The Whitewater Rivers of Vermont Their Biology, Geography, and Recreational Use

Note: The evaluations and opinions contained in this report are those of the consultant and do not necessarily represent the policies of the Agency of Natural Resources.

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Written April 1987
Revised March 1992

State of Vermont

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Dear Reader,

As part of its responsibility to protect the existing uses of Vermont's waterways, the state initiated a contract to explore the geography, biology, and uses of Vermont river rapids or "whitewater." The Agency of Natural Resources is pleased to provide you with "The Whitewater Rivers of Vermont," completed by private consultants Jerry Jenkins and Peter Zika. I believe this detailed discussion about Vermont whitewater will be extremely useful to those interested in effectively protecting, preserving and restoring exceptional river resources.

The evaluations and opinions offered in this report are those of the author and do not necessarily represent the policies of the Agency of Natural Resources. Although this report is an important step in cataloging the whitewater rivers of Vermont, the Agency specifically cautions that the report is not intended to represent the definitive list of important whitewaters in Vermont. Boaters should realize that this document is not intended as a working guidebook to whitewater runs, and should be prepared to rely on their own scouting of any run unfamiliar to them.

The discussions and river descriptions offered by Mr. Jenkins and Mr. Zika will contribute to an important dialogue on protecting Vermont's whitewater rivers. The Agency encourages the reader to submit comments on the report to the Department that may be included in an appendix of a future edition.

Sincerely,

Stephan B. Syz, Chief
Water Resource Planner

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ACKNOWLEDGMENTS

This report is possible because of the accumulated knowledge of rivers and rivercraft in the boating community, and because it is a tradition of that community to aspire to accurate knowledge and to share it freely.

Many people helped in many different ways. Those that we can thank by name are:

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All of these people -- named or unnamed -- have invested much time in the development and practice of whitewater boating; collectively they possess a remarkable body of skills, experiences, and information which they have been unstintingly generous about sharing with us, and which has been a joy for us to learn.

In preparing this report we made constant use of five sources of information: the museum collections of the Pringle Herbarium at the University of Vermont, the river basin studies of the Vermont Department of Water Resources, the fisheries reports of the Vermont Department of Fish and Game, the hydrological data assembled by the United States Geological Survey, and the river descriptions prepared by the Appalachian Mountain Club, and in particular their 1983 *AMC River Guide* to New Hampshire and Vermont. Much of our job was to compile and transfer things that other people had discovered. We wish to acknowledge our debt to the discoverers, and to the institutions that preserve their findings and make them available. Scholarship is always a collective effort, and if we have been in any way successful in our efforts to assemble a geography of Vermont whitewater it is because we had ideas and information from over a hundred years of previous research to draw on.

Like all researchers, we have conceptual as well as factual debts. In many ways our basic understanding of rivers derives from two books: Leopold, Wolman and Miller's *Fluvial Processes in*

Geomorphology (Freeman, San Francisco, 1964) and H. B. N. Hynes' *Ecology of Running Waters* (University of Toronto, 1970.) Everyone interested in rivers should read both books; anyone who has will recognize how much we have learned from them.

In the interval between the drafting of this report and its eventual appearance in print some twenty people reviewed the manuscript and made many helpful suggestions. We are grateful for all their effort and ideas, and extend particular thanks to Ray Gonda for his comments on some rivers we were unfamiliar with, Charles Ratte' for his criticism of the section of Geology, Mike Kline, Steve Sease and Stephan Syz for their labors as general editors, and Cathy Kashanski for supervising the preparation of the maps and final typeset manuscript.

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CHAPTER 1. AIMS, METHODS, SOURCES, LIMITATIONS

This report is the result of a survey of Vermont whitewater rivers commissioned by the Vermont Department of Water Resources. The project began early in 1984. This report appeared in draft form in July 1985, was revised and updated in April 1987, and has had minor revisions to prepare it for publication in March 1992. It is not as new as it was five years ago, but the information seems to have aged well, and we hope you like it.

Our goal was to produce an atlas of Vermont whitewater streams, and to evaluate their importance for fishing, boating, biological and geological conservation, and water quality.

We discovered early in the project that the geography of these different topics did not coincide. Since we could not produce five separate river atlases, we chose to focus on the streams most important for boating and evaluate them as completely as we could.

In order to keep the field work to a manageable size we made further restriction and only made field examinations of river segments two miles long or longer. This again corresponds to the boater's interests: shorter rapids are sometimes used for practice and play, and sometimes are difficult enough to be interesting in themselves, but rarely get the use that longer rapids do. We cover short rapids in an appendix, but for the most part did not devote any field work to them.

The study was begun as a joint project of Jerry Jenkins and Peter Zika. Accident and commitments prevented us from working together as fully as we wished. Peter Zika gathered the bulk of the botanical and biological information. Jerry Jenkins did the majority of the boating, was responsible for the analysis and interpretation of the biological and geological data, and is the author of the text. The report bears both our names because we both contributed information, and because the design and many of the conclusions were cooperative efforts. But because it had to be written by the first author alone, many of the opinions and interpretations are his, and he accepts responsibility for errors and misapprehensions.

The study was conducted in the following way. We researched published sources, most particularly the Appalachian Mountain Club *River Guide*[1] for New Hampshire and Vermont, and talked to as many boaters as we could. From this we drew up a list of whitewater streams that were used for boating. We then set out in March 1984 to boat as many of these as possible, and to field check the others. In this we were handicapped by a dry and short whitewater season, and so in many cases had to rely on descriptions from other boaters. We also visited several races and whitewater gatherings, and interviewed as many boaters as possible.

In the summer of 1984 we compiled biological information. Botanical data was drawn from herbarium records, from our own studies of the last 17 years, from work done in connection with the Vermont Waterfall and Gorge Survey[2], and from inventories of about 30 sites along streams for

1. *AMC River Guide. New Hampshire, Vermont*. Appalachian Mt. Club, Boston, 1983.
2. J. Jenkins & P. Zika, *The Waterfalls, Cascades, and Gorges of Vermont*, Vermont Agency of Natural Resources, Waterbury Vermont, 1983.

which we needed more information. Information about game fish came from interviews with fishermen and fish biologists, from the excellent book *Vermont Trout Streams* (Allen, Antczak & Shea, 1985), and from summaries of fisheries in state river basin plans. Information about other fish was supplied by Dr. George LeBar of the University of Vermont and Rich Langdon of the Vermont Department of Environmental Conservation. But even with their help we still were not able to arrive at a satisfactory treatment of the rarer species, and feel this is a definite lack.

Insects were a problem. Much information exists in the literature, but is rarely specific to Vermont, or in forms accessible to non-specialists. The fly-fishing literature provide interesting treatments of the dominant species in the major streams, but does not deal with rare species. Dr. Ross Bell of the University of Vermont contributed some very valuable information on beetles. Elsewhere in the United States and Canada there has been good recent work on mayflies and stoneflies, but as far as we can determine there have been no recent studies of them in Vermont.

No field geology was done. During the whitewater season you can't see much of the rocks, and we did not have the time to make (or, in all honesty, the geological training to profit from) a separate series of summer visits. Instead we concentrated on combining field data on the occurrence and intensity of whitewater with geological and hydrological data from published sources, and studying the results graphically. This approach proved quite fruitful, and as a result we think we have some new insights into the relations between regional geomorphology and whitewater, and a new way of identifying potential whitewater streams from map data.

After the report was written in 1985 the senior author continued to make boating and scouting trips to a number of rivers, with the goal of acquiring first-hand information on the rivers at a variety of levels which would enable him eventually to produce a guide book for boaters. At the time of publication he has boated 43 of the 49 stream segments described in this guide, and scouted five of the remaining six at high water. The results of this continuing field work have been incorporated into this edition of the report.

* * *

Any study like this has strengths and shortcomings. It may help the reader if we set them down explicitly here so that the reader will not trust our conclusions more than our information merits, and in the hopes that the shortcomings may be remedied by new investigations, or from sources we did not discover.

First strengths: We have a lot of first-hand information based on actual descents of whitewater rivers, both by ourselves and by others. We have good information on game fish based on many years of fisheries research, and a pretty good picture, based on our own and other people's research, of the general pattern of river shore botany. We have been able, using this information, to analyze the pattern of occurrence of whitewater as a whole, and to discover some new facts about the hydrology and plant communities of whitewater streams. We have been able to develop criteria for recognizing potential whitewater streams from maps, and have used this method to estimate how many currently unused streams may have whitewater, and what the degree of difficulty of these streams is likely to be.

Then weaknesses. We still have much to learn about the true difficulty of a number of streams, particularly at unusual water levels. We don't know enough about the distribution of non-game fish, know nothing about the distribution of the rarer stream insects, and know very little about the common ones. And finally, our botanical information is based mostly on spot-checking rather than continuous surveys. Hence it gives a good account of the common plants but overlooks the rare ones that occur locally. These plants certainly exist: the reader should realize that the river shores are not as uniform botanically as our spot-surveys might make them seem to be.

* * *

A few notes on equipment and methods. We used four boats in this study. The first was an 11' fiberglass canoe from Northeast Boats, then of Newport, Vermont. It was designed as a pack canoe for flatwater. We added a plywood deck and floatation to it and used it in tight ledgy streams, and discovered that it had some hidden whitewater genes and seemed to delight in water of an intensity that might have amazed its designers. Our second boat was a 16' royalex Mad River Explorer which was sunk and eventually lost in the line of duty. It was a fine and forgiving river boat, and, prior to its unmerited loss, displayed all the staunchness and sea-keeping abilities for which this design is famous. Our third boat, which was for three years our workhorse for solo trips, was a 14' Blue Hole Sunburst. It is a steady and comfortable boat and is apparently as unsinkable as a duck. And finally our current boat is an MJM from Millbrook Boats, a lightweight whitewater slalom boat designed and built by John Berry of Riparius, New York. Slalom boats are perforce light and agile, but, as with thoroughbreds in general, can also be willful and unforgiving. The MJM has been a delight because it is both very able and very mannerly...

Our paddles varied. For the first two years the combination of low stream levels and our improvisatory style of paddling meant that our paddles often had to do double-duty as poles and levers, and hence we favored stout stubby models, built something like Little John's staff. Subsequently both the water and our manner of approaching it have improved, and we have come to rely on several paddles made by Mitchell, of Canaan, New Hampshire. The Mitchell paddles are light and wonderfully balanced, and seem to be well suited for for our tight rivers.

The senior author paddles one-handed, and early in this study spent some time experimenting with a variety of ring-shaped paddle grips with bearings and swivels. He has subsequently abandoned these in favor of a conventional T-handle with slight modifications to improve the grip. He will be glad to share these with anyone interested.

* * *

All the the values for river slopes and about half of the values for the areas of watersheds used in this report were calculated directly from topographic maps. For the most part we used 15' maps, which were the best available in the north and west of Vermont in the mid '980's. River slopes are poorly mapped, and such calculations are invariably crude averages over one mile or more, and do not reflect the slopes of individual rapids. Watersheds were approximated by polygons rather than calculated planimetrically. When an entry says that the watershed is " ca. 1000 sq. km." it indicates that it is one of our own calculations, and probably at best accurate to +- 15%.

CHAPTER 2. ABOUT WHITEWATER AND WHITEWATER BOATING

This chapter presents general information about whitewater and explains the special terms used in the rest of the report. It is intended for readers unfamiliar with whitewater, and contains nothing that is not generally available in books on canoeing and river conservation. A number of the points mentioned here receive fuller discussion later in the report, and the reader is referred to the appropriate chapters for details.

Words printed in italics are used in a technical or restricted sense here, and are defined as they occur.

2.1 What is Whitewater?

Whitewater is turbulent, aerated water. It is found where streams have steep slopes and high velocities, or where there are obstacles to the flow, or where the stream descends over ledges or falls. *Headwater streams* with slopes exceeding 100'/mile have continuous whitewater except at the lowest flows. *Upland streams* with slopes from 20'- 100'/mile are whitewater streams at medium and high water, and smooth at low water. *Valley streams* and *major rivers* with slopes from 5'- 20'/mile may have isolated rapids, especially at high water, but are otherwise not whitewater streams.

Whitewater is generally used to refer to any turbulent water; in this report we use the word in a more restricted sense to refer to rapids whose intensity is Class II or higher, as measured by the international rating system for river difficulty which will be explained later in this chapter. For mild (Class I) rapids, and for streams with fast but not necessarily turbulent water we use the term *quickwater*.

Whitewater rapids may be continuous or intermittent. Streams with gradients over 40'/mile usually have essentially continuous rapids. Streams with gradients from 20'-40'/ mile may have continuous or discontinuous rapids, depending on the nature of the channel. (See Chapter 4.) Streams with gradients under 20'/mile invariably have only discontinuous rapids.

2.2 Why is Whitewater Important?

Whitewater is important in at least four ways.

First, regarded as an interesting part of the landscape, falls and rapids are lively and exciting and often quite beautiful. To many of us they are places where we can experience the power and wildness of nature. To many others they are choice spots for relaxation and refreshment.

Second, falls and rapids are often biologically distinctive. The high flows and high oxygen content make fast water effectively more fertile than slow water and so, like other fertile communities, whitewater streams tend to be rich in species. We have a number of fishes that are largely restricted to quickwater and whitewater, and a small but interesting group of plants that are associated with ledges along whitewater segments of streams. A number of mayflies and stoneflies are only found in whitewater streams, and are both interesting in themselves and important to fish and fishermen. And finally there is one moderately rare vascular plant (the riverweed *Podostemum*) which grows on submerged rocks and which is limited to whitewater rivers.

Third, whitewater segments affect the oxygen balance of the streams in which they occur, and so influence the biology of the whole stream. Fish and other aquatic creatures depend on oxygen dissolved in the water. Organic pollution and agricultural runoff decrease oxygen concentrations by stimulating the growth of bacteria and algae. These consume dissolved oxygen[1], and this in turn limits or eliminates many fish and invertebrates. Oxygen tends to be depleted from smooth water and restored by falls and rapids. This is of considerable importance both in pristine streams where oxygen levels are low because of low summer flows, and in lowland streams where oxygen levels are low because of treatment plant effluent, agricultural runoff, or impoundments.

And finally whitewater streams are used recreationally by boaters, who find in the running of them a surprising variety of emotional, physical, and intellectual satisfactions. A major part of this report will be devoted to describing the suitability of different streams for different sorts of recreational use. To do this we will need to borrow the vocabulary and the perspectives of the whitewater boater. To make this intelligible to the reader who is not a paddler we supply the follow brief introduction to the sport.

2.3 Whitewater Boats & Boaters

People descend rivers in tubes, inflatable rafts, and open and closed boats. *Tubes* are popular, easily handled craft, if somewhat overly symmetrical and hence unresponsive. *Open boats* -- which for our purposes means open canoes -- are the traditional inland rivercraft, and are used by both casual and expert boaters. They vary from traditional designs, which are fairly similar to cruising and tripping boats, to very specialized designs that are used for racing or running high-intensity rivers. *Closed boats*, including decked canoes and kayaks, are specialized for whitewater, though kayaks are increasingly used for general river and lake travel as well. Again they vary from recreational designs to specialized racing and acrobatic designs. *Inflatable rafts* come in several sizes and seriousnesses. The small ones are used interchangeably with tubes on mild rivers, while the larger and tougher ones are used in white water, and in expert hands can negotiate water that is too heavy for any rigid boat [2].

1. Algae produce oxygen in the daytime but consume at night. In addition dieing masses of algae sink to the bottom and decay, again consuming oxygen.
2. The above are paddle- or current-powered watercraft. Powered rafts and pontoon boats (jet boats) are often used in whitewater elsewhere in the country, but are rarely seen in the east.

On warm summer days tubes may outnumber all other rivercraft. They cost $4-8 at garages, and can be rented from many campgrounds and local stores. They can be used by anyone and are wet, sunny, relaxing, and well-loved. Their use is restricted, we hope, to non-whitewater rivers[3]. Tubing is a traditional summer recreation, and an amazingly pleasurable one. What other kind of travel costs nothing, requires as little equipment, preparation, or effort, and takes you to such beautiful places in so comfortable a manner?

An inflatable raft is essentially a tube with a floor. Light-weight ones are suitable only for mild water, and are used in much the same casual way as tubes. Others are specifically designed for whitewater. These range from small rafts for one or two people to large ones for ten or more people. Their virtue as whitewater boats comes from their size and flexibility. Because they can bounce off rocks they don't have to be narrow and maneuverable like a canoe, and because they are wide and can bend they can survive drops and holes that would sink a narrower craft or capsize a stiffer one.

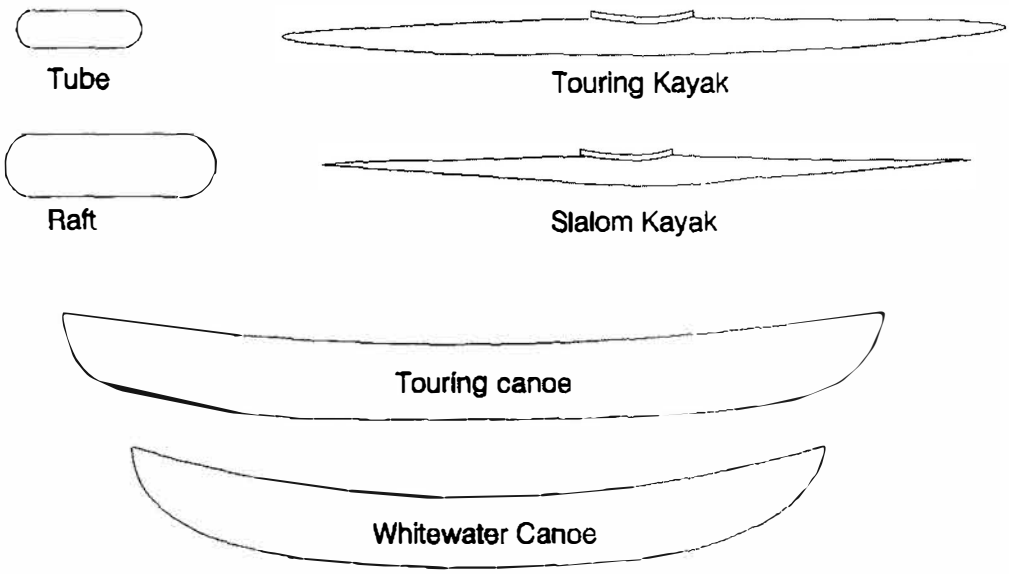


Figure 2.1 Whitewater Boats

Open canoes are by far the most generally used river boats in Vermont. They differ widely in design. Those used in whitewater are invariably keelless, usually designed for maneuverability and high strength, and usually fitted with some form of flotation to reduce the amount of water that can be taken in. While whitewater boats may look superficially similar to lake and flatwater

3. In the fall 1986 water release on the West River two people floated down the upper Class III rapids in tubes, without lifejackets, paddles, or protective gear. This is foolhardy in the extreme; had they gone into one of the large holes they could easily have been killed.

canoes they are in fact highly specialized boats with the ability to survive (and in fact to excel) in conditions where a flatwater boat would be sunk or destroyed. This needs to be stressed. WHEN WE SAY IN THIS REPORT THAT A RIVER IS SUITABLE FOR OPEN BOATS WE MEAN FOR OPEN WHITEWATER BOATS, AND CAUTION THAT THIS DOES NOT MEAN THAT THEY ARE NEGOTIABLE BY OPEN CANOES NOT SPECIFICALLY DESIGNED AND OUTFITTED FOR WHITEWATER.[4] Using an unsuitable or improperly equipped canoe in whitewater is hazardous at best, and at worst life-endangering.

Decked canoes and kayaks look very similar to each other. The chief distinction is that you kneel in the canoe and use a single-bladed paddle, and sit in the kayak and use a double-bladed paddle. They are similar in maneuverability and river-worthiness, but require different skills. The double-bladed paddle gives the kayaker great stability, control and acceleration. Hence kayaks are both easy boats for the novice paddler, and also the choice of experts interested in acrobatics or in descents of extremely violent rivers. The single-bladed paddle of the decked canoeist cannot reach as far as the kayak paddle, and cannot be switched from side to side as quickly. It is a more classical and a more limited tool, although its limitations are in part offset by the greater leverage and freedom of body movement afforded by the kneeling position. Because of these limitations more strength and paddle technique is required of the canoeist than the kayaker. Decked canoe paddlers are often racers or have a racing background, tend to be very powerful paddlers, and are regarded by the rest of us with considerable admiration.

Kayaks and kayakers are common, and often seen in good-sized groups. Decked canoes are much rarer, and rarely seen except at races or water releases.

Decked boats have two advantages over undecked boats: they cannot be swamped by waves, and they can be righted by a paddle roll if they capsize. They can thus handle rougher or more continuous water than open boats, assuming equal skill on the part of the user. Thus an intermediate level kayaker can often negotiate rivers that would require expert skills in an open boat[5].

Decked boats also have disadvantages, the principal one being that the boater may become pinned in the boat and drowned if a capsized boat broaches on rock before he can roll it up or exit from it underwater. Hence decked boat paddlers often stay in groups so that they can assist each other in an emergency, while open boats are often chosen by small parties and people that like to boat alone[6].

On the whole, open boats are more common than decked boats on Vermont rivers, the main exceptions being a few very difficult streams and the water releases on the West River. In part

4. Here and subsequently we use capitals to indicate that we are warning of potentially dangerous or deadly hazards.
5. Since this was written a number of expert boaters have learned to roll open boats, and have used them for descents of Class IV and Class V rapids, including the Grand Canyon of the Colorado.
6. The official word on boating alone, from the American Whitewater Alliance Safety Code, is that it is "not recommended." It is proscribed by many whitewater clubs and is definitely more dangerous that boating in a group. None the less it is practiced by some boaters who enjoy the isolation and the risks, and by some resource geographers as a professional necessity. It should not be attempted by anyone who is not a confident technical boater and familiar with the risks involved.

this is because we have very few streams with the kind of waves or drops that are best suited to closed boats, in part because we do not have the kind of club activity that produces large numbers of kayakers, and in part because the open canoe is still the traditional vehicle for river exploration and adventure, and hence the natural choice of many Vermont boaters.

2.4 The Parts of the River

The difficulty of whitewater boating comes from the presence of a number of interesting and disruptive things in river channels.

Obstacles are just that. Rocks of course, but also stumps, logs, debris dams, bridge footings and piers, ice flows, fences, miscellaneous cables and wires, and even the river banks themselves. A particularly dangerous class of obstacles, called *sweepers* or *strainers*, are one like downed trees and undercut rocks that block the surface of the river but allow the current to continue under the obstacle. The current under them can pull a capsized boat or a swimmer down and it or her or him underwater.

Drops are places where the water cascades over a ledge or rock and drops vertically. Drops of 1-2 feet are essentially always runnable[7], Drops of 3-8 feet can be run in ordinary open boats if the geometry and the waves are right, and drops of up to 25 feet are run by experts in closed boats or specialized open boats, again assuming that the geometry is right. In many cases the problem is not the drop itself, but the presence of holes and mush and rollers directly underneath it.

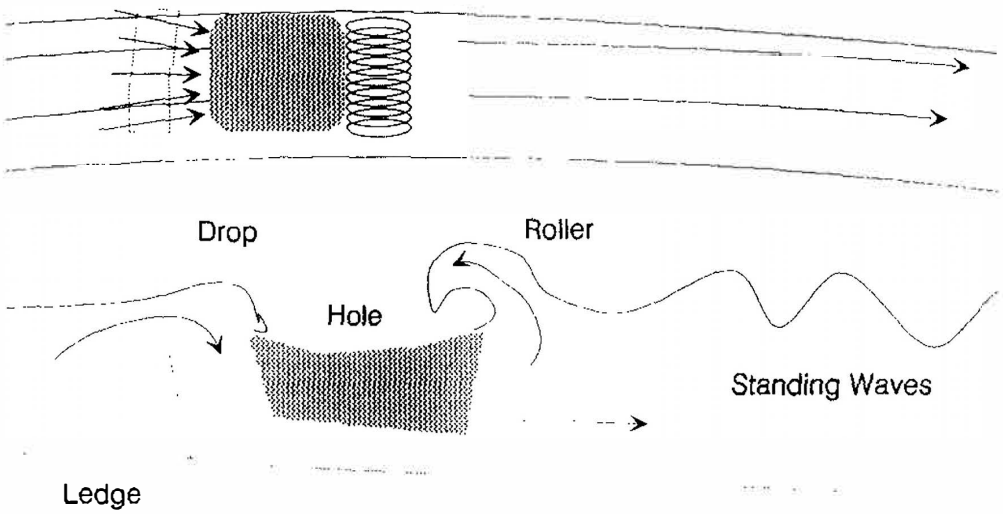


Figure 2.2 A Drop, Hole, and Roller

7. The only exception to this might be where a large river flows over a low-head dam and creates a powerful backwash and a dangerous hole below the dam.

Holes are turbulent places below drops where there is a lot of air and foam (mush) and very little real water. They often end in a roller (see below) and are hard to paddle through because they are below the rest of the river and so once you are in them you have to paddle uphill, against the water flowing into them, to get out. In addition, water in the hole is all mush and there is nothing solid for you to brace your paddle against. Boats sink in them and get swamped. Small holes 6" to 1 foot deep are great places to practice balance and surfing and bracing, and also fun to try to get out of. Large holes 1-2 feet deep are fun for boaters with expert skills, and are pleasant swims on warm days for the rest of us. Holes over 2' deep -- that is, deep enough that what when you are in them the fish in the rest of the river are about at your eye level -- are somewhere between very scary and life-threatening.

Rollers (also called *reversals*) are recirculating waves at the foot of drops or holes where the surface water is moving upstream and the lower water is moving downstream. Essentially they are waves that are breaking upstream. They are difficult to run because the water is moving against you, and hitting them can feel just like hitting a rock. They are also hazardous because you can get caught and trapped in them. Boaters also call the dangerous ones *keepers*, and treat them with great respect.

Standing waves are deepwater waves that occur where water is decelerating below a drop or steep pitch. They are soft waves because they are not breaking, but can be high and steep, and can have rocks hidden within them. They are most troublesome to open boats, and especially to conventional two-man canoes (which have a lot of weight in the ends and don't rise well to waves.) Closed boats usually run them easily.

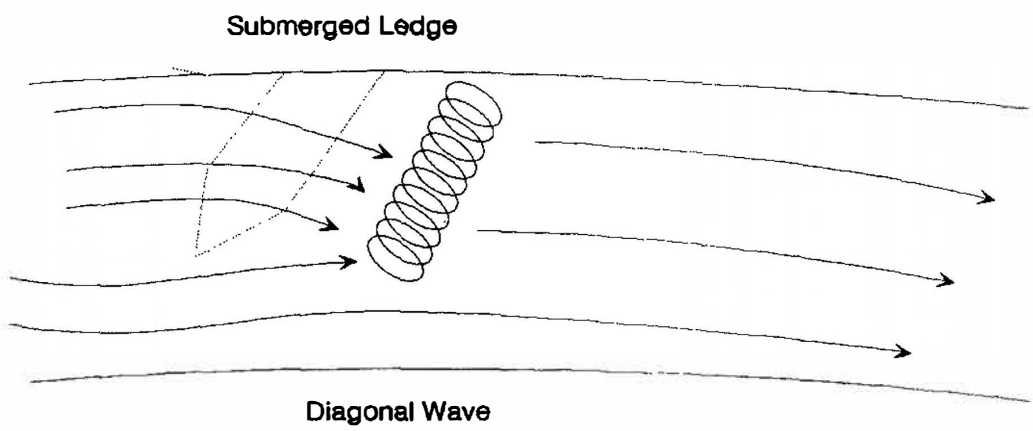


Figure 2.3 Diagonal Waves

Diagonal waves are breaking waves angled across the stream and caused by cross-currents. They tend to swamp boats and roll them over all at once and can be very difficult to run.

2.5 Levels of Paddling Skill

In this report we describe runs as suitable for *beginning, intermediate* and *expert boaters*, and it may help readers if we can define just what it is a boater of a given level can and can't do. This is most easily explained by associating each level of skill with the type of whitewater to which that level of skill is appropriate.

We define *mild whitewater* as water that can be run straight ahead. In mild whitewater all you need to do is to steer the boat, keep it reasonably steady in waves, and dodge the rocks. The paddler is essentially going where the river takes him, and only needs to maneuver enough to go around obstacles. A paddler with a reasonable amount of river or lake experience will be able to negotiate this kind of water on his first try, and so we say that these runs are appropriate for *beginning* whitewater paddlers. NOTE THAT A BEGINNING WHITEWATER PADDLER IS NOT A PERSON BEGINNING CANOEING ALTOGETHER, BUT RATHER SOMEONE WITH A MODERATE AMOUNT OF BOATING EXPERIENCE JUST BEGINNING TO PADDLE WHITEWATER. To begin paddling whitewater a paddler must have good forward strokes, know how to balance the boat, and be able to use the conventional steering strokes in the bow and stern. Anyone beginning canoeing altogether will need a moderate amount of lake or flatwater river experience before beginning whitewater.

More difficult whitewater -- *medium whitewater* -- can not be run straight ahead. Instead the boat must be maneuvered backwards and sidewards to avoid obstacles and waves, and must be spun completely around to go from current to still water (eddies) or vice-versa. The maneuvers involved are called ferries, side-slips, and eddy turns. They involve two important techniques -- the ability to backpaddle and the ability to *brace* against the water by using a stroke that supports much of the paddler's weight -- which are rarely used in flatwater boating. We define an *intermediate boater* as one who understands these maneuvers and the paddle strokes required to execute them, and who is in addition sufficiently riverwise to know when these maneuvers are appropriate, and how difficult or dangerous it will be to accomplish them. In practice this means perhaps one or more seasons of boating, or perhaps 20-60 hours actual time in whitewater.

Difficult whitewater is whitewater in which there is sufficient current to prevent effective backpaddling[8], or in which, by reason of the current speed or obstacles, the boater cannot avoid paddling through large waves, highly turbulent water, or major drops and holes. In these conditions the exact path that the boat takes is often critical, and the boater must be able to maneuver with considerable accuracy and speed. In addition she or he must be able to keep the boat stable in cross-currents and turbulence, and to recover from near-capsizes by bracing or rolling. Technically this means the boater must be able to accelerate the boat across or against high currents, to position the boat precisely among obstacles in turbulent water, and to do rolls or half-rolls -- turn the boat over on its side and snap it back up at will. We define an *expert boater* as a person who

8. Typically boaters can paddle whitewater boats at a maximum speed of 4-6 miles per hour. If the current is larger this they will not be able to hold the boat stationary or move upstream, and their ability to avoid obstacles and position themselves above drops will be correspondingly limited.

can do all of this, and who in consequence who possesses the ability to paddle water near the limits of navigability for his particular craft. Expert paddling usually requires several hundred hours of experience in whitewater, and, in addition to the physical skills just mentioned, implies the ability to interpret highly difficult water and to anticipate the maneuvers necessary to get through it.

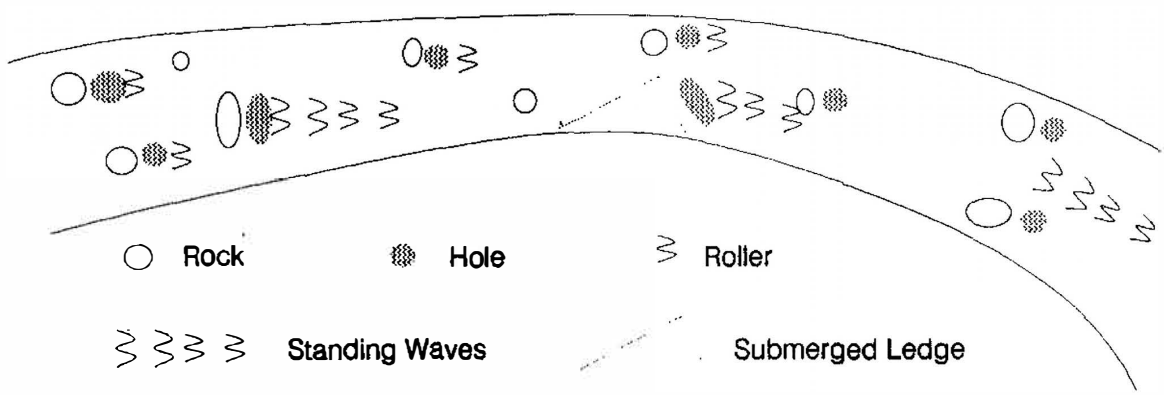


Figure 2.4 Difficult Whitewater

2.6 **River Classifications**

It is vital in any discussion of boating to be able to compare the difficulty of different runs. The range of intensity of whitewater is very large, and this means that it is important for boaters to be able to predict what they will encounter. On the one hand a boater -- even one who has considerable whitewater skills -- will be risking his boat and perhaps his life if he gets into a river too difficult for him. On the other hand he will be unable to employ or develop his skills unless he can find water of sufficient difficulty.

Table 1: International Scale of River Difficulty

Class I: Very Easy.

Moving water with a few riffles and small waves. Few or no obstructions.

Class II: Easy.

Easy rapids with waves up to 3' high and wide clear channels that are obvious without scouting. Some maneuvering is required.

Class III: Intermediate

Rapids with high, irregular waves often capable of swamping an open canoe and narrow passages that require complex maneuvering. May require scouting.

Class IV: Difficult.

8. Typically boaters can paddle whitewater boats at a maximum speed of 4-6 miles per hour. If the current is larger this they will not be able to hold the boat stationary or move upstream, and their ability to avoid obstacles and position themselves above drops will be correspondingly limited.

Long difficult rapids with constricted passages that require precise maneuvering in very turbulent waters. Scouting from shore is often necessary.

Class V: Very Difficult

Extremely difficult, long, and very violent rapids with highly congested routes which nearly always must be scouted from shore. Rescue conditions are difficult and there is significant danger to life.

Class VI: Extraordinarily Difficult.

Difficulties of Class V carried to the extreme limits of navigability. Nearly impossible and very dangerous. For experts only, after study and with all precautions.

In this report we use the American Whitewater Alliance's system for classifying whitewater. An official version of the classification is given in Table 2-1 and a practical translation of the classification in terms of equipment and skill in Table 2-2 at the end of this chapter.

A narrative summary of the tables might go like this.

Class I water has more foam than flatwater and makes for attractive boating, but requires no special skills and is not interesting in itself to whitewater boaters.

Class II is a lot of fun and good practice for everyone, can often be run without specialized equipment and technique, and is the highest grade that many occasional whitewater boaters like to run. It requires good river-sense but not a high level of boat-handling skills, and does not challenge the serious whitewater enthusiast.

Class III is the bread and butter of the serious whitewater boater. Class III water is big enough to require special boats and gear and precise boat-handling, but is rarely really scary or life-threatening. Class III water begins at about the point where you realize that it will be easy to swamp an open boat, and extends to what were, at least 15 years ago, considered the limits for open boats. Class III water commonly typically has substantial drops and big waves that you can't go around, and often has passages where you must choose and follow a route exactly, and where a mistake of a few feet can turn you over. The water is difficult enough that it is a challenge but it is usually not extremely dangerous. Class III rapids are enjoyed by many people who are skillful boaters but not experts or professionals.

Class IV and *Class V* rapids are bigger yet. The water looks violent, even from the shore, and is often quite dangerous. There are major drops, deep holes, very confused cross-currents and irregular waves, and often recirculating waves that can trap a boat or paddler. Possibilities for safe rescue are often limited, and there are often few places where a boat can escape from the current. Rapids of this level of difficulty are both technically demanding and potentially very dangerous. Boaters who run Class IV and V water are always taking risks. Most boaters who regularly do Class IV or Class V water are in some sense professionals: experts with a number of years of experience, instructors and whitewater guides, racers, and so on.

* * *

Anyone using river classifications should be aware of several things.

First,the difficulty of many rivers changes dramatically with the water level, and so a river that is Class II at medium water may be Class III or higher in flood[9].

Second, the degrees of difficulty correspond not only to different levels but different kinds of technique. Thus the experienced Class II boater running a Class III stream for the first time will discover not only that he is not good enough at doing things, but that doesn't even know that he should be doing.

Third the ratings are subjective. They differ from one guidebook to another, and from one region to another. and with the recent experiences, adventurousness, and sometimes the emotional needs of the person doing the classifying.

Fourth, there are more types of water than there are classes in the rating system. Two streams, even though they have the same classification, may feel different and require different skills.

And last: in rating whitewater you must consider not only the difficulty of the river, but the circumstances under which it will be run and the potential seriousness of an accident. The American Whitewater Alliance recommends that any run where the water temperature is below 40 or where rescue and evacuation is difficult be rated one class higher than normal. We find this a good rule of thumb. Much of our whitewater boating takes place right after snowmelt, and we particularly stress the dangers involved in boating in cold water.

Table 2: Relations Between the River Difficulty & Skills & Equipment Required

CLASS	LEVEL OF SKILL REQUIRED	EQUIPMENT REQUIRED	COMMENTS
Class I	Flatwater boat-handling	Any boat	Not interesting for whitewater boaters
Low Class II	Easy maneuvering	Life jackets mandatory. Helmets in closed boats. Special whitewater boats not necessary.	Can be run by boaters without special whitewater training.
High II	Basic whitewater skills (sideslips, ferries, eddy turns) required.	Boats must be designed for whitewater, with adequate strength and extra flotation.	Good solid water but not scary. Scouting usually not required.
Class III	Strong open boat handling with good bracing	" "	Often requires scouting. Often threatening to boats but rarely to life. Experts consider it good relaxing fun.

9. The amount that a rapid increases -- or sometimes decreases -- in difficulty as the river level increases depends on the slope of the river and the kind of rapid. This is treated in more detail in Chapter 4.

	strokes and ferries required. A good roll is desirable for closed boats.		
Class IV	Expert open or closed boat skills. Rolls mandatory in closed boats.	Mostly closed boats, or specialized open canoes with full flotation.	Scary or worse, even for experts. Scouting mandatory.
Class V	Expert to elite boat-handling skills required: strong rolls, great power & speed.	" " Shore team equipped for rescue is often used.	Always dangerous to life. Needs many pre-cautions.
Class VI.	Limits of what can be run: an uncertain category, rarely used in New England.		

2.7 River Levels

Since the difficulty of a rapid depends on the water level, we need some way of specifying the water level to which a particular river description applies. The best way of doing this is by giving actual flows, and this is the method we have used when gauge data was available. The next best way is by the height of the river in relation to some reference point. This is the system that many boaters actually use on familiar rivers, but it depends on a personal set of reference points, and so is not very useful for someone visiting a strange river.

In this report we often describe river levels in an approximate way based on the height of the river with respect to the channel bars and top of the banks. This way of specifying levels, while not capable of fine distinctions, is independent of particular reference points, and can be used by someone unfamiliar with the landmarks along a particular river. Our system is a modification of the one used in the AMC guides, and goes as follows:

At *low water*, which is the typical level for much of the year, the river has a shoreline within its channel, and extensive bars are exposed. Most Class II and Class III rapids are not runnable at this level.

