Level Lip Spreader	LS
Lateral Under drain	LU
Overland Flow	OF
Oil-Grit Separator	OGS
Perforated Pipe Attenuator	PP
Riprap Swale	RS
Sediment Basin	SB
Small Sediment Basin-berm	SBB
Municipal Storm Drain	SD
Sand Filter	SF
Septic Tank	ST
Stilling Basin	STB
Treatment Tanks	TT
Underground Retention Basin	URB
Vortex Separator	VS
Wetland	WL
Wet Pond (Retention)	WP

Appendix 5

The maps in Appendix 5 identify specific location suggestions for installing structural BMP's recommended in this report. The maps are numbered and are referenced by number in Table 1 and in the watershed-specific tables located in the individual watershed assessments of Part 2. Suggested locations are based on a number of factors, including proximity to existing discharge point, availability of public land, and site characteristics such as slope, vegetation, and soils. See implementation recommendations in Part 2 individual watershed assessments for more detailed descriptions of locations.

Map #	Receiving Water	Sewershed
Map **1**:	Bartlett Brook	**A**-Bay Court **B**-Shelburne Road 1
	Lake Champlain	**C**-Holmes Road **C**-Shelburne Road 2
Map **2**:	Englesby Brook	**A**-Proctor St-Hadley St. **A**-Shelburne Road-Outlet Mall **B**-Richardson Terrace
Map **3**:	Potash Brook	**A**-Corporate Way 1 **B**-Williston Road **C**-San Remo Drive **D**-Williston Road-Pinetree **E**-Williston Road 2 **F**-Mills Ave. **G**-Timber Lane
Map **4**:	Centennial Brook	**A**-Staples Plaza 2 **B**-Williston Road-Dorset St.
Map **5**:	Centennial Brook	**A**-Airport Parkway-White St.
Map **6**:	Morehouse Brook	**A**-W. Spring St.-Malletts Bay Ave.
Map **7**:	Muddy Brook	**A**-Engineers Drive **B**-Griswold Industrial Park
Map **8**:	Indian Brook	**A**-Essex Jct. High School 1 **B**-Five Corners North
Map **9**:	Sunderland Brook	**A**-Ames **B**-Fort Ethan Allen 6
Map **10**:	Sunderland Brook	**A**-Pearl Street East

Map #	Receiving Water	Sewershed
Map **11**:	Winooski River	**A**-Pearl Street 1 **B**-Pearl Street 2
Map **12**:	Sunderland Brook	**A**-Meadows Industrial Park 1
Map **13**:	Lake Champlain	**A**-Austin Drive
Map **14**:	Lake Champlain	**A**-Upper Shore Road 1
Map **15**:	Winooski River	**A**-Five Corners **B**-Hiawatha Ave. **C**-So. Summit-South Street
Map **16**:	Potash Brook	**A**-Laurel Hill Drive **B**-Shelburne Road 8 **C**-Shelburne Road 7 **D**-KMart
Map **17**:	Winooski River	**A**-Lower Main St. **B**-East Allen Street **C**-Woolen Mill **D**-Upper Main Street **E**-Barlow Street **F**-Hickock St.-W. Allen St. **G**-Mid Main Street-East Spring Street
Map **18**:	Lake Champlain	**A**-Burlington High School
Map **19**:	Winooski River	**A**-North Ave. 2 **B**-Gazo Ave.



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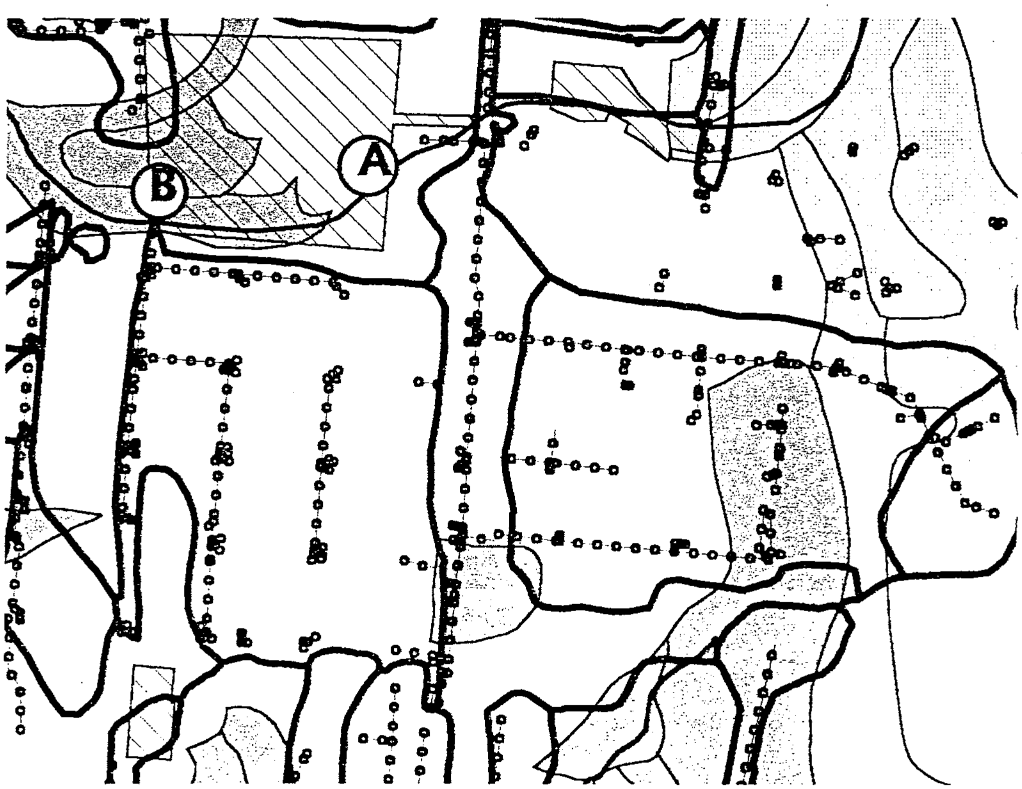