At *medium water*, typical of average spring flows and rainy periods, the river covers many bars and reaches the channel walls on both sides. This is the level at which most Class II and Class III rapids become runnable.

At *high water*[10] the river is halfway or more up the banks. The channel bars are all flooded, and the willow and alder thickets on the tops of bars have water a foot or more above the bases of the trees. At this level the smallest streams first become runnable, and many other streams have increased in difficulty by at least one class from medium water. Some Class II rapids are 'drowned' and become quickwater at this level, while others rise to Class III.

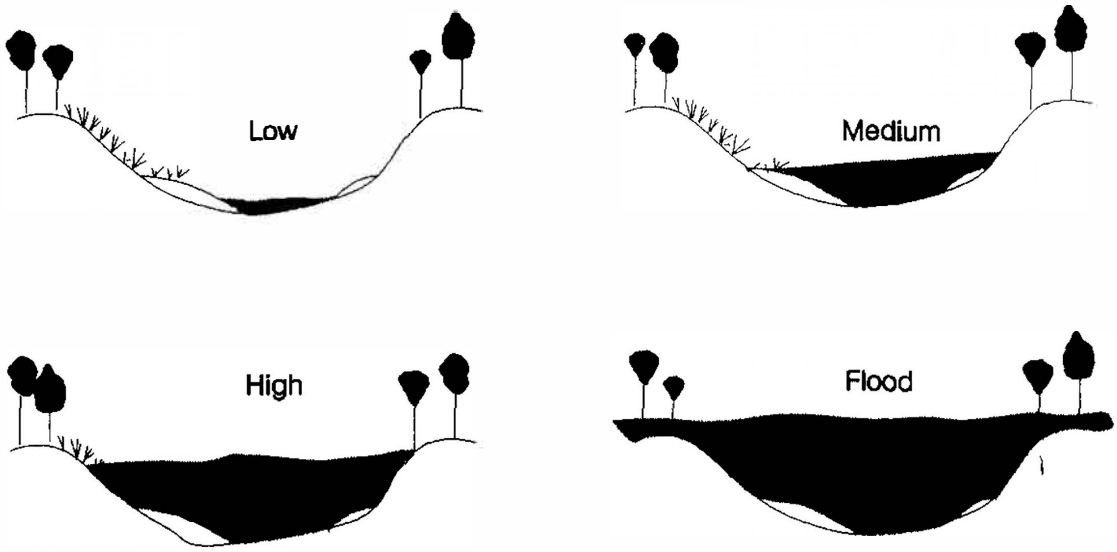


Figure 2.5 River Levels

At *flood* (which is equivalent to what the hydrologist calls bankfull) the river is just at the top of the banks, and flooding low areas. At this level many rivers, even non-whitewater rivers, become dangerous. The current speeds are typically high[11], eddies are widely separated or absent altogether, and fallen trees, debris dams, and flooded thickets can be common. The water is often turbid, making it hard to see snags or rocks. Many whitewater rivers are extremely dangerous at this level, and can only be run by experts.

2.8 Safety

Because the recreational use of white water involves unavoidable risks, we think it important that the reader be informed about these risks, and about what can be done to minimize them.

10. Our highwater is lower than that in the AMC Guide; their highwater equals our flood.
11. Flatwater rivers can reach current speeds of 4-8mph in flood. They may not have rapids but can still be quite dangerous because at these speeds only very strong paddlers can backpaddle fast enough to avoid obstacles.

Whitewater boating is intrinsically dangerous. So is flying, skin diving, or for that matter driving a car at 40 miles per hour. As in those activities the fact that it is dangerous does not imply that it is unreasonably risky, or that all the participants are daredevils who are primarily there because they enjoy the risks.

The comparison with flying seems particularly appropriate. In both activities the surroundings -- turbulent water in one case and the sky in the other -- are inhospitable and potentially life-threatening. In both activities you have to take precautions to protect yourself against the manageable dangers, and use foresight and judgment to avoid the unmanageable ones. If you follow the precautions and judge the risks intelligently -- which is to say keep your ratings up to date, fly only well-maintained aircraft, pick reasonable weather, and do your preflight checks religiously -- you are engaging in a disciplined and somewhat adventurous activity but not an unreasonably dangerous one. If you ignore the precautions -- fly an unreliable aircraft through a snowstorm at night two years after your instrument rating expired -- you are trying to kill yourself.

The point of the analogy is that whitewater boating is a technical activity, and in any technical activity your safety depends on an number of things. First, and paramount, comes your ability to recognize danger and take precautions against it. Second, and only possible once you have learned to recognize dangerous, comes your steadfast refusal to do things for which you are not trained or equipped. Third is the adequacy of your equipment. And last is your technical skill.

Note that understanding and precautions comes before prudence, equipment, or technique. You can't be prudent until you can recognize danger. if you do not understand the dangers and have not taken the right precautions, neither prudence, equipment, nor skill will save you.

The precautions and rules that whitewater boaters use may be divided into those concerned with preventing injuries and saving lives after a boat capsizes, and those concerned with preventing capsizing in the first place. The first group are considered mandatory for everyone. The second group is more a matter of choice, it being up to the individual boater to decide whether he is willing to risk a spill and possibly lose his boat or not.

With respect to personal injuries the principal facts are as follows.

The main dangers to life in whitewater are cold, turbulence and entrapment. The most serious accidents are drownings caused by hypothermia or violent water, and head injuries caused by rocks. Shoulder dislocations occur moderately frequently, but otherwise fractures are rare. Lacerations and contusions are common. Crushing injuries and internal injuries can occur, but are rare.

The use of wetsuits, life jackets, and helmets is absolutely essential. With them it is possible avoid serious injury in most boating situations. Without them your life may be in danger, even in relatively mild water. The standard practice is to use life jackets in all whitewater situations, wet suits whenever the water temperature is below 50 F, and helmets for all closed boat paddling, and in open boats in Class III or higher rapids.

With these precautions the possibility of traumatic injury is reduced, and you have a good chance of being able to swim through most rapids, up to and through Class III. The principal remaining danger is that of being trapped (which, unless assistance is available, means being drowned) in an overturned boat.

Paddlers get trapped either when a boat is held against an obstruction by the current, or when they overturn in a hole what has a recirculating wave. To minimize this danger the following precautions are mandatory:

- All boaters must have had experience exiting from an overturned boat in whitewater.

- Any unknown river must be carefully scouted for strainers, undercut rocks and banks, and recirculating waves.

- Great attention must be paid to the stowage of ropes, and to any other gear or fittings that might prevent your escaping an overturned boat.

- All decked boats must be sufficiently strong that they will not collapse and pin the boater in them if they broach on a rock.

- Decked boats paddling difficult water must generally go in groups, and be equipped with rescue gear and trained in river rescue.

- Parties trying difficult water where the possibility of self rescue is limited must station rescuers with throw ropes on shore before running the rapid.

The success of all these precautions depends on the assumption that a swimmer will be able to survive if he gets free of his boat. In many situations - long rapids, drops with recirculating waves, tight gorges - this is not so. Here the rule is simple: only experts go into these situations, and then with a rescue party standing by. This implies that other boaters must learn to recognize water in which even a properly equipped swimmer is in danger, and avoid running it.

A final note on training and preparation. Much depends on the boater's ability to remain calm and do the right things after being thrown suddenly into the water. For this there is no substitute for practice, and we recommend that boaters practice emergency techniques and self-rescue under actual whitewater conditions. The shock of a sudden dunking in ice-cold turbulent water is great, and unless you have encountered it before it is all too easy to panic and do the wrong thing.

* * *

The above rules are all concerned with the prevention of drowning and serious injury after an accident occurs. Most boaters wish to go farther than this and avoid any accidents that threaten their boats, or force them to swim in cold or violent water. This kind of safety is mostly achieved by good preparation, equipment, and technique -- which is to say by the development of a whole

complex of skills, which are treated at length in standard texts on boating. As mentioned above, this level of safety involves considerable personal choice; most boaters want to increase their skills, and this frequently involves some risk to equipment, and always involves the possibility of a swim.

Even allowing for matters of personal choice, it is generally true that the most prudent boaters (whom we define as one who does not enjoy even brief swims in 35 degree water, and who can't afford to buy a new boat each weekend), follow the main tenants of the safety code of the American Whitewater Alliance, which are to do the following:

-Use a boat designed for whitewater, with extra flotation to displace as much water as possible after a capsize or swamping, and fitted with bow and stern lines or, in the case of kayaks, with grab loops.

-Carry bailers, spare paddles, throw ropes, and carabiners to assist in rescues.

-Secure equipment carefully in the boat.

-Test all new equipment before using it in serious water.

-Secure themselves with knee pads or straps.

-Practice paddling skills in flatwater and mild whitewater.

-Scout rivers for particularly difficult or dangerous conditions.

-Be exceedingly wary of high water levels.

-Be familiar with rescue techniques and practice swimming in whitewater.

-Be very careful of any rapid in which it will be difficult to stop the boat or reach a safe shore.

2.9 Recent Boating Accidents

Prior to the 1987 revision of this report the Vermont Department of Public Safety made available to us their accident reports on canoe accidents from 1975 to 1986. The figures provide a strong, and in many ways a very sad, confirmation of our assertion that proper preparation and equipment reduces the risk in whitewater boating to an acceptable minimum.

In the 16 year period for which we have figures there were 17 fatal canoeing accidents, resulting in 18 fatalities. The fatalities break down like this:

- Five persons, most of whom could not swim, drowned after capsizing in calm water.

- One person was killed from injuries after being run down by a motor boat.

- Two persons drowned in capsizes after they had been drinking heavily.

- One person drowned after the capsize of an overloaded boat in a river.

- One person died of hypothermia after a capsize in May in Lake Champlain.

- Two more persons died in Lake Champlain after capsizing in rough water.

- One person launched a canoe directly above a dam and was swept into the spillway and drowned..

- One died when a boat was launched in fast water directly above a bridge which was partially blocked by brush. The boat capsized and was pinned against the bridge abutment drowning one of the two paddlers.

-Four persons died (in three separate accidents) while running Class II whitewater in open boats. One of these accidents was in the winter and hypothermia was probably involved.

Fifteen of the victims were boys or men, three were women. No one was over 30. Most were reported as being able to swim, but as having little boating experience.

Note that none of the 18 deaths involved experienced boaters in serious whitewater. Only four involved whitewater at all, and all of these were inexperienced boaters who failed to take the most elementary precautions. And, most critically, none of the the 18 people were wearing life jackets, and none of the three victims of hypothermia were wearing wet suits. In three cases -- the motorboat collision, the pinning against the bridge, and the accident at the dam spillway, protective gear might or might not have helped. In the other fifteen cases it could easily have prevented a fatal accident.

The pattern of inexperience and improvidence in these accidents is very similar to that of a number of the cases reported by Charles Walbridge.[12] This suggests three tentative conclusions. The first is that properly equipped whitewater boaters in water of average difficulty, while definitely at risk, have not been involved in very many accidents.[13] The second is that bad judgment, bad seamanship, and simple inexperience are involved in a majority of fatal accidents. And third is that wearing lifejackets would probably prevent at least half of the fatalities.

12. Charles Walbridge, 1986, *American Canoe Association River Safety Report 1982-1985*, ACA, Lorton, VA
13. Since there was written there was a fatality on the lower West River in which a kayack paddler was trapped and drowned Class II water. This is unfortunate, but doesn't alter the general conclusions.

2.10 Challenges & Satisfactions

Having dwelt, necessarily, on risks and accidents, we need to balance the scales by saying a little about unique joys of whitewater boating. Our purpose is to explain why we think the sport an important one, and to invite readers who are not boaters to try it.

All sports require things of the participant. Physically whitewater requires energy and quickness, and both sustained and explosive strength. Like nordic skiing or bicycling it is a whole-body sport, intensely muscular, very rhythmic, and demanding sensitive balance and timing. Mentally it requires alertness, sustained concentration, and, interestingly enough, a kind of calm and detachment.

It is different from many other sports in that it requires an unusual sort of spatial insight. The boater is in spatially complex situation, where boat, paddle, and water are all moving in different ways, and it is necessary to continuously evaluate this, and to balance boat against paddle, and both against the water.[14] And while doing this you also have to be looking downstream and marking obstacles and choosing your line. The mental demands often exceed the physical. Boaters will often finish a difficult run and still be physically fairly fresh, but feel that they have used their powers of attention and concentration to the utmost.

All sports give satisfactions, often in proportion to the demands they make. The boater has a number of them. First is the pleasure of the liveliness of the boat and the water. Boating of all sorts is intrinsically gay, and whitewater, which uses tiny boats in the midst of big waves, perhaps the gayest of all. Then the pleasure of communication. Boating takes place in an environment of great power and complexity, and the boater feels it and touches it and moves about in it; when he is expert and observing and philosophic enough, he eventually comes to understand the power and be able use it to his advantage. And finally there is of course adventure, which is to say risks undertaken with foresight. The boater has to plan, and calculate the water and the danger, and eventually commit himself to the rapid and see what happens.

A important part of any sport is the nature of the world it lets us enter. In boating we use natural places -- often ones of great beauty -- but with the interesting feature that the places we go are places that are inaccessible to us without our boats. In this whitewater boating has much in common with flying and climbing. All three give us access to places that are close at hand, but which we normally cannot enter. This makes boating very attractive to many of us whose pleasure or work involves travel and observation, because when we are in the midst of rivers we can see and understand things that we cannot encounter elsewhere.

14. Boaters will understand this, but other readers may need an explanation. In many whitewater situations you are leaning far out of your boat and using the force of the water against the paddle blade to generate lift which supports and stabilizes you. You look for contrary forces, so that you can find a current that pulls left and clockwise on your paddle while the boat is pushing counter-clockwise and right. Your body is the bridge between the two, and at any moment part of your weight rests on the paddle, and part on the boat. Misjudge the combination of forces, or let any one of them change too suddenly and you can find yourself upside down looking at fish before you even know that anything was wrong.

* * *

Our purpose in presenting this brief description of the boater's discipline and pleasures has been twofold. First, we wish to counter a widespread misapprehension that the main emotional satisfaction of boating comes from the defying of physical danger, and that the main tools for doing this are a combination of raw strength and high-tech equipment. This is of course not true. Most boaters seek to minimize personal danger in order to become free to enjoy the other pleasures of the sport. And strength and equipment, while essential, are only two tools among many.

Second, we would like to substitute for the image of boating as a sport dominated by strength and hazard one that we think is more truthful. The boating we have encountered while preparing this report is a sport with a varied group of participants which requires both intellectual and physical discipline, and gives in return a variety of excitements and satisfactions, not the least of which is the opportunity to be in and learn from a unique and extremely powerful natural environment.

And we might conclude by observing that for some of its participants at least, boating is also important because it is ancient, or more correctly because it is timeless. For all our improvements in equipment and technique, the boater in heavy whitewater still confronts the same threats and challenges that the neolithic paddlers did, and is no less dependent on his own ability and understanding of the river than they were.

Speaking personally for a moment it seems to us that this ancientness is a very powerful part of boating. It is a way of dissociating ourselves from the modern assumptions of human invincibility and the efficacy of material power which are implicit in much of our culture and hence much of our sport. In our opinion this dissociation is of great value; it allows us some remission from the man-made world, and gives us the opportunity to experience fears and awarenesses which people have, perhaps since the beginning, had to expose themselves to natural beauty and natural danger in order to learn.

Map 1: Streams Surveyed in This report

CHAPTER 3. VERMONT WHITE WATER RUNS

In this chapter we give a general picture of Vermont whitewater. We summarize and classify the streams currently thought to have boatable whitewater and try to assess the importance of individual streams. We also discuss the likelihood of there being unknown whitewater streams, and present a provisional list of currently unknown streams which might contain boatable whitewater.

As elsewhere in the main body of this report, we confine ourselves to whitewater segments of two miles or longer. See Appendix 1 for a brief summary of short or isolated rapids.

3.1 Geography of Recreational Streams

To get a picture of the distribution and nature of Vermont whitewater it is convenient to divide the whitewater segments by the size of the rivers, and by whether the channel is bouldery or alluvial.

The *large rivers* (Otter, Winooski, Lamoille, Connecticut, etc.) are streams with drainage areas of over 700 sq. km. and widths of over 100'. For the most part they have slopes of less than 10'/mile, and bottoms without large rocks.[1] They have whitewater only where they cross bands of resistant bedrock which create ledges and locally steeper slopes, or where the river has been confined to a gorge. Most such places are short, but occasionally there are several miles of rapids. Many of the rapids on big streams have been dammed, and at present only two substantial rapids occur on large rivers in Vermont. One is on the Lamoille the other one on the Missisquoi. Both are very valuable. They are wider and so offer more alternate routes than many of our other rapids, and are extremely powerful and exciting at high water, and in addition are often runnable in summer, late fall, and late winter, when there is no other boatable whitewater in the state.

* * *

Medium-large rivers have watersheds between 300 and 700 sq. km., and average widths between 50 and 100 feet. Streams in this size range can vary considerably in character. One group of them (the Battenkill, Williams, lower West, and lower White) run in broad alluvial valleys on fairly soft bedrock, and have average slopes of 10-20' per mile. These only produce rapids over ledges or at sharp bends, or where the river encounters locally harder rocks. Because they have only scattered (and for the most part mild) whitewater they are often excellent rivers for general touring. Big broad valleys retain a lot of groundwater, and these rivers stay higher much longer than the smaller streams in rockier situations, and so are more useful in the late spring and summer.

A second group of medium-large rivers have segments that are confined by hard rocks to fairly narrow and steep-walled valleys, usually with rocky banks and comparatively little alluvium. They meander less and develop steeper slopes than they might in a larger valley. Typically these streams have a *re-steepened* longitudinal profile which, instead of being uniformly concave like

1. The mixed metric and English units, here and elsewhere, are a regrettable consequence of having topographic maps and river guidebooks with English units, and hydrological data in metric units.

most rivers, has an inflection point at which it becomes conves and then concave again (See Chapter 4, Figure 21.).

Re-steepened profiles are unusual. As we will see in the next chapter, they are critically important to whitewater boating, because they allow streams to have more intense water than they would normally be entitled to.

Good examples of this sort of stream are the West River in Jamaica, the Black River below Cavendish, and the White River below Stockbridge. All of these occur in similar geological situations: hard, highly metamorphosed, garnet-bearing schists west of the axis of Green Mountain Anticline. In each case the volume of water is typical of a medium-sized stream but the slope is between 20- 50'/mile, typical of smaller streams. This situation -- a small river slope with a medium river volume -- creates excellent recreational whitewater. Geologically these streams are similar to some of the famous Adirondack and White Mountain streams which drain large intermontane lowlands but then descend steeply through narrow granitic valleys.

Re-steepened streams in this size range are not common in Vermont, but the ones we have are very important for recreational boating. Typically they have broad rapids with big rocks and well-defined eddies. Boaters like this kind of a stream because they have plenty of space to maneuver in. In such streams the intensity of the rapids depends more on the depth and volume of the water than it does on the speed of the current, and so you can have the pleasure of big waves and holes without the risk of dangerously fast currents.

All of our re-steepened streams are on the eastern slope of the Green Mountains, probably because the rocks on this side of the mountains are soft enough to have allowed streams to cut headwards (toward the west) a considerable distance, and so the east-flowing streams have larger watersheds and tend to be less steep than the west-flowing streams. The streams draining the western slope of the mountains are mostly shorter and have smaller drainage basins; they descend through a region of extremely hard quartzites and gneisses where the slopes are steep and there is little or no alluvium, and so tend to be smaller, steeper, and have shorter seasons than the eastern streams.

* * *

The bulk of Vermont whitewater is on somewhat smaller streams than those discussed above. We call streams with watersheds between 100 and 200 sq. km. *medium-sized*, and distinguish them from the large and medium-large streams in that they are commonly at higher altitudes and often have steeper slopes. The ones that are important for whitewater occur either in upland valleys or on steep slopes where a stream descends from a plateau to join a larger river. They are typically 25-50' wide, and vary widely in their slope and in the amount of alluvium in their valleys.

One distinctive group of medium-sized streams comprises the *west-slope streams* of the southern and central Green Mountains. These streams typically are very steep, have small watersheds, and devote much of their time to making large round boulders of quartzite and gneiss and then pushing them downstream. A spectacular example of a west-slope stream is the Big Branch in Mt.

Tabor. It runs in a deep ravine, which is one of the rockiest and most handsome places we know in the state, and is a formidable, boulder-tossing stream with a slope on the order of 400'/mile. It is presently regards as much too steep to be paddlable, and, so far as I know, has never been descended.

Sadly, very few of the west-slope streams are runnable. In the first place, their watersheds are small, owing to most of the mountain drainage having been captured by the headwards erosion of the eastern slope streams. In the second place, at the base of the western scarp of the Green Mountains there is an abrupt transition from quartzite to dolomite, and a corresponding change in the landscape from very steep to almost flat. Dolomite -- which is a great rocks for swamps and cedar and rare plants -- is totally worthless for whitewater. The streams come down the quartzite with great energy and promise, and then abruptly subside and become lowland streams with little or no usable whitewater in between.

The New Haven River is the one important exception to this pattern. It originates below Lincoln Gap, and then descends in an area where the west-slope quartzite band is wider, and the transition between mountain scarp and valley correspondingly less abrupt. The runnable portion of the New Haven begins on a mountainside shelf near Lincoln. There are continuous rapids for the next 11 miles, adding up to a total descent of some 850 feet, with maximum slopes of about 100'/mile. The upper segments are Class II, the middle gorge a formidable Class IV-V, and the lower segments a pushy and serious Class III, with at least one Class IV drop. So far as we know this is the longest continuous whitewater run in the state, and also one of the most difficult.

* * *

Elsewhere in the state the rocky upland streams of medium size are a more manageable and a very interesting lot. They tend to occur in narrow valleys or ravines with comparatively little alluvium, and to have lots of boulders and sometimes small ledges in their channels. Only rarely do they have major ledges or falls. Many of them have a fairly short runnable section, bounded above by the point where they are too small or steep to run, and below by the point where they cease to have sufficient slope and the rapids become intermittent.

These runnable stretches, commonly 4-8 miles long and with slopes from 30-60'/mile, afford what we might call the classic Vermont whitewater run: a pretty stream, often in the woods or in a sparsely settled valley, with technical Class II-III water with lots of turns and obstacles and maneuvering. Such streams commonly have more or less continuous rapids without dangerous ledges or gorges. They are sporty and delightful at medium water and very fast, technical and demanding at high water.

Streams of this sort occur throughout the state. The upper Lamoille, Saxtons, Winhall, and Green Rivers are among the best known, and are heavily used by both local and visiting boaters. The East and West Branches of the Deerfield, the Waits, the Clyde, the Moose, and the West Branch of the Ompompanoosuc are equally fine, but are less well known and much more rarely used by visitors. All are treasures. They rarely offer long runs or extremely heavy water, but they are great streams, full of excitement and pleasure, and perfect examples of how nice a small river can be.

These streams characteristically occur fairly high in the watersheds and hence have a short and early season, though some (like the Moose) have upland swamps in their watersheds which prolong the season and others come up well after rains. Consequently they are used mostly by fairly dedicated cold-water paddlers, and this may be the reason that they are not as generally known as some of the larger streams. Also there seem to be more early-season streams than early-season paddlers, and a number of streams of this type receive only occasional use, mostly from nearby boaters. An example is the West Branch of the Deerfield, a fine upland Class II stream that gets loyal use from local boaters but has never been put in a published guide and so far as we know gets no use from visitors at all.

A few of the medium-sized streams have slopes in the 60-100'/mile range. Such streams are invariably mountain streams with very difficult technical whitewater. The only ones currently used are a group of bouldery streams, analogous to the *west-slope streams* but a little less steep, in southeastern Vermont. We call them *mountain Class IV's*; they are very important to boaters because they provide some of the best technical whitewater in the state. They tend to be shallow and very fast, and to have very short seasons. Because of their steepness their intensity varies greatly with their water level, and it is hard to catch them at a runnable level. Too little water and they are impossibly scratchy, and a little too much water and they are dangerously fast.

The last group of medium-sized streams, the *medium-sized alluvial streams* are a mixed lot. They are too small and flat to have much whitewater, but when they have enough slope and water they can be quite exciting. Typically they are fast but not rocky, and are best at very high water. When they are up they offer a unique sort of boating: eye-opening currents, sudden bends with undercut banks and a lot of waves, fallen trees, and narrow channels with brush and stumps and barbed-wire fences. Some of them have unique specialty rapids -- old mill-dam sluices, curiously placed bridge abutments, or, in one locally famous instance, a Class III drop over two refrigerators followed by a dangerous ferry above a '65 Plymouth. We call such streams -- respectfully -- *cow pasture steeplechases*. They are not major streams by regional standards but they get a surprising amount of local use, and many of the boaters we interviewed had one or two of these streams that they were fond of.

* * *

The last category of streams includes the *small streams* with watersheds under 100 sq. km. Most of these are headwaters streams with channels under 25' wide and gradients above 50'/mile. Such streams occur in all the mountain watersheds in the state. Most of them are too small to run, or so steep that they have more rocks than water in them and are, as the boaters say, too bony.

Small headwaters streams of this sort generally become wide and (barely) deep enough to boat when they have about 50 sq. km. of drainage area. As explained in the next chapter, many of our small mountain streams leave their primary valley and enter the valley of a larger stream before they acquire this much drainage area. When this happens their slope invariably decreases, and they generally cease to be whitewater streams. This is why so many nice small streams that promise well near their headwaters fail to develop good boatable whitewater further down.

Two small streams, the Hancock Branch in the White River drainage and the New Haven in West Lincoln, are supposed to be good whitewater runs. Both are small steep streams with slopes in the 50-65'/mile range and watersheds of between 50 and 75 sq. km. They are reported to have Class II or low Class III water, and to be attractive runs. Our scouting suggests that they are fast and tight but not as pushy and dangerous as larger streams with similar slopes.

We call these streams the *tiny Class II's*. We believe that there are a number of them in the state that are not currently used, and offer a list of some that might be potential whitewater runs in the last section of this chapter.

* * *

Finally there is one stream that, sadly, is the only one of its kind in Vermont. This is the lower Mad River, from Moretown to the Winooski. It is a stream with a slope of about 30'/mile in which much of the whitewater is concentrated in short isolated gorges and rocky drops of Class III-IV difficulty. In this respect it is like some of the great streams of the Adirondacks and the southern Appalachians. Streams of this type are very important for boaters because they have bigger waves and more complicated drops than the bouldery streams we have called mountain Class IV's, and so provide more technical challenges to the advanced boater.

3.2 General Characteristics of Vermont Whitewater

While Vermont streams differ greatly among themselves, in this section we overlook these differences and offer three generalizations.

First, most Vermont whitewater is on medium-sized streams that are from 25-50' wide and have watersheds of 100-200 sq. km. We have only two extended rapids, both fairly short, on major rivers, and only one intense rapid -- the famous upper West River Run below the Ball Mountain Dam -- on a medium- sized stream.

Second, Vermont whitewater runs are most commonly bouldery streams with fairly uniform gradients. With the exception of the lower Mad River and a few of the experts-only gorge runs, most of our whitewater does not involve chutes, very narrow passages, cascades, or large drops. This means that while we do not have much of the dramatic, vertically complex Class III-IV water loved by advanced closed-boat paddlers, we do have much fine open-boat whitewater.

And third, Vermont whitewater runs occur in an enormous variety of settings. These include deep forests, mountain ravines and gorges, small upland valleys, two cedar swamps, a number of broad intervales, and even in the middle of several villages and one city. Many are in places of great beauty and individuality. This is especially true of some of the large rivers with open valleys and long views such as the White, the West near Townshend, and the northern Connecticut. But it is also true of a number of the smaller rivers with more enclosed landscapes. The East Branch of the

Deerfield, for example, is an exceptionally beautiful river, even though you do not see past the shores and surrounding forests.

* * *

What do these generalizations mean to boaters?

First, some drawbacks. In comparison with the most celebrated runs elsewhere, Vermont streams tend to be somewhat smaller, shorter, less ledgy and less vertically complex. They also tend to have shorter seasons. They do not for the most part offer highly challenging individual rapids. The Mad and the West are are the only Vermont streams directly comparable to some of the nationally famous streams of northeastern New England or the southern Appalachians. Vermont has few opportunities for running complex rapids on large rivers where there are many possible routes. It also has essentially no summer whitewater, and no opportunities for extended whitewater tours of several days or more.

Second, some advantages. We probably have more good bouldery streams than any other eastern state. This is because the outcrops of Precambrian quartzite and gneiss which make the roundest and most formidable boulders are rare elsewhere in the northeast. These streams are often tight, very fast, and highly technical. They offer steep continuous whitewater in which you never slow down from the time you put in till the time you take out. And they are extremely exciting and taxing: once you are used to their demands the more leisurely alternation of rapids and slower segments you find on some of the big famous streams elsewhere seems comparatively tame.

To some extent, the limitations of Vermont streams make for interesting challenges. Because our streams have comparatively few violent drops, open boats are at less of a disadvantage in our high-level streams than they are elsewhere. As a result we have a number of paddlers who specialize in open canoes, and can take them almost anywhere in the state that a kayak can go.

Likewise our reliance on natural runoff, while certainly restricting our boating season, in many ways expands our boating horizons. Vermont boaters, and for that matter rural New England boaters in general, are forced to paddle whenever and wherever they can, and so explore more streams and probably paddle more at odd times of year than boaters who depend on the big streams and planned water releases. This, at least to some of us, is a good thing. It means that the sport is more individual and serendipitous, and that we, as boaters, are forced to be both tolerant and adventurous.

Map 2: Touring Streams With Mild (Class I) or Short Isolated Rapids. A number of other streams might be mapped here as well depending on what is considered a mild rapid.

3.3 Summary of Whitewater Runs by Degree of Difficulty

The following table summarizes our current information on the features and importance of the whitewater segments included in this report. The rating system, which is similar to that used in the Vermont Waterfall and Gorges Study (Jenkins & Zika 1983), is explained in the next section.

Table 3: Summary of Vermont Rivers Segment Included in this Report

	Length (miles)	Slope ft./mile	Ave. Class	Max. Class	Rating
Quickwater Rivers with Mild or Isolated Rapids					
Battenkill	20	10'/m.	0-I	II	high
Winooski (above Montpelier)	20	'/m.	0-I	II	
Mad (Irasville-Moretown)	8	20'/m.	I	II	high
Lamoille (middle section)	20	'/m.	0-I	IV	high
Missisquoi (East Richford-Richford)	6	15'/m	0-I	III	high
Connecticut (upper section)	20	'/m.	0-I	II	high
Ottauquechee (Bridgewater to Woodstock)	8	20'/m	0-I	II	
White (Gaysville to Hartford)	30	10'/m.	0-I	III	high
West (Townshend to Newfane)	18	10'/m.	0-I	II	high
North Branch of Deerfield	7	20-30'/m.	I	II	
Small Class II Streams, Watersheds ca. 100 Sq. Km. or Less					
Clarendon	4	50-20'/m.	II	III	
Wild Branch of Lamoille	4	50'/m.	II	II-III	high
Hancock Branch of White	3	65'/m.	II	III	
First Branch of White	3	40'/m.	I-II	III	
West Branch Ompompanoosuc (above Strafford)	3	20'/m.	I-II	II	
Williams (Gassets to Chester)	5	25'/m.	I-II	II	
West River (above Londonderry)	7	40-20'/m.	I-II	?III	
East Branch of Deerfield	6	40'/m.	II	III	high
Green River	8	30'/m.	II	III	high
Medium-sized Class II Streams, Watersheds 100-400 sq. km					
Lewis Creek	3	25'/m.	II	II	
Huntington	10	30'/m.	I-II	II-III	high
Mad (above Irasville)	4	30'/m.	I-II	II	high
Clyde	4	25'/m.	II	III	high
East Branch of Passumpsic	8	25'/m.	I-II	III	
Black River (Irasburg)	5	20-30'/m.	I-II	II	
Waits	9	50-30'/m.	I-II	III	high
Ompompanoosuc	2.5	25'/m.	II	III	

Map 3: Class II Whitewater Segments

Ottauquechee (West Bridgewater to Bridgewater)	7	25'/m.	II	III	high
Black (below Cavendish)	7	35-40'/m.	II	III	high
Williams	7	15'/m.	0-I	II,IV	high
West (Newfane to Brattleboro line)	6	15'/m.	I	II	high
West Branch #1 of Deerfield (above Searsburg Reservoir)	4	40'/m.	II	III	high
Moose (below E. St. Johnsbury)	3	40'/m.	II	II	

Medium-large and Large Class II Rivers, Watersheds over 400 Sq. Km.

Lamoille (below Fairfax)	3	'/m.	II	III	high
Missisquoi(below East Sheldon)	1	10'/m.	II	II	high
West (Jamaica-Townshend)	5-6	30'/m.	II	III	
White River (Stockbridge-Gaysville)	5	22'/m.	I-II	III	high

Upland Class III Streams, Watersheds 100-300 Sq. Km.

Mill	6	60'/m.	?III	III	
New Haven (below Rocky Dale)	6	80'-50'/m.	III	IV	high
Lamoille (above Hardwick)	8	40'/m.	II-III	III	high
Lamoille (Wolcott Ledges)	2	15'/m.	I	III	high
Nulhegan	4	varies	I,III	IV	?high
Moose (Rt. 2 to East Saint Johnsbury)	4	60'/m.	I-III	III	
Saxtons	8	40-50'/m.	II	III	high
Middle Branch of Williams	8	60'/m.	II-III	III	
West River (Londonderry to Dam)	7	40-50'/m.	II-III	III-IV	high
Ompompanoosuc West Branch (below Strafford)	5	60'/m.	II-III	III	high
Moose (below Victory Bog)	3	40'/m.	II-III	III-IV	high
Wardsboro Brook	4	90'/m.	III-IV	IV	high
Winhall	6	60-70'/m.	III	III	high
West Branch of Deerfield (below Searsburg Resevoir)	4	50'/m.	III	IV	

Medium-large Class III Streams with Watersheds over 400 Sq. Km.

West River (below Ball Mountain Dam)	2-3	40-50'/m.	III	IV	high

Class IV and Higher; All Medium-sized, Watersheds ca. 100-230 Sq. Km.

Middlebury (below Ripton)	3	230'/m.	IV-V	V	high
New Haven (Lincoln to Bristol)	3	110-70'/m.	IV	V	high
Mad (below Moretown)	7	25-60'/m.	III-IV	IV	high

Map 4: Class III Whitewater Runs.
Many of these have Class IV segments
at high water.

3.4 The Most Important Whitewater Runs

One of our tasks in this study was to rate the overall public importance of the various recreational whitewater runs.

Obviously any such ratings are strongly dependent on your personal biases and on the assumptions built into whatever rating system you use. But equally obviously it is very useful, when you are trying to justify the protection of rivers, to have priorities.

To justify our ratings we must first say something about different groups of boaters, and what is important to each group.

The users of whitewater runs differ in a number of important ways. One is in the kind of water and level of difficulty they prefer. There are dedicated boaters who only boat Class II water, and have no wish to do anything else. For them the White River and Huntington and lower Lamoille are very important runs, while the famous Class III runs of the upper West or the New Haven are of no importance. There are equally dedicated boaters for whom the Class III streams are the most important. And there are a few elite boaters for whom runs like the New Haven Gorge or Wardsboro Brook at high water -- runs which less that 30 people in the state would probably even think about attempting -- are the only ones difficult enough to really challenge their abilities.

The second way that whitewater users differ is in the amount that they travel. This controls the number of streams they have to choose among and greatly influences their preferences.

The most mobile users seem to be weekend boaters from urban areas. Their definition of an important stream is one that it is worthwhile to travel a few hundred miles to run. Their preferences usually run to big, exciting, reliable streams, and often to streams where they will meet other traveling boaters. Our weekend boaters are very familiar with the large-volume streams like the West and White, and tend to have no knowledge of the smaller, more remote, or less predictable streams like the Moose and the upper Lamoille.

Another group of travelers are the canoe clubs, both in Vermont and from elsewhere, who run organized trips and instructional weekends on a variety of streams. They tend to look for streams that are safe for a group with varying abilities, and that have enough space -- both at the access points and on the river -- to accommodate large groups. They also prefer streams that are well-known to their leaders and have reliable water levels. Like the weekend boaters the clubs favor the large, well known streams. But they also run a number of smaller streams like the Huntington and Black which have rapids of consistent difficulty and which don't rise and fall as quickly as the steeper mountain streams.

Map 5: Class IV or Higher Whitewater Runs

For a third group of users whitewater boating is a daily rather than a weekend only activity. This include many resident boaters who try to take advantage of the short Vermont whitewater season by boating as much as they can during the weeks when the water is up. It also includes the schools and outdoor centers that run boating classes and various racers, instructors, and other dedicated boaters who want to be able to practice. For them the most important runs are the ones within a half hour drive of their home or base. Many such boaters, particularly the ones that teach or that like to practice throughout the season get a lot of use from short isolated rapids that are good play and practice places. Such a rapid, especially if it runs in the summer, may get as many or more hours of use in the course of a year than many of the famous streams which are only runnable for a few weeks in the spring.

This group -- call them the weekday users -- depend a lot on small, streams and isolated rapids that are given short-shift in guidebooks and hardly known to out-of-state boaters. Streams like the Rock River, and the Wild Branch are very important to them, as are individual pitches like the Wolcott Ledges, the Sharon Dam, the Dummerston ledges, and so on.

Finally there are a surprising number of boaters whose preferences are dominated by loyalties to particular rivers. These loyalties can be very strong. We met excellent boaters who boated only one or two favorite rivers, and would hang up their paddles when those rivers were not running rather than go elsewhere. When boaters have intense personal relationships with particular rivers these rivers of course become the most important for them, and this may be quite independent of the regional reputation or objective features of that river.

* * *

Given then that there are both very different kinds of rivers and very different kinds of river users, we proceeded to develop a rating system in the following way.

We started with the observation (see Chapter 4) that recreational whitewater runs of 2 miles or more are rare in the state, and hence concluded that every such run is *important* and deserves protection.

We then said that a run was to be considered *highly important* if it met any of the following conditions:

- It was outstanding in the state for length, intensity, wildness or beauty.

- It had a typical season of two weeks or more and received consistent use by boaters, consistent use being defined as either regular use, at least on weekends, throughout its runnable season, or regularly scheduled use by organized boating groups or institutions.

- It was uniformly Class II or higher and had a continuous whitewater run more than 4 miles long and a watershed at the bottom of the run of 100 sq. km. or more.

- It was the best example of water of that category within a fifty- mile circle.

- It was usable for practice in wet periods in the summer or fall.

We thus rated any rivers highly important if they were exceptional within the state or the region, or offered 4 miles or more of continuous rapids, or had a season of several weeks and a known group of users, or was available for use in summer or spring. We considered rivers important but not highly important if they were smaller in volume or shorter in length, had mostly intermittent rapids, had short seasons, or did not have a known group of users.

Please note three things about this classification.

First, it reflects the current use of the river but does not depend on it. An unspectacular stream will be highly important if it receives consistent use, but an exceptional stream will still be highly important even if it is not currently used.

Second it is regional, recognizing that a stream may be highly important if it is exceptional within a 50-mile circle, even if though it is not exceptional in the state as a whole.

And third that in many cases we do not know how much use a river gets. Rivers like the Ottauquechee may be underestimated here, and need to be reclassified if it turns out that they are used consistently.

Table 4 summarizes the important streams in each category.

Table 4: Streams Currently Known to Be Highly Important for Whitewater Boating

Class I Streams With Occasional Rapids	
Battenkill	exceptionally beautiful touring stream, heavy use
Mad (Irasville-Moretown)	beautiful rocks and scenery, much used
Lamoille (middle section)	heavy use, very handsome touring stream, interesting short rapids and falls
Missisquoi (East Richford-Richford)	prettiest and least disturbed part of the mid dle Missisquoi; good summer rapids
Connecticut (upper section)	only rapids left on Connecticut; wildest, cleanest and least spoiled section of the river; good summer rapids
White (Gaysville to Hartford)	very popular tour; fine river, many interest ing small rapids, 2 good summer rapids

West (Townshend to Newfane)	popular tour in summer and whitewater run in spring; fine scenery, excellent practice rapids, much used by groups and for teaching
Small Class II Streams, Watersheds ca. 100 Sq. Km. or Less	
Wild Branch of Lamoille	continuous Class II-III run over 4 miles long
East Branch of Deerfield	fine continuous mild whitewater in wild & undisturbed setting; dedicated local following
Green River	continuous rapids for 6-8 miles, beautiful woodland setting
Medium-sized Class II Streams, Watersheds 100-400 sq. km	
Huntington	very popular stream with the best and longest Class II run in the Burlington region
Mad (above Irasville)	very popular stream, exceptionally attractive rocks and setting
Clyde	best whitewater in Memphremagog drainage unique surroundings, beautiful run
Waits	popular run, best whitewater in region, interesting ledges
Ottauquechee (West Bridgewater to Bridgewater)	4 miles of continuous whitewater
Black (below Cavendish)	popular run, over 4 miles of continuous rapids, interesting and unusual Class III segment
Williams	several rapids that run in late spring or summer, loyal local following
West (Newfane to Brattleboro)	beautiful rocks and setting, very popular run, town line) much used for teaching, excellent summer rapids.
West Branch of Deerfield (above Searsburg Resevoir)	continuous rapids, undisturbed woodland setting, best Class II run in the region, loyal local following
Medium-large and Large Class II Rivers, Watersheds over 400 Sq. Km.	
Lamoille (below Fairfax)	unique rapids in midchannel on a large river; popular run, handsome wooded section of the river, can be run in summer
Missisquoi (below East Sheldon)	very handsome segment of the river, unique rapids in midchannel on a large river.
West (Jamaica-Townshend)	famous and very popular run, beautiful set ting, over 5 miles of Class II

White River (Stockbridge-Gaysville)	popular run, very beautiful and unspoiled valley
Upland Class III Streams, Watersheds 100-300 Sq. Km.	
New Haven (below Rocky Dale)	difficult and continuous run, popular with advanced boaters, the most difficult eastern Vermont stream that gets regular use
Lamoille (above Hardwick)	longest Class III run in northern Vermont, popular with local and visiting boaters, used by Sterling College
Lamoille (Wolcott Ledges)	unique ledge run, can sometimes be used in summer
Saxtons	popular run, 8 miles of continuous whitewater
West River (Londonderry to Dam)	most difficult ledges in the region, also over 4 miles of continuous whitewater
Ompompanoosuc West Branch (below Strafford)	most demanding stream in region, over 4 miles of continuous whitewater
Moose (below Victory Bog)	best Class III water in the region
Wardsboro Brook	most continuously difficult stream in region
Winhall	over 4 miles of continuous, upper level whitewater
Medium-large Class III Streams with Watersheds over 400 Sq. Km.	
West River (below Ball Mtn. Dam)	nationally famous stream; very popular for recreation, formerly used for regional and national competitions
Class IV and Higher; All Medium-sized, Watersheds ca. 100-230 Sq. Km.	
Middlebury (below Ripton)	uniquely difficult wild gorge; steepest stream that has yet been run in Vermont
New Haven (S. Lincoln to Bristol)	difficult Class V gorge; unique piece of water.
Mad (below Moretown)	beautiful stream; two Class III-IV gorges; some rapids run in summer

Table 5: Important Individual Rapids That Can Be Used For Practice

Length of Segment	Average Difficulty		Importance
Battenkill (above Arlington)	1/4 mile	II	high
Connecticut (Hartland Rapids)	1/2 mile	II-IV	high
Connecticut (Lyman Dam)	50 yards	II-III	high
Lamoille (below Johnson)	50 yards	II-?IV	high
Lamoille (Wolcott Ledges)	2 miles	III	high
Missisquoi (East Highgate)	1/4 mile	II-III	?
Missisquoi (Richford Ledge)	50 yards	III	high
Missisquoi (Swanton ledges)	50 yards	II-III	?
Moose (St. Johnsbury Ledges)	1 mile	III-IV	high
Otter (Beldens Gorge)	1/2 mile	III	high
West River (Dummerston Ledges)	1/2 mile	II-III	high
White (old dam at Sharon)	50 yards	II-III	high
White (West Hartford)	50 yards	II-III	high
Williams River(ledges below Chester)	1/4 mile	II-III	high
Winooski (2 rapids below Middlesex)	1/4 mile	II-III	high
Winooski (Salmon Hole in Winooski)	100 yards	II-III	high

3.5 The Potential Whitewater on Unknown and Little-used Streams

A number of the boaters we talked to felt there were still a number of good whitewater streams that were currently unknown. Their feeling was that none of these would be large streams, but that there would be a number of medium-sized Class II and Class III streams comparable to those currently in use. We originally inclined to the same opinion. Early in our survey we learned of two fine Class II streams that were not in the guidebooks, and so believed that it would be fairly easy to find more.

To investigate this we plotted a number of hydrological features of known whitewater streams against their size and degree of difficulty. We then used these plots -- which are explained in detail in the Chapter 4 -- to derive the following empirical generalizations:

- All currently known whitewater streams have watersheds over 50 sq. km., measured at the bottom of the run. [2]

- A stream typically does not have enough watershed to be boatable until it is about 7 miles long (or is formed from the juncture of two tributaries that meet at an angle of 90 degrees or greater and have a combined run of over 7 miles) and has dropped 1500' or more below its headwaters.

- For Class II streams the product of the square root of the watershed in square kilometers and the slope in feet/mile will usually be over 250[3]; for Class III streams this product will usually be over 550. For a stream with the minimum runnable watershed of 50 sq. km. this means a slope of 40'/mile is needed to produce an interesting whitewater run.

- Because steep streams tend to be shallow, streams with slopes near 100'/mile need minimum watersheds of 100 sq. km. to be runnable. Streams with slopes in the 50-70'/mile range are definitely runnable with smaller watersheds.

Having formulated these rules, we then looked at the 15' topographic maps of the state and computed the slopes of all streams with watersheds of over 50 sq. km. The results were interesting.

We found no new streams with watersheds much over 100 sq. km. that had sufficient slopes to have whitewater. This means that, by our methods at least, there appear to be no unknown streams that are comparable to the medium-sized (watershed over 100 sq. km.) streams that supply 95% of the recreational whitewater that is currently used. This was quite surprising to us. It is a testimony both to the thoroughness with which boaters have explored the state, and to continuing efforts by the Appalachian Mountain Club to summarize this information in its river guides.

We did however find three streams (the North Branch of the Lamoille, the Jail Branch south of Barre, and the Rock River above Williamsville) with watersheds of near 100 sq. km. and slopes in the 50-100'/ mile range. These figures are similar to those for Wardsboro Brook and the Williams Middle Branch, two known whitewater runs, and so we estimated that these streams will have Class III or greater whitewater at medium levels. Subsequently we discovered that the Rock River is currently used as a Class III stream, and that the Jail Branch is Class III+ but the runnable section is quite short and not very attractive. We still don't know anything about the North Branch of the Lamoille.

Based on our experiences with the Middle Branch of the Williams and the Wardsboro, we would further predict that these streams will only become runnable at medium high water, and that at moderate or high levels they are likely to be quite fast and perhaps dangerous.

We also found 18 other small streams, scattered throughout the state, with watersheds of 50-75 sq. km. and slopes that typically vary from 70-80'/mile at the top of the run and 40-50'/mile at

2. 50 sq. km. is conveniently equivalent to about 20 square inches on a 1:62,500 topographic map.
3. Once again, we apologize for these ridiculous units. In English units the slope-watershed product (feet per mile x square miles) is equal or greater than about 100 for Class II streams and 200 for Class III streams.

the bottom (Table 3-3). All of these are headwaters streams. If they are runnable at all[4] they should be Class II-III, and are likely to be tight and fast but not prohibitively violent or dangerous. By analogy with the upper New Haven or the Hancock Branch some of them may be very pleasant small runs. We suggest that these streams deserve investigation. if even one out of three of them are boatable we will have greatly extended the list of headwaters Class II streams.

Whether or not these streams prove eventually to be useful whitewater runs will depend on two main things. The first is whether the combination of slope and watershed will produce water that is deep enough to be runnable at medium water levels. A common failing of headwaters streams is that they get faster rather than deeper with moderate increases in flow (Chapter 4), and so are either too rocky to run, or suicidally fast. The second is whether they have unrunnable drops, dangerously tight passages, or natural or man-made obstacles. We suspect that a number of them will fail either the first or second condition. But considering how many there are to choose from it is quite possible that a number will turn out to be runnable streams of at least local importance. We recommend them to boaters for observation and exploration, but with the caution that these are tight, steep, and potentially nasty little streams, and that careful scouting and circumspect experimentation will be necessary.

* * *

To sum up what we know about unknown streams. As a result of a study of the slope-watershed products of whitewater streams we believe that all the major whitewater runs on medium-sized and larger streams have already been mapped. We have found three possible additions to the list of small, steep, Class III-IV streams, and about 18 candidate Class II-III streams. All the possible additions are very small and moderately steep. Their utility remains to be shown: it will depend to a large extent the local details of their channels, and also on whether boaters enjoy using these very small streams, and on how much use their short seasons permit.

Table 6: Possible Whitewater Runs

These are streams that appear from from an examination of topographic maps to be potential whitewater runs. NONE OF THEM HAVE BEEN FIELD CHECKED.

Stream	Town	Segment	Slope (ft./mile)	Length (miles)	
Willoughby	Barton	below E. Brownington	50-100	5	
E. Br. Nulhegan	Bloomfield	below Camp 6	50-80	6	small, steep, inaccessible
N. Br. Lamoille	Belvidere	below Belvidere Center	40-80	6	watershed ca. 100 sq. km.
Miller Run	Sheffield	below Sheffield	25-40	7	? low Class II

4. Note that our method only looks at average slope, and that some -- probably many -- of the streams in Table 3-3 have drops or falls.

Sleepers River	Danville	below N. Danville	50-100	4	small & steep
Peacham Hollow	Peacham	E. Peacham-Barnet	60-80	6	small & steep
Dog River	Roxbury	Roxbury-Northfield	50-100	6	small & steep
Stevens	Williamstown	Williamstown-S. Barre	30	6	may be low Class II
Jail Branch	Barre	East Barre-Barre	80-100	3	watershed ca. 100 sq. km.
Tabor Br. of Waits	Topsham	below E. Topsham	40-60	5	small & steep
South Br. of Waits	Corinth	below Corinth	30-50	3	Lower gorge probably not runnable
W. Br. of White	Rochester	below Corner School	50-70	4-5	small & steep
W. Branch of White & Tweed	Pittsfield	below Pittsfield	40-60	3	small & steep
Poultney	Middletown	Middletown Springs -Poultney	50-70	6	small & steep
N. Br. of Ottauquechee	Bridgewater	above Bridgewater Center	50-70	3	small & steep
Bernard Brook	Pomfret	above S. Pomfret	50-60	?5	very small
Lulls Brook	Hartland	4 m. above Hartland	50-80	4	small & steep
Mill Brook	W. Windsor	above Brownsville to Windsor	60-100	5	gorge by Ascutney may not be runnable
Green River	Sandgate	Sandgate to W. Arlington	50-70	3-4	small & steep
Whetstone Brook	Brattleboro	below Richardson Mtn.	50	2	gorge & falls in Brattleboro
N. Br. of Hoosic	Stamford	below Heartwellville	40-50	3-5	very small
Rock River	Newfane	above S. Newfane to Williamsville	60-100	3-4	watershed 100 sq. km.; lower gorge ? not runnable

CHAPTER 4. PHYSICAL GEOGRAPHY OF WHITEWATER STREAMS

This chapter is concerned with the relations between geology, hydrology, and whitewater. We first ask what physical conditions are necessary to create a boatable whitewater stream and why these occur on some rivers rather than others. We then address the more general question of why is boatable whitewater is comparatively rare in Vermont. And finally we ask a specific question of considerable importance to boaters, which is how the intensity of the whitewater in a particular stream changes as the flow increases.

The reader who is uninterested in geographical speculation for its own sake may wish to note that the ideas propounded in this chapter have practical applications. They tell you where you can and can not expect to find whitewater streams. They afford a way of determining the potential intensity of the whitewater of an unknown stream. And they give some insight into how difficult a particular stream that you have seen at one level will be at other levels.

This is the most technical chapter in this book, and also the most original. To make it as clear as possible we have organized it in textbook fashion as a series of questions and answers, and have confined all but the most essential mathematical detail to footnotes.

We use the following terms and abbreviations:

Q	quantity of water flowing down a stream; called variously the *volume, flow*, or *discharge*, measured as a volume of water per sec.
D	average depth
W	average width
V	average velocity
S	average slope (gradient)
P	average stream power, measured as the energy dissipated per second per unit area of stream bottom
Mean Flow	(= annual mean flow) the average flow for the whole year
Max Flow	(= maximum monthly mean flow) the average flow for the wettest month (usually April)
Min Flow	(= minimum monthly mean flow) the average flow for the driest month (usually August or September)

SD standard deviation of annual flows

4.1 What are the Physical Measures of the Intensity of a Whitewater Stream?

The boater has three immediate physical measures of the whitewater around him: the amount of the channel that is blocked by rocks, the size of the waves and holes he encounters, and the speed at which the current is pushing him through the waves and towards the rocks.

These measures are a moderately good quantitative translation of the difficulty of a stream, and we, in theory at least, we could make a table something like this:

Table 7: Approximate Relationship Between the Physical Features of the Stream and the Intensity of the Whitewater

Intensity of Water	Class II	Class III	Class IV
Amount of channel obstructed by rocks	0-25%	0-50%	0-80%
Size of waves or holes (feet)	1-3	3-4	4-6
Average current (mph)	2-4	3-6	5-8

There is of course overlap between the classes and room for argument, but most boaters would probably agree that once they start encountering 3' holes and a channel half blocked by boulders that the stream has stopped being a Class II.

The boater's measures of intensity are difficult to use in a written description of a stream segment. This is because they are local measures in the sense that they vary a lot from place to place within even a short segment of stream. And also it is quite difficult to actually measure waves and currents. Hence we need more general measurements that correlate with the boater's local ones. To find these, we ask what general factors control current speed, turbulence, and rockiness.

A useful starting point is that in any given stream the velocity is related to the depth and slope:

$$V = k(SD)^{0.5} \qquad (1)$$

k is a constant that depends on the channel shape and roughness, and, as is the way of such things, is not really constant but depends on the ratio of depth to width, and usually increases a bit as the stream gets deeper. This expression is the basic equation for open channel flow: it says that

other things being equal velocity increases directly, but somewhat sluggishly with slope and depth. It explains why the small increases of slope associated with river bends often have substantial effects on the speed of the stream, why all rivers run faster in flood, and why boaters consider the slope of a river segment to be a primary measure of the intensity of the whitewater to be expected.

A second important observation is that both velocity and turbulence are related to the total flow in a stream.[1] As the flow increases the stream becomes deeper, and by equation (1) must become faster. And as more water piles up on top of rocks or below drops and chutes the height of the waves and the total amount of turbulence must increase. This accounts for the commonplace observation that streams get more violent as their flow increases, and also the less well known fact that of two streams with similar slope the one with the larger volume (total flow per second) will be the more intense.

This latter fact is not always appreciated by boaters and guide books, and needs a bit more discussion. Rivers with larger average flows are of course wider than those with smaller flows. If their widths were proportional to their flows the larger stream would be equivalent to two smaller streams as in B in the diagram:

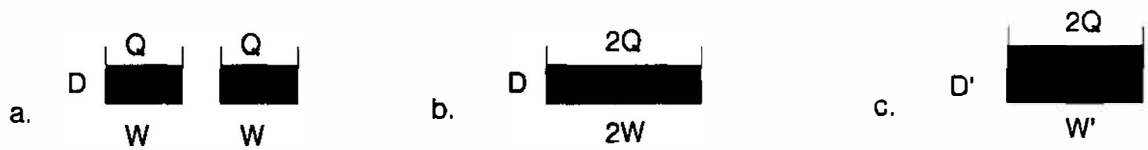


Figure 4.1 Scaling Of Width and Depth to Flow. If the two streams in a. are combined to produce a single stream, width does not double (scale linearly as in b. but rather both width and depth increase (scale as power functions) as in c.

If this was true the amount of flow per unit width, Q/W would be the same, and streams of the same slope and different average flows would have the same intensity. But this is not the case, since the larger stream accommodates its greater flow by increases in both width and depth (and hence in velocity), as in C.[2] But this means that the volume of water flowing over each unit width per second -- Q/W -- increases and so the larger stream is also more intense. And it also suggests that rather than use flow by itself as a measure of intensity a more meaningful quantity would be Q/W, the flow per unit width, since this is a measure of the amount of water passing over any single place in the river.

1. There are a few exceptions to this: see the discussion in the last section of this chapter.
2. Empirically the width of different streams, or of different points on the same stream, is proportional to a fractional power of the flow. The power differs in different geological settings. In the northeast it is approximately 0.5 and hence $W=cQ^{0.5}$.

Since intensity appears to depend on both slope and flow per unit width it is reasonable to combine them, and to measure the whitewater potential of a stream by the product P = QS/W. Besides giving us a single quantity to work with this is also conceptually attractive because P is the stream power per square foot -- the amount of potential energy that gets changed into heat per square foot per second.[3] Since turbulence is the principal way that streams dissipate their potential energy, it is reasonable to hope that the stream power will be a good physical measure of the average turbulence, and hence of the average difficulty of the whitewater in a stream.

We will return to the use of stream power to estimate the intensity of whitewater after we deal with the question of how to estimate Q. But before we leave this topic we should note that the word average at the end of the last paragraph introduces a potential difficulty. The quantity P measure the average rate at which a stream dissipates power. The actual rate varies from place to place, for two reasons. First, the slopes of most streams fluctuate with a wavelength of something like 10-20 times the stream width. And second, in addition to the fluctations caused by changes in slope there are local peaks created by rocks and drops. Hence the real power dissipation of a stream looks something like this:

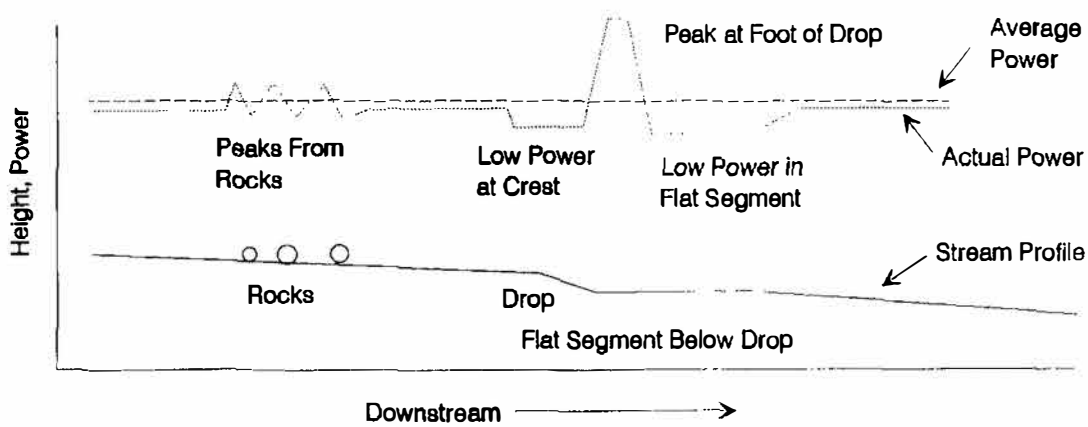


Figure 4.2 Actual and Average Power. The average power (dashed line) is roughly constant throughout this segment. The actual (local) power (dotted line) varies over short distance because of obstructions and variations in slope.

What the boater is most concerned about is the peak power, not the average. The average power P will be a useful measure only if it predicts the peaks.

3. Q is the amount of water passing through any cross section per unit time; S the drop per unit length; QS the amount that a unit length of the whole river drops per unit time; hence QS/W is mass of water per unit area x the drop per second per unit area, which is the power per unit area.

If the peaks are closely spaced and regular in height then the average power is proportional to the power the boater actually will encounter, just like our conventional designation of our domestic electricity as 120 volts is a reasonable description of a potential that actually fluctuates through some 360 volts. But if the peaks are not regular then the average stream power won't tell us much about the real difficulty of the stream.

This brings us to an important point. In every whitewater stream there will be local variations in slope and obstructions to the flow -- ledges and drops and chutes and rocks and bars -- which we will refer to collectively as the stream's roughness. At the rough places the energy dissipation is higher than the average, and the boater can expect to encounter the roughest water. As will be explained later in this chapter, in some streams the roughness consists mostly of boulders that the stream has moved itself. Since the size of a boulder that a stream can move depends on the depth of the water and the strength of the current, in these streams the roughness (which depends on the average stream power) doesn't vary too much, and is approximately predictable from the slope[4] Such streams commonly have regular oscillations in slope, and hence have power dissipation curves something like this:

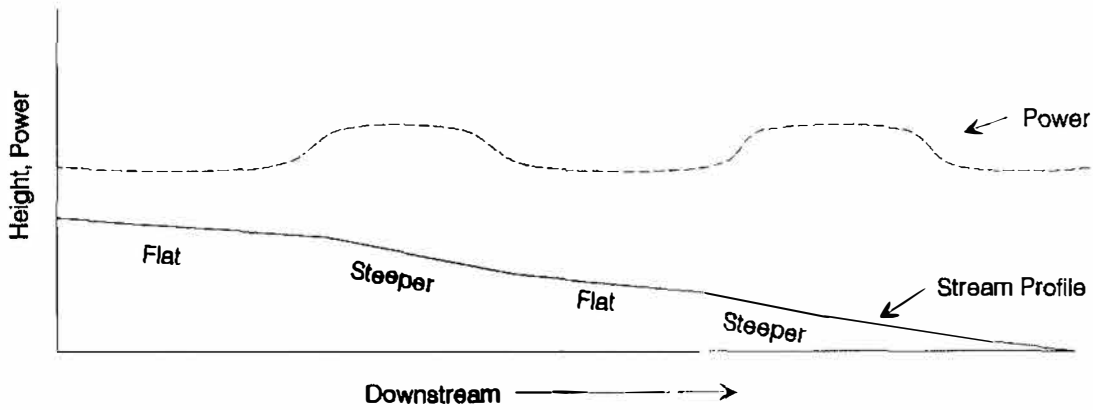


Figure 4.3 Regular Oscillations in Slope and Associated Oscillations in Stream Power. This is commonly called the riffle-pool sequence.

In other streams the roughness comes from variations in the bedrock, or from large boulders that were moved by landslides or post-glacial streams, and which cannot be transported with the power presently available to the stream. Such streams can have large peaks in their power curves, as in Figure 4-4.

To sum up. In streams with a movable bed and normal pool-riffle sequence roughness varies in a predictable way. Hence average power, as determined by average slope and volume, parallels peak power and can be used to predict the difficulty of the whitewater. In streams with bedrock

4. We also have to take into account the supply of boulders that the stream has available, which in turn depends on the bedrock geology. See below.

features and big boulders roughness varies independently of the average slope, and the power peaks and points of greatest difficulty are not related to the average slope.

Thus roughness is the wildcard in the hydrological deck. It is a critical determinant of the quality and difficulty of the whitewater, and one only partly predictable from general rules.

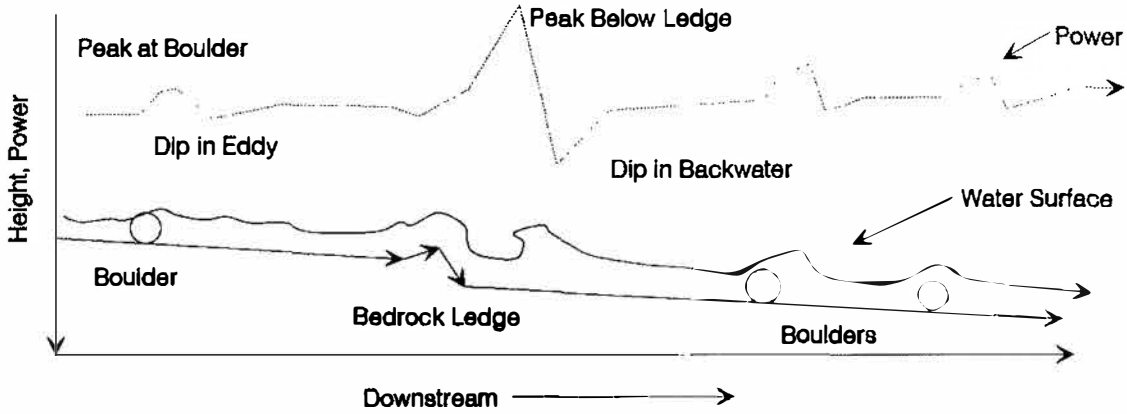


Figure 4.4 Stream With Sharp Power Peaks Caused by Local Variations in Roughness

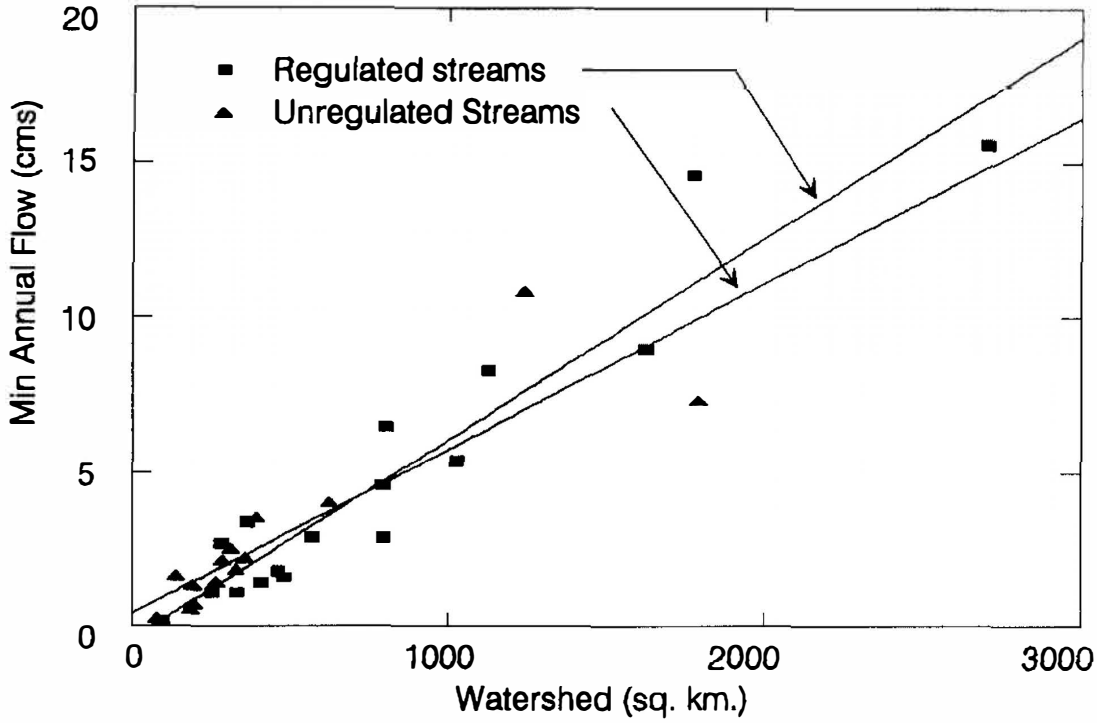
4.2 What Determines the Average and Peak Flows of a Stream?

Assuming that P will be a useful measure of the intensity of at least some streams, we now need to know how to estimate its components, the flow, the slope and the width. We start by considering average and peak flows.

Basic data on stream flows comes from the gauging stations operated by the United States Geological Survey. At present there are about 36 such stations in operation in Vermont. In addition we have some records from perhaps 25-30 others that operated previously. These provide the basic quantitative information on stream flows and flood frequencies which we have used in this report. Table 8 summarizes the USGS gauge data for all the gauged streams with watersheds over about 60 sq. km.

Because gauge data is only available on a few whitewater streams we need another means of estimating flows. The size of the watershed is the logical choice, and fortunately it correlates very well with mean flows, and moderately well with maximum and minimum monthly flows. This is shown in Figures 4-5-7, which are graphs of the data from Table 4-1. A triangle indicates an stream without dams, and a rectangle a regulated (dammed) stream. The regression lines show that maximum flows are on dammed streams slightly lower than those on unregulated streams, but that the difference is small and barely significant. Also there are some exceptions. Flood control dams without permanent pools, like Townshend Dam on the West River, are drawn down

4. We also have to take into account the supply of boulders that the stream has available, which in turn depends on the bedrock geology. See below.



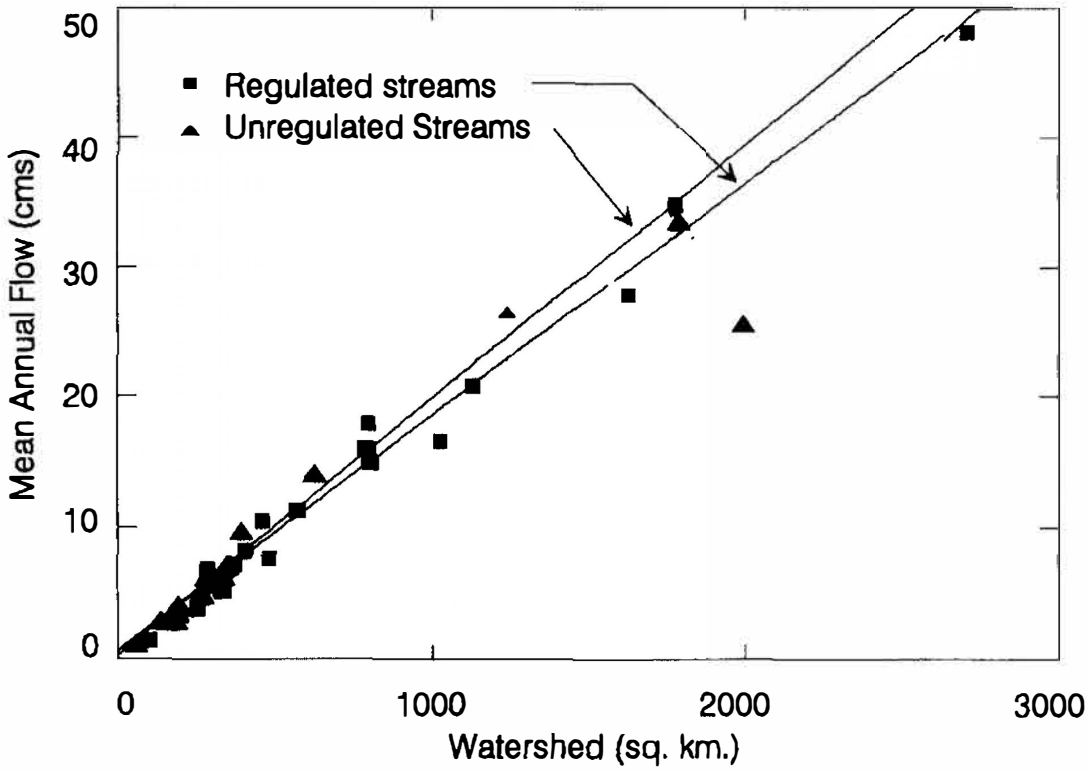


Figure 4-5 (above), 4.6 (below). Minimum Monthly and Mean Monthly Flows vs. Area for Vermont Streams With USGS Gauges. Regression lines for regulated streams (streams with hydro- or flood control dams) and unregulated streams are not significant at the 95% level.

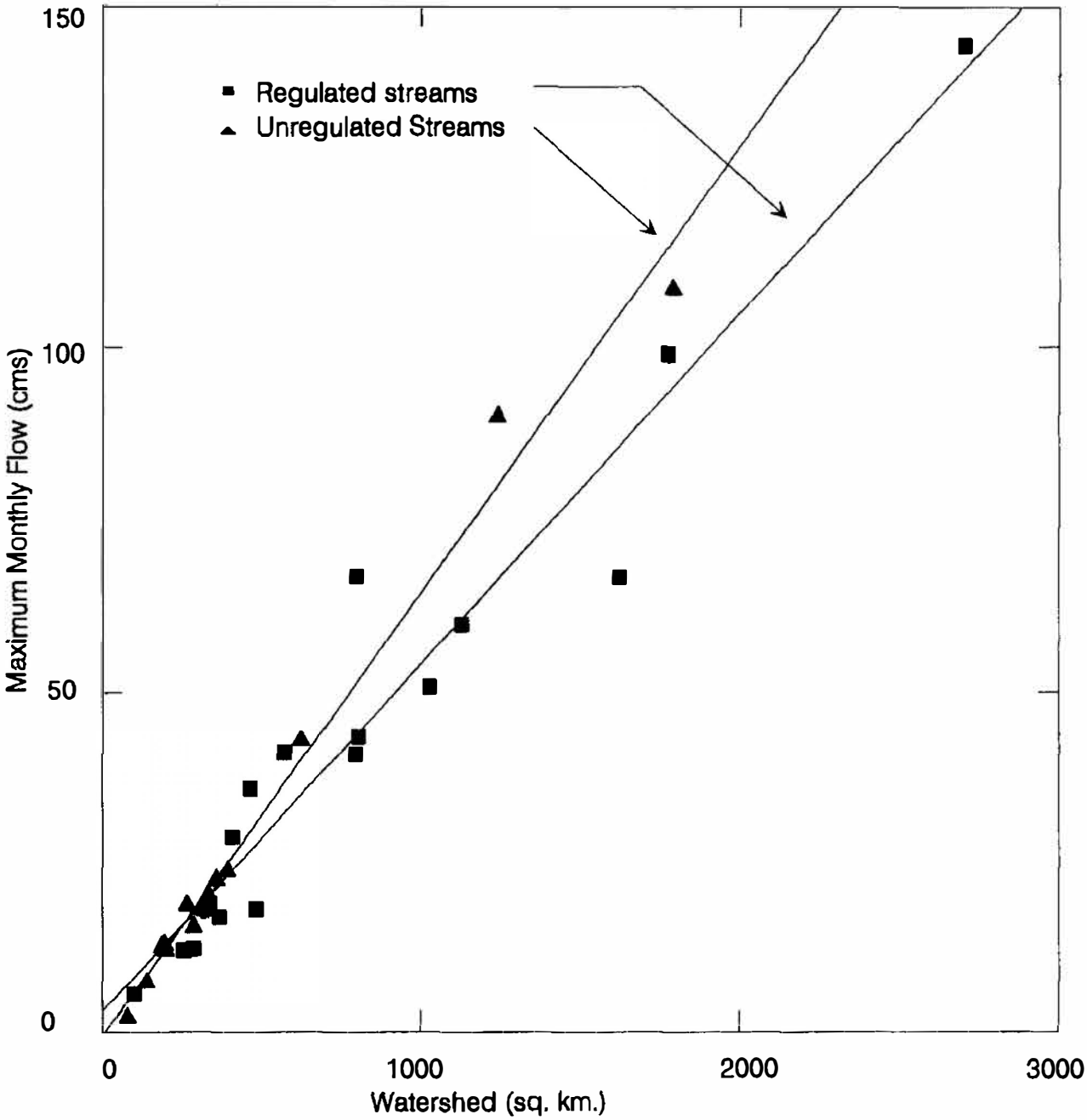


Figure 4-7. Maximum Monthly Flows vs. Area for Vermont Streams With USGS Gauges. Regression lines for regulated streams (streams with hydro- or flood control dams) and unregulated streams are barely significant at the 95% level.

rapidly at the end of the spring runoff period, and actually give larger mean flows in the wettest month than would be expected for a an undammed river. And streams like the lower Otter where there are a number of large reservoirs for power generation have less than 50% of the spring flow that would be expected of an undammed stream of equivalent watershed.

Table 8: Hydrological Data For Vermont Streams With USGS Gauges and Watersheds of Over 60 Sq. Km.

Stream	Location	Watershed (sq. km.)	(cms)	Mean (cms)	Max (cms)	Min ated	Reg. SD
AYERS BROOK	RANDOLPH	79	1.3	2.1	0.2	0.34	
BATTENKILL	ARLINGTON	394	9.7	23.8	3.5	1.90	
BLACK	N. SPRINGFIELD	409	8.2	28.9	1.4	+	2.10
BLACK	COVENTRY	316	5.8	18.2	2.5	1.30	
CLYDE	NEWPORT	368	7.3	17.1	3.4	+	1.26
DOG	NORTHFIELD FALLS	197	3.4	12.2	0.7	0.88	
EAST BR PASSUMPSIC	EAST HAVEN	139	3.0	7.4	1.6	0.63	
JAIL BRANCH	EAST BARRE	100	1.5	5.7	0.2	+	0.44
LAMOILLE	GEORGIA	1777	35.0	99.1	14.6	+	45.60
LAMOILLE	JOHNSON	803	15.2	43.5	6.5	+	3.06
LITTLE	WATERBURY	287	6.8	12.4	2.7	+	1.68
MAD	MORETOWN	360	7.3	22.6	2.2	1.60	
MISSISQUOI	RICHFORD	1241	26.3	90.0	10.8	4.90	
MOOSE	ST. JOHNSBURY	332	6.3	20.2	1.8	1.70	
MOOSE	VICTORY	195	4.0	12.9	1.3	0.80	
OMPOMPANOOSUC	UNION VILLAGE	337	5.5	19.1	1.1	+	1.46
OTTAUQUECHEE	NORTH HARTLAND	572	11.3	41.1	2.9	+	2.65
OTTER	RUTLAND	795	15.7	40.9	4.6	+	3.60
OTTER	MIDDLEBURY	1627	27.9	66.7	9.0	+	6.90
PASSUMPSIC	PASSUMPSIC	1129	20.9	59.8	8.3	+	4.08
POULTNEY	FAIR HAVEN	484	7.6	18.2	1.6	+	2.17
SAXTONS	SAXTONS RIVER	187	3.4	12.7	0.5	1.03	
WALLOOMSAC	N BENNINGTON	287	6.3	15.6	2.1	+	1.13
WELLS	WELLS RIVER	255	4.0	12.2	1.1	+	1.06
WEST RIVER	NEWFANE	798	17.9	66.8	2.9	+	3.40
WEST RIVER	JAMAICA	464	10.4	35.8	1.8	+	2.65
WHITE RIVER	WEST HARTFORD	1790	33.6	108.6	7.3	7.23	
WHITE RIVER	BETHEL	624	14.0	42.9	4.0	2.30	
WILLIAMS	BROCKWAYS MILLS	267	4.9	18.8	1.4	1.30	
WINOOSKI	MONTPELIER	1028	16.7	50.8	5.4	+	4.00
WINOOSKI	ESSEX	2704	48.3	144.2	15.6	+	11.05

Flows are in cubic meters per second (cms). 1 cubic meter/second (cms) = 35.5 cubic feet/second (cfs). 1 square kilometer = 0.386 square miles. Mean = mean annual flow, max = maximum monthly mean, min = minimum monthly mean, SD = standard deviation of annual flows.