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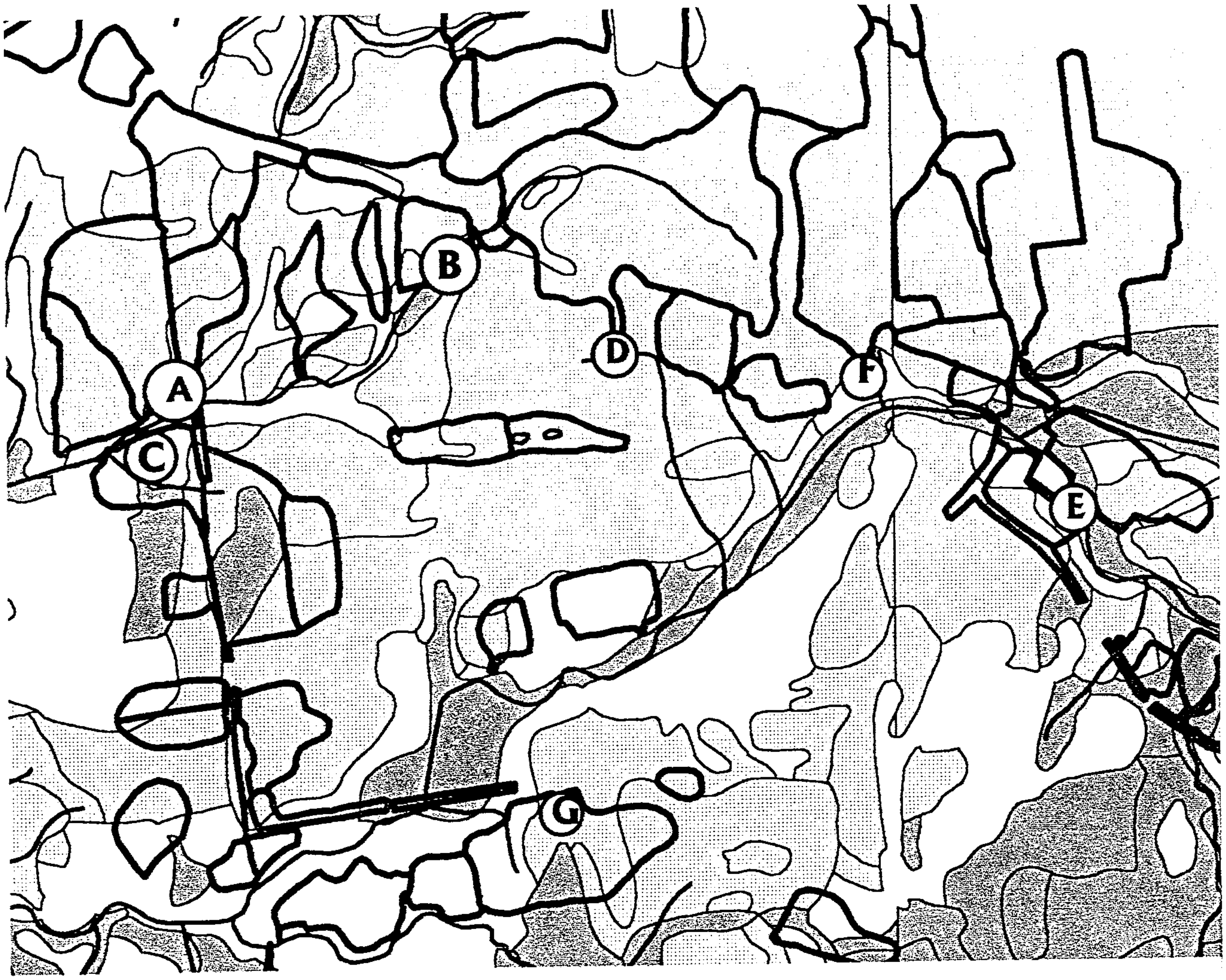

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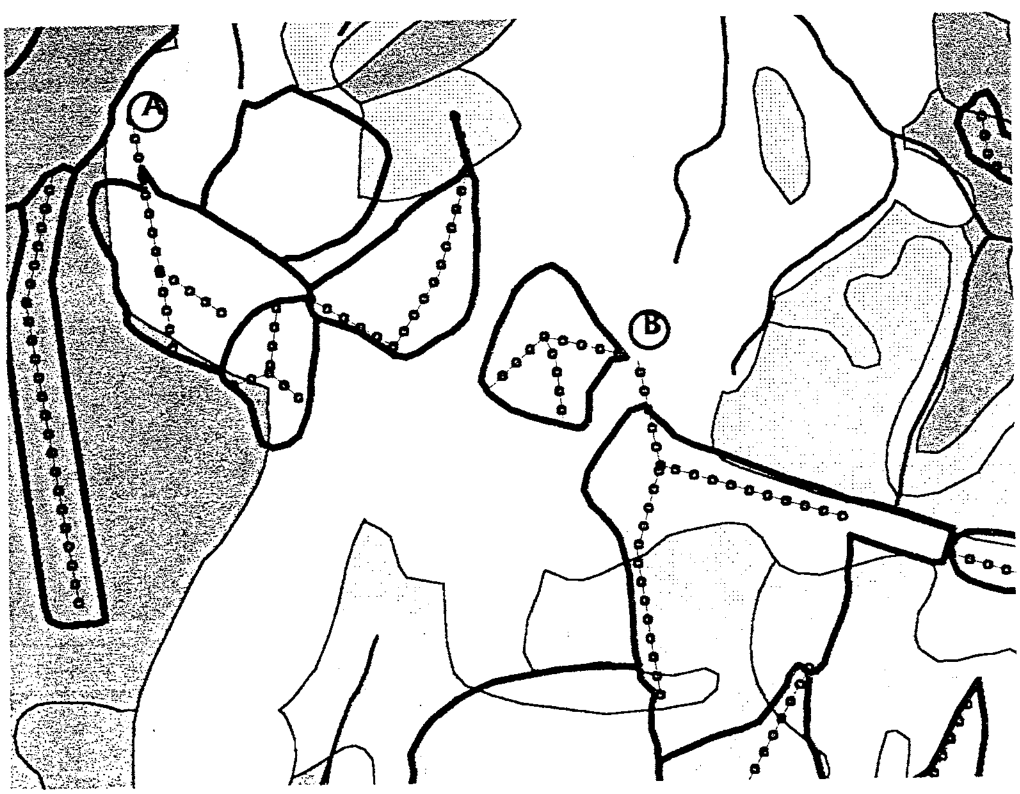