With the exception of streams with large reservoirs, it remains generally true that mean flows throughout Vermont are closely related to the size of the watershed. This is an important because it gives us a fairly easy way of estimating and comparing flows on streams for which we have no direct gauge data -- which is to say on the majority of our whitewater streams.

4.3 Do Variations in the Yields of the Different Watersheds Affect the Occurrence of Whitewater?

We need to consider whether the scatter in Figure 4-1 is random or systematic. Watersheds differ from one another in the amount of precipitation they receive, and in the speed at which precipitation migrates through the watershed and appears as streamflow. It is conceivable that these variations might produce predictable variations in the amount of stream flow produced produced by watersheds of a given size.

A convenient measure of this is the average amount of streamflow produced per unit area (cubic meters per second of average streamflow per square kilometer of watershed) which is called the *yield* of the watershed. We wish to know if variations in yield affect the occurrence of whitewater.

The total precipitation in different parts of Vermont varies between about 36 and 44 inches per year, or some 20% around the state average. The driest part of the state is the Champlain Basin and the wettest the central Green Mountains. If we were to focus on small watersheds we would probably see similar variations in annual yield. But when we look at larger drainages the pattern is different, or rather there ceases to be much of a pattern at all.

Table 9 gives the annual yield for the major gauged streams. There is about a 25% variation in yield between the lowest and the highest watersheds, but the variations do not follow any obvious geographic pattern. The reason is probably that the major streams flow through a number of different areas with different rainfall patterns -- notice that the White for example has a yield of 0.022 cms/sq.km. in its upper watershed, but 0.018 cms/sq.km. at its mouth.
Furthermore, there is apparently no correlation between annual yield and whitewater, because there are flatwater and whitewater streams at both ends of the table. This is reasonable. We expect that over long periods of time stream channels adapt to the prevailing yield, and hence that there is no strong theoretical reason why a wetter watershed should have more intense streams.

Table 9: Annual Yield For Gauged Watersheds

Stream	Gauge location	Yield
JAIL BRANCH	EAST BARRE	0.015
POULTNEY	FAIRHAVEN	0.015
WELLS	WELLS RIVER	0.015
OMPOMPANOOSUC	UNION VILLAGE	0.016
WINOOSKI	MONTPELIER	0.016
AYERS BROOK	RANDOLPH	0.016
DOG	NORTHFIELD FALLS	0.017
WINOOSKI	ESSEX	0.017
OTTER	MIDDLEBURY	0.017
SAXTONS	SAXTONS RIVER	0.018
WHITE RIVER	WEST HARTFORD	0.018
WILLIAMS	BROCKWAYS MILLS	0.018
MOOSE	ST. JOHNSBURY	0.018
PASSUMPSIC	PASSUMPSIC	0.018
LAMOILLE	JOHNSON	0.018
BLACK	COVENTRY	0.018
OTTAUQUECHEE	NORTH HARTLAND	0.020
OTTER	RUTLAND	0.019
LAMOILLE	GEORGIA	0.019
CLYDE	NEWPORT	0.019
BLACK	N. SPRINGFIELD	0.019
MAD	MORETOWN	0.020
MOOSE	VICTORY	0.020
MISSISQUOI	RICHFORD	0.021
WALLOOMSAC	N. BENNINGTON	0.021
EAST BR PASSUMPSIC	EAST HAVEN	0.021
WEST RIVER	NEWFANE	0.022
WEST RIVER	JAMAICA	0.022
WHITE RIVER	BETHEL	0.022
LITTLE	WATERBURY	0.023
BATTENKILL	ARLINGTON	0.024

The yield is in cubic meters/sec of flow per sq. km. of watershed.

4.4 Are High Variance Streams Also High Intensity Streams?

We learn more if instead of considering the average yield we look at how the flow in a watershed varies from year to year or month to month. We would expect that this would be more closely related to the occurrence of whitewater, because it would be a measure of how often the system runs at peak power, and of how high the peaks are.

There are a number of reasons the variability of flows might be informative. First, some streams only become whitewater streams when the flows are high. Second, if, as seems empirically true, the channel cross- section is determined by average flows[5] then the higher the peaks in relation to the average the more cramped the stream will be and hence the more turbulent. And third, peaks may be the events in which the stream can move the large boulders that supply the roughness in many of our whitewater runs, and so streams with more peaks might have rougher channels.

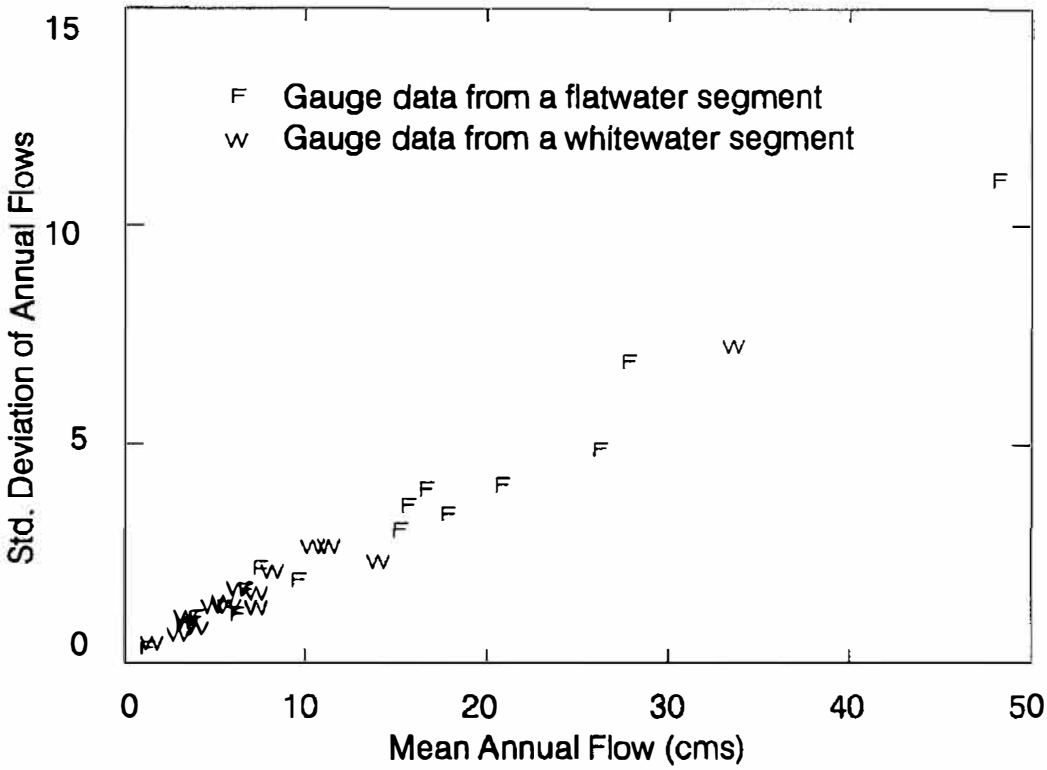
Figure 4-8 graphs the standard deviation[6] of the annual flows against the area of the watershed. The figures are taken from USGS data. The standard deviations increase uniformly with area, which simply means that the ratio of standard deviation to mean flow is roughly the same on different size streams. This is the statistical norm, and merely says that big streams and not very different from small streams except that they are bigger. Thus the percentage variation in yearly flows is about the same on all of our streams.

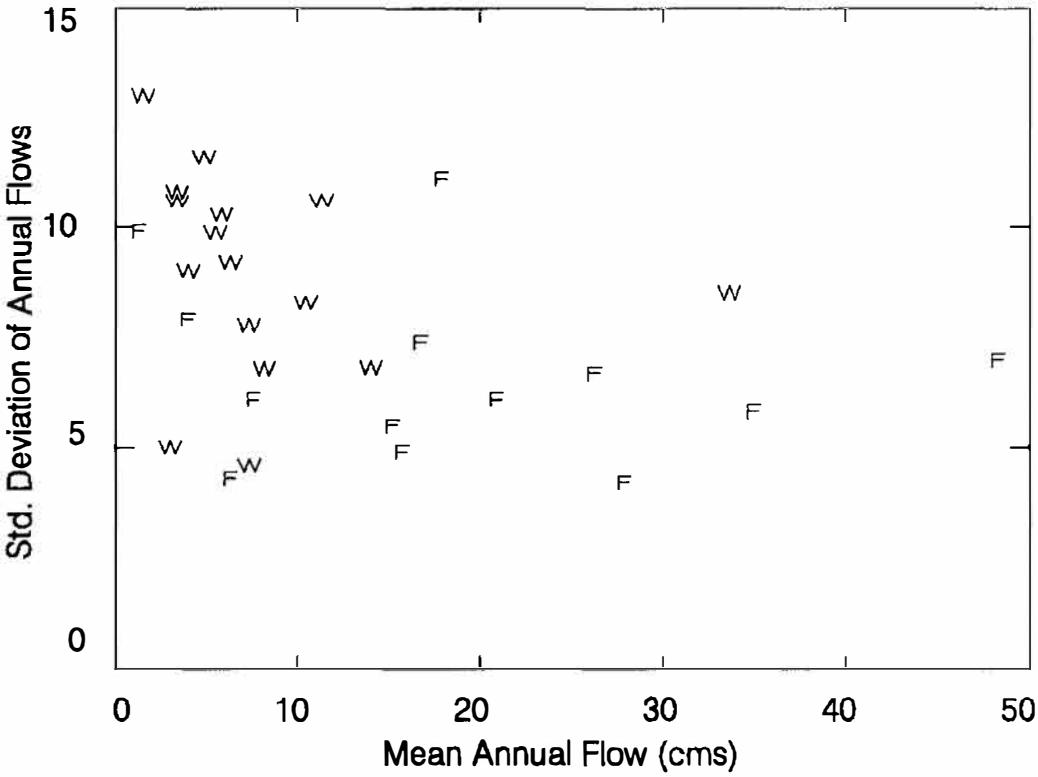
The standard deviations of the monthly flows, shown in Figure 4-9, are considerably more interesting. The figure contrasts with the previous one in that the variability of monthly flows does not increase with area at all, but is in fact greatest for the small streams. It also shows that streams have very individual amounts of variability, and that some whitewater streams are among the most variable. But it certainly does not show any simple correlation between variability and the intensity of the whitewater.

The standard deviation of the monthly flows is a measure of month to month variability throughout the year. In a whitewater stream we are really interested in how much the stream peaks in the spring, and a better measure of this is the ratio of maximum monthly flow to mean flow. This is shown in Figures 4-10. The numbers represent average intensities of spring whitewater for those streams that are used as whitewater runs.

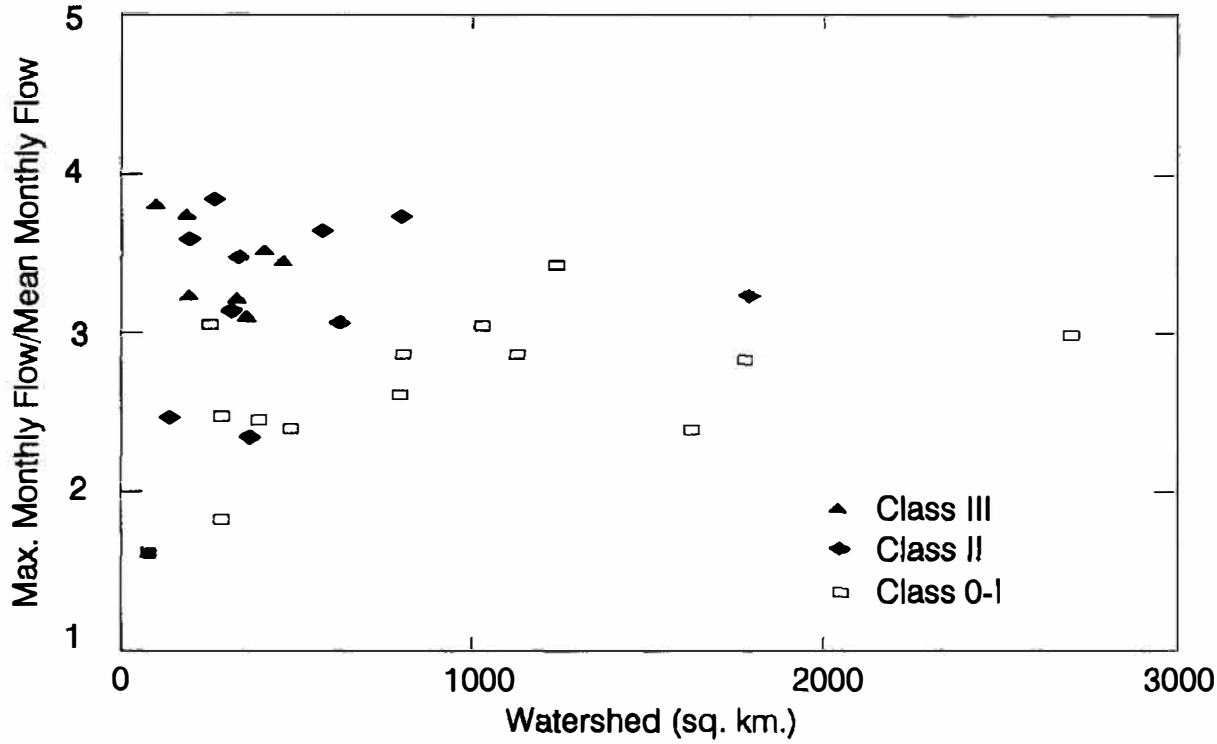
Several relationships emerge from Figure 4-10. First the maximum variability is more independent of stream size than the minimum variability.[7] Second, the whitewater streams tend to be more variable than the non-whitewater streams with equivalent watershed, and even more interesting, the Class III streams in most cases are more variable than the Class II streams with the same watershed.

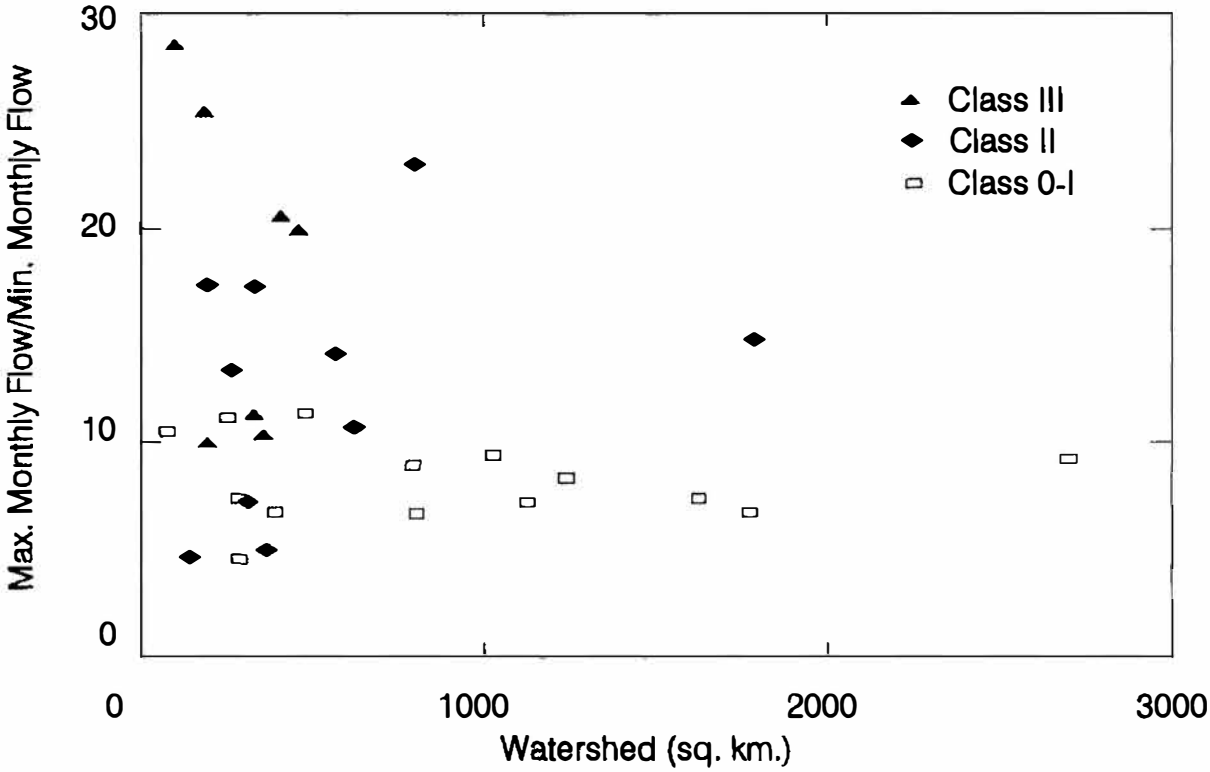
5. This is not necessarily true. Geomorphologists differ about what level of flows are most important for forming channels. Probably the 'morphogenetic' flows will be somewhat larger then the average flows, but how much larger we can not say. In any event, as long as the peaks lie above the flows to which the channel is adjusted, the ratio of peak flow/morphogenetic flow will be a measure of how much turbulence is to be expected.
6. The standard deviation is the square root of the sum of the squared deviations. If A is the average annual flow and Ai the average annual flow of the ith year, then the standard deviation is the square root of the sum of the twelve squared differences $(Ai-A)^2$. It measures of how closely a group of events -- in this case yearly or monthly flows -- cluster around their average. A high standard deviation means that exceptionally low or high flows happen relatively frequently; a low one the reverse.
7. Jenkins & Zika's Hydrological Law of Unknown Significance





Figures 4-8 (above) and 4-9 (below). Standard Deviations of Annual and Monthly Flows for 18 Vermont streams With USGS Gauges. Standard deviations of annual flows are directly proportional to mean annual flows for both whitewater and flatwater segments, indicating that the percentage variability in annual flows is roughly independent of stream size. Standard deviations of monthly flows are weakly inversely proportional to stream size for both whitewater and flatwater segments, indicating that small streams have highly variable monthly flows; in addition whitewater segments are clustered and tend to be somewhat more variable than flatwater segments of the same size.





Figures 4-10 (above) and 4-11 (below). Ratios of Maximum to Mean and Maximum to Minimum Monthly Flows versus Area for 18 Vermont Streams With USGS Gauges. Solid symbols are whitewater segments. Whitewater segments tend to be more variable than flatwater segments, and Class III segments somewhat more variable than Class II.

The last observation has an interesting corolary with important biological implications. If instead of graphing the ratio of maximum month to mean we graph (Fig. 4-11) the ratio of the maximum month to the minimum, the graph that results is essentially a 3-fold expansion of the previous graph with the streams in almost the same relative positions. Thus Class III streams vary more greatly in both directions. they not only run higher in the spring but lower in the fall.

Thus there seems to be a rough relation between the ratio of monthly maximum and mean flows and the intensity of the whitewater. It can not be used on streams for which there is no gauge data, but it is none the less helpful in forming a concept of the sort of flow conditions and of the type of watershed that produces good whitewater.

4.5 What is the Relation of the Slope and Watershed to the Occurrence of Whitewater?

Equation (1) at the beginning of this chapter says that the velocity in a stream is proportional to the slope times the square root of depth. If two streams have the same depth but different slopes, the steeper one flows faster, as common sense suggests and observation abundantly confirms. The faster stream will dissipate more energy per second at obstructions, and will also be more difficulty to paddle because it will carry boats into these obstructions faster. Further, since the water pressure increases with the square of the velocity, the faster stream exerts considerably greater pressures against obstacles, and in particular against boats that are lodged against rocks, or boats trying to paddle through breaking waves and rollers. This is why steeper streams are both harder and more dangerous to paddle than flat streams, and they command considerable respect from boaters.

The slopes of Vermont streams range from under 3' per mile to over 1000' per mile. The streams with very high slopes are unrunnable. They tend to be small streams which are blocked by boulders and interrupted by waterfalls, and even when this is not the case the steepness itself is prohibitive because it causes the water to reach dangerously high velocities before the stream is deep enough to be boatable. So far as we know the steepest stream that has as yet been descended in Vermont is the Middlebury Gorge with a slope of approximately 230' feet per mile, and it is the opinion of many boaters that the practical limits may navigability may be somewhere near this, at least for the present. Descents of this steepness are hardly part of everyday boating, and the steepest streams that get regular use have slopes in the vicinity of 100' per mile. In other parts of the country the limits are about the same: boaters from North Carolina and Georgia say that they consider any stream with a slope of much more than 100-120' per mile to be unrunnable, or runnable only under special conditions.

This means that a number of our famous gorges and mountain streams, like the Cavendish Gorge with a slope of 200' per mile, or the Big Branch in Danby with a slope of 400' per mile, are currently considered to be beyond the limits of navigability, except possibly for teams of experts under special conditions.

On the other hand streams with slopes below 15'-20' per mile for the most part have no whitewater. Some of these stream have very large discharges and so the total stream power can be very high, but typically they are also quite wide and so the power per unit area is low. In addition they tend to have smooth bottoms and so lack the roughness needed to make interesting turbulence. Several important exceptions occur, most notably in the lower White and Lamoille Rivers. These are places where there are belts of resistant rock that have created short rapids by constricting the flow, introducing roughness, and making the slope locally higher than the average.

Table 10: Slopes and Levels of Difficulty Classifications for Whitewater Segments

Stream	Begins	Ends	Slope (ft/mile)	Watershed (sq. km.)	Class
MIDDLEBURY	E. RIPTON	MIDDLEBURY	230	110	V
NEW HAVEN	W LINCOLN	ROCKY DALE	110	130	IV
DEERFIELD W.BR. #2	HEARTWELLVILLE	READSBORO	100	130	IV
WARDSBORO	WARDSBORO	JAMAICA	90	96	III-IV
HANCOCK BRANCH	ROBBINS BRANCH	WHITE RIVER	65	50	II-III
WINHALL	GRAHMVILLE	WEST RIVER	65	160	III-IV
MILL	E. WALLINGFORD	CLARENDON GORGE	60	170	III
OMPOMP. W.BR.	STRAFFORD	RICE'S MILLS	60	140	III
WILLIAMS, MID. BR.	SIMONSVILLE	CHESTER	60	90	III
NEW HAVEN	ABOVE W. LINCOLN	W. LINCOLN	55	55	II-III
NEW HAVEN	ROCKY DALE	NEW HAVEN MILLS	50	267	III-IV
WILD BRANCH	CRAFTSBURY	WOLCOTT	50	100	II-III
WEST	BALL MT.DAM	SALMON HOLE	50	464	III
DEERFIELD, W. BR.	SEARSBURG RES.	HARRIMAN RES.	50	230	III
SAXTONS	GRAFTON	SAXTONS RIVER	45	187	II-III
LAMOILLE	GREENSBORO BEND	HARDWICK	40	220	II-III
MOOSE	SNOWMOBILE BR.	NORTH CONCORD	40	210	III
MOOSE	E. ST. JOHNSBURY	PASSUMPSIC RIVER	40	332	II
WAITS	WAITS RIVER	BRADFORD CENTER	40	340	II-III
WEST	LONDONDERRY	BALL MTN. RES.	40	380	III(IV)
DEERFIELD, W. BR.	1ST BRIDGE	E. BR. CONFLUENCE	40	120	II
DEERFIELD, E. BR.	SOMERSET RES.	W. BR. CONFLUENCE	40	85	II
BLACK RIVER #2	WHITESVILLE	PERKINSVILLE	35	350	II-III
MAD	MORETOWN	WINOOSKI RIVER	30	375	III-IV
HUNTINGTON	HANKSVILLE	HUNTINGTON GORGE	30	150	II
CONNECTICUT	LYMAN DAM	BLOOMFIELD	30	300	I-II
WEST RIVER	SALMON HOLE	EAST JAMAICA	30	700	II
GREEN	GREEN RIVER	LEYDEN, MASS.	30	110	II
LEWIS CREEK	PRINDLE CORNERS	N. FERRISBURG	25	180	II
CLYDE	SALEM POND	CLYDE POND	25	355	II
PASSUMPSIC, E. BR.	E. BURKE	CONF. WITH W. BR.	25	200	II
OMPOMPANOOSUC	POST MILLS	E. CORINTH	25	130	II
OTTAUQUECHEE	W. BRIDGEWATER	WOODSTOCK	25	500	I-II

WILLIAMS	GASSETTS	CHESTER	25	95	I-II
DEERFIELD, N. BR.	WEST DOVER	HARRIMAN RES.	25	95	I(II)
CLARENDON	CLARENDON SPRINGS	WEST RUTLAND	20	100	I-II
MAD RIVER	WARREN	MORETOWN	20	360	I-II
BLACK #1	IRASBURG	COVENTRY	20	316	I-II
WHITE RIVER	STOCKBRIDGE	BETHEL	20	624	I-II
WEST	WESTON	LONDONDERRY	20	180	I
LAMOILLE	FAIRFAX	ARROWHEAD LAKE	15	1777	II
WILLIAMS	CHESTER	BROCKWAYS MILLS	15	267	I
WEST	TOWNSHEND	CONNECTICUT RIVER	12	1100	I-II
WINOOSKI	MARSHFIELD	MONTPELIER	11	500	I(II)
BATTENKILL	SUNDERLAND	NYS LINE	10	394	I(II)
MISSISQUOI	NORTH SHELDON	SHELDON SPRINGS	10	1500	II
WHITE	BETHEL	CONNECTICUT	10	1790	I-II
LAMOILLE	CADYS FALLS	CAMBRIDGE	5	803	I

Thus the whitewater streams that are run by most boaters most of the time have slopes that lie between about 25' per mile and 100' per mile. These slopes are not very great. Twenty-five feet per mile corresponds to 1 part in 200, which is barely discernible to the eye. One hundred feet per mile corresponds to 1 part in 50, which is about equal to the slope of the floors in many old houses, and is about half of the maximum grade permitted on interstate highways.

The actual gentleness of what a boater calls a steep stream is worth stressing. Many people, underestimating the slipperiness of water and its capacity of attaining great speed on mild grades, conceive that canoeists, like skiers, can descend 20 or 30 degree grades. This is of course a misconception. A 30 degree slope has a gradient of 2500' per mile. Even the streams themselves can't descend this without breaking up into cascades and falls. Whitewater boating takes place in valleys rather than on slopes, and any stream that is even vaguely reminiscent of a ski-slope, or that would make an American car shift gears, is certainly too steep to boat.[8]

Table 4-10 gives the slopes and levels of difficulty of the whitewater streams treated in this report. The slopes are taken from topographic maps, and are only approximate. Photogrammetric mapping is not very accurate at low slopes, and in any case when working from contour maps with a 20-foot contour interval it is often necessary to average the slopes over a mile of channel to get a reasonable figure. The steeper the slope the more accurately it can be determined, but in any case the boater should remember that on a stream with a nominal steepness of 30' per mile the actual steepness encountered may vary between 20' per mile and 40' per mile owing to that oscillations in slope mentioned above. The levels of difficulty apply to moderate spring water levels, not to flood. The notation III(IV) means a stream that is mostly Class III but has individual

8. Most experienced paddlers automatically look downstream and estimate the average slope visually. Class II streams look pretty flat. Any time they see a segment where the river has a noticeable slope coming up they get ready for bigger water.

Class IV rapids. The notation III-IV means that the stream is on the boundary line between III and IV, and the difficulty depends critically on water level.

The table shows that the slope of a stream is only an approximate measure of the difficulty of the whitewater. Class II runs have slopes all the way from 20-50' per mile, and this range of slopes overlaps with many Class III runs and even a few borderline Class IV runs.

If instead of just looking at slope we use both slope and watershed we get a much clearer separation of streams of different levels of difficulty. It is easiest to see this graphically: Figure 4-12 shows a plot of slope against watershed, with different symbols corresponding to different levels of whitewater. The streams of approximately equivalent difficulty lie in curved bands, and we see that where two streams have the same slope and different classifications, the more difficult one almost always has more watershed than the easier one.

Further more, the curved bands of streams of similar difficulty in Figure 4-12 are approximately parallel to curves connecting points of equal stream power. These curves are obtained by using the empirical approximation that the average width varies with the square root of the discharge.[9] Since further the discharge is proportional to the watershed, we have, to within a constant:

$$P = QS/W = QS/Q^{0.5} = Q^{0.5}S = cA^{0.5}S \qquad (2)$$

We call the quantity $SA^{0.5}$ the slope-watershed product or estimated stream power.

To see how stream power relates to the level of difficulty look again at Figure 4-12. The two solid lines are plots of points for which P = 400 and P = 850 milli-lugbills.[10] It will be seen that they more or less stay circumscribe the bands of Class II and Class III streams, at least in the region where we have enough examples to define the bands clearly. Hence it appears P is a moderately good measurement of the intensity of whitewater, at least in geologically similar streams.

This is also shown in Table 4-11, which compares the stream power approximated by equation 2 with the degree of difficulty.

9. This is an average of many different streams, and only approximately true for any particular stream.
10. Units in physical science are named after eminent practicioners of the field to which the units are appropriate, and so we call the quantity 1000 kilometer-feet per mile one lugbill, after Jon Lugbill, the American who has dominated international C1 whitewater racing for the last decade.

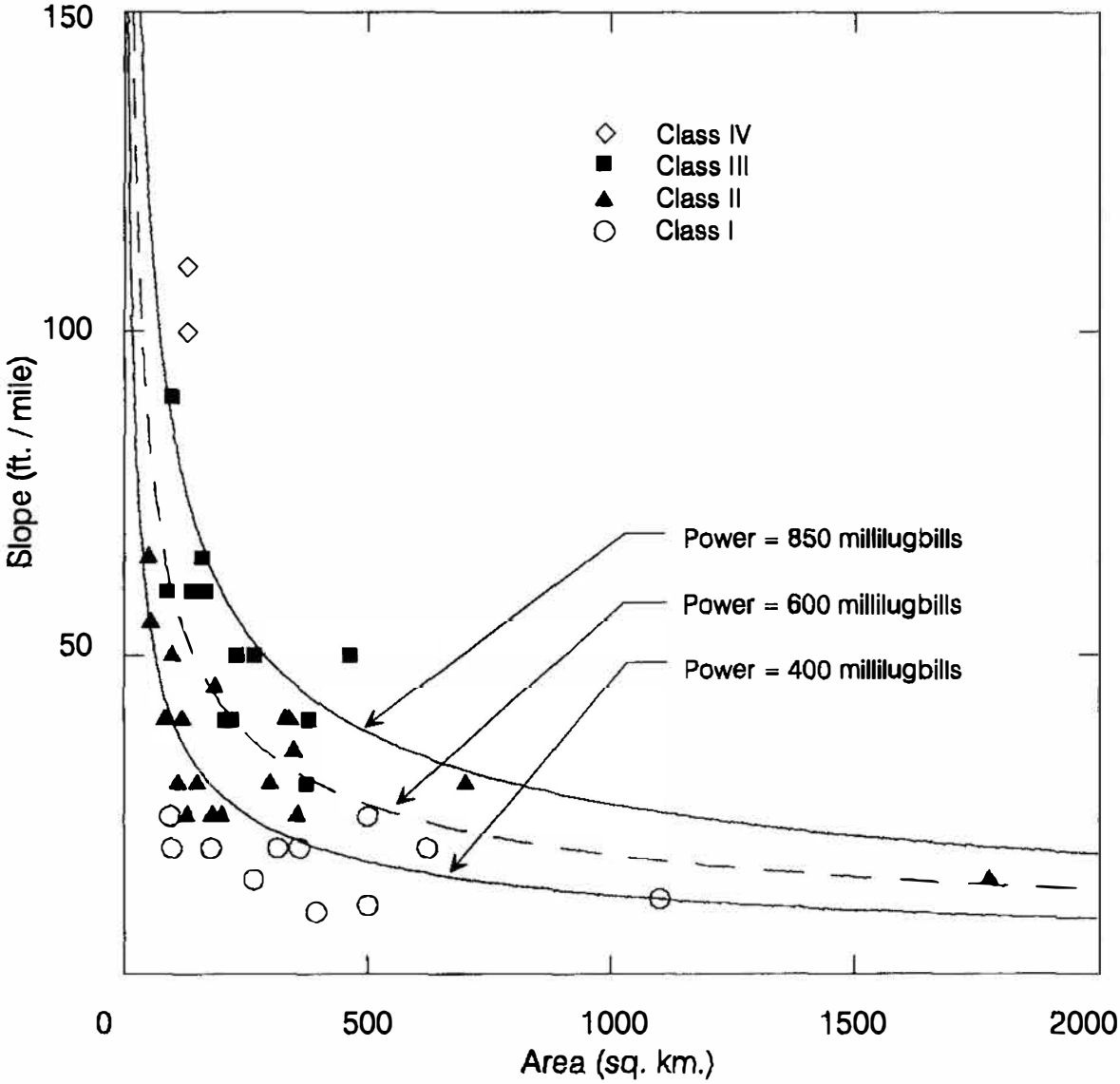


Figure 4-12 Relations Between Slope, Drainage Areas and Stream Power. Each symbol represent a whitewater segment; the shape of the symbol indicates the average difficulty of the whitewater.The curves are lines of constant power ($SA^{0.5} = P$). In general streams of similar difficulty lie in bands parallel to the constant power curves, rather than in horizontal bands of equal slope. The filled symbols are streams with medium (Class II - Class III) whitewater. These for the most part have stream powers bwetween 400 and 850 mill-lugbills. The dotted line represents points with a stream power of 600 milli-lugbills, and is approximately the lower boundary of the Class III streams.

The table shows that while the separation of degrees of difficulty is still not perfect, it is considerably better than that achieved by slope alone. Considering that we are using a crude approximation for stream power and that we have no way of taking into account the difference in geological personality of a stream, it is surprisingly good. Hence the estimated stream power provides a reasonably good estimate of the kind of whitewater that will be encountered in a stream, and we may propose the following rule of thumb:

> If an unknown stream has a watershed of over 50 sq. km. (20 sq. miles) and if further the product of the slope in feet/mile and square root of the watershed in square km. is equal or greater than 250 it is likely to be a usable whitewater stream. If further the slope-watershed product is less than 600 it will likely average Class II; if between 600 and 900 it will likely average Class III; and if over that Class IV.

Table 11: Estimated Stream Power and Level of Difficulty for Whitewater Segments

Stream	Begins	Run ends	Power	Class
MIDDLEBURY	E. RIPTON	MIDDLEBURY	3680	V
NEW HAVEN	W LINCOLN	ROCKY DALE	1210	IV
DEERFIELD, W.BR. #2	HEARTWELLVILLE	READSBORO	1100	III-IV
WEST	BALL MT. DAM	SALMON HOLE	900	III
WARDSBORO	WARDSBORO	JAMAICA	900	III-IV
WINHALL	GRAHMVILLE	WEST RIVER	845	III-IV
MILL	E. WALLINGFORD	CLARENDON GORGE	780	III
NEW HAVEN	ROCKY DALE	NEW HAVEN MILLS	750	III-IV
DEERFIELD, W. BR.	SEARSBURG RES.	HARRIMAN RES.	750	III
MOOSE	E. ST. JOHNSBURY	PASSUMPSIC RIVER	720	II
WAITS	WAITS RIVER	BRADFORD CENTER	720	II-III
OMPOMP. W.BR.	STRAFFORD	RICE'S MILLS	720	III
WEST RIVER	SALMON HOLE	EAST JAMAICA	690	II
WEST	LONDONDERRY	BALL MTN. RES.	680	III(IV)
NEW HAVEN	ABOVE W.LINCOLN	W. LINCOLN	675	II(III)
BLACK RIVER #2	WHITESVILLE	PERKINSVILLE	665	II(III)
LAMOILLE	FAIRFAX	ARROWHEAD LAKE	630	II
SAXTONS	GRAFTON	SAXTONS RIVER	630	II-III
LAMOILLE	GREENSBORO BEND	HARDWICK	600	II-III
MAD	MORETOWN	WINOOSKI RIVER	570	II(IV)
MOOSE	SNOWMOBILE BR.	NORTH CONCORD	560	II-III
WILLIAMS, MID. BR.	SIMONSVILLE	CHESTER	540	II-III
CONNECTICUT	LYMAN DAM	BLOOMFIELD	510	I-II
WILD	BRANCH	WOLCOTT	500	II
WHITE RIVER	STOCKBRIDGE	BETHEL	500	I-II
CLYDE	SALEM POND	CLYDE POND	475	II
HANCOCK BRANCH	ROBBINS BRANCH	WHITE RIVER	455	II-III

DEERFIELD, W. BR.	1ST BRIDGE	E. BR. CONFLUENCE	440	II
WHITE	BETHEL	CONNECTICUT	420	0-I(II)
WEST	TOWNSHEND	CONNECTICUT RIVER	396	I-II
MAD RIVER	WARREN	MORETOWN	380	II
MISSISQUOI	NORTH SHELDON	SHELDON SPRINGS	380	II
HUNTINGTON	HANKSVILLE	HUNTINGTON GORGE	360	II
BLACK #1	IRASBURG	COVENTRY	360	II
DEERFIELD,E. BR.	SOMERSET RES.	W. BR. CONFLUENCE	360	II
PASSUMPSIC, E. BR.	E. BURKE	CONF. WITH W. BR.	350	I-II
LEWIS CREEK	PRINDLE CORNERS	N. FERRISBURG	325	II
OMPOMPANOOSUC	POST MILLS	MUD POND BRIDGE	300	II(III)
GREEN	GREEN RIVER	LEYDEN, MASS.	300	II(III)
WEST	WESTON	LONDONDERRY	280	I-II
WILLIAMS	GASSETS	CHESTER	250	II-III
DEERFIELD, N. BR.	WEST DOVER	HARRIMAN RES.	250	I-II
WINOOSKI	MARSHFIELD	MONTPELIER	242	I-II
WILLIAMS	CHESTER	BROCKWAYS MILLS	240	I-II
CLARENDON	CLARENDON SPRINGS	WEST RUTLAND	200	II
BATTENKILL	SUNDERLAND	NYS LINE	190	I (II)
LAMOILLE	CADYS FALLS	CAMBRIDGE	140	I
OTTAUQUECHEE	W. BRIDGEWATER	WOODSTOCK	50	I-II

Power = slope x (watershed)$^{0.5}$ (feet/mile x sq. km.)