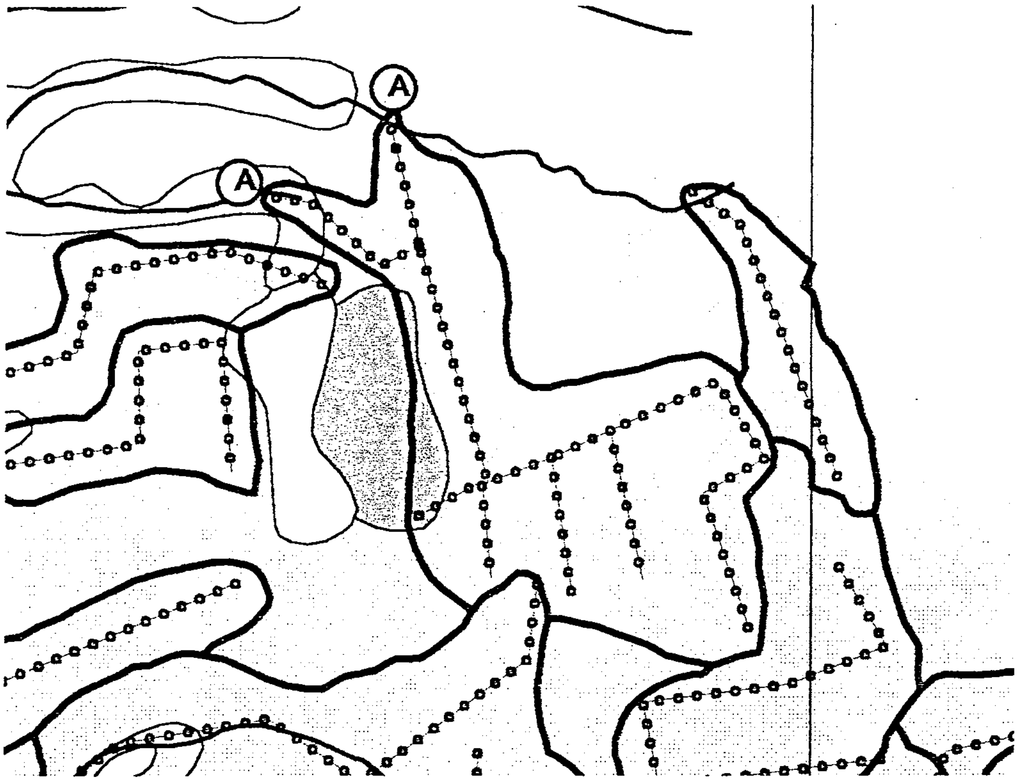

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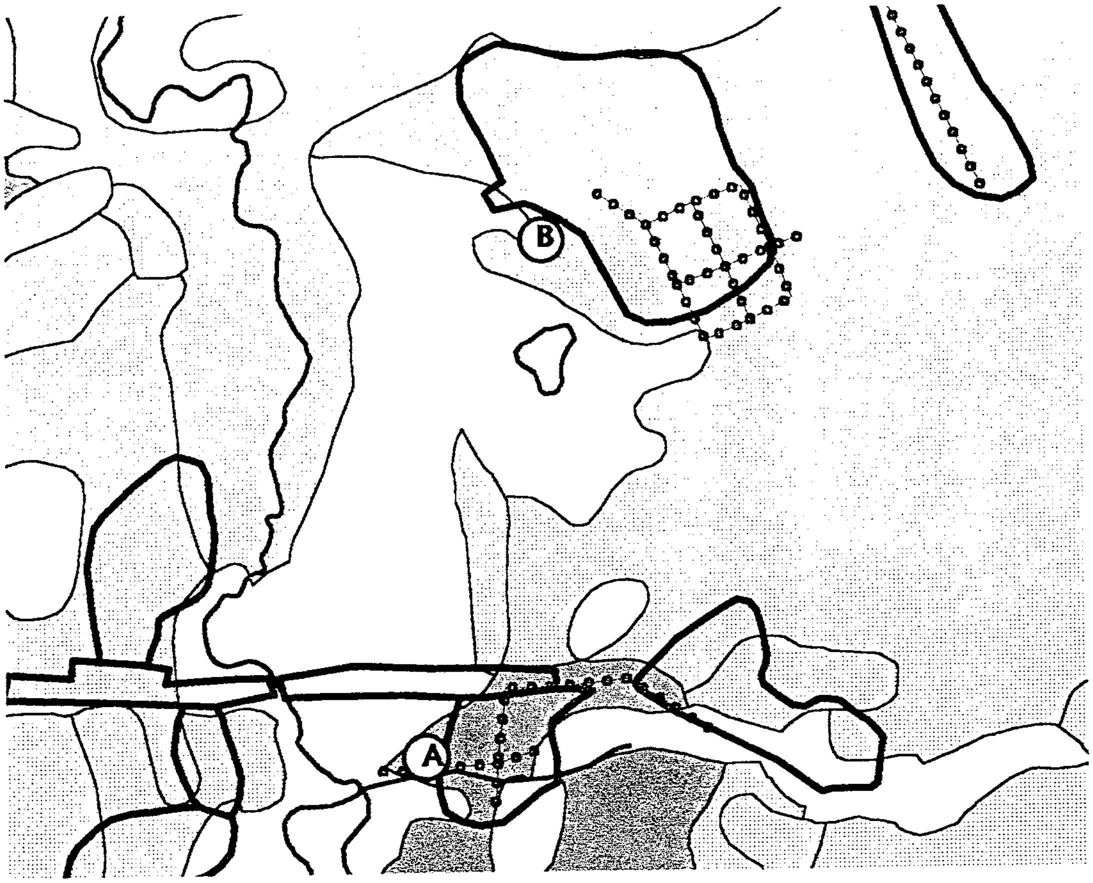

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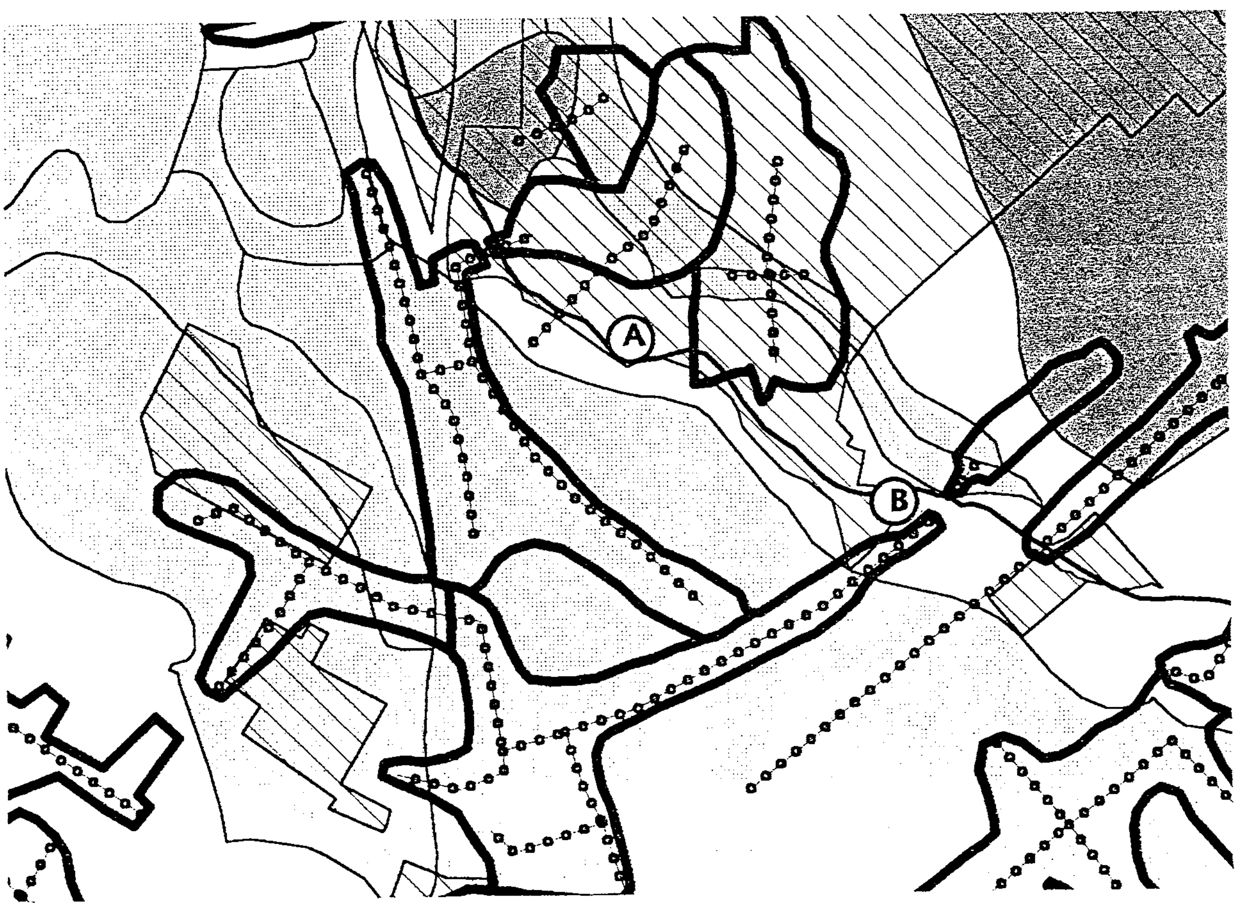

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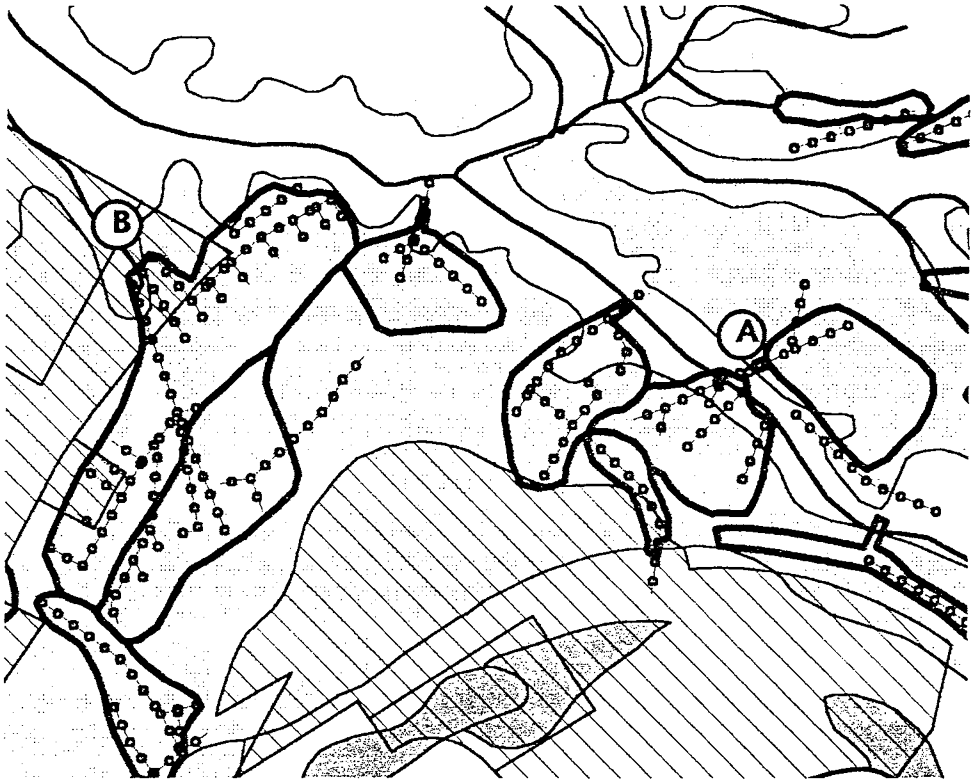