4.6 An Example: The Mettawee

We give an example of how power calculations can be used to predict the intensity of the water on an unknown stream.

The Mettawee river arises on Dorset Mountain, the second-highest peak in the Taconic Mountains. The bedrock is softer here than in the southern Green Mountains to the east, but the relief is high. No runnable whitewater is known in this part of the Taconics. The Mettawee is not currently used as a whitewater run, but looks nice and steep and rocky in its upper segments, particularly between Dorset and Dorset Hollow. The AMC Guide says that it is a Class I run with some Class II water below North Rupert, that it might be possible to start at the VT 30 bridge in Dorset, and that the rapids are pleasant.

7.5 minute topographic maps are available for Dorset, Pawlet, and Wells, so it is possible to make fairly accurate determinations of slopes along the 20 mile segment between the headwaters on Dorset Mountain and the NY-VT border near Granville, New York. Table 4-5 gives slopes, approximate watersheds, and the estimated stream power for the segments we are interested in.

Table 12: Slope, Watershed, and Estimated Stream Power for Stations Along the Mettawee

Station	Location	Mile	Slope (ft./mile)	Watershed (sq. km.)	Stream Power (ft./mile * km.)
1	Dorset Hollow	2.5	170	10	540
2	just above Dorset	5	110	30	600
3	East Rupert	7.5	50	38	360
4	Dorset-Pawlet line	11	28	66	230
5	Pawlet	13	22	160	270
6	NY-VT line	19	13	345	250

Comparing these numbers to those in Table 4-4 and Figure 4-8 for known streams, we can form an idea of what the stream is like at each station.

- At Station 1 the stream has a formidable slope but a tiny watershed, and is essentially a mountain brook. Because of the small watershed, even though the slope is typical of Class V water the stream power is more like that of a stream on the borderline between Class II and Class III. A stream of this size is of course not runnable.

- At Station 2 the stream is still very steep; the watershed is 3x as large, but probably still too small to run. The power is about the same, the decrease in slope having more than offset the increased watershed. At 30 sq. km. it is still too small to be runnable.[11]

-- At Station 3 the stream has left the hills and turned into the main Dorset-Pawlet valley, which was likely carved by a former and larger river. There is an abrupt decrease in slope to 50' per mile in the 2.5 miles between station 2 and station 3, and a corresponding decrease of about 40% in the power, which is now typical of an average Class II stream. The watershed of 38 sq. km. and slope of 50' per mile are close to that of the Hancock Branch (65' per mile, 50 sq. km.) which is reported to be a nice miniature whitewater stream. Hence it is conceivable that this stream might be runnable at high water, provided that the channel was clear

11. In a whimsical moment in 1986 we paddled from about a mile below Station 2 to Station 3, mostly to see if boating a stream with 30 sq. km. of watershed was possible. We found that the rapids were pleasant and undramatic Class II or low Class III, and that the stream was quite narrow. We also discovered nine trees completely blocking the channel -- some of them at fairly dangerous places -- in the first mile. Overall the boating was tricky but not very much fun. Our scouting suggests that this will generally be true for streams of this size and slope, and that there is every reason to regard 50 sq. km. of water shed as the absolute lower limit of enjoyable boating, if not of possible boating.

enough and there were no fences or dangerous obstructions. The bedrock in this area does not form either ledges or hard round boulders, and so we would expect that the stream would not have much roughness and would have for the most part Class I or mild Class II water, with fast current but few holes or waves.

-- At Station 4 the gradient has dropped to 28' per mile, still potentially Class II water, but the power has dropped to that typical of Class I streams, while the watershed is still smaller than that of most whitewater streams. Thus this is probably at most a quickwater stream.

-- At Stations 5 and 6 the slope continues to decrease, though this is offset by considerable increases in the watershed resulting from the entry of tributaries, and hence the power stays constant.

From these calculations it appears that the Mettawee comes down out of Dorset Hollow as a mountain brook whose power is in the Class III range, enters the main valley (presumed to be geologically older than the present stream that fills it), rapidly decreases in power to a Class I stream, and then stays at approximately constant power all the way down the valley. In boater's terms it is unrunnable in the hollow and a touring rather than a whitewater stream below. It appears that there might be 1-3 miles of Class I to Class II water in the transition, and that this segment, if runnable at all, will correspond to the Class II streams in the upper left of Figure 4-8, and will be tight and fast and need very high water.

* * *

The above procedure -- which we may call slope-watershed analysis -- seems to be a useful way of looking at unknown streams, and we suggest that boaters might want to make similar calculations for potentially interesting streams in their own areas. The slopes are best estimated from the contours on 7.5' minute maps, which are considerably more accurate and easier to use than the 15' maps, but which, in 1992, are finally available for the whole state.[12] Drainage area is easiest to measure on smaller scale 1"= 1 mile maps. An approximate but adequate way of calculating areas is to first draw the watershed in accurately, then approximate the boundaries by straight lines and calculate the area as a sum of triangles.

4.7 Does Runnable Whitewater Occur Along Headwaters Streams?

In order to locate currently unknown streams that might be boatable we computed slope-watershed products for a number of points along small streams. The results of our assessment of the potential whitewater on these streams was given in Chapter 3. Here we are concerned with the more general question of whether the headwaters streams -- the small streams that descend from primary watershed on mountain slopes -- generally have a runnable segment.

12. A number of the new provisional topo maps use the English scale of 1:24000 but have elevations in meters. In all metric units the basic unit is 1000 km-m per km or 1 hearne (after Cathy and Davey Hearne, two Americans who are world-champion C1 racers.), and the conversion is 5.28 lugbills per hearne.

!
If they do this means that most mountain streams have a least short whitewater segments, and the amount of small-scale whitewater available to boaters is considerably larger than that currently documented in guidebooks.

And conversely, if headwaters streams do not tend to have runnable whitewater this means that the current estimates of the amount of whitewater are largely correct, and that whitewater consequently is both a scarce resource, and restricted to geographic situations that are to some extent atypical.

As a result of the examination of slope-watershed data, we found that many small headwaters streams in Vermont share the following features:

- In the segment between the headwaters and their first intersection with streams (or stream valleys) substantially larger than themselves, their slope and watershed are inversely related in such a way that the average stream power stays approximately constant.

- The average stream power for headwaters streams is approximately 600 milli-lugbills, corresponding to whitewater on the border between Class II and Class III. This is true of streams in different parts of Vermont and on a number of different types of rocks. This only applies to streams in mountain watersheds whose headwaters are on steep slopes somewhere near the angle of repose for wooded slopes.[13]

- Where a stream intersects a larger valley the power often drops abruptly and then stabilizes at a new value which is maintained for some distance down the valley.

These observations, which were discovered at the end of our study and need considerably more study, suggest two useful generalizations:

- As suggested originally by the geologist John Hack,[14] headwaters streams are in equilibrium in the sense that they distribute their erosive power evenly along their length.

- If this is the case, any headwaters stream that attains sufficient watershed to be boatable before it intersects a larger stream will have Class II-III whitewater.

The first of these generalizations has a surprising consequence. It is mathematically equivalent to saying that all headwaters streams have approximately the same profile, and that they all have approximately the same relations between length, vertical drop, and total watershed. This means that, always assuming that the power is constant, we can draw a picture like Figure 4-13 that will be the same for all headwaters stream.[15]

13. It has been tested on a a sample of streams from different parts of the state, but it needs much more extensive testing to see if it is generally true.
14. J. T. Hack, 1973, *Drainage Adjustment in the Appalachians*, in Morisisawa, Marie, ed. *Fluvial geomorphology*,, SUNY, Binghamton NY.
15. See the Appendix to this chapter for a proof of this.

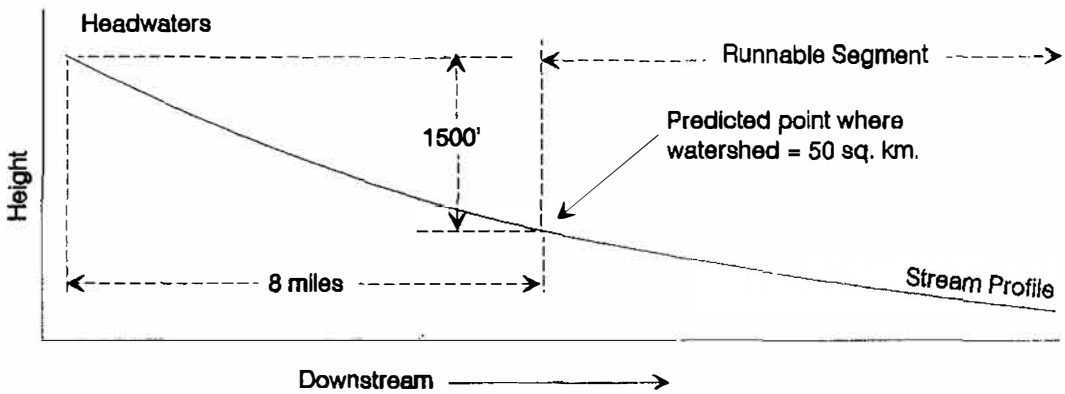


Figure 4.13 Predicted Longitudinal Profile for a Headwater Stream With a Constant Power of 600 Milli-lugbills.

This can be said in another way. If it is true that headwaters streams have approximately the same stream power, and if this power remains constant as you move down the stream, then the point at which the stream attains a sufficient watershed to become boatable will always be about the same distance horizontally and vertically from the headwaters.

For purposes of discussion we will define **headwaters whitewater streams** as streams whose profiles are like Figure 4-13, and which become boatable as soon as they reach a point of adequate watershed, and which have roughly constant stream power from the headwaters to the boatable section. We might imagine that in a mountainous state most whitewater streams are of this type, and hence that whitewater streams will be common in all parts of the state where there were mountain watersheds. As we will see in the next section this is not so.

4.8 Why is Boatable Whitewater Rare?

The total area of Vermont is about 9,600 square miles. Using the conventional estimate of 1.4 miles of stream channel per square mile of surface it should contain in excess of 13,000 miles of river and streams. Most of this will in the form of small headwaters streams. The amount of boatable stream channel seems to be approximately 10% of this, or about 1300 miles. Of this some 200 miles of stream channel (or around 2% of all the stream channel and 20% of all the boatable channel) contains Class II or higher whitewater.

This seems odd. If only slope mattered one might suppose that, since all streams start with slopes too steep to run and end with slopes too mild to produce whitewater, there would be someplace on every stream which had the right slope to provide a segment of runnable whitewater

Such a picture fails to take into account the need for both slope and volume. Headwaters streams commonly have adequate slope and power, but (like the upper Mettawee of the previous section)

13. It has been tested on a a sample of streams from different parts of the state, but it needs much more extensive testing to see if it is generally true.
14. J. T. Hack, 1973, *Drainage Adjustment in the Appalachians*, in Morisisawa, Marie, ed. *Fluvial geomorphology*,, SUNY, Binghamton NY.
15. See the Appendix to this chapter for a proof of this.

inadequate volume. As they descend they gain watershed and volume, but encounter larger valleys and loose power. Hence by the time many streams are big enough to be boatable they are no longer powerful enough to have whitewater.

Diagrammatically it looks like this. Here is a stream that keeps its slope while it gains volume, and hence has a runnable segment:

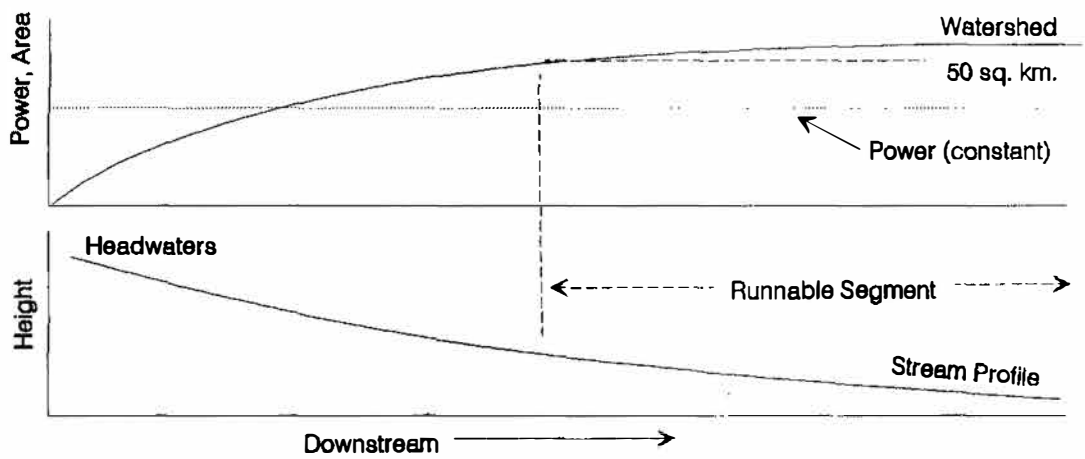


Figure 4.14 Longitudinal Profile of a Stream With Constant Power. The lower figure shows the profile, the upper figure the watershed (solid curve) and power (dotted line.) This stream maintains its slope and hence its power past the point where it has 50 sq. km. of drainage, and so is runnable.

While here is a stream that loses its slope before it gains volume:

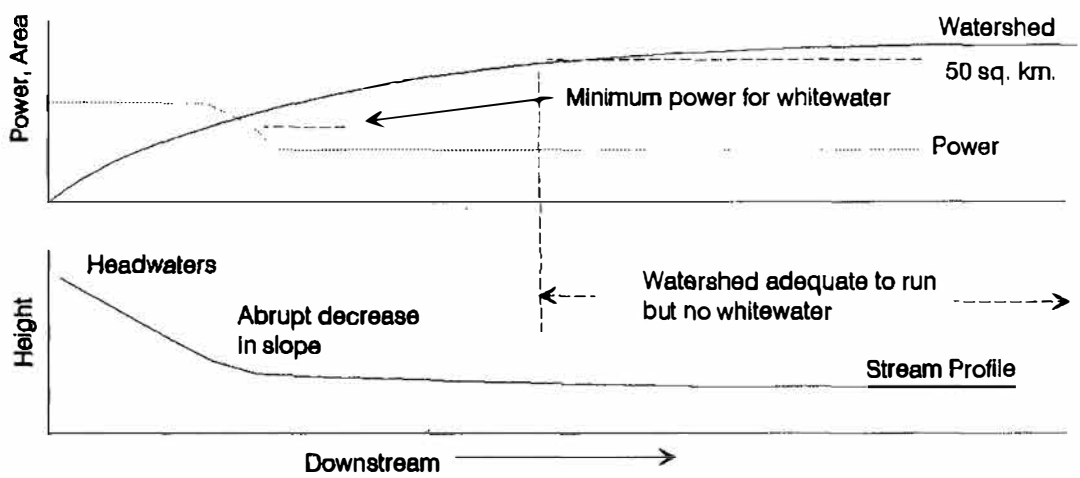


Figure 4.15 Longitudinal Profile of A Stream With an Abrupt Decrease in Slope Below the Headwaters. This stream flattens out before the watershedbecomes large enough for it to be boatable. The power decreases and falls below the minimum necessary for whitewater.

The comparative rarity of headwaters whitewater runs can be shown by taking Figure-12 and and looking at the far left edge wehere the slopes are over 50'/mile and the drainage area under 75 km. sq., which would be of many headwaters streams. If headwaters streams were important as whitewater runs many of the stream segments would lie in or near the shaded region.

But in fact only a few streams boatable streams lie in this region. Most of the whitewater runs have slope-watershed products that are substantially different from those of headwaters streams, and hence comparatively few of the known whitewater runs occur in headwaters segments. This is born out by an examination of stream profiles, as explained in the next section.

Our initial problem -- explaining the rarity of boatable whitewater -- has just multiplied. Now we need to explain why headwaters streams in Vermont so rarely develop runnable whitewater, and also where the majority of our whitewater streams -- which are not near their headwaters and would be expected to have low slope and power-- get the extra power to turn them into whitewater streams.

The answer to the first question is suggested by our analysis of the Mettawee in the previous section. It appears that streams alter their slope and lose power abruptly when they intersect the valleys of larger streams. Thus the critical question for the existence of whitewater is whether the stream has a long enough valley to attain runnable size before it bumps into a larger valley and loses power. In the case of the Mettawee the valley length was not quite sufficient. The stream moved out of its own primary valley into a larger valley (presumably cut by a former stream that was larger and had a lower slope) 6 miles below its headwaters, and started to lose power when it had less than 50 sq. km. of area.

We have noted above that all constant power streams with the same power have the same profile. Now if it is true that many headwaters streams have a power of 600 milli-lugbills, this means that is possible to calculate the slope, drop from the headwaters, and watershed to be expected at various distances from its headwaters, using the equations derived in the Appendix. The results, which of course are only approximate, are interesting because they tell us the approximate minimum distances that a headwaters stream must run and fall before it is big enough to be boatable, and thus define the dimensions of the smallest watershed likely to have boatable whitewater. If real watersheds tend to be larger than this and have the same proportions, whitewater will be common on headwaters streams. If they run smaller or are differently proportioned it won't be.

Table 4-13 gives the predicted slope, watershed, and fall for various points along a stream with a constant power of 600 milli-lugbills, and Figure 4-16 illustrates this graphically.

Table 13: Predicted Longitudinal Profile of A Stream With a Constant Stream Power of 600 milli-lugbills

Watershed (sq. km.)	Expected Slope (ft/mile)	Expected Distance From Headwaters (miles)	Expected Fall From Headwaters (feet)
50	85	8	1500
100	60	11	1700
200	42	17	1850
400	30	22	2000
800	21	36	2100

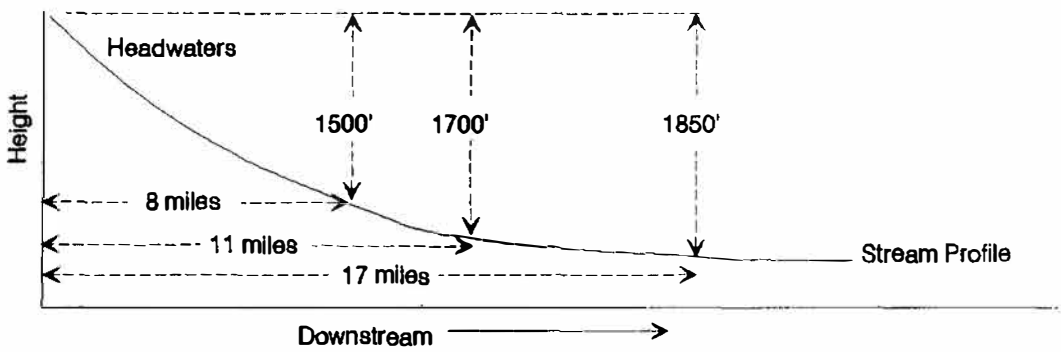


Figure 4.16 Predicted Longitudinal Profile for a Stream With a Constant Power of 600 Milli-lugbills.

Using these numbers can we make the following approximate rules:

> Unless the length and and relief of a watershed is such that a stream has room to run 8 miles and fall 1500 feet from its headwaters without entering the valley of a larger stream with substantially lower slope, it will not be boatable.

When we look at the watersheds and vertical drops of headwaters streams throughout Vermont it turns out very few meet this test. Of the hundreds of small primary streams in the state only about 20-25, to judge from topographic maps, have long enough and deep enough valleys to acquire the watershed necessary for whitewater.[1]

The reason for this is related to geographic scale, and to a basic, but quite curious, geomorphic fact. We tend to have landscapes of steep slope and small extent, and landscapes of gentle slope and large extent, but very little in between.

1. See Table 3-3 and accompanying text for a list of some of these streams.

To see how this works consider Figure 4-17. The lower figure is our constant-power stream profile, 8 miles long x 1500' high, average slope 150' per mile. The upper figure shows a typical Vermont mountain range, 2000-2500 feet above the valleys, 6-10 miles total width. Adjacent to it is a major lowland valley, with an average slope on the order of 100' per mile or less. We ask whether we are likely to find a stream with the profile shown in either the average mountain range or the valley C.

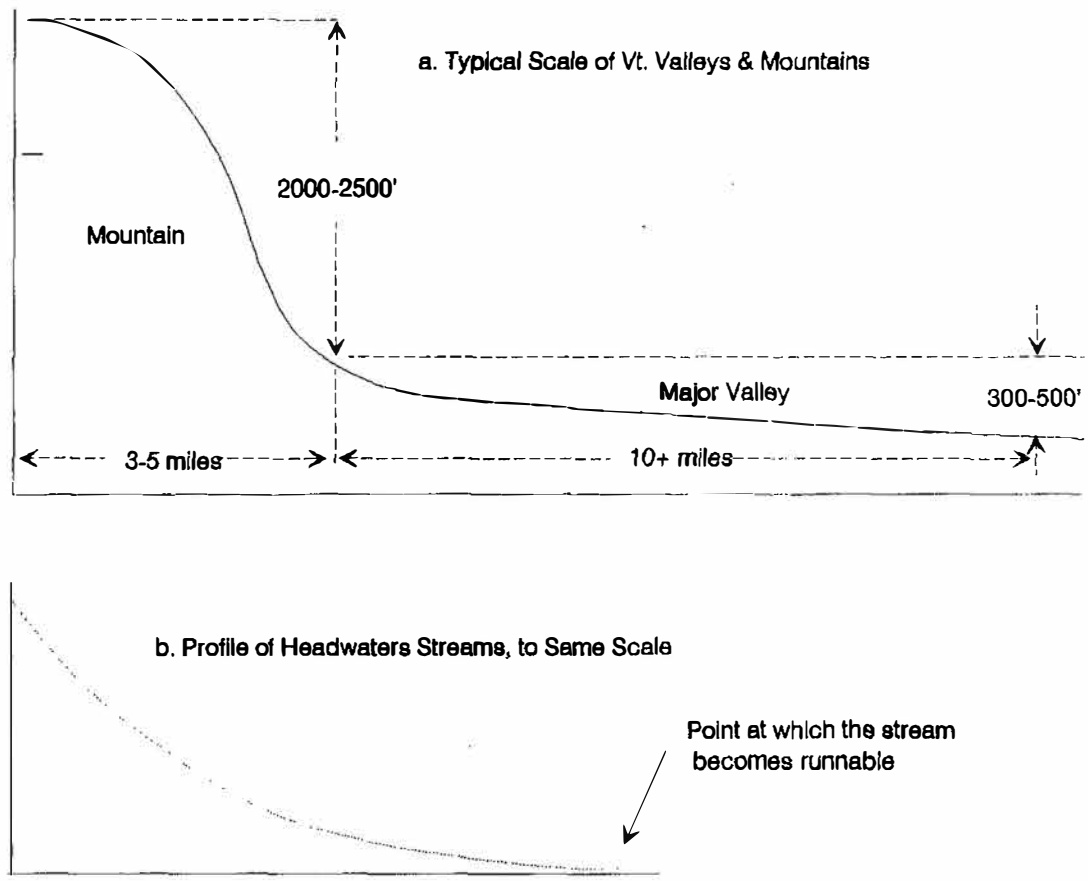


Figure 4.17 Common Scale of Vermont Valleys & Mountains Compared to that Required For Runnable Whitewater on Headwaters Streams. The lower figure shows the minimum length and height required to get runnable whitewater on headwaters streams.

The answer is either no or rarely. .The stream is too high to fit in the valley and too long to fit in the mountains. The only place it might be accomodated is at between the mountains and the valley, but for this to happen the transition between mountain and valley cannot be too abrupt.

To say this more visually.. An eight-mile long headwaters stream segment won't fit into the normal tributary valleys that lie perpendicular to the mountain ridges, because the half-width of most of our average ranges -- 3-5 miles -- is not big enough. It also won't fit into the the major valleys because, while they may be long enough, they do not have enough relief. If there were more intermediate land forms -- for example long interior valleys running parallel rather than perpendicular to the drainage divides, or gradual transitions between slopes and valleys -- we would have more places to put an eight-mile long headwaters stream. But there are not, and hence headwaters whitewater streams are rare.

An interesting quantitative way of looking at this is to map what geomorphologists call the 'subenvelope', which is a measure of the average relief of the landscape. Figure 4-19 is taken from the *Geomorphology of New England* by Charles Denny.[2] The contours (in 100 meter intervals) show the difference between the highest and lowest points within a 4 mile square, and hence are a measure of the maximum stream gradients. For much of Vermont they are under 200 meters per 4 miles, or ca. 150' per mile. But to attain the minimum runnable watershed of 50 sq. km. a headwaters stream must drop 1500' per 8 miles or average ca. 180' per mile. Hence the average relief in most of Vermont -- height of land to valley floors -- is insufficient for mountain streams to fall enough to reach runnable size before the bump into the valley floor. And conversely in the few areas that have enough relief the slopes are mostly too great, and the primary valleys, though plenty high enough, are not long enough.[3]

4.9 What Produces Whitewater On Non-Headwaters Streams?

We now come back to the conclusion of Section 4.7, which is most runnable whitewater does not occur in regions of steep slope and high average stream power, but rather in relatively flat valleys where the average stream power is that typical of Class I streams. What happens to such streams to allow them to attain the higher intensities that we are interested in?

The answer was indicated in a general way in Chapter 3. Whitewater streams often have a dip in their profile, which means that they have a segment with locally higher power.

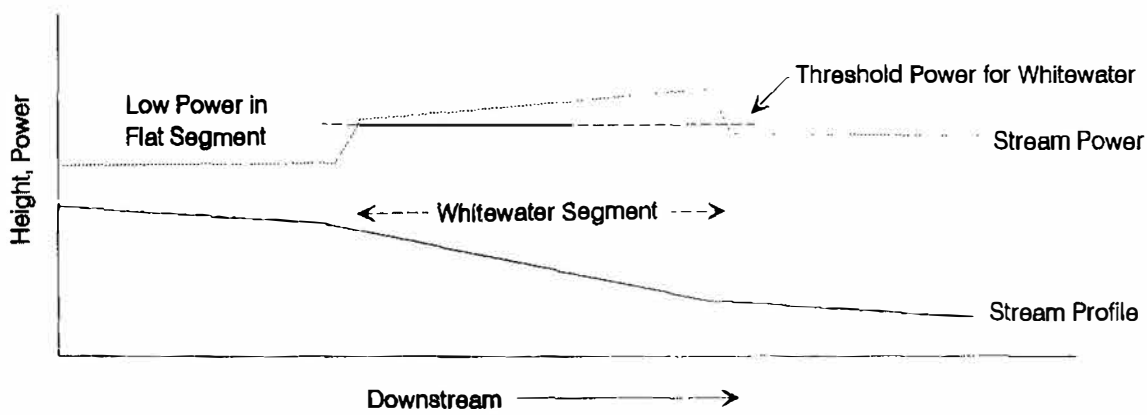


Figure 4.18 Stream Power and Profile for a Stream With a Dip ('Resteepened Segment') in its Profile.

2. USGS Professional Paper 1208, U.S. Geological Survey, Alexandra Va., 1980.

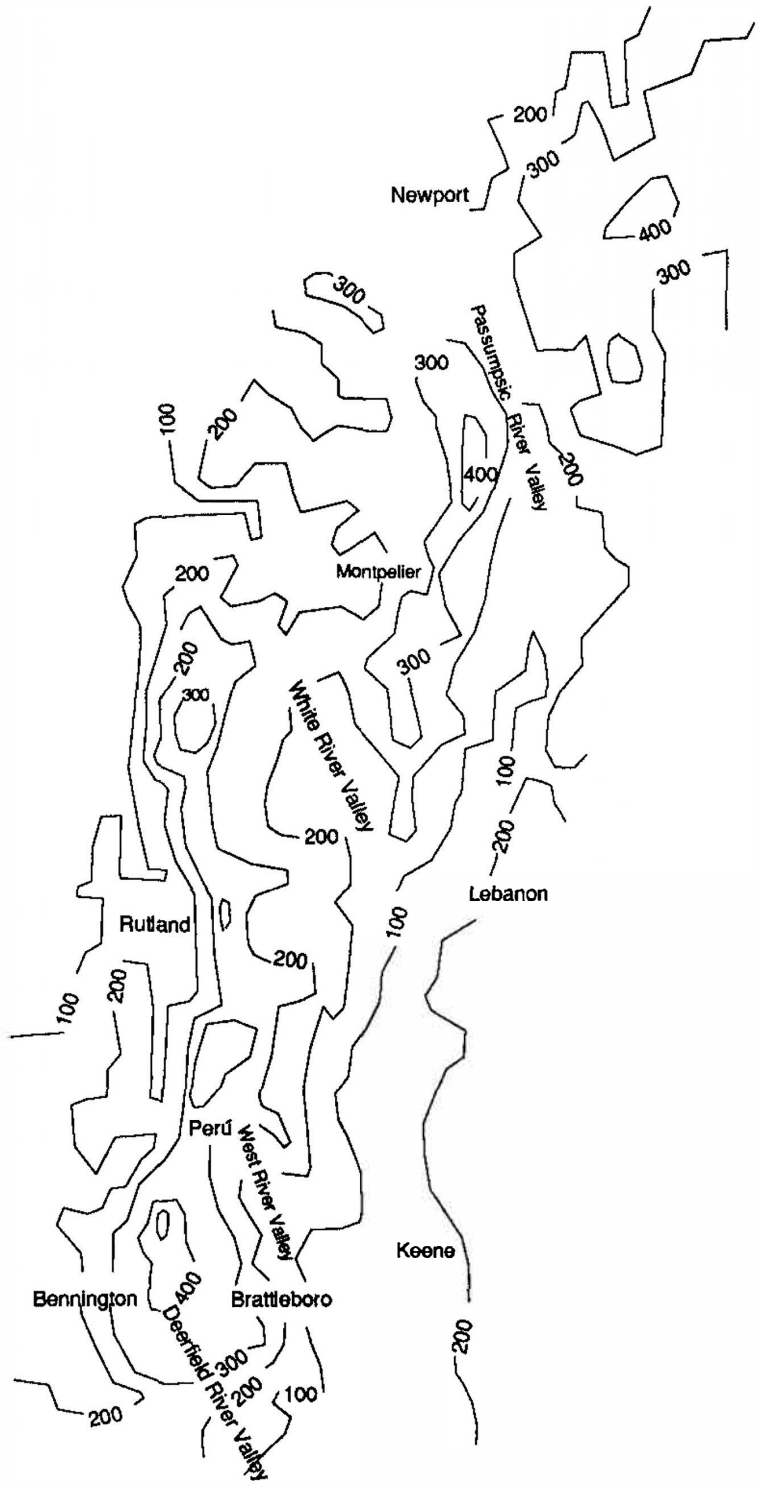


Figure 4.19 Subenvelope Map of Vermont Redrawn from Charles Denny, *The Geomorphology of New England,* USGS Pro. Pap. 1298, 1980.

3. Note that the spacing of the subenvelope contours becomes closer as you approach the mountains, indicating that the transition from valleys to mountains is abrupt.

The increase in the power corresponds to the steepness of the dip. If the dip is steep enough the power can be above that found in the headwaters.

Some streams instead of having a dip in the profile have a straight segment:

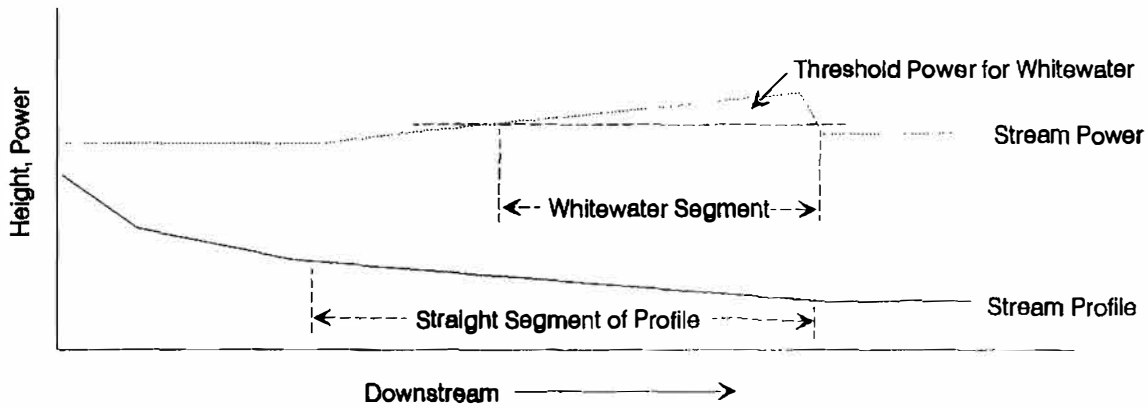


Figure 4.20 Stream Power and Profile for a Stream With a Straight Segment in its Profile.

The result is the same: instead of the power staying the same or decreasing it increases.

In Chapter 3 we called both of these cases 're-steepened' profiles. To assess how important the re-steepening of streams was for the development of whitewater runs we determined the slopes and approximate profiles of a number of whitewater streams. The results were clear cut: three quarters of the whitewater streams had dips in their profiles, and in many of the remaining ones there was a marked suggestion to a straight segment, and evidence that the power increased downstream.

Thus it seems that the great majority of Vermont whitewater runs are in streams with re-steepened profiles, and are in some sense hydrologically unusual. This, we believe, accounts for their rarity; they are not found on streams with normal profiles, and only exist because the local geology alters the normal stream profiles.

* * *

In a moment we will turn to the relation between bedrock geology and stream gradients. Before doing this it might be useful to sum up the conclusions of the last three sections.

- The normal stream profile (Fig. 4-13) typical of headwaters streams should produce at most Class II whitewater, and will not produce any whitewater at unless the relief of the watershed over 1500' is high and the primary valleys are about eight miles long.

- In all but about 20 Vermont streams -- all of which are small and most of which are not currently used by boaters -- the preceding geometric conditions are not met, and the headwater sections of streams produce no runnable whitewater.

-- A stream whose profile has a straight segment or a dip (Fig. 4-13) will increase its power above what is predicted by the normal profile, and can have whitewater of any class.

-- *Almost all the major whitewater runs depend on this sort of re-steepening.*

Table 14: Classification of Whitewater Runs by Stream Profile

Resteepened Profile	Straight Profile	Concave Profile
Black	Winhall	Hancock Br.
Black (1)	Wardsboro	Green River
Clarendon	Deerfield W. Br.	Deerfield E. Br.
Clyde		
Mad		
Middlebury		
Mill		
Missisquoi		
Moose (2)		
New Haven		
Nulhegan		
Ompompanoosuc		
Ompompanoosuc W. Br.		
Passumpsic		
upper Lamoille		
Waits		
West		
Winoosk		

4.10 How Does Bedrock Geology Influence Stream Gradients?

Two related pieces of evidence suggest that the presence of the dips and straight segments in stream profiles which are responsible for most major whitewater runs is controlled by bedrock geology.

The first is a general regional correlation between the hardness of the bedrock and both the gradient of large streams and the overall relief in each 4-mile square.[4] Areas with rocks of highly met-

4. Charles Denny, 1980, *op. cit.*

amorphic grade are supposed to have higher local relief, and higher gradients in the larger streams, than those with lower metamorphic grades. This seems to be generally true in Vermont, though with important local exceptions. Metamorphic grade generally increases eastwards in Vermont. The majority of the large streams in the chlorite and biotite metamorphic zones in western Vermont produce at most Class I-II whitewater[5], while similar-sized streams on higher-grade rocks eastwards produce Class III water.

The second piece of evidence comes from local geological detail. In a number of streams the presence of whitewater segments, gorges, and isolated rapids is associated with the presence of particular strata, or with a situation where a river crosses between strata of different composition or metamorphic grade. The following examples, drawn from geological maps and our field observations, are suggestive.

- Both the Battenkill and Clarendon Rivers have local areas of steep slopes where they cross from the Clarendon Springs Dolomite onto the Shelburne Marble, a harder and more crystalline rock.

- The West River develops rapids in its lower stream where it crosses a granite pluton in Dummerston.

- The steepest slopes on both of the West Branches of the Deerfield, on the main stem of the West River, and on the Black River occur after the stream leaves the Precambrian quartzite and crosses onto the Readsboro member of the Cavendish formation, a belt of Cambrian schists. The slopes of all three stream become flatter after they leave the Readsboro.

- Similarly the Clarendon Gorge on the Mill River occurs just after the stream leaves the Precambrian Mt. Holly gneiss and crosses into Cambrian quartzite and quartzite schist. The stream then flattens out, and then develops a second gorge when it hits a resistant marble.

- The Standing Pond member of the Waits River formation (Devonian amphibolites and schists) is associated with small gorges and ledges on several widely separated rivers: the Ottauquechee, Green, Saxtons and possibly the White.

- The Cheshire quartzite is associated with a number of exceptionally steep streams (for example the Big Branch in Danby with a slope of 200' per mile and a stream power of 1600), and also with substantial whitewater rapids on the Lamoille, Missisquoi, and New Haven Rivers, again in widely separated parts of the state.

5. Important exceptions to this generality are the stream segments on the highly resistant Cambrian quartzites. Stream gradients are related to the erodibility of the bedrock. In general metamorphic grade is a useful but imperfect measure of the comparative erodibility of bedrock. Other factors like solubility, texture, joint patterns, faults and crush zones, and structural orientation are also of great importance. We use metamorphic grade and general stratigraphy for our comparisons because they have been mapped on a large scale and are available for armchair study, which is the way botanists do geology.

- The Mad River steepens where it crosses onto the Ordovician Stowe schist, which is supposed to be of higher metamorphic grade than the surrounding rocks.

- The Moose and the Clyde rivers steepen as they encounter sillimanite-grade metamorphism at the edge of granite plutons.

We cite these examples to suggest relations between bedrock and the stream slope, but not to assert that these relationships are either simple or uniform, or that counter-examples do not exist. There are other streams -- the Waits and West Branch of the Ompompanoosuc for example -- which seem to maintain the same slope while cutting through a number of strata of different metamorphic grade. Here the structural control of slope is not obvious. And there are others like the Huntington, the Black, and the Browns, which steepen abruptly while traversing regions that are mapped as geologically uniform.