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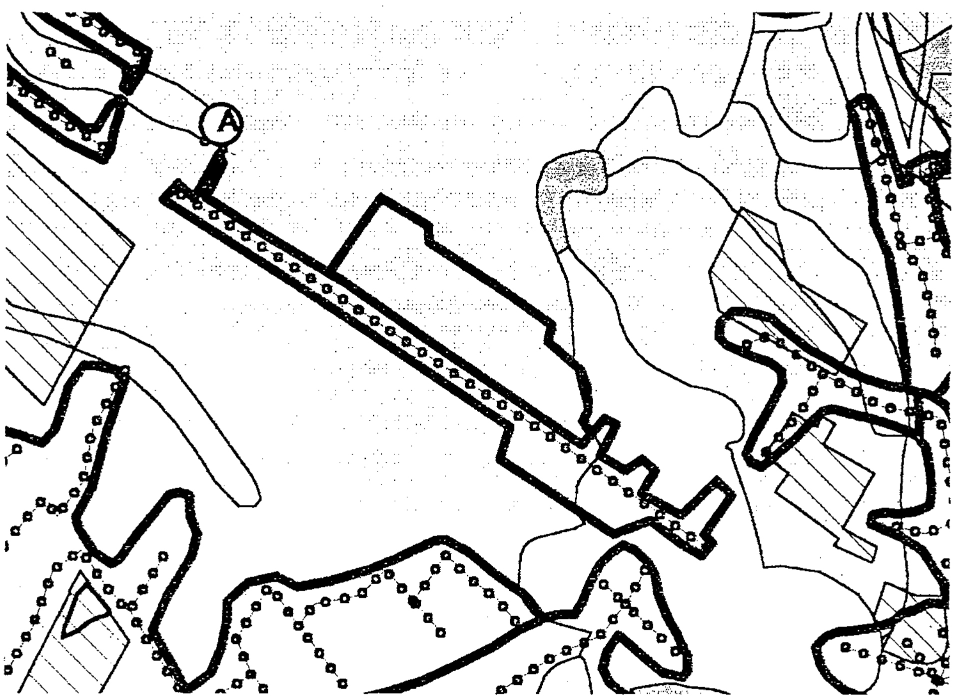

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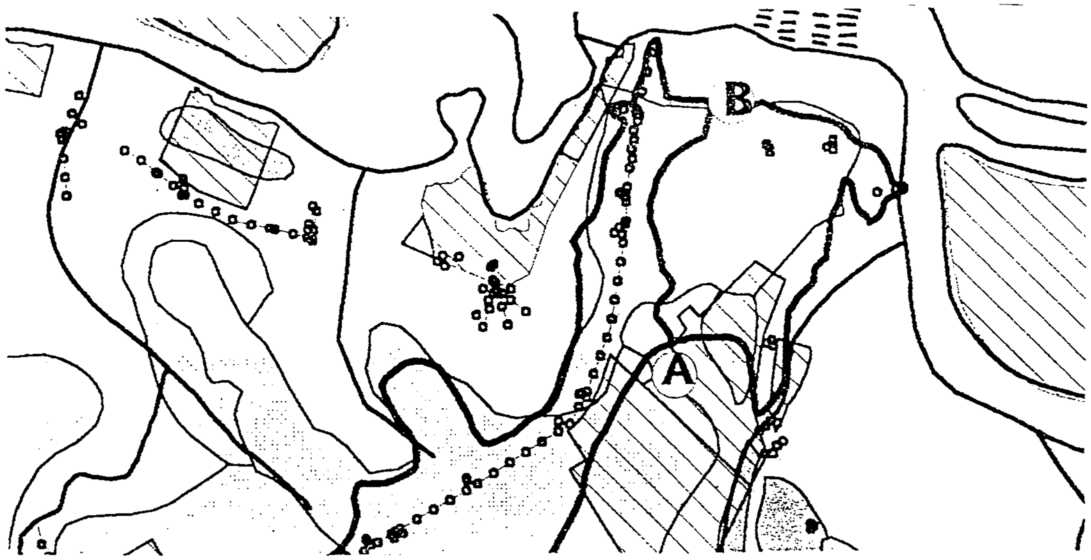

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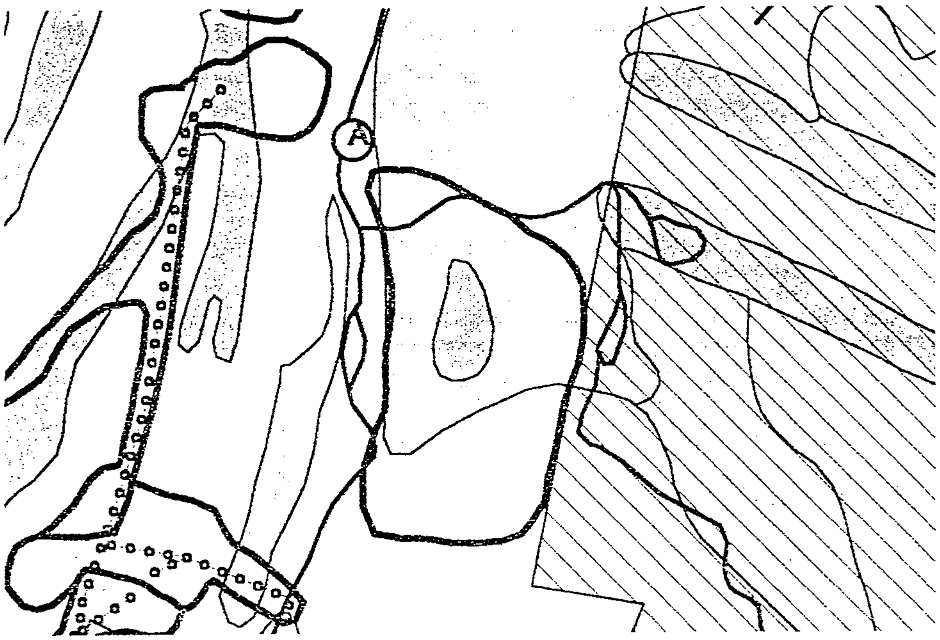

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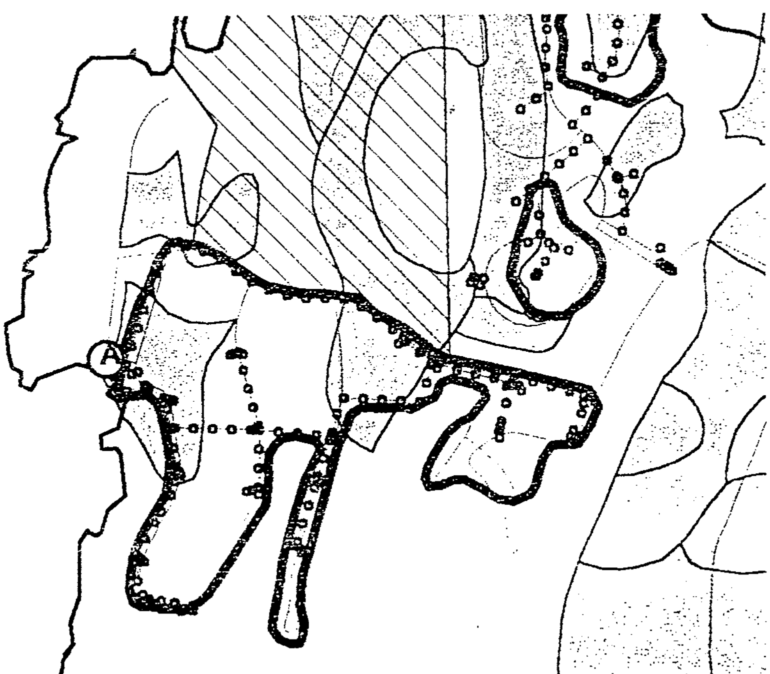

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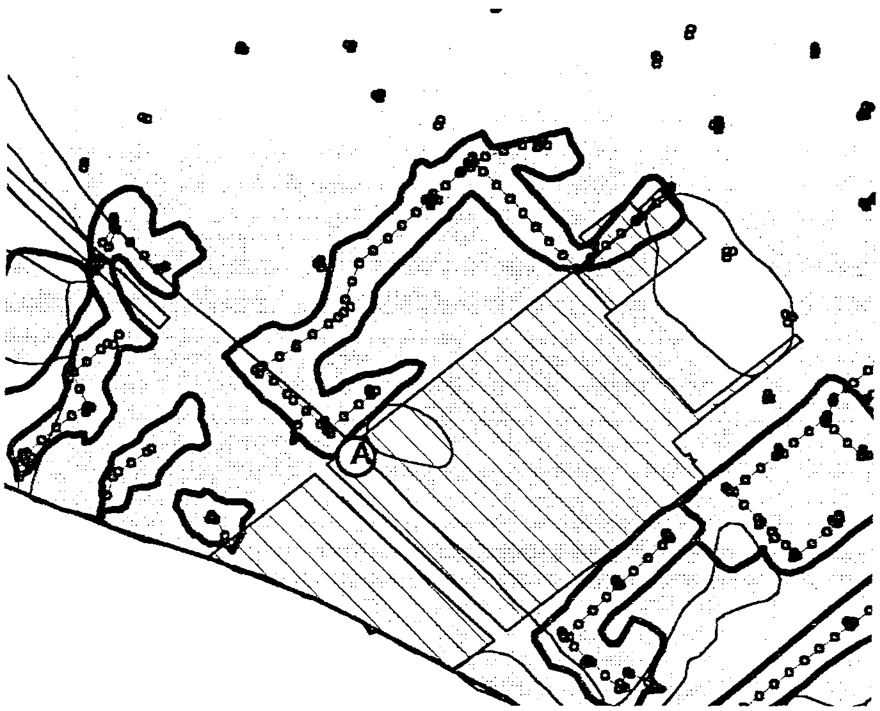