A full account of the geological control of slope would certainly have to go beyond considerations of lithology and metamorphic grade and look the factors mentioned in the footnote on the preceding page. It might also have to look at historical relations between streams and their tributaries. This is a puzzling subject since no generally accepted models of hillslope or drainage evolution are currently available. We will broach this subject, with great tenativeness, in Section 5.11

To summarize before turning to the question of roughness: there is certainly evidence that bedrock exerts control over stream slopes. Furthermore it appears that the local increases in slope that generate the majority of Vermont whitewater runs are often associated with stratigraphic boundaries and the local presence of rocks of a higher metamorphic grade. But the relations between bedrock and slopes are not consistent, and do not, by themselves, account of all the changes in slope.

4.11 What Determines the Roughness of a River Channel?

We now turn to the next question, which is the nature of the local variations in slope that have been called roughness and which do much to determine the character of the whitewater that a boater will encounter.

Recall that the roughness of a stream comprises all the obstacles that cause local turbulence and hence local peaks in the stream power. Roughness varies in amount and kind from stream to stream, and gives streams their individual difficulties and character. It is essential for whitewater boating, in that it provides both the problems for the boater to solve, and the hydraulic tools -- eddies and countercurrents and surfing waves and so on -- to solve these problems.

As an example of the importance of roughness consider three rivers of equal total power. Assume that one has a gravel-bottomed gravel channel with only small stones, one has a channel with large boulders, and one runs in a smooth but narrow rock-walled gorge. Assume the power is equal to that of an average Class II stream. The river in the gravel channel will have lots of waves, especially at the outsides of bends and below places where the gradient is slightly steeper,

but it will have no holes or obstacles, and will be pleasant but undemanding boating. The one in the boulder channel will have a lot of breaking waves and holes, and depending on the size of the rocks and the way they are placed it may demand tricky maneuvering, and be substantially more difficult than the first stream. The third stream may operate in a hydraulic regime called 'shooting flow' where the water is very fast and the surface smooth and without waves. This stream may not appear as rough as the second but may be in fact more difficult because of the high speed, lack of eddies where a boat can escape the current, and the violent turbulence that occurs when the water eventually decelerates.

* * *

To treat roughness systematically it is useful to divide it into three categories. We made up technical-sounding names for them, but the ideas are simple.

Boundary roughness is caused by curves in the channel boundary. Bends and small fluctuations in slope (which are really curves in the bottom) cause the water to change speed and direction, and when this happens turbulence results.

Turbulence at bends is a standard example of boundary roughness. Bends create heavy waves on the outer bank, and when combined with rocks or ledges can create some very nasty diagonal waves where water is thrown back off a rock wall. They also tend to have somewhat steeper slopes than the straight reaches in between them, and so can have some of the most severe water in a given reach.

Slope variations are another common form of boundary roughness. Gradual variations in slope occur with a more or less regular periodicity (typically at a spacing of between 10 and 20 times the stream width) in most streams streams. They create patches of smooth water at points where the slope is increasing and the water accelerating, and trains of standing waves ("haystacks") where the slope is decreasing and the water decelerating. Essentially the water is pulled out thin and smooth when it accelerates, and gets piled up and bumpy when it decelerates.

While bends and gentle fluctuations in slope contribute to the roughness in all streams, there is one class of streams in which they are the major source of excitement. These streams are usually small streams, often with high gradients, in alluvial valleys. Many of them are geologically underfit, meaning that they are occupying a valley that was carved or filled by a larger predecessor. They lack the power to transport rocks from their headwaters and, if the valley is smooth and geologically uniform, often lack ledges as well.

Streams dependent on boundary roughness generally have low slopes and only mild Class I-II whitewater, and are pleasant but tame boating. The rare examples with steep slopes can be very interesting, and at highwater offer a unique and hair-raising whitewater experience, consisting mostly of screaming around bends at high speed and wondering what is going to be on the other side of them.

Bed-Load Roughness or *Rolling-Rock Roughness* is roughness caused by boulders that the stream has moved itself. We call these *emplaced boulders* to distinguish them from bedrock ledges. The largest boulders may range in size from 1' to 10', and occupy anywhere from a few percent to over half the stream channel. Their effect is to create obstacles, eddies, holes, and breaking waves. Boulders are often distributed fairly evenly, and produce streams with continuous rapids. The intensity of the resulting water varies with the size and abundance of the boulders, but can be anywhere from Class II to Class V. Class I streams seem to lack the power to move boulders, and have little roughness at all.

Emplaced boulders occur on many streams, but are far more abundant on some streams than others. The truly bouldery streams occur in areas where the bedrock consists of Precambrian or Cambrian quartzite or gneiss -- hard, internally uniform rocks that break into massive chunks and then tend to chip away at the edges rather than splitting. Such boulders may migrate some distance from the actual outcrops, and are common on streams that are connected by a continuous steep-gradient channel to a headwaters area on quartzite or gneiss. They do not seem to cross low-gradient segments, and are much less common on segments where the whitewater results from secondary steepening.

Classic examples of streams that derive their roughness from emplaced boulders are the West and its tributaries, the various upper branches of the Deerfield, the Middlebury, and the Moose.

Conversely there are a number of streams that might be expected to be bouldery from their steepness and situation, but are not. Examples are Lewis Creek, the Ompompanoosuc, the Third Branch of the White, and the Ottauquechee above Bridgewater. When compared to streams of similar slope but more bouldery complexion -- the West Branch of the Deerfield or the Middle Branch of the Williams for example -- they are considerably easier and less exciting to run.

The distribution and size of boulders is an intriguing puzzle; we have several observations but no firm conclusions.

First of all it is clear that massive, fine-grained, non-foliated rocks -- granites, gneisses, quartzites, etc. -- make excellent boulders. Likewise it seems that soft and extensively layered rocks like phyllites, slates, limestones, and some schists break up into small chunks and don't produce boulders. Thus the upper tributaries of the Lamoille (which originate on granite plutons) and the West and Deerfield Rivers (which originate on massive Precambrian gneisses and quartzites) are uniformly bouldery. And contrarywise the streams of the northeast and northwest edges of the state, which are underlain mostly by limestones in the east and slates and phyllites in the west, tend to have very few boulders.

Second, many large boulders have local sources, and may have been carried into streams by landslides and remained there because the stream doesn't have the power to move them.

Third, many other boulders occur some distance from their sources, and have been transported by water or ice. The size of the boulders to some extent reflects the average slope and intensity of the stream, because the steeper and more powerful the stream the bigger the boulders that it can

move. We have good evidence that in some streams many boulders move each spring, and that in these streams the occurrence of boulders is related to the power of the stream.[6]

And finally, it seems that many other streams have boulders that move only rarely or not at all, and are often located a considerable distance below their sources, and often separated from their sources by flatwater segment which would seem to lack the power of moving them. We speculate that these are fossil boulders in the sense that their distribution reflects previous rather than present conditions in the valley. But whether they were brought in the ice, or rafted by ice, or quarried out of till, or pushed by intense post-glacial streams we do not know.

An interesting feature of a number of the most bouldery streams is that they often have very even slopes, and almost never have ledges, waterfalls, or drops. This has been remarked on in the geological literature. We suppose that the stones grind the bedrock down and leave a smooth channel. In any event this makes for a distinctive kind of boating. In boulder streams the basic intensity of the whitewater water is almost constant, increasing only at bends and in the vicinity of exceptionally big rocks. The streams are easy in one sense because you don't have to worry about drops and giant waves or holes, but they are also hard because the gradient never lets up, and you have to keep working from one end of the run to the other. These continuous, bouldery runs may be something of a Vermont specialty, relating to our extensive belts of Precambrian quartzite and gneiss. In any event, they are quite distinct in character from runs where the principal roughness is structural.

* * *

Structural roughness includes any roughness caused by bedrock -- ledges, falls, cascades, gorges, rock-walled chutes, and so on.

Structural roughness can arise in a number of different ways. In stratified rocks you can have hard layers overlying softer ones, a situation which often produces high-angle falls that recede upstream and leave a gorge behind them. A number of the falls and gorges in the Champlain and Hudson watersheds have this origin. In metamorphic schist you often have considerable folding, and the parts of folds where the layers are vertical seem to be much less erodible than places where they are horizontal. Many waterfalls, cascades, and rapids are associated with vertical folds in schist. A number of gorges are also found in vertically folded schist, though it is still not obvious to us why this should be so. Possibly the vertical beds form a sandwich with weak layers between stronger layers, and the river cuts vertically, following the weak layer.

Another instance of structural roughness -- unfortunately very rare in Vermont -- is the granite stream. Many of the classic whitewater streams in New Hampshire, Maine, the Adirondacks, and many places in the southern Appalachians, are on granite. Granite streams tend to descend like staircases, with fairly smooth segments separated by steep drops, and are loved by high-level boaters. This is probably because granite tends to have deep, continuous, widely spaced cracks

6. We have observed that many streams which develop substantial amounts of ice move a lot of rocks, and suspect that the rocks may be plucked from the bottom when the ice breaks up.

and joints, and seems to wear by splitting parallel to these cracks or by plucking whole blocks away rather than by removing small fragments.

What all these instances of structural roughness have in common is that they produce non-uniform constrictions and slopes, and so create highly varied whitewater in which each rapid is an individual problem. White water features like abrupt drops, narrow passages, and tricky waves and cross-currents are typically of streams with structural roughness and uncommon elsewhere. The rapids on structurally intricate streams are often discontinuous, with stretches of fairly flat water in between, and are often what boaters call technical, meaning that they are spatially complex and require very accurate placement and balancing of the boat. They are also unrelated in difficulty to the average power of the stream. The stream may have on the whole the slope and watershed of a Class II stream, but have individual drops and rapids that are one or two classes harder. The lower Mad River is an excellent example of this. It plots with the Class II streams in Fig. 4-12, but is considered to be a Class III-IV run.

Streams dominated by structural roughness are rare in Vermont. The Mad is probably our best example, followed by the New Haven. The White and West are large streams that have individual rapids generated by structural roughness in the lower parts of their valleys. The Black (Cavendish) is an example of a Class II boulder stream with Class III drops of structural origin. Many gorges and isolated rapids are structural: those on the Huntington, Browns, Third Branch of the White and middle Lamoille are good examples. And many of the most difficult passages in a number of Class III streams like the upper Lamoille, Waits, Saxton's and Moose are structural, though you only realize this if you examine the stream at low water.

We have only a few geological generalizations about structural roughness. In Vermont it is most commonly found in limestone and schist; in both rocks it is associated with intricate folding and especially where the layers are nearly vertical. It is occasionally associated with quartzites: good examples occur on the Winhall and New Haven Rivers. It is scattered widely through the state but less common in regions of biotite or lower grade metamorphism than in regions of garnet or higher grade; it is generally but not wholly absent from the Precambrian and lower Cambrian core of the southern Green Mountains. And it is found commonly on small streams in granite areas of the state but rarely results in good whitewater, mostly because large streams seem to avoid going through granite plutons if they possibly can.

4.12 How Does the Intensity of Whitewater Vary with Water Level?

We conclude this chapter with a brief explanation of how the intensity of rapids varies with water level. It is well known that some streams become extremely difficult at high water. It is less well known but equally true that other streams actually become smoother at high water. To my knowledge the matter has never been carefully treated in the boating literature and so we devote a section to it here. Besides being of practical importance, it is also useful as an explanation of why we stress in the river descriptions that the difficulty of some rivers might be different at high water, and do not do so for others.

We start with the obvious remark that as the flow of a river Q at a particular point increases the depth D, width W and velocity all increase. The equations are not linear and hence the increases are not necessarily proportional: doubling the flow does not, except in special cases, double width or depth or velocity. We have to look at how a given increase in Q is apportioned between the depth, width, and velocity. We will find that slope is critical, and that in particular the relations between depth and velocity and depth and power are very different for streams of different slope. Physically the volume Q and the slope S are the independent variables to which the other variables must adjust, and so what we would like to obtain are equations giving the depth, velocity and power at a point on a stream as functions of Q and S.

The variables Q,S,V,D, and W are connected by two general equations. The first is the basic equation of open channel flow connecting velocity to flow and depth

$$V = k(SD)^{0.5} \tag{3}$$

where k is a constant depending on the channel's resistance to flow. The second is the 'continuity' equation that says that the total flow past a point is equal to the product of the average depth, width, and velocity

$$Q = DWV \tag{4}$$

In addition, for a given place on a given stream, we have some empirical relation between width and the depth generated by the geometry of the channel cross section. The cross-section is commonly concave upwards, and a useful approximation, true for many channels, is that the channel profile is parabolic and the depth varies roughly as the square of the width:

$$D = aW^2 \tag{5}$$

where a is a constant. We use this approximation in what follows. Deviations from this relationship affect the details but not the general conclusions.

Since we are only interested in the general form of the relationship between the variable we can set a equal to one. Doing this and eliminating W from (4) we get

$$Q = D^{3/2}V \tag{4A}$$

Solving (3) and (4A) simultaneously we can display the way depth and velocity depend on the volume and slope

$$V = Q^{1/4}S^{3/8} \tag{6}$$

$$D = Q^{1/2}/S^{1/4} \tag{7}$$

$$V/D = S^{5/8}/Q^{1/4} \tag{8}$$

$$= S^{1/2}/D^{1/2} \tag{8A}$$

Recalling that the stream power P per unit area is QS/W = DVS we can substitute for V from (3) and get

$$P = D^{3/2}S^{3/2} \tag{9A}$$

$$= V^3 \tag{9B}$$

$$= S^{9/8}Q^{3/4} \tag{9C}$$

Remember that all of these equations have constants that we are ignoring, and depend on the exact form of the relationship between depth and width.

In words these equations say the following things:

- As the volume of water in a stream the depth and velocity both increase. The depth increases as the square root of the volume, and so faster than the velocity which increases with the fourth root of the volume (Eq. 6-7).[7]

- At a given point on a stream the ratio of velocity to depth decreases with the square root of depth as the flow increases, and so when a stream becomes four times deeper we would only expect its velocity to double (Eq. 8).

- Comparing points with different slopes on the same stream the velocity increases with the 3/8 power of the slope and the depth decreases with the 1/4 power of the slope (Eq. 6-7). This means that if the slope increases from say 20' per mile to 40' per mile, the velocity will increase to 1.3 times the original velocity, while the depth will decrease to about 0.84 times the original depth. Thus steep streams are fast and shallow.

7. This is, by the way, a fortunate thing. Whitewater boating is only possible over a fairly limited range of velocities (say from 2mph to 8mph, a range of 4x). The range of boatable depths and flows in a given river may be considerably greater. The sluggish increase of velocity with depth means that the depths and flows can change a lot without the velocity getting out of bounds. If velocity increased linearly with depth or (mercy!) with flow boating would be suicidal.

- Comparing two streams of similar size but different slopes, the velocity to depth ratio will vary as the 5/8 power of the slope. Imagine that the slope of the first is half the second, and that during a rainstorm we see the water rise the same amount -- say from one foot deep to three feet deep -- in each (Eq. 8). The velocity will increase in both streams, but the velocity increase will be 1.6 times greater in the second stream than in the first (8A). Thus steep streams gain velocity faster for a given increase in depth than shallow streams. (This is why boaters pay a lot of attention to small fluctuations in gauge level on rivers that have particularly steep pitches.)

- The power of a stream increases as either the 3/4 power of volume (at constant slope), the cube of velocity, or, the 9/8 power of slope (at constant volume). Doubling the volume of a stream increases the power by about 1.7; doubling the slope at constant volume increases the power by about 2.2. And in the example we gave above, where two streams of the same size experience equal rises, the one with twice the slope will have about four times the increase in power of the other (Eq. 9A-C).

Translated back into concrete terms, what the equations say is that steep streams are faster and much more powerful at the same depth than flat streams. They also add more speed and much more power for the same increase in depth. This is a basic fact of whitewater life. Steep streams are fast when they first become runnable, and become very fast -- pushy the boaters say and that is an understatement -- at medium water. At highwater they often become more than anyone wants to handle, not so much because they become impossibly turbulent, but because they become impossibly fast. Even the experts can't paddle against a firehose.

The increases in power with increasing slope are also consequential. As long as the stream is not so deep that it completely covers the rocks -- drowns out rapids boaters say -- a steep stream will be substantially more turbulent than a flat one, even when the obstacles creating the turbulence are about the same size. This explains why some steep and uninhibited streams can reach an honest Class III intensity when they are barely deep enough to float down, and why we say that, unlike flatter streams, these streams don't have any easy level.

Equation (7) has an interesting consequence. Since depth varies with the square root of the volume, the higher a stream already is the more water it takes to raise it further. This is one reason why large floods are rare. And since depth varies inversely with the fourth root of slope effect is more pronounced on steep streams. If one stream is twice as steep as another, it takes 1.4 times as much water to reach any given level as the flatter stream. Steep streams are in a sense slipperier, and get rid of their water faster without letting it pile up. This is one reason (another is that they tend to occur in watersheds with little storage) why they have short seasons. Only very high flows near the annual peaks make them rise to boatable levels.

It follows from this that while steep streams are perhaps the most violent, the greatest increases in depth tend to be on very flat rivers with deep, vertical-sided channel banks. It make take a 50 year flood to make a small wild mountain streams rise ten or fifteen feet; this amount of rise may happen several times a year on a big flat stream. Since velocity necessarily increases with depth this

has the consequence that some of the highest current speeds a boater will ever see can occur on big low-gradient rivers in flood, where their great depth and smooth channels make up for their lack of slope. Where there is little turbulence the great velocity may go unnoticed. Boaters should realize that the current they would encounter were they to boat some of are large flat rivers at flood time may be as great or greater than that in many famous whitewater runs.

* * *

Up to this point we have assumed that the slope[8] of a river at any given place is a fixed quantity, independent of the depth of the water. This is not really true, and the reasons it is not true tell us a lot about the behavior of rapids at high water levels.

First consider what happens when water goes over a rock or down a drop. The quantity of interest is the average path taken by a piece of water. A dip in this path makes a local peak in the power, and the bigger the dip the higher the power peak.

As long as the depth of the water is not more than about 2X the height of a drop or an obstacle the bulk of the water is deflected by it. The deflection -- and hence the local slope -- increases with increasing depth and the turbulence becomes greater. This is shown by the change between A. and B. below.

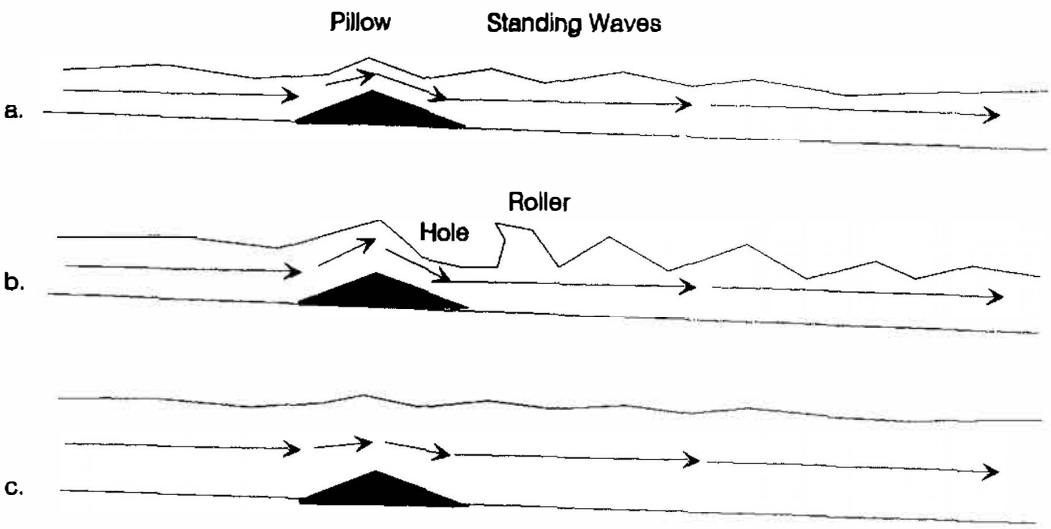


Figure 4.21 Average Path of a Mass of Water Over an Obstacle at Three Different Flows. Note that the deflection, and hence the turbulence, is greatest (b.) at medium depth, and less at both high and low water.

8. Formally the slope is the inclination of the average path taken by a volume of water at a given cross section. When the water is slow the flow lines parallel the bottom and the 'effective slope' -- the slope of the water -- is the same as that of the stream bed. As the water gets deeper the flow lines need no longer parallel the bottom, and the effective slope can be very different from the slope of the bed.

If the depth of the water becomes several times the height of the obstacle, the bulk of the water can go over it without large changes in slope. The flow lines smooth out, effectively spreading the local disturbance over a larger distance, as a large wheel spreads out a pothole. There is very little turbulence at the surface, and we say the rapid has been drowned out. This is shown in C.

The same smoothing out occurs over more gentle transitions of slope. At low levels many Class II streams have alternating stretches of rapids and quickwater resulting from regular oscillations in slope. The fastest current is in the steep sections, and the highest waves at the 'energy dumping section' when the slope decreases and the water decelerates.

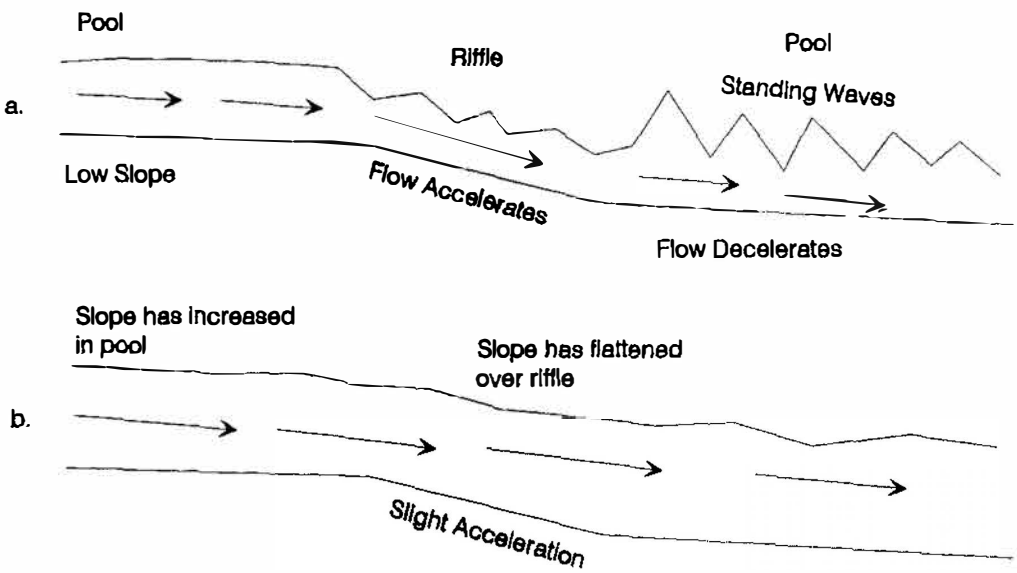


Figure 4.22 Drowning of Riffles. As the flow increases the flow lines cease to flow the changes in bottom slope in short riffles or steep pitches. The slope becomes uniform, the water ceases to accelerate and decelerate, and the standing waves vanish.

As the water level increases rapids like this first become more intense but then eventually drown out. At highwater the slope of the water surface becomes more even than that of the bottom, velocities are more even, deceleration zones don't occur, and the stream may have substantially fewer standing waves. Boater commonly assume that these rapids have lost intensity because the rocks are all submerged. This is partly true, but it is also true that at high water the whole slope of that rapid has changed, and that at high water the decrease in slope may offset the increases in depth and prevent the power from increasing.

This is the reason that many Class II rapids on large, not-too-rocky streams subject to moderate increases in depth become faster but less turbulent at high water.

It is usually either a relief or a disappointment when boaters discover that a rapid has decreased in intensity at high water. It can be much more alarming when they discover that another rapid on the same stream has done just the opposite.

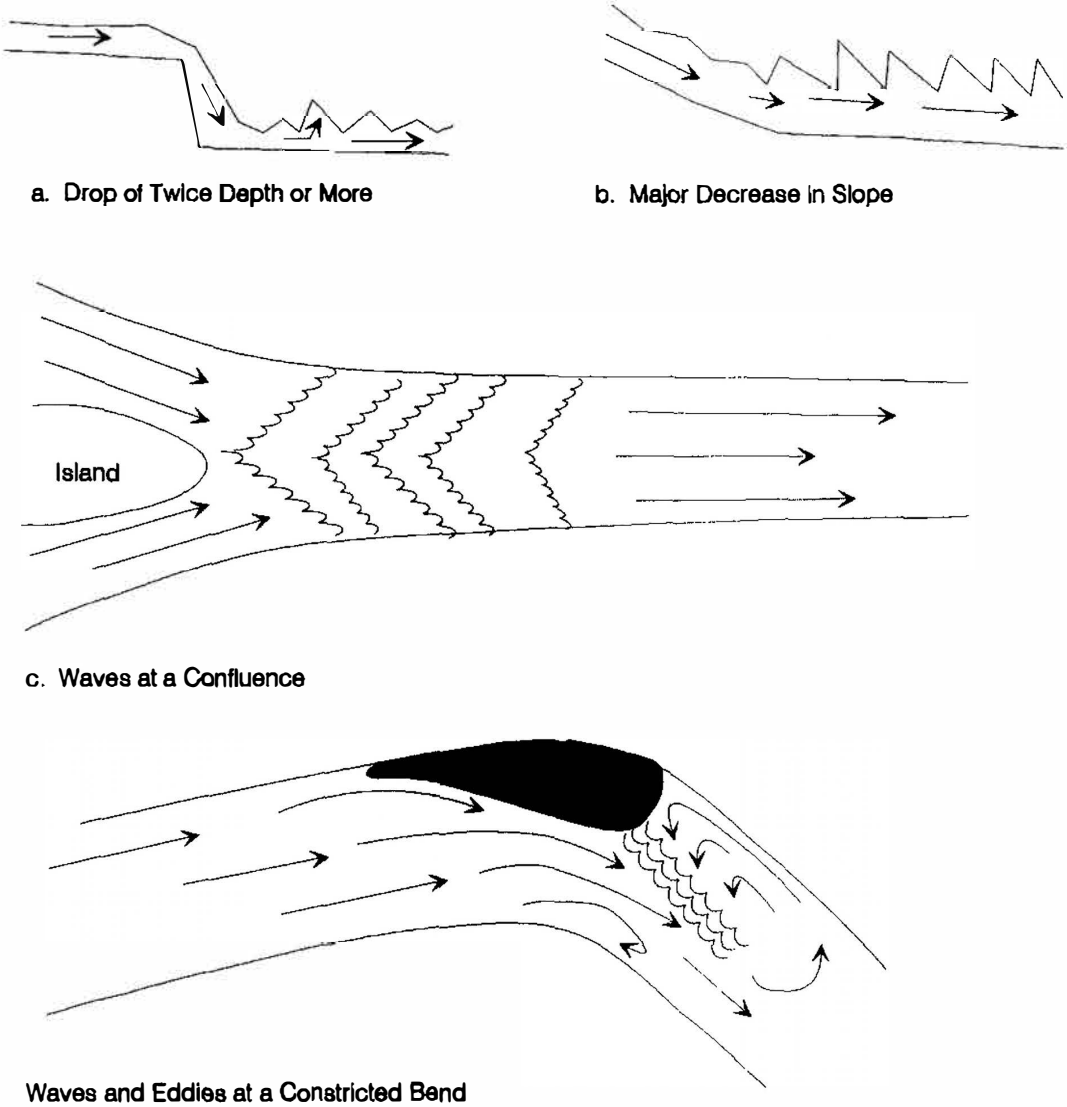


Figure 4.23 Four Types of Rapids That Increase In Intensity at High Water.

Our observations suggest that there are at least four sorts of rapids that always increase in intensity. These include:

- rapids caused by large drops or rocks, where the depth of the stream is less than half the size of the drop or obstacle. This obviously includes large steep ledges, but may also include sloping ledges.

- rapids caused by a large-scale change in slope at the foot of a steep pitch.

- rapids caused by abrupt corners or constrictions.

- and rapids where two currents meet, for example below an island or at a confluence.

There are many rapids of this sort in Vermont. Some well known examples are on the West below Jamaica, at Beldens Gorge on the Otter, and above Gaysville on the White. These rapids are essentially undrownable and the higher the river gets the heavier they get. Most of them are Class II water but rise to high Class III and in some cases Class IV at high water. For this reason they are among our most important and dangerous rapids: important because they afford very difficult boating at high levels, and dangerous because at high levels they may be dramatically more difficult than the rest of the stream they are on.

4.13 Geomorphological Retrospect

This chapter has been fairly detailed and quantitative, and it may help if we review it in general terms, and try to show how the processes that generate whitewater and whitewater landforms are related to other geomorphological processes.

We start from the observation that, at least from our preliminary data, that many mountain streams in Vermont have the same intensity, and that for any given stream the intensity is approximately constant throughout the upper parts of the watershed.

Assume for a moment that this is true, and ask why it should be so. The natural hypothesis is that stream profiles are equilibrium landforms in the sense that streams adjust their slopes by erosion so that their power is uniform and their erosional rates constant from place to place.

While this explains why a single stream should have uniform power, it doesn't explain why the same should be true of different streams, especially on mountains of different heights and with different bedrock. If this is in fact true -- and we certainly have not demonstrated this -- it says that, in a limited geographic area at least, there is a natural scale of valley carving, by which we that the processes that cut ravines into mountain sides use the same pattern again and again. This starts to get interesting. It seems to us that maximum power would not be constant from stream to stream were there not some basic control mechanism -- as simple as the amount of rainfall or as complicated as a hypothetical maximum rate of slope weathering or maximum transport of weathered materials, to which the stream's capacity for incision is tied. This is susceptible to investigation: the logical next step is to inquire whether the maximum power of headwaters streams varies in other states and other mountain ranges, or if there are important regional variations in Vermont that we have not yet found.

As we follow the stream downwards we eventually find that the average power starts to decline. Often this is associated with the stream's entering the valley of a larger stream. The decline is an established geomorphological fact, but it seems to us its significance has not been realized.

To think about this, assume that we have a stream (0) with equal stream power P from its headwaters (A) to its mouth (B). Over time the stream cuts backward into the mountain and perhaps lowers its divide as well, and its headwaters become the point a'. How does its profile evolve? One possibility (1) would be for the power dissipation to remain both equal to P and equal at all points along the stream. This essentially translates the curve (0) to the left and downwards, and is only possible if there is no fixed base-level -- i.e. if the point b can be lowered[9].

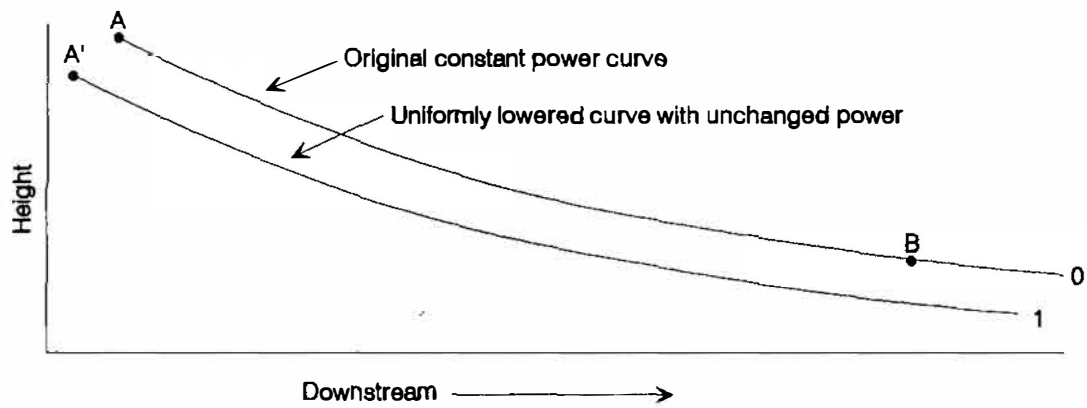


Figure 4.24 Hypothetical Evolution of a Stream With Constant power by the Simultaneous Lowering of the Headwaters and Mouth.

But often the level of point B is fixed, either because it is a lake or sea level, or because is is part of a larger and more slowly evolving river system. In this case there is no way that the stream can both keep its power equal to P and equal at all points along the profile. What does it do then?

Several possibilities are shown in Figures 4.25 and 4.26. One possibility (1) is that the stream evolves in such away that the power remains uniform throughout the profile. In this case it must lower its power to some P'<P.[10] This model, which is consistent with a number of contemporary ideals about geological systems evolving in such a way as to equalize energy dissipation, essentially says that the headwaters and the mouth are tied, and if the mouth can no longer cut downwards, then the rate of energy dissipation and hence of erosion in the headwaters must decrease. If low rates of energy dissipation mean a stream is getting old, this model essentially it says that all parts of the stream get old together.

A second possibility is (2) that the stream keeps a region of power P in the headwaters but P is no longer constant along the profile but decreases as you approach b. In this model the headwaters

9This is true because only one curve of constant power can be drawn through two fixed points. See the Appendix to this chapter for further discussion.
10. To see this reflect that constant power requires a fixed relation between the length L and the drop y on the graph, and if L is longer than y must be greater, and this is impossible if b is fixed.
11. See the Appendix to this chapter for more details.
12. cf. Ilya Prigogine & Isabelle Stengers *Order Out of Chaos*, Bantam Books, 1984, Chapters 5-6.

are essentially remain youthful, and at constant power, and the effects of fixing the base level at B propagate upstream, but only to a transition zone and not all the way to the headwaters.

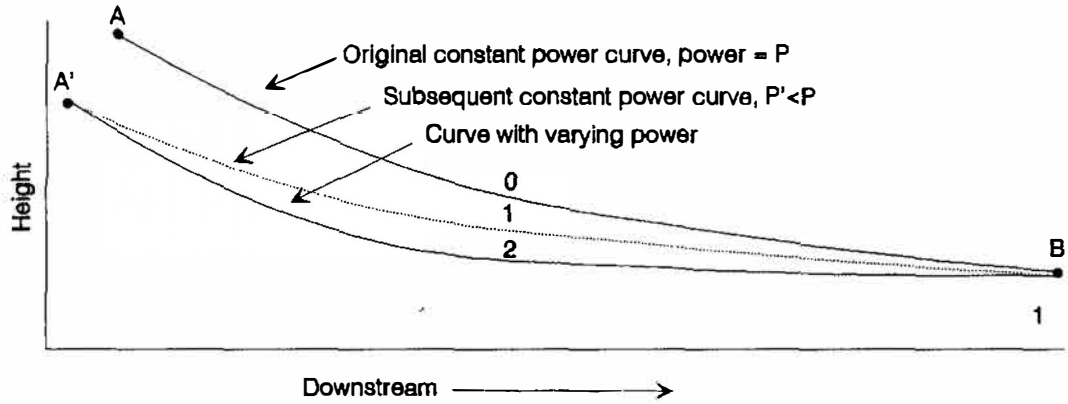


Figure 4.25 Hypothetical Evolution of a Stream With Constant power by the Lowering of the Headwaters With a Fixed Mouth. Curve 1 is is the profile that would be generated if the stream power remains equal from headwaters to mouth. The slopes are everywhere lower than those of Curve 0, and so the power P' is less than the original power P. Curve 2 is segmental: it has a region that parallels Curve 1 and so still has power P, and then a transition to a region of lower power.

It seems to us that (2) is closer to what we actually see than (1). Our inference from this is that the slopes and power in the headwaters regions of streams are controlled by hillslope processes which are independent of the the slopes of the lower part of the stream. They are not necessarily young in any meaningful sense of that words, but they are perhaps in a certain sense ageless.

If these conclusions are factually correct, they support a model of landscape evolution that is a little discordant with a number of contemporary ideas. Basically they imply that landscapes will either evolve from (or possibly avoid all together) states in which energy dissipation is spread evenly throughout watersheds, towards states where the energy dissipation is less uniform. And specifically, as the whole landscape is lowered and the total potential energy in the river system becomes less, the dissipation of energy will be increasingly concentrated in the headwaters.

This sort of model is similar to other geological models in which discontinuities of slope -- scarps and knick points and so on -- are not gradually effaced but instead propagate themselves. It seems to us that some principle of decreasing uniformity of energy dissipation is necessary to explain the existing landscape.[11] It is common for headwaters streams to have abrupt transitions between high energy dissipation and low energy dissipation segments, and often very little in between. And there is no general reason why this should not be the case. Some current thinking in thermodynamics[12] suggests that while the total energy of any isolated system of course decreases, there

9This is true because only one curve of constant power can be drawn through two fixed points. See the Appendix to this chapter for further discussion.

10. To see this reflect that constant power requires a fixed relation between the length L and the drop y on the graph, and if L is longer than y must be greater, and this is impossible if b is fixed.

11. See the Appendix to this chapter for more details.

12. cf. Ilya Prigogine & Isabelle Stengers *Order Out of Chaos*, Bantam Books, 1984, Chapters 5-6.

is no universal tendency for non-equilibrium systems to attain uniform internal distributions of energy or energy flows, and that in fact when a system is far enough from equilibrium the reverse may be the case.

* * *

The classical exposition of river geomorphology emphasizes the mutual interdependence of different parts of river channels by speaking of the fluvial system, and by dwelling on the adjustments of flow, slope, bed load, channel form, and erosive power to one another. To make these points most clearly it is customary to focus on slow rivers in alluvial channels, though it is becoming increasingly plain that there are many kinds of adjustments and equilibria in steeper, rock-channeled streams as well.

What has been interesting to us in this study is the extent to which whitewater -- which is surely as conspicuous a part of the behavior of upland streams as flood plains and deltas are of lowland streams -- cannot be explained without referring to the extent to which streams depart from equilibrium conditions. A well equilibrated stream, in an area of uniform bedrock, will at most have Class II-III whitewater in its upper watershed, and none below. To get higher intensity whitewater some one of the geological constraints -- the hardness of the bedrock, the local uniformity of the bedrock, the ratio of peak to average yields for the watershed, or the supply of large boulders to the channel -- has to depart from the average, and be resistant enough to withstand the greater erosional forces to which it is subjected. Whitewater is possible only as long as boulders and gorges are not worn away and reduced to smooth channels, or steep watershed with high ratios of peak to mean flows reduced to flatter ones, or locally steeper rapids smoothed out and equilibrated with the slopes above and below.

To us this is significant for two reasons. First, it suggests to us that the parts of the river system are less tightly coupled than we originally believed, and that for this reason the fluctuations of the system away from average conditions are a good deal greater than would be expected in a well equilibrated system. And second because, from a biological point of view, the extreme values an environment takes are critically important for the creatures that use it, whether they be fish or birds or flowers or boaters. To which creatures we are now ready to turn.

Appendix to Chapter 4

To derive an equation for the profile of a stream with constant power, we assume that the volume Q is proportional to the watershed, and that further there is an empirical relation between the watershed and the length to the headwaters L such that

$$L = kA^b$$

where L is the length from the headwaters to a point p along the stream, A the watershed above that point, and k and b are constants. For Vermont streams this takes the approximate form

$$L = 1.2\ A^{0.6} \tag{10}$$

or

$$A = 0.74\ L^{1.66} \tag{11}$$

with L in miles and A in square miles.

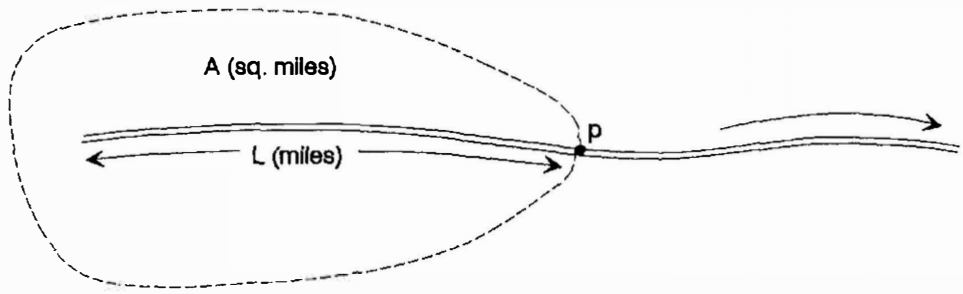


Figure 4.26 Definition of A and L.

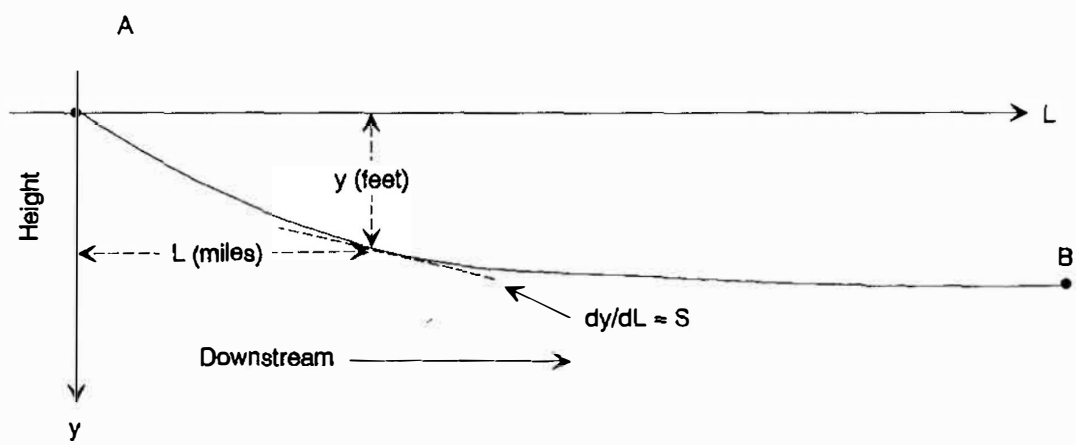


Figure 4.27 Definition of y and S. To keep the equations as simple as possible distance below the headwaters is taken as negative.

Let y be the vertical drop from the headwaters to p. Since constant power means empirically (Eq. 2 above) that $SA^{0.5} \approx P$ where P is a constant, and since the slope at p may be may be written in differential form as dy/dL, we have

$$A^{0.5}dy/dL = P$$

$$dy = PA^{-0.5}dL$$

or, using (11)

$$dy = 0.86\ P\ L^{-0.83} \quad (12)$$

This integrates to give

$$y = 5\ PL^{0.17} \quad (13)$$

which is the equation of the stream profile, or

$$y = 5.2\ PA^{0.1} \quad (14)$$

giving the relation between watershed and anticipated slope. (Note that P in these equations must be expressed in units of sq. miles x feet/mile.) These equations are of course only approximately true: they depend on (11) which in turn assumes that the watershed above a point has the common rounded triangular form. For particularly narrow or broad watersheds the constant in (10) will differ, and perhaps the exponent as well, and as a result equations (13) and (14) will be different. But still as long as the power is constant there will be predictable relations between Y, L, and A, and it will remain true that for a given power there is only a single curve of constant power passing through any given point. And thus our assertion that constant power streams have a fixed relation between length, fall, watershed and power remains true.

* * *

To see why we favor a model of landscape evolution in which power dissipation becomes increasingly unequal over time imagine that at one moment, early in the evolution of a river system, the average power dissipation is constant throughout the system. Then ask what happens as the system continues to evolve by cutting valleys headwards, lowering divides and so on. To answer this observe between two points in a watershed, such as A. and B. in the figure on the next page, only one stream profile of constant power may be drawn. Other profiles such as b' that connect the same points do not have constant power, and other profiles of constant power such as a and c that pass through A do not pass through B.

This means that, in this model, any geological evolution will do one of two things. It will either make the power distribution unequal, or lower the stream power everywhere. In the second case the power of the whole stream system declines with time. Thus it appears that the state where the power is equal throughout a whole river systems is an unstable one, and would only be maintained if the rates of headwards erosion and the lowering of divides were identical everywhere --

a very unlikely assumption, especially as it turns out that divides are often the parts of the watershed most resistant to lowering.

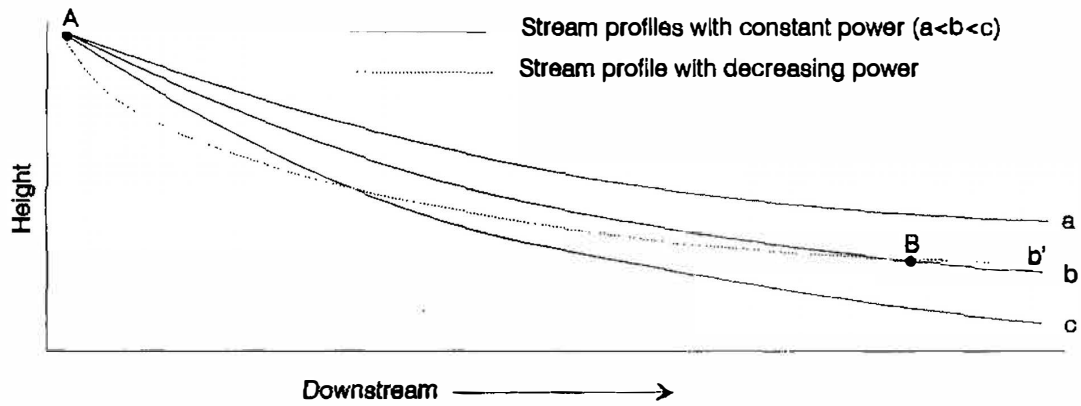


Figure 4.28 Geometry of Constant Power Curves. A family of constant power curves (a,b,c) may be drawn through any point A, but only one of them passes through a second point B. Specifying B specifies the power, and the lower B is the higher the power. Other curves that connect A and B do not have constant power. Curve b', for example, has a higher power than b in the headwaters, but a lower power for most of its length.

Hence there are two reasons why the assumption that streams evolve towards a condition of equal stream power may be a poor basis for a theory of landscape evolution. The first is that this condition implies that all the stream profiles in a given watershed are segments of the same curve, and hence that there is a single scale or gauge that can be applied throughout the watershed. This is too restrictive and uniformitarian to account for the landforms we actually see. And secondly it suggests that this basic scale or gauge will change uniformly with time, and hence that all stream systems with geometrically similar landforms are of the same age. This is not necessarily false, but seems to underestimate the historical variety we actually encounter.

CHAPTER 5. THE BIOLOGY OF WHITEWATER AND QUICKWATER STREAMS

This chapter deals with a series of related topics: the general biology of whitewater streams; the factors influencing the quality of fisheries; the use of streams by mammals and birds; river shore plant communities; and sites for rare plants and animals. It concludes with a summary of the biological results, and a ranking of the biological importance of whitewater streams. The plan is to begin with features common to all the streams, then consider the geographical and ecological factors that differentiate particular streams or watersheds, and finally consider biological features restricted to particular sites on particular streams.

In appraising the biology of streams we make three assumptions. First that all animals and plants are important to the world, whether or not we can isolate their particular importance to human affairs, or associate them with particular human partisans. Second that the community of animals and plants at a particular site may be of value either because it is unusual or because it is exemplary -- that is by being unlike what is commonly seen, or by being an intact and healthy example of what should be commonly seen. And third, that the conservation of both unusual and exemplary communities is of great importance.[1]

Much of this chapter applies both to what we are calling whitewater streams in the strict sense (streams with Class II or above water at peak flow) and what we call quickwater streams (streams with moderate current and riffle areas with moderate turbulence and Class I rapids). Biologically the two sorts of streams are often much alike. If we divide streams by intensity, as in Fig. 5-1, it turns out that the greatest biological difference is probably between quickwater and whitewater, rather than between the different levels of whitewater.[2]

Streams with limited oxygenation and muddy bottoms

Stillwater streams (impoundments, small lakes, etc.)
Slow-water streams (gradients less than 5'/mile)

Streams with substantial oxygenation and sand, stone, or gravel bottoms

Quickwater streams (gradients 5-15'/mile, riffles or Class I rapids)
Recreational whitewater streams (gradients 15-100'/mile, Class II-IV rapids)
Torrential streams (gradients 100-500'/ mile, Class IV-V or unrunnable)

Figure 5-1: Stream Types

1. This last point is often neglected by the over-emphasis on rarity as a criterion for the conservation of non-game species and their habitats. This is a bad mistake, not because rare species are not interesting and important, but because the rare species are by definition of very sporadic distribution, and so an exclusive focus on their conservation refuses to take any responsibility for the conservation and quality of the most widespread parts of the biological landscape.
2. In terms of Figure 5.1, the greatest difference is between types 2 and 3, and the next greatest between types 4 and 5.

A more direct way of putting this is that it makes a great deal of biological difference if a stream has riffles and turbulence or not, and a moderate amount of difference if it ever has "torrential" currents in the 8-15 mph range. But it seems to matter much less, at least to stream animals and plants, whether a stream is all Class I water, or has Class II or III water as well.[3] In this report we are dealing with a fairly small group of streams that were selected because they had (for the most part) Class II or higher water and were sufficiently large to be boatable. It is important to realize that most of the biological features of these streams are not too sensitive to the size of the stream or the intensity of the whitewater, and so will also be found in smaller or less intense streams. Thus the small group of whitewater streams that we describe in detail here are biologically representative of, and can serve as a sample of, Vermont's fastwater streams as a whole.

5.1 General Biology of Quickwater Streams

We begin with a short account of the general biology of clean quickwater streams and rivers. Our purpose is to acquaint the non-specialized reader with the things that live in streams, to explain why quickwater streams are unusually rich environments, and to explain how their richness depends on the presence of fast-moving water. The information in this section is excerpted from the technical literature on stream biology, and is not peculiar to Vermont. Readers wishing a more detailed exposition of the points covered here might consult *The Ecology of Running Water* by H. B. N. Hynes (University of Toronto, 1970). The work is a classic of the limnological literature, and contains much information that is directly applicable to Vermont streams.

Consider a stream that is of moderate size (too big to jump across), with natural banks, unpolluted water from a watershed without excessive soil erosion, and sufficient gradient to have numerous shallow riffle areas where the bottom is stony and there is whitewater in the spring and turbulent flow in the summer.

Such a stream commonly has the following features:

- Water which is well aerated at both high and low water levels.

- Maximum current speeds of 4-10 miles per hour at high water.

- A bottom which is dominantly stony or gravely, with finer sediments stored beneath a stony ('armored') surface.

- Some pools with slow water and finer bottom material.

- Shores and bars that are variously stony or gravely.

3. There are probably at least two reasons for this: first because insects and stream algae are choosy about whether the bottom is stony or soft, but not about whether the stones are large or small. And second because most whitewater streams only have whitewater for brief periods of the year, and for much of the rest of the time have current speeds and levels of turbulence that are identical with those in quickwater streams.

- Occasional ledges or gorges, or, in the case of Class II or higher streams, numerous boulders in the stream channel.

- Significant populations of microscopic algae (mostly diatoms & blue-green algae, also some red algae) attached to stones.

- Smaller and variable amounts of macroscopic algae (blue-greens, greens, and reds) attached to stones.

- Considerable amounts of coarse vegetable debris from wooded parts of the watershed, which is transported at high water and accumulates in the channel at low water.

- Considerable amounts of fine soil and vegetable debris, both carried in the water itself and mixed with the gravel and stones in the stream bed.

- Significant populations of aquatic insects (mayflies, stoneflies, caddisflies, various flies, some beetles & dragonflies), which feed variously on algae, bacteria, and soil and vegetable debris.

- Smaller but also significant populations of mollusks, worms, and other invertebrates using the same food sources.

- Significant populations of predatory insects, particularly stoneflies, beetles and dragonflies.

- A number of species of fish, many of which are fast swimmers that feed by sight and demand moderate to high oxygen levels.

- A small flora of aquatic vascular plants, for the most part limited to areas where the current is slow and so avoiding whitewater rather than depending on it.

- A small flora of aquatic mosses, commonest in small streams, and in areas where the current is high but the rocks are stable.

- A larger flora of bar and bank plants, mostly flowering plants but including some ferns and mosses.

- A number of birds who either feed regularly on or around the streams, or who visit them during migration.

- A number of animals who either live in the water, or feed regularly on or near the stream.

Three ecological observations are important for understanding this sort of stream.

- Streams with stony bottoms, clear and well-oxygenated water, and moderately fast current, normally have diverse populations of stream invertebrates, and particularly insects. The

stony bottom provides stable habitat. Well oxygenated and fairly clean water is necessary for the majority of stream insects. And the current both replenishes the oxygen supply among the stones and gravel and brings the debris which is the insect's major food source.

- The invertebrates are a primary food source for fish, birds, and bats, and the streams where they are numerous are productive habitats for vertebrates.

- Streams with fast water tend to disturb their banks more than slower streams, and so have more diverse streamside plant communities with more species of shrubs and herbs. The diversity of the riverbank plant communities in turn influences the number of kinds of animals that can use them. The more diverse a community is the more different kinds of leaves, seeds, and insects there are for animals to feed on, and the more kinds of habitats there are for nesting birds and animals. In general, the animal diversity of a community is related both to the structural diversity (ranges of sizes, layers, and growth forms) and to the taxonomic diversity (number of species) of the plant community. The shore communities of quickwater streams are both taxonomically and structurally diverse. Episodic disturbance by floods gives them considerable structural diversity, and, as we will explain shortly, they are surprisingly diverse in plant species.

Figure 5-2 is a diagram of the food chains in a quickwater stream. The heavier arrows denote the most important relationships. Note that of the three primary foods particulate vegetable debris carried by the current is the most important. This is one of the reasons why it is crucial for the economy of a stream that there be adequate current and clear water. The current effectively does the animals' foraging for them. It carries food to them and makes it practical for them to use a dilute food source. It is also essential that the water be clear. The filter-feeding insects aren't able to separate vegetable debris from a high concentration of suspended silt or clay, and the predatory insects and fish hunt by sight, and so need reasonably clear water as well.

To document the variety of animals and plants connected with quickwater and whitewater streams, we have provided two summary tables. Table 15, which draws on our own field work, gives the most common plants. Table 16, which combines published information with our own observations, gives the common animals. The information on insects and invertebrates is gathered from the general taxonomic literature, and from limited stream insect studies done some years ago by the first author. Note that only the genera are listed: at present we cannot even guess how many species of invertebrates there are in Vermont rivers.

With reference to these tables several general points can be made.

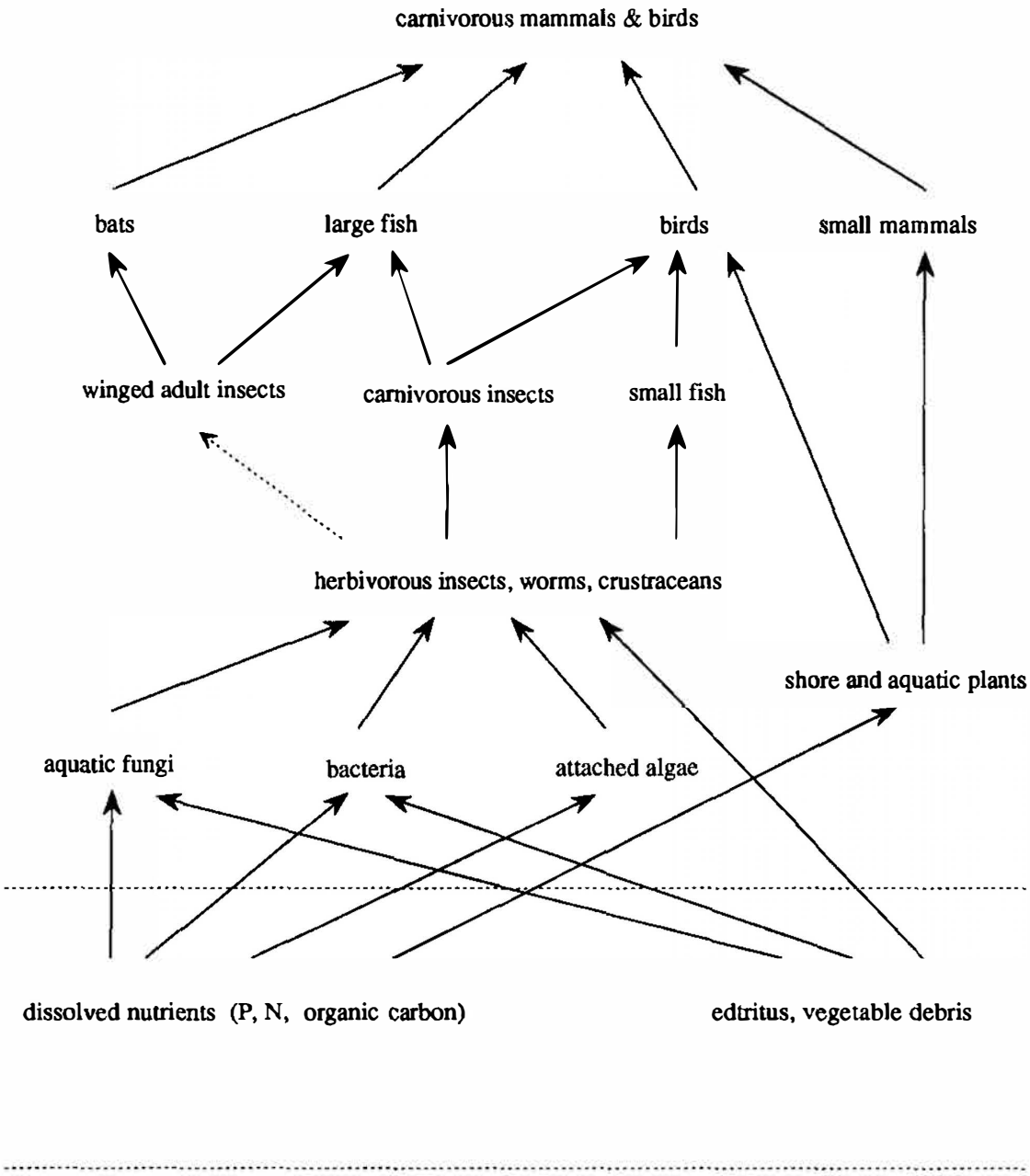


Figure 5-2: Feeding Relationships (Food Chains) in a Quickwater Stream
The solid arrows are trophic (feeding) relations, the dotted arrow is a developmental relation.

- Most healthy streams with moderately fertile watersheds of moderate size are biologically rich communities.[4] They are patchy environments with many edges and gradients and hence able to offer opportunities to many species. They are subject to annual disturbance and so are not monopolized by a few highly successful species. And they are concentrated environments in the sense that they have the use of water, organic materials, and mineral nutrients gathered from a whole watershed.

- A measure of their biological richness is the ratio between the fraction of the land surface which they occupy, and the disproportionate number of animals and plants in and around them. We do not have any good figures on this point, but estimate that all the Vermont rivers and streams (whitewater and not) are under 1% of the total area of the state but contain at least 30% of the native vascular plants of the state. We also estimate that they are used regularly by 30-50% of all the terrestrial vertebrates in the state, and are visited, at least casually, by upwards of 80% of all the terrestrial vertebrates.

- Compared to slower streams, quickwater and whitewater streams of the sort considered here are always more diverse, and often more productive as well.[5] Almost all the higher animals using streams -- birds, fish, mammals, amphibians -- depend on the insect populations. A productive stream is invariably one with a large insect population. The population also should be taxonomically diverse, because this assures that insects larva of many different sizes are present, and that swarms of adult insects emerge from the water throughout the season.

- Many of the insect species found in whitewater streams have specific adaptations to quickwater. These include flattened or torpedo-shaped forms, clinging legs, reduced gills (which presume well oxygenated water), good swimming ability, and feeding adaptations for straining particles out of the current or scraping algae off rocks. Because of these adaptations some of these insects are essentially obligate quickwater species which exist nowhere else. Their continued existence in our fauna depends on the continued presence of clean whitewater and quickwater streams.[6]

- It is quite possible that some of the fish are similarly specialized, and are restricted to, or at least prefer water with a certain average current speed. With our limited botanists' resources we have not been able to find good information on the ecological preferences of New England fish, but in the general ecological literature there are some studies on stream zonation that suggest that a number of fish -- shad, some of the darters, brook trout, some minnows, sculpins, etc. -- definitely prefer fast current, and are common only in portions of rivers with adequate slope.

4. By biologically rich we mean intricately structured and diverse, but not necessarily productive. For a discussion of productivity see below.
5. Small first- and second-order woodland streams which are unproductive and tend to have depauperate fish and invertebrate communities are exceptions to this generalization.
6. It might be worth noting here that the riverside plants are in general much less restricted to a particular range of current speeds than the animals. A few of the plants -- the riverweed *Podostemum ceratophyllum*, the sedge *Carex torta* and several of the willows and aquatic mosses -- are more or less confined to streams with moderate current. But, with these exceptions, the riverside plants are for the most part an unspecialized group, and the existence of this habitat is not critical for their survival.

- The trout fishermen's predilection for rocky turbulent streams has a sound biological basis. Trout can live in many kinds of water, but are still for the most part fastwater animals. They are fast swimmers which feed on swimming and drifting insects and demand high dissolved oxygen levels. They depend on streams with high insect populations and clear water, well oxygenated in which to hunt them.

- The extent to which trout depend on quickwater streams varies with the species. Brook trout spend most of their lives in quickwater. Atlantic salmon (which is just a big trout) and rainbow trout often live in lakes and slower streams but move to fastwater to spawn. Brown trout are least dependent on quickwater of any of our species, though it is still true that some our best brown trout fisheries are in quickwater streams.

- An interesting example of the association of trout with whitewater can be found in the European literature. European ecologists classify stream segments according to the fish occurring in them, and have shown a good general relation (for streams of a given size) between the type of fish and the slope of the stream. For example, in European streams between 50 and 150' wide, comparable to many of our whitewater streams, the zone dominated by trout ranges in slope 90'/mile to about 25'/ per mile. The zone that has a mixed fishery of trout and 'fast-water cyperinids' ranges from about 30'/mile to 6'/mile. In boaters' terms this means that most European Class II-IV streams have a fishery dominated by trout, while Class I-II streams have a mixed fishery. It is interesting that the trout streams in Vermont in which there are naturally reproducing trout populations fall into this same range of slopes, with the brook trout found in the steepest streams and the rainbow trout in the flattest. Thus while it is not true that trout and trout fishing are limited to whitewater streams, it does seem true that all the best river fishing is in streams with at least moderate current, and that streams with moderate amounts of quickwater and riffles are on the average better trout streams than those with flatwater.

- The productivity and the diversity of these streams depend critically on the combination of current, adequate oxygen levels, clean water, and natural stony bottoms and will be decreased when any one of these elements is altered. The quickwater animals and plants are in one sense a very tough group, able to survive in a violent environment, but in another sense very delicate in that they are quickly injured when that environment is altered.

The last point, about the vulnerability of whitewater streams to alteration is important because many biologically important whitewater streams have already been damaged. The major quickwater streams in Vermont have on the average a dam every 10-15 miles. In addition, many of the undammed segments have substantially altered bank communities, or polluted waters, or artificially graded channels. We regard the remaining unaltered streams as exceptionally valuable, both because they can tell us what a natural stream should be like, and because they are what we have left of a formerly much more extensive resource. We want to stress the importance of preserving the remaining ones. They are biological vessels whose contents are out of proportion to their size. Like the tropical forests, but much closer to hand, they have faunas which are only partially known. And again like the tropical forests, they are subject to continuing modification

and damage, and we face the possibility of losing animal species before we even know what they are.

We now turn from considering whitewater streams as a group to examining the geographic and individual differences between streams. In the case of fisheries, which we look at first, there are a number of well documented differences between streams. In the case of birds and mammals the differences are either less important or less understood. And finally in the case of the plants it seems that there are surprisingly few differences between streams, and the community is in some ways unusual precisely because it is so geographically uniform.

Table 15: Common Plants of the Channels and Banks of Whitewater & Quickwater Rivers

This table is based recent fieldwork by the authors.

Aquatic plants attached to stones or in pools

Lichens

Dermatocarpon fluviatile

Mosses

Fontinalis sp p.
Amblystegium spp.
Drepanocladus spp.
Hygroamblystegium spp.
Hygrohypnum spp.
Leptodictyum riparium
Eurynchium spp.

Liverworts

Chiloscyphus pallescens

Algae

Batrachospermum
Chaetophora
Lemanea
Microspora
Mougeotia
Oscillatoria
Phormidium
Rhizocolonium
Schoizothriz
Spyrogyra
Stigeocolonium
Ulothrix
Zygnema
plus many diatom genera

Vascular plants

Anacharis canadensae	slow water
Podostemon ceratophyllum	slow water
Potamogeton gramineus	stones in fast water

Perennial herbs of gravelly and stony bars that are subjected to annual flooding.

The following herbs are the perennial species that were present at over 1/3 of the 34 sites surveyed.

		Number of Sites	% of Sites
Twisted Sedge	*Carex torta*	26	76.4
Joe Pye Weed	*Eupatorium maculatum*	25	73.5
Sensitive Fern	*Onoclea sensibilis*	21	61.7
Grass-leaved Goldenrod	*Solidago graminifolia*	21	61.7
Reed Canary Grass	*Phalaris arundinacea*	20	58.8
Bentgrass	*Agrostis stolonifera*	19	55.8
Coltsfoot	*Tussilago farfara**	18	52.9
Umbellate Aster	*Aster umbellatus*	17	50.0
Meadow Horsetail	*Equisetum arvense*	17	50.0
Boneset	*Eupatorium perfoliatum*	15	44.1
Timothy	*Phleum pratense**	15	44.1
Late Goldenrod	*Solidago gigantea*	15	44.1
Meadow Rue	*Thalictrum polygamum*	15	44.1
Ground Nut	*Apios americana*	13	38.2
Calico Aster	*Aster lateriflorus*	13	38.2
Rough-stemmed Aster	*Aster puniceus*	12	35.2
Blue-joint Grass	*Calamagrostis canadensis*	12	35.2
Daisy	*Chrysanthemum leucanthemum**	12	35.2

* = an alien speciues

Woody plants of gravel or cobble shores

These commonly live above or partially mingled with the herbs on bars and shores subject to less regular or less violent flooding.

		Number of Sites	% of Sites
Heartleaf Willow	*Salix rigida*	23	67.6
Meadowsweet	*Spiraea latifolia*	16	47.0
Bank Grape	*Vitis riparia*	16	47.0
Speckled Alder	*Alnus rugosa*	14	41.1
Red Raspberry	*Rubus idaeus*	11	32.3
Woodbine	*Parthenocissus quinquefolia*	9	26.4
Silky Willow	*Salix sericea*	9	26.4
Silky Dogwood	*Cornus stolonifera*	8	23.5
Purple-flowering Raspberry	*Rubus odoratus*	8	23.5
Poison Ivy	*Rhus radicans*	7	20.5

Plants of rocky ledges and gorges.

The ledge flora consists of a number of distinctive mosses and liverworts, a few specialized vascular plants(including some interesting rarities) and a number of unspecialized vascular plants of fairly wide ecological range. The bulk of these plants live above the high-water level and were are not tabulated here the reader is referred to the Vermont Waterfall and Gorge report for a full discussion of the river gorge flora.

Openings at the top of the banks

Flood-caused openings in alluvial woodlands or at the upper edge of the channel often have a number of characteristic species of tall herbs. Their flora includes a number of the taller plants of bars and shores as well as a group of species that prefer fine soil and do not grow on cobbles or gravel. Examples are:

Brome Grass	*Bromus latiglumis*
Brome Grass	*Bromus purgans*
Wild Rye	*Elymus spp.*
Wood Reed	*Cinna arundinacea*
Sunflower	*Helianthus decapetalus*

This group of plants is not strongly connected with the presence of whitewater in the channel and was not studied in this report.

Table 16: General Zoology of Quickwater & Whitewater Streams

From various sources, as indicated.)

Birds (From field observations by the authors.)

1. Species nesting regularly along shores or in streamside thickets.

Common Merganser	common in N. Vt.
Green Heron	
Spotted Sandpiper	nests on cobble shores
Kingfisher	nests in tunnels in banks
Bank swallow	nests in tunnels in banks
Willow Flycatcher	scarce
Alder Flycatcher	scarce
Winter Wren	small wooded streams only
Yellow Warbler	nests in thickets
Yellowthroat warbler	nest in thickets
Louisiana Waterthrush	wooded streams only
Swamp Sparrow	shrub thickets
Song Sparrow	nests along banks

2. Species feeding commonly along streams (many others feed along streams from time to time.)

Osprey	
Bald Eagle	migration only
Woodcock	
Eastern Kingbird	
Tree Swallow	
Barn Swallow	
Cedar Waxwing	
Redwinged Blackbird	especially in migration
Common Grackle	

Mammals (From observations and literature.)

1. Commonly living along streams

Star-nose Mole
several shrews
White-footed Mouse
Meadow Vole
Red-backed Vole
Beaver
Muskrat
River Otter

2. Commonly feeding by streams (many other species feed casually)

all bats
White-tailed Deer
Moose
Black Bear
Mink
Racoon

Amphibians & Reptiles

Green Frog	common summer resident, breeds in shallows
Common Toad	common summer resident, breeds in shallows
Painted Turtle	slower streams only
Garter Snake	streamside thickets
Smooth Green Snake	" "
? Water Snake	? occasional in slower streams

Fishes (From data compiled by Dr. George LeBar, UVM)

Lampreys		
Silver Lamprey	*Ichthyomyzon unicuspis*	
Northern Brook Lamprey	*I. fossor*	
Sturgeons		
Lake Sturgeon	*Acipenser fulvescens*	Endangered
Trout		
American Shad	*Alosa sapidissima*	Recently re-established
Rainbow Trout	*Salmo gairdneri*	Introduced
Atlantic salmon	*S. salar*	
Brown Trout	*S.* trutta	Introduced
Brook Trout	*Salvelinus fontinalis*	
Smelts		
Rainbow Smelt	*Osmerus mordax*	
Minnows and Carps		
Cutlips Minnow	*Exoglossum maxillingua*	
Common Shiner	*Notropis cornutus*	
Blacknose Dace	*Rhinichthys atratulus*	
Longnose Dace	*R. catarctae*	
Creek Chub	*Semotilus atromaculatus*	
Fallfish	*S. corporalis*	
Suckers		
River Carpsucker	*Carpiodes cyprinus*	Special concern
Longnose Sucker	*Catostomus catostomus*	
White Sucker	*C. commersoni*	
Northern Hog Sucker	*Hypentilium nigricans*	Special concern
Silver Redhorse	*Moxostoma anisurum*	Special concern
Black Redhorse	*M. duquesnei*	Special concern
Shorthead Redhorse	*M. macrolepidotum*	Special concern
Greater Redhorse	*M. valenciennes*	Special concern
Sunfishes		
Smallmouth bass	*Micropterus dolomieui*	
Perches		
Eastern sand darter	*Ammocrypta pellucida*	Special concern
Fantail darter	*Etheostoma flabellare*	
Johnny darter	*E. nigrum*	
Walleye	*Stizostedion vitreum*	
Sculpins		
Mottled sculpin	*Cottus bairdi*	
Slimy sculpin	*C. cognatus*	

Aquatic Insects

(From published ranges in the taxonomic literature; since this table was assembled sampling by Doug Burnham, Steve Fisk, and their colleagues in the Special Studies unit of the Department of Environmental Conservation has added a considerable number of taxa to this list.)

Caddis Flies (Trichoptera)

Brachycentridae:	*Brachycentrus* (common in fast water) *Micrasema* (mountain streams)
Glossomsomatidae:	*Agapetus* *Glossoma* (cold fast streams) *Proptila* (slower streams)
Helicopsychidae:	*Helicopsyche* (warm streams, lakes)
Hydropsychidae:	*Cheumatopsyche* (warm streams, polluted streams) *Diplectrona* (cold fast streams) *Hydropsyche* (many sorts of streams) *Macronema* (large rivers) *Parapsyche* (cold streams) *Potaymia* (large rivers)
Hydroptilidae:	*Agraylea* (large rivers) *Leucotrichia* (strong currents) *Hydroptila*
Leptosomaatidae:	*Leptosoma* (cool streams)
Leptoceridae:	*Ceralea* (beds of aquatic plants) *Mystacides* (slow current) *Oecetis* (slow and medium current) *Setodes* *Triaenodes*
Limnephilidae:	*Apatania* (mountain streams) *Asynarchus* ? *Frenesia* (cold streams) *Goera* *Hesperophylax* (small streams) *Hydatophylax* *Limnephilus* (mostly slow streams, rarely whitewater) *Neophylax* *Platycentropus* *Pycnopsyche* (wooded streams)
Molanidae:	*Molanna* (slower rivers)
Odontoceridae:	*Psilotreta* (riffiles)
Philopotamidae:	*Chimarra* (riffles) *Dolophilodes*

Phryganeidae:	*Ptilosomis*
Polycentropodidae:	*Polycentropus* *Cyrnellus* (large rivers) *Neureclipsis* (slow currents) *Phylocentropus* (fine sediment)
Psychomyiidae:	*Lype* (small streams) *Psychomyia*
Rhyacophilidae:	*Rhyacophila*

Mayflies (Ephemeroptera)

Ephemerellidae:	*Ephemerella* (slow or fast water; active swimmers)
Leptophlebidae:	*Paraleptophlebia* (slow water or riffles) *Leptophlebia* (slow water or riffles)
Caenidae:	*Caenis* (muddy bottoms)
Tricorithidae:	*Tricorythodes* (slow to medium water with fine bottom)
Heptagenidae:	*Stenonema* (specialized for fast current) *Stenacron* (specialized for fast current) *Epeorus* (specialized for fast current) *Heptagenia* (specialized for fast current) *Rithrogenia* (specialized for fast current) *Cinygmula* (specialized for fast current)
Ephemeridae:	*Ephemera* (slower streams, pools in whitewater streams)
Potomanthidae	*Potomanthus* (medium water)
Baetidae:	*Baetis* (medium water with organic debris) *Pseudocloeon* (riffles) *Centroptilum*
Baetidae:	*Cloeon*
Siphonuridae:	*Spihonurus* (medium water) *Isonychia* (whitewater)

Stoneflies (Plecoptera)

No habitat information is available, but the stoneflies as a group are largely animals of well-oxygenated stony streams with good current.

Pteronarcidae:	*Pteronarcys*
Peltoperlidae:	*Peltoperla*
Nemouridae:	*Nemoura*
Perlodidae:	*Isogenus* *Isoperla*

Taeniopterigidae:	*Brachyptera*
	Taeniopterix
Chloroperlidae:	*Hastaperla*
	Alloperla
Capniiidae:	*Paracapnia*
	Allocapnia
Leuctridae:	*Leuctra*
	Capnia
	Paraleuctra
Perlidae:	*Neoperla*
	Perlesta
	Acroneuria
	Paragnetina
	Phasganophora

True Flies (Diptera)

Chironomidae	(non-biting midges: fast and slow streams)
Rhagionidae	(snipe flies: fast and slow streams)
Empididae	(dance flies)
Simuliidae	(black flies: always in fast water)
Tabanidae	(horseflies: mostly slow water, in debris)
Tipulidae	(craneflies: organic debris, fast and slow streams)
Heleidae	(biting midges: fine sediment, large and small streams)
Blepharoceratidae	(net-veined midges: small fast streams)

Dragonflies & Damselflies (Odonata)

Apparently no species breed in fast water, but many hunt over whitewater streams.

Beetles

Dryopidae	(mysterious little water beetles)
Psephenidae	(water pennies: fast water)
Elmidae	(riffle beetles: fast water)
Hydrophilidae	(water scavengers: slow or medium current, warm water)
Dytiscidae	(predacious diving beetles: slow to fast streams, cold water)
Hydraenidae	(small beetles; on shores or rocks)

Alder Flies (Megaloptera)

Sialidae	(slow and fast water)
Corydalidae	(slow and fast water)

True Bugs (Hemiptera)

Gerridae	(water striders: mostly slow & fast water)
Veliidae	(broad-shouldered water-striders; fast and slow water)]

Other Invertebrates (Compiled from the taxonic literature.)

Molluscs

Sphaeridae	(pea clams, soft bottoms)
Unionidae	(freshwater mussels, slow & medium water)
Anycllidae	(limpets)
Physidae	(pouch snails)
Lymnaeidae	(pond snails)
Planorbidae	(orb snails)
Bulimidae	(operculate snails)

Other Groups (families not compiled)

crayfish
flatworms
isopod crustraceans
hairworms
mites
leeches
annelid worms
sponges

5.2 Factors Influencing the Fisheries of Whitewater Streams

Fishing is one of the two major recreational uses of whitewater streams. In this section we review the factors that influence fish populations. This material is not original with us. We include it here because it is essential for any discussion of stream conservation, and so that we may make some observations on the relation of fisheries to other aspects of whitewater biology and geography.

The quality of a particular fishery depends on a number of things: the presence of adequate summer flows and temperatures; the cleanness and oxygen content of the water; the general productivity of the watershed and in particular its insect populations; the susceptibility of the stream to floods; the presence of shade, pools, and good spawning sites along a stream; the presence of migratory fish in the watershed; the amount of fishing; and the extent to which fish are supplied from hatcheries.

Adequate flows and temperatures are important for all fish, but most particularly for trout. Trout avoid stream temperatures above the mid 70's, and may die if the temperatures reach the low 80's. A number of whitewater streams, particularly those in mountain watersheds, are mostly fed from surface runoff rather than ground water. These streams invariably run low in the summer, and, when not deeply shaded, also become quite warm. The best fisheries are usually in watersheds in which there are extensive glacial gravel deposits (Battenkill, Winooski, Lamoille, White) that feed the streams from groundwater, or where there are large reservoirs that provide constant flows of cool water (West River, Lamoille, East Branch of Deerfield, etc.). Not all reservoirs are beneficial. Some do not provide minimum summer flows,and some supply the river with heated

water from their surface. Where such conditions occur (Missisquoi, Winooski below East Montpelier, Black River, etc.) the fishing can be very poor.