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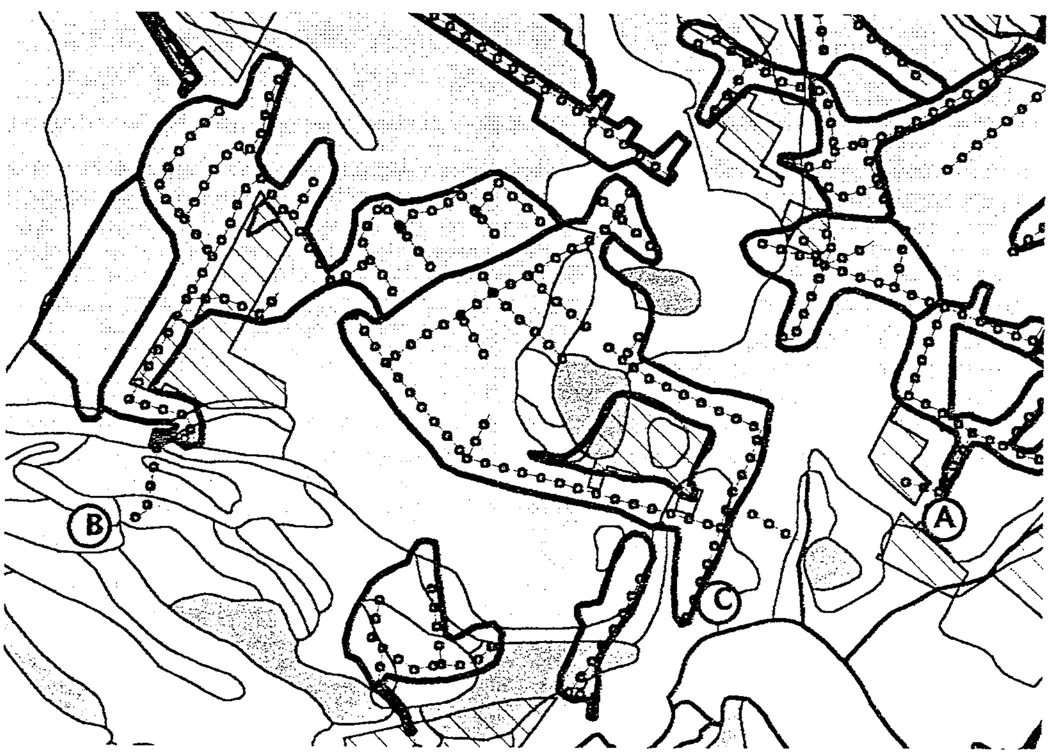

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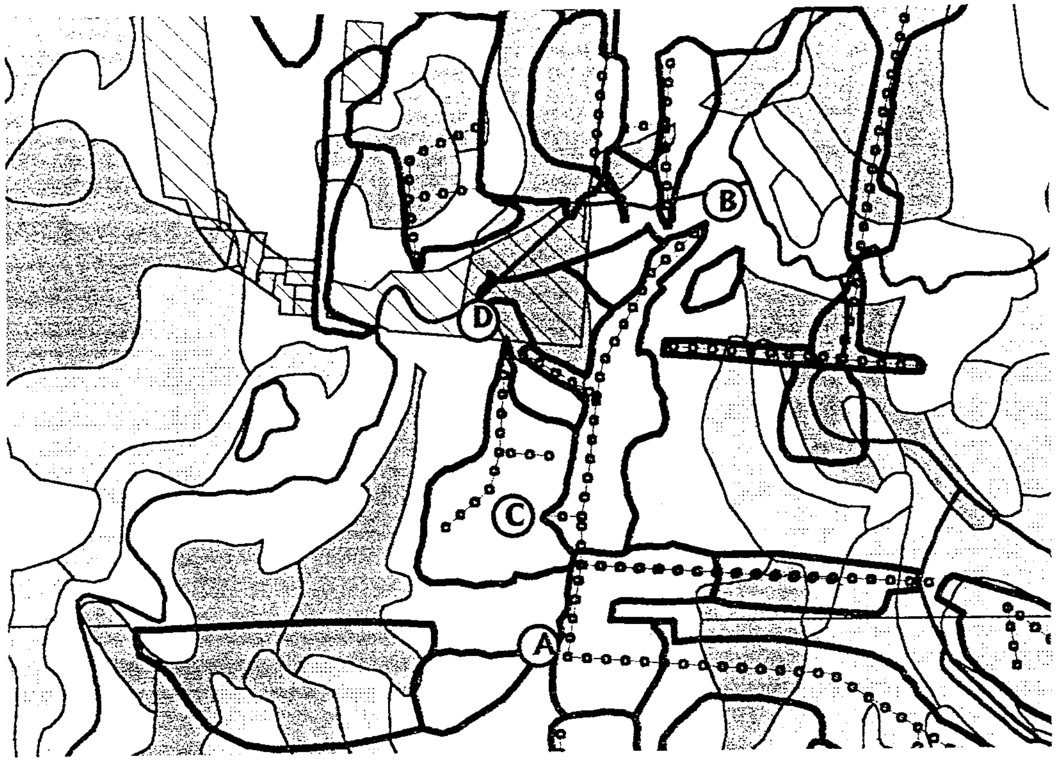

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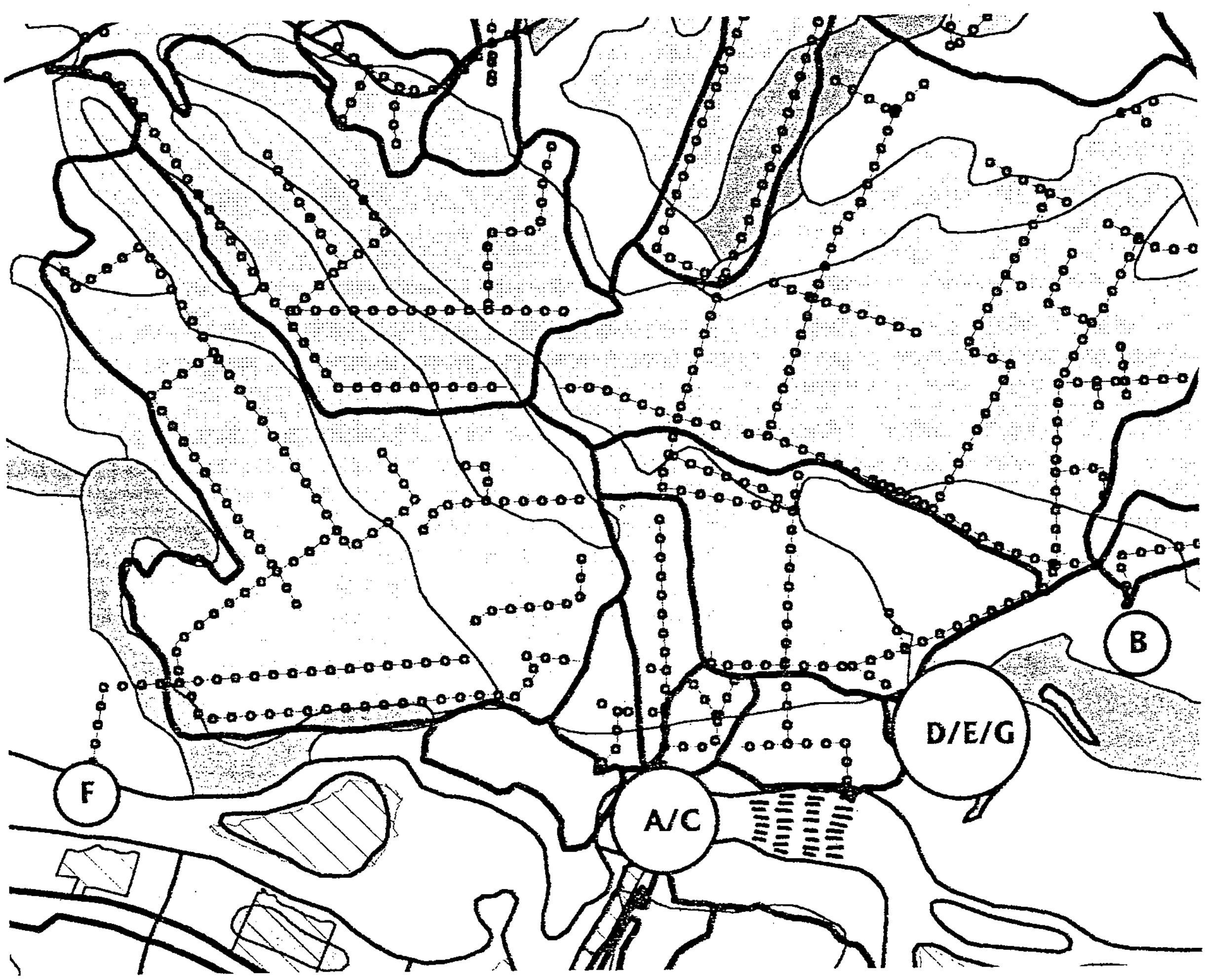

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Target Maps #1-19 Key

Targeted Stormwater Discharges
Stormwater Lines
Surface Waters
Parks
Public Land
State of Vermont Property
Storm Sewersheds
Soils Suitable for Stormwater BMP's
Adams-Windsor Series
Covington Series
Duane-Deerfield Series
Enosburg-Whately
Livingston
Muck/Peat
Munson-Belgrade
Munson-Raynham Series
Vergennes Series

Part 2: Individual Watershed Stormwater Management Evaluations

Part 2 consists of eight individual watershed evaluations; Allen and Muddy Brooks are combined as a single watershed unit for the purposes of this evaluation. Each evaluation consists of the following:

1) Watershed Description - a brief narrative describing the location of the watershed.

2) Land Use - a brief narrative describing current and future land use in the watershed.

3) Soils - a brief description of soils in the watershed, particularly as they relate to potential stormwater management options.

4) Riparian Corridor and Biological Evaluations - discussion of the results of these activities conducted in the watershed.

5) Watershed Management Goals - a list of goals related to watershed stormwater management.

6) Existing Zoning - a summary of current zoning policies in each watershed.

7) Education Strategy - a generic narrative describing elements of a watershed education strategy.

8) Implementation Strategy - recommendations for implementing stormwater BMP'S at targeted sewersheds are described here.

9) Resources - a preliminary list of resource materials for the watershed.

10) Recommendations - watershed management recommendations, both generic and site-specific, that if implemented, would have a high likelihood of positively influencing water quality management goals in the watershed.

11) Table of significant stormwater discharges in the watershed.

12) Table of stormwater BMP implementation recommendations and estimated costs.

13) A series of maps and figures depicting data layers and information created and assembled during the course of this project.

The intent of reporting results in watershed format is to facilitate the incorporation of these findings into comprehensive watershed management plans for each of the project watersheds. These evaluations are not comprehensive management plans and should not be viewed as such. The intent is for these evaluations to serve to focus planning efforts and to provide a basis for evaluating specific implementation activities that will most likely result in environmental benefits in the form of minimized pollutant loadings to the target watersheds and to Lake Champlain. A second objective is restoration of impaired riparian and aquatic habitat and the biologic communities that those habitats support. Above all, it is the hope of this project that these findings will stimulate the development of comprehensive multi-jurisdictional watershed planning efforts within the project area, resulting in watershed management conducted across political boundaries with full investment by local and regional authorities.

This project has assembled and/or created a number of Geographical Information System (GIS) data layers relevant to watershed planning in the project area. Information from these data layers is presented in a series of figures attached to each watershed evaluation. Pending completion of data layer transfer to the Vermont Center for Geographic Information, these data layers with their associated data tables, will be available to local and regional planners.

This project recognizes that local governments in the project area have made tremendous commitments to protecting and preserving the natural resources associated with surface waters. Local and regional planning, zoning, and conservation commissions have established a strong record of environmental concern. In order to fully realize effective watershed management, it is critical that individual missions, goals, objectives, and policies be consolidated under the umbrella of comprehensive watershed planning and management. It is hoped that the findings of this project will assist those responsible for planning and environmental management in the project area in their efforts to restore, protect, and preserve the aquatic resources of these highly vulnerable developing watersheds.

Individual evaluations are included for the following project watersheds:

Allen-Muddy Brooks
Bartlett Brook
Centennial Brook
Englesby Brook
Indian Brook
Morehouse Brook
Potash Brook
Sunderland Brook

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