The *cleanness and oxygen content* of the water are important to most of our game fish. As noted above, they are active, oxygen demanding-animals that hunt by sight and depend on insect populations that can be harmed by turbidity and siltation. In most of the whitewater streams we studied the water quality is excellent, and the presence of mild whitewater and riffles keeps the oxygen content high through the summer. The only major exceptions are some of the larger streams, particularly the Missisquoi and lower Lamoille, where the poor water water quality and low oxygen levels are said to limit the fishery. Minor but locally important exceptions also occur. We noted a number of instances of local pollution. Two common types were scouring or sedimentation connected with logging or highway construction, and flow diversions below dams where the flows were very low and the water poorly oxygenated.

The *productivity* of different watersheds, as reflected both in fish and insect populations, differs markedly from stream to stream. It is lowest on softwater streams in quartzitic or granitic watersheds. It is generally higher on schists, amphibolites and phyllites, and highest on limestones. Thus many of the high streams on Precambrian and Cambrian metamorphic rocks are quite unproductive, while the limestone rivers on both sides of the mountains often have excellent fisheries. Examples of good limestone streams are the Clyde, Barton, upper Lamoille, some of the Winooski and its tributaries, and of course the Battenkill. Examples of poor streams on acid rocks are the upper West, the Deerfield drainage, and many of the high-altitude streams in the western watersheds of the Green Mountains.

The relationship between productivity, bedrock type, and stream water chemistry is well established both in the U.S. and in Europe, but it does not seem to be known just how the chemistry influences the productivity. It is generally assumed in the fishing literature that either the stream pH or the dissolved calcium level or both play some direct role in the nutrition of fish or aquatic insects, but in spite of a number of ecological studies the exact connection is unclear.[7]

The geographic connection between acid rocks and infertile watersheds is not as universal as is often believed. While it is true that limy streams are usually fertile it is not true that all streams on acid bedrock are infertile. Where there is good natural or artificial flow regulation, as in the East Branch of the Deerfield, the upper Connecticut, or most importantly the West and White rivers, the fisheries may be excellent in spite of predominantly acid bedrock. And in many of the mountain streams with admittedly poor fisheries, the cause may not be the bedrock itself, but a combination of the bedrock, altitude, slope, low summer flow, and perhaps most important, the susceptibility of the stream to sudden floods.

This last factor, the *frequency of flooding*, plays an important and much overlooked role in stream biology. Floods that are intense enough to move the average rocks of a stream bottom kill many

7. In the specific case of the rainbow trout it seems well established from laboratory and stocking experiments that their eggs or sperm are sensitive to acidity, and that reproduction fails when the pH is below about 5.5. PH values of 5.0 or lower occur in many mountain watersheds in Vermont, and probably account for the absence of rainbow trout in many upland watersheds, even where they have been stocked heavily.

stream invertebrates, and wash many more downstream. The insects on which fish feed are strongly dependent on stable stream bottoms, and can be almost completely wiped out by any flood intense enough to change the channel or to move stones along ('scour') the stream bottom. Floods of this intensity may also fill pools with sediments or stones, destroy algae populations, and, if severe enough, may kill fish. All of this decreases the productivity of a stream, essentially setting the season clock back, until the algae, invertebrate, and finally fish populations can recover. For a moderate flood the recovery may take from a few months to a year. For a severe flood it may take several years. Thus the interval between floods becomes critical to productivity. If the flooding is local and only scours a small area this can be recolonized within a week or two by insects drifting down from other parts of the stream. But if a flood is large enough to scour a substantial amount of stream channel it will be at least a year, and sometimes two or three, before the insect populations are restored. Thus if a stream tends to flood severely once a year or more it will never build up good insect populations, and will never support a good fishery.

The reader may recall from Chapter 4 that streams differ a great deal in the ratio of their maximum to mean flows, and that the streams that rise suddenly after rains tend to have intense turbulence and to be good whitewater runs. These same streams tend to alter their channels and channel bottoms frequently, and as a consequence often have poor fisheries.

Thus flashy and intense streams with high ratios of maximum to mean flows are for the most part poor fishing streams. These streams include a number of small bouldery streams that move a lot of rocks and make fast tricky whitewater runs. The Wardsboro, Winhall, Mill, Deerfield West Branch and a number of others fall into this category. They can be recognized in the field by the presence of loose cobbles and boulders along the shores, by well-rounded stones with impact marks on all sides, and by the lack of an 'armored' or 'paved' channel bottom. On the other hand many of our streams with substantial amounts of structural roughness -- the Saxton's and the White are good examples -- derive their intensity from bedrock features rather than flashiness, disturb their bottoms less, and are considerably better habitat for fish.

A *spatially varied habitat* is critical to a good fishery. Fish need shade and deep pools for coolness and protection. They need access to current in order to feed and eddies behind rocks to escape from the current and conserve energy. And many species need gravel in order to spawn. A stream that lacks these amenities will have a poor fishery, even if the more general features of the habitat such as average temperature and summer flow and fertility are good.

Individual streams differ in their provision of shade and pools and rocks and spawning sites. Some of the best trout streams are those in regions with highly folded metamorphic rocks, and have what we have called 'structural roughness'-- natural drops and pools, exceptionally large boulders, narrow rocky constrictions, and so on. Two of the state's most important fishing streams, the West and the White, have this sort of roughness, as do a number of other good streams like the Saxtons and the New Haven. By virtue of their extensive bedrock outcrops they can offer fish the spatial complexity of a rough stream, without the disadvantages of high current, unstable channel bottoms and low depth that occur in streams where the roughness is associated with steep slope. All of these streams are excellent recreational whitewater streams. As noted in Chapter 4 the structural roughness gives them more difficult whitewater than would be expected

from their slope alone. They are instances of streams in which -- contrary to the flashy streams discussed above -- good whitewater and good fisheries go together.

In the name of flood control and bank stabilization, people often decrease the small-scale variety of streams by straightening bends, removing trees and overhanging vegetation, and replacing natural channels with artificially graded ones which are more uniform. The fisheries of many streams -- the Ottauquechee for example, and a number of segments of the Lamoille and Missisquoi -- have suffered from these changes. Whitewater streams are often damaged in this way. They are themselves more damaging to highway embankments and bridge abutments than other streams, and in return are more commonly subjected to alteration and channelization. When a stream's productivity is already marginal because of steepness or recurrent flooding this kind of alteration can destroy the fishery altogether.

Migrating fish are of great significance in a number of streams. The most famous migrants are the anadromus fish -- in Vermont salmon and shad -- that formerly made spring runs up the Connecticut River and a number of tributaries. The salmon runs ceased about 1802, four years after the Connecticut River was first dammed. A large Federal salmon restoration project began about 10 years ago, and it is hoped that within a few years there will again be substantial salmon runs in the Connecticut, West, and White Rivers. We have heard that there is also an attempt being made to restore the shad, but do not know the status of this project.

Elsewhere in Vermont local migrations are of importance. In many watersheds the best trout reproduction is in the upper tributaries, and important local migrations of brown and rainbow trout take place between the tributaries and the main stem. In addition to these short-distance migrations, there are longer seasonal migrations of rainbow trout, land-locked salmon, and walleyed pike from lakes into rivers. The migration of salmon and rainbow trout from Lake Memphremagog in the Black and Barton rivers is probably the best known of these, but there are also runs of salmon in the upper Connecticut, and of steelhead rainbows in Lewis Creek.[8]

The *stocking of fish* certainly has considerable effect on fisheries, though just how necessary or beneficial the effects of stocking really are is often disputed. We include comparatively little information on stocking here. Policies change from year to year, and the artificial maintenance of fish populations is not really relevant to our primary concern, which is the existence and conservation of the natural features of streams. Likewise we say very little about the effects of *fishing pressure* on different streams, and the extent to which the present productivity of a stream is depressed below its potential because of use. The latter is of course vitally important to conservation, but also very hard to determine, and would take us far beyond our basic concerns.

5.3 Specific Fisheries in Whitewater Streams

8. Formerly there were important migrations of sturgeon from Lake Champlain spawning areas in whitewater segments of the Lamoille, Winooski, and Missisquoi Rivers. These were migrations were eliminated by dams early in this century.

In Table 5-3 we attempt to rate the fisheries of individual streams, and to indicate any environmental factors which are known to be (or seem likely to be) limiting the fish populations of each stream.

The ratings and observations are very provisional. Almost every stream has some fish, and is fished successfully by some fishermen, and nearly every species of cookable fish has some partisans and some detractors. The productivity and fishability of the major streams has been documented by electro-shock surveys and creel censuses, and the data from these studies are very suggestive. Because such information is costly to obtain it is necessarily incomplete: for many streams, and even for many segments of the most important streams, we have little or no survey data and have to rely on the personal observations of fishermen and fisheries biologists. We offer the tables as a crude introduction to the geography of Vermont fisheries, and warn the reader that stocking policy and environmental conditions change from year to year, and the quality of fisheries with them.

Table 17: Fisheries in Whitewater Streams

This chart covers only the whitewater segments of these streams; for the location of the segments see Table 5-7. An asterisk preceding the name of a fish means that a restoration program is planned or is being carried carried, but that there is no fishery as yet. An asterix in the column for fishing quality means that natural reproduction is important in this fishery. Put & take = a fishery maintained through extensive stocking of legal-sized fish. A plus in one of the columns means that particular factor (for example temperature) is less than ideal, and may restrict the quality of the fishery. A dash in one of the columns indicates that that factor is not known to be limiting.

Temp. = temperature; Slope = slope too steep; Acid. = acidity; Flow = flows too low in summer; Fld. = stream prone to flooding; Dams = dams present, problems with impoundments, flow diversions, or interruption of migrations; Dist. = disturbance of natural bank or channel communities. Ww. Fish = warmwater species.

Stream	Fish	Quality of Fishery	Migrants	Possible Limitations						
				Temp.	Slope	Flow	Acid.	Fld.	Dams	Dist.
Battenkill	brown t. brook t.	high*	brown t.	-	-	-	-	-	-	+
Black (1)	brown t. brook t. rainbow t. salmon	high*	brown t. rainbow t. salmon	-	-	-	-	-	-	-
Black (2)	brook t. brown t.	put & take		+	-	+	-	-	+	+
				(variable flows from power dams)						

Clarendon	brown t. brook t. rainbow t.	?		+	+	-	?	-	+	
Clyde	rainbow t. brook t.	high*	salmon	-	-	+	-	-	+	+
				(variable flows from power dams; recent logging reported)						
Upper Connecticut	rainbow t. brown t.	high*	? salmon	-	-	-	-	-	-	?
Deerfield East Branch	brook t.	high*		-	-	-	+	-	-	-
Deerfield West Branch	brook trout	?		?	-	+	+	+	+	-
				(variable flows below Searsburg reserv.)						
Deerfield North Branch	brook trout	?		?	-	+	+	-	-	+
				(problems with pollution, development)						
Deerfield West Br. (2)	brown t. brook t.	?		?	+	+	+	+	-	+
Passumpsic East Branch	brook t.	? *		quality of habitat not known						
Green	brook t. brown t.	moderate		-	-	-	?	-	-	-
Hancock Branch	brook t. rainbow t. brown t.	? moderate*		-	?	?	-	?	-	-
Huntington	brook t. brown t. rainbow t.	moderate		-	-	-	+	-	-	-
Lamoille (upper)	brook t. rainbow t. brown t.	high*		+	-	-	-	-	-	+
				(some pollution, disturbed channel & banks)						
Lamoille (lower)	brown t. (below Milton)	low	salmon	+	-	-	-	-	+	+
				(pollution, altered habitat, dams)						
Lewis Creek	brook t. rainbow t. brown t.	moderate	*salmon rainbow t.	-	-	-	-	-	+	+
Mad	brook t. brown t.	moderate* (put & take)		+	-	?	+	-	+	+
				(development of valley, heavily fished)						
Middlebury	brook t.	moderate*		-	+	-	+	+	-	-
Mill	brook t. brown t. rainbow t.	? low*		+	+	?	+	+	-	+
				(some channelization done in 1970's)						

Moose (upper)	brook t. brown t. ww. fish	? low *		+	+	-	+	+	-	-
Missisquoi (Sheldon Sp.)	brown t. ww. fish	low	*salmon	+	-	+	-	-	+	+
				(some pollution, dams, disturbed habitat)						
New Haven	brown t. brook t. rainbow t.	moderate*	rainbows brown t.	-	+	-	+	+	-	-
Ompomp.	brown t. brook t. rainbow t.	low		+	-	-	-	-	-	-
				(toxic mine drainage reported; stream banks cleared extensively)						
Ompomp. West Branch	brook t. brown t.	moderate		(no habitat data; toxic mine drainage						
Ottauquechee	brook t. rainbow t. brown t.	?		+	-	-	?	+	-	+
				(extensive channelization & bank development)						
Saxtons	brook t. rainbow t.	put & take		+	-	-	?	+	-	-
Waits	brown t. rainbow t.	? moderate		+	-	-	?	?	?	?
				(good rainbow populations)						
Wardsboro	brook t.	low *		+	+	+	+	+	-	-
West above Ball Mt.	brook t. brown t.	? low *		+	-	-	?	+	+	-
West below Ball Mt.	brown t. bass ww. fish	high * *	*salmon *shad	+	-	-	-	-	+	-
				(trout fishery limited by temperature)						
White	brown t. brook t. rainbow t. bass & ww. fish	high * *shad	*salmon	+	-	-	-	+	-	+
				(some channelization below Bethel)						
Wild Branch	brook trout	low *		-	+	?	-	+	-	+
				(banks largely cleared)						
Williams	brook t. brown t. bass rainbows	put & take		+	-	?	-	?	-	+
Winhall	brown t. brook t.	? *		?	+	+	+	+	-	-

Winooski above Montpelier	brown t. brook t.	moderate*	+	-	-	-	+	+	+
			(recent flood damage)						
Winooski below Montpelier	brook t. brown t. rainbow t.	moderate*	+	-	-	-	-	+	+
			(local problems with pollution, bank disturbance)						

5.4 Use of Individual Streams by Wildlife

The quality of streams as habitat for mammals and birds doubtless varies, but at present we have very little information from which to draw any conclusions about the causes or the patterns involved. We know that a few species (common merganser, red-back vole) are common only in the northern part of the state, and not regularly seen in watersheds south of the Winooski. We believe that there is a general relationship between the productivity of a stream and the amount of use it receives from mammals and birds, but have to admit that we have only casual observations supporting this rule, and cannot consider it a general fact. And finally we believe, and can support by a number of observations, that the amount of use by mammals and birds depends not only on the quality of the stream itself, but on the quality of the shore and forest communities that surround it.

Since much of this survey was done in the early spring (and often at flow levels that did not encourage leisurely study of the shores) we have no systematic notes on the extent and naturalness of streamside communities. The best we can do is offer (Table 5-4) a list of four whitewater streams which, for various reasons, seem to have exceptional habitat for wildlife and birds.

Table 18: A Partial List of Whitewater Streams With Excellent Habitat For Mammals and Birds

Stream	Segment	Habitat
Battenkill River	below Arlington	good alluvial woods & streamside thickets
Moose River	Snowmobile Bridge to N. Concord	just below Victory Bog, thus adjacent to large wetlands & much forest; remote, unsettled area
Clyde River	Salem Pond to Clyde Pond	runs through several miles of deep cedar swamp, but not in a remote area
Deerfield River East Branch	Somerset Reservoir to confluence with W. branch	good streamside marshes; whole watershed is wild, much used by animals

One of these, the East Branch of the Deerfield is unique among Vermont whitewater streams and deserves special notice. It is not paralleled by any roads, and is surrounded by approximately 400 square miles of forest with no paved roads and fewer than 20 houses. It is relatively undisturbed: as far as I know no logging has occurred in the watershed for over 50 years. In addition it has long segments bordered by sedge marshes (which do not occur as extensively on any other whitewater stream), and so has excellent habitat for mammals and birds. Both because of the remoteness and the excellent habitat it receives much use from animals and birds. We have rated it as highly important for wildlife. It is the only whitewater stream to receive such a rating.

5.5 River Shore Plants

As part of this study we made a survey of river shore plants, confining ourselves to the vascular plants and to areas within the channel that flood at least every other year.[9] We were trying to determine how much the plant communities, viewed as a natural resource, varied from stream to stream, and also to get a better scientific understanding of an interesting and in several respects puzzling natural community. We drew on a number of sources: historical collections in museums, published records, our own researches of the last 17 years, and data gathered from sites visited in this survey and the previous gorge and waterfall survey.

Our object in doing this plant survey was to determine:

- What plants actually occurred along whitewater rivers.

- To what extent these plants were restricted to whitewater rivers.

- And to what extent did the plant communities of different streams vary in different regions of the state, or in sites with different bedrock and hydrology.

For comparative and quantitative purposes the most important data came from plant lists of 34 sites on 15 rivers. The field surveys were done by Peter Zika, mostly in July and August 1984. We estimate that they are approximately 90% complete, meaning that for an average site of 40-50 species about 2-3 plants were either overlooked or were not identifiable at the time the site was surveyed. The sites were chosen casually: some are shaded, some open, some on fine sediment, some on cobbles or among boulders. The size of the area sampled varied, but in all cases was sufficiently large to include all the plants common along that part of the river. The intent was to get varied and more-or-less random records of what actually grows along the rivers, rather than to select and sample communities of uniform size and appearance. The intensity of the whitewater at the sampling sites ranged from Class I to Class III and the slopes from about 10'/mile to 50'/

9. The purpose of this restriction was to eliminate thickets and woods above the actual channel, which are less affected by the intensity of the stream.

mile. They thus give an overall view of plants of whitewater streams, and include plants from all the habitats normally encountered within stream channels.

When we began the study we expected that riverside communities would be small and fairly uniform, and would contain a number of special riverside species. We also expected, reasonably enough, that they would reflect the bedrock, regional plant geography, and the local intensity of the whitewater. The results contradicted all these expectations. We found that a large number of species can occur on river shores (i.e that community diversity is high); that individual shores differ considerably (i.e. that community homogeneity is low), and that the individual species range widely and that their distribution does not correlate well with either regional geography, bedrock geology, or local river conditions.

Table 19: Community Statistics For Channel Plants of Whitewater & Quickwater Streams

Number of sites sampled:	34
Total # of species:	368
Average # of species/site:	43.2*
Number of alien species:	89 (24.2%)
Average # of aliens / site:	8.4
Average % of alien species per site:	19.5
Estimated number of species commoner here than in any other community (modal species):	7-10 (2.6-3.6%)
Number of modal species in the 43 commonest species:	2
% of commonest 43 species that are modal:	4.3
Index of Homogeneity (# of occurrences of 43 most common species x 100/ # of occurrences of all species):	42.1
Index of Diversity (Total # of species at all sites - ave. # of spec./site x 100)/ln(# of sites):	91.5

* By convention the 43 commonest species in the community are called the prevalent species.

The data from the 34 sites were sorted and analyzed using standard computer database techniques. We did not attempt to do any kind of a gradient analysis, but did calculate community statistics using the methods developed by J. T. Curtis and his associates at the University of Wisconsin.[10] The main species are listed in Table 5-1. Community statistics are given in Table 5-5, and species lists for individual sites are given in Appendix B.

10. (J. T. Curtis, *The Vegetation of Wisconsin*, U. Wisconsin Press, Madison, 1960, Chapter 4.)

5.6 Plant Diversity

Because we only have presence and absence data and do not have data on the abundance of species, our measures of diversity are actually measures of species richness.

Useful measures of species richness include the number of species at individual sites, the average number of species per site, and the ratio of the number of species in all the samples to the average number of species in an individual sample.

A total of 373 species were encountered at the 35 sites, with an average of 45 species per site, and a range of XX. Comparable figures for the total number of species in other plant communities in Vermont are not available but by comparison with published figures for other states the total number of species encountered is substantially greater than that for most other communities.[11] Since the river shore community has a fairly small total area and (see below) few ecologically specialized species, we take this as a measure of the extent to which this community overlaps in composition with other communities.

The average of 45 species per site is about in the middle of what we have encountered in Vermont, and also of what is reported in the literature. It is larger than that of the more restricted wetland, cliff and beach communities, and smaller than that of the most varied forests. Our interpretation is that the individual sites studied are not very large and do not comprise many stable microhabitats with their own floras, but that the community as a whole has a large pool of possible species to draw from, both because the habitat is fertile, and because the frequent disturbance by floods provides good opportunities for colonists.

The ratio of the total number of species to the average number of species per site is 373/45=8.2. This number measures the extent to which the sites vary in composition. The ratio normally increases as more sites are studied and so is not useful for comparative purposes. A more useful number, called the index of diversity, may be defined as:

$$\frac{\text{total number of species in all sites - average number of species per site}}{\text{natural logarithm of number of sites}}$$

Effectively it measures the amount by which the total species pool exceeds number of species seen at an average site, but weights this in accord with our statistical expectation that the total species pool will grow logarithmically as we sample more sites. For our 35 river shores the index has a value of 91. This compares with values of 9-70 for various communities reported by J. T. Curtis from Wisconsin, and confirms what we said about variability in Section 5.5. Thus river banks, which we sometimes tend to think of as fairly simple groups of plants, draw from a large species pool, and differ greatly from each other.

11. J.T. Curtis gives the following figures for the total number of species in various plant communities in Wisconsin: submerged aquatics, 51; bogs, 130; exposed cliffs 157; northern sedge meadow 177; northern mesic forest 254; boreal forest 328.

5.7 Importance of Weeds and Aliens

The prevalence of weedy species in a community is a good indicator of how much disturbance the community gets, and of whether it is dominated by species specialized for particular habitats (which will usually out-compete weeds under stable conditions) or by less-particular species with weedy tendencies of their own. Of the 368 species encountered, 89 (24%) are listed as aliens (plants believed to have entered our flora in the last 200 years), and the rest are natives. The percentage of aliens is midway between the very low values (2-10%) encountered in native woodlands and densely vegetated wetlands, and the higher values (30-50%) encountered in grasslands and in weed communities on disturbed ground. The number of alien species varies considerably from one site to another, and seems to depend on the vegetation near the river, being higher for rivers adjacent to meadows and disturbed sites than for those with wooded banks. Many of the aliens are uncommon, and so are less important than their percentage of the total number of species might indicate: while they make up 24% or 1/4 of the species list they make up only 16% (1/6) of the list of the 43 'prevalent' species.

5.8 Modal Species

The modal species of a given community are species that are commoner there than in other communities. The percent of modal species in a community is a measure of how separate that community is from others, and also of the extent to which the plants in that community share a common set of adaptations or tolerances and hence are specialized for that community.

Lacking data on other plant communities we cannot determine with accuracy how many of the 279 native species are modal in the sense that they are commoner in this plant community than in any other. We estimate that the number is very low, perhaps 7-10 overall, and that of the common species only 5 (*Carex torta*, twisted sedge; *Elymus riparius*, wild rye; *Apios americana*, ground nut; the grass *Sphenopholis intermedia*; and the collective species *Apocynum cannabinum* (including *apocynum medium*) Indian hemp) are in any sense riverbank specialists.

This figure of 5 species among the 43 most common (= 9%) is very low; in Wisconsin the figures typically range from 25% for forest communities to over 75% for some wetland and aquatic communities. It indicates that this community contains very generalized species with wide ecological ranges, and that it shares its species widely with other communities.

There may also be an historical explanation for the low percentage of modal species. A number of the species from this community are commonly encountered in open ground and wetlands of human origin. It is quite possible that a number of common plants -- for example late goldenrod, calico aster, grass-leaved goldenrod, red fescue, several of the panic grasses, and a number of others -- were most commonly found on cobble river shores in pre-settlement times, and have subsequently expanded into anthropogenic sites, and are now commoner there than in their original habitat.

5.9 Community Homogeneity

Homogeneity is a measure of how much individual instances of a community differ from each other. It reflects the size of the species pool, the extent to which individual sites differ ecologically, and the extent to which the random arrival of colonists determines the flora of a site.

A simple measure of homogeneity is obtained by first determining the average species density, 43 in our case, next determining the 43 commonest species (the 'prevalent' species), then computing

$$\frac{\text{total number of occurrences of the prevalent species}}{\text{total number of occurrences of all species}}$$

This fraction will be 1 if the same species occur at all sites and 1/(number of sites) if no two sites have any plants in common. In our case it is 42.1%. In comparison to published values for other communities this is moderately but not exceptionally low[12], and indicates that our samples differ considerably from one another. This is partly because the habitats at the edge of channels vary a lot and we made no attempt to restrict our survey to sites with similar character or physiognomy. But it also certainly reflects the large species pool, and the influence of chance arrivals on the flora.

The normal procedure when confronted with an inhomogeneous community is to try to divide it, by a process called ordination, into more homogeneous subgroups with uniform immediate environments. Our data does not permit this. Physical conditions within stream channels vary dramatically over short distances, and we did not sample -- and probably could not have sampled -- in such a way that each species list represents the plants of a single uniform microenvironment.

This is also reflected statistically in the more-or-less random co-occurrences of the common species. A crude analysis of the occurrence of the commonest species detected no groups of species that were common but did not co-occur, suggesting that it would not be possible, from our data, to break the community into ecologically specialized sub-communities in a meaningful way. This was in some ways disappointing: we had hoped that certain groups of dominants might favor certain intensities of whitewater, and give us another off-season index of the kind of boating to be expected on an unknown stream. We are not convinced that this is impossible, but will only say that as yet we cannot propose a table of whitewater indicator species for the next AMC guide.

5.10 Geographical & Geological Variation

In many plant communities the species list of individual sites reflect the position of the site within the region, and often the bedrock geology as well.

12. Curtis reports typical homogeneities of 50-60% for forest, prairie, sedge meadow and bog communities. The only communities he found with homogeneities under 42% were beach (34.1%) and cliff (35.2%, 39.7% for exposed and shaded cliffs).

This was not true of our channel communities. While individual sites differ considerably among themselves, we were able to identify only a very few species that were characteristic of particular parts of the state, or that seem sensitive to altitude or bedrock geology. Out of the 279 native species encountered in our samples all but about 20 can be found throughout the state and occur in many different sorts of soils. This is at first surprising, because out of the flora as a whole probably 50% or more of the species have geographical or chemical restrictions, and in consequence it is usually easy to examine a species list from a woodland or wetland and community and tell whether the bedrock is limy, and at what altitude or in what part of the state it occurred. The absence of strong geographical and chemical indicators confirms for us the unspecialized nature of the species that occur along stream. Weedy species of wide ecological latitude are traditionally wide-ranging geographically, and often indifferent to bedrock chemistry.

To look at the geological control of this community more carefully, consider Tables 5-6 and 5-7 which show the effects of limy and acid rock on the frequency of occurrence of the most common rivershore species. These were prepared by taking 9 sites where the bedrock was unequivocally limy and comparing these to another 17 sites where it just as definitely was not. Table 5-6 shows that the lists of prevalent species and the community statistics were generally similar at both sites. (It also shows that, on face value, the community on the acid sites was more diverse and richer in species, the reverse of what is generally true in other communities.) Table 5-7 lists 22 species whose percentage abundance seems to differ between acid and limy sites. (Here again it seems that more species are common on acid sites, but this might easily be an artifact caused by the small number of limy sites.) Note that there are very few species that are apparently restricted to acid soils, and none restricted to the lime soils. Thus while we have, at least apparently, a difference in abundance of species, few if any species are unambiguous indicators.[13] This may be because the species aren't as choosy as we might like to believe they are, or because river shores have mixed soils gathered from all over the watershed and do not reflect the local bedrock.

In any event, the example is instructive and should be a caution to field workers, many of whom share the authors' deep but apparently mistaken belief that they can deduce the soil pH and parent material by looking for indicator species.In some habitats this may work; on river shores it apparently doesn't.

Table 20: Comparison of the Prevalent Species of Limy and Non-limy Sites

Prevalent Species from 9 Limy Sites			Prevalent Species from 17 Non-limy Sites		
	#	Presence (%)		#	Presence (%)
Carex torta	8	88.8	*Carex torta*	14	82.3
Salix rigida	7	77.7	*Agrostis stolonifera*	13	76.4
Eupatorium maculatum	6	66.6	*Eupatorium maculatum*	13	76.4

13. Note that we have not ruled out the possibility that some of the rarer plants are, as many botanists believe, restricted to a single type of bedrock. Inevitably you have only a few occurrences of any rare species, and so have trouble separating habitat preferences from chance occurrences. The best evidence for distinct habitat preferences comes when a group of rare species co-occur at a few sites. This is discussed later in the chapter.

Phalaris arundinacea	6	66.6
Sphenopholis intermedia	6	66.6
*Tussilago farfara**	6	66.6
Ulmus americana	6	66.6
Vitis riparia	6	66.6
Apios americana	5	55.5
Equisetum arvense	5	55.5
Eupatorium perfoliatum	5	55.5
Thalictrum polygamum	5	55.5
Agrostis stolonifera	4	44.4
Cornus stolonifera	4	44.4
*Festuca pratensis**	4	44.4
Juncus dudleyi	4	44.4
Matteuccia struthiopteris	4	44.4
Mimulus ringens	4	44.4
Onoclea sensibilis	4	44.4
*Phleum pratense**	4	44.4
*Saponaria officinalis**	4	44.4
Solidago gigantea	4	44.4
Solidago graminifolia	4	44.4
*Taraxacum officinale**	4	44.4
Tsuga canadensis	4	44.4
Acer saccharum	3	33.3
Alnus rugosa	3	33.3
Aster puniceus	3	33.3
Aster umbellatus	3	33.3
Carex hystericina	3	33.3
Carex sp. (ovales)	3	33.3
*Chrysanthemum leucanthemum**	3	33.3
*Dactylis glomerata**	3	33.3
Festuca rubra	3	33.3
Glyceria striata	3	33.3
Hypericum perforatum	3	33.3
Leersia oryzoides	3	33.3
Myosotis scorpioides	3	33.3
Panicum clandestinum	3	33.3
Populus balsamifera	3	33.3
Spiraea latifolia	3	33.3

Onoclea sensibilis	13	76.4
Ulmus americana	13	76.4
Salix rigida	12	70.5
Solidago graminifolia	12	70.5
Aster umbellatus	11	64.7
Aster lateriflorus	10	58.8
Equisetum arvense	10	58.8
Oxalis europaea	10	58.8
Panicum clandestinum	10	58.8
Spiraea latifolia	10	58.8
Alnus rugosa	9	52.9
Hypericum perforatum	9	52.9
Phalaris arundinacea	9	52.9
Solidago gigantea	9	52.9
*Tussilago farfara**	9	52.9
Aster puniceus	8	47.0
Clematis virginiana	8	47.0
Eupatorium perfoliatum	8	47.0
*Phleum pratense**	8	47.0
Populus tremuloides	8	47.0
Rubus idaeus	8	47.0
Solidago canadensis	8	47.0
Verbena hastata	8	47.0
Acer negundo	7	41.1
Betula alleghaniensis	7	41.1
Betula papyrifera	7	41.1
Calamagrostis canadensis	7	41.1
*Chrysanthemum leucanthemum**	7	41.1
Elymus riparius	7	41.1
*Poa compressa**	7	41.1
Salix sericea	7	41.1
Thalictrum polygamum	7	41.1
Tsuga canadensis	7	41.1
Vitis riparia	7	41.1
Acer rubrum	6	35.2
Athyrium filix-femina	6	35.2
Fraxinus americana	6	35.2
Glyceria striata	6	35.2
Mimulus ringens	6	35.2
Oenothera biennis	6	35.2
Parthenocissus quin.	6	35.2
Pinus strobus	6	35.2
*Prunella vulgaris**	6	35.2
*Ranunculus acris**	6	35.2
Acer saccharum	5	29.4
Agrostis scabra	5	29.4

Limy sites:	
Total species at 9 sites:	202
Ave. number of species/site:	41
Diversity index:	73
Non-limy sites:	
Total species at 17 sites:	268
Ave. number of species/site:	50
Diversity index:	130

Table 21: Species With Apparent Preferences for Limy or Non-limy Sites

= number of sites Pres. = Presence (% of total number of sites)

	Abundance at 17 Non-limy Sites		Abundance at 9 Limy Sites	
	#	Pres.	#	Pres.
Aster umbellatus	11	64.7	3	33.3
Aster lateriflorus	10	58.8	2	22.2
Oxalis europaea	10	58.8	2	22.2
Clematis virginiana	8	47.0	1	11.1
Solidago canadensis	8	47.0	0	0.0
Verbena hastata	8	47.0	2	22.2
Elymus riparius	7	41.1	1	11.1
*Poa compressa**	7	41.1	1	11.1
Salix sericea	7	41.1	1	11.1
Oenothera biennis	6	35.2	1	11.1
Parthenocissus quinquefolia	6	35.2	1	11.1
Agrostis scabra	5	29.4	0	0.0
Bromus ciliatus	5	29.4	0	0.0
Galium asprellum	5	29.4	0	0.0
Panicum lanuginosum	5	29.4	0	0.0
Sphenopholis intermedia	6	66.6	3	17.6
Apios americana	5	55.5	5	29.4
*Festuca pratensis**	4	44.4	3	17.6
Juncus dudleyi	4	44.4	2	11.7
Matteuccia struthiopteris	4	44.4	4	23.5
Carex hystericina	3	33.3	1	5.8
Festuca rubra	3	33.3	2	11.7

5.11 Summary Description of River Channel Plant Communities

Combining the statistical observations above with our more general field impressions we can give following general description of the plant community of whitewater river channels:

- It contains many colonizing species of fairly wide geographical and ecological latitude, and comparatively few ecologically or geologically specialized species.

- It is not, contrary to what you might expect, a wetland flora. Only about 25% of its species are normally considered to be wetland species.

- It has a significant but not particularly high percentage of introduced species. These, while common, are rarely the dominants species,

- It is a restrictive habitat in that only a few species are generally common and thus equipped to persist and thrive here.

- But it is not a restrictive habitat in that water, space, and nutrients are plentiful, and so it has a large species pool and many temporary species that do not regularly occur in the community.

- It is an inhomogenous community whose examples differ individually but at the same time a community that is geographically and ecologically fairly uniform.

We interpret these observations this way. We conjecture that some of the site-to site variation reflects the influence of differing microenvironments at different sites. But we also conjecture that much of the variation reflect high local rates of extinction and the vicissitudes of a recolonization process that is as apt to draw on the surrounding non-river communities as it is on other sites within the channel. We further speculate that were river sites always recolonized from other river sites we would see a much less diverse flora with a higher percentage of ecologically specialized species. We think that the lack of edaphic and geographic differentiation partly reflects the prevalence of colonizing rather than permanent species in the flora, but is also in part an artifact caused by the fine-scale mixing of different soils and water conditions at each site. And finally we speculate that the community is the historical source of a number of species that currently have a wide distribution in anthropogenic habitats, and so, prior to European settlement, might have contained more ecologically restricted species and been better demarcated from the flora as a whole than at present.

5.12 Rare Animals and Plants of Rivers

Rare animals and plants are often interesting simply by virtue of being rare. But, quite apart from their rarity, they are biologically important because they are often good indicators of environments with particular features or particular histories, and because they are the most restricted and

usually the most vulnerable members of the biota and so need special efforts to assure their sur vival.

We do not wish to overstate their importance, or lead the reader to assume that all rarities are equally precious. Some are just strays, casual and impermanent here and commoner elsewhere. Others have sparse and erratic distributions, and are reasonably numerous overall but appear rare either because they are never numerous at any single site, or because they are not regularly found in a particular ecological situation and so are hard to look for. Many are fairly common but hard to see, and others -- as we continue to discover -- just haven't been looked for. But none the less there are a number of species that are both genuinely rare and strictly dependent on the existence of particular habitats, and hence on the conservation of particular habitats.

The amount of knowledge we have of rare species differs dramatically for various groups. The rare mammals, birds, and higher plants are well known. The rare insects, with the exception of butterflies and beetles, are very poorly known. Other groups fall in between, but tend toward the poorly known end.

With the exception of the vascular plants it is impossible to give even a summary account of the rare species of river animals and plants, and we confine ourselves here to reporting bits of information, and indicating generally whether rarities may be expected in the group.

5.13 Rare Invertebrates

Our information on rare invertebrates comes from Dr. Ross Bell, an entomologist at the University of Vermont. He speculates that there are many rare invertebrates, and probably a number of undescribed species as well, in Vermont rivers in general and in the whitewater rivers in particular. He notes that after 20 years of work on the beetles of Vermont he and his students are still adding species to the fauna, and that some of these have very limited distributions.

Dr. Bell supplied us with the following examples of rare beetles associated with white water rivers.

Bembidion rufotinctum is a tiny beetle that for many years was known only from a few sites in North America, including 2 rapids on the Connecticut River and also the Winooski Gorge. Recent studies have shown that there may be three species instead of one, and that they may be more widespread than believed. Hence it may well occur at other rapids in Vermont, but it hasn't been looked for systematically and at present its statewide distribution is unknown. A related species, *B. rollandi*, is known in Vermont from a single locality on Lake Champlain and two on the West River. As with the preceding species there has been no thorough attempt to find it at other sites.

The tiger beetle *Cicindela margipennis* occurs on cobble beaches along the Connecticut river. In Vermont it occurs at Sumner's falls and a few nearby islands. It is known elsewhere in the country from about seven states, and is proposed as a federal endangered species.

The tiger beetle *Cicindela puritanica* was discovered on the shores of the Connecticut River at Charleston, N.H. It has not been seen there or anywhere else since 1931.

The tiger beetle *C. ancocisconensis* is a rare species of bouldery rivers; the only known Vermont station is on the West River at Jamaica State Park.

The dwarf wedge mussel *Alismidonta heterodon* was formerly widespread in eastern Canada and the United States, but requires well oxygenated water and has suffered from the damming of many rivers. It is currently known from less than 10 sites nationwide, one of which is Sumner's Falls on the Connecticut River.

These are only a few examples,taken from three out of several hundred families of aquatic invertebrates in the state[14]. The point is clear: there are rare species of invertebrates associated with rocky shores and whitewater streams. Many of these are associated with very specific habitats or apparently limited to a small number of sites, and hence vulnerable to changes at those sites.

5.14 Fish

It is not possible at present to say what Vermont fishes are rare and where they are found. Dr. George LeBar of the University of Vermont is currently researching the statewide distribution of fish, and in a few years his work may give us a considerably greater understanding than we currently have. In the meantime we can site the following species as examples:

The lake sturgeon, *Acipenser fulvescens*, is currently listed as an endangered species in Vermont. It is a lake fish that spawns in turbulent water, and formerly lived in Lake Champlain and spawned in the Missisquoi, Lamoille, and Winooski watersheds until its access to those streams was blocked by dams. It was also heavily fished, but the crucial factor in its decline is probably its inability to reach its spawning sites. It has declined throughout North America, and is on several state endangered lists.

The eastern sand darter, *Ammocrypta pellucida*, is listed as a species of 'special concern' which is a backwards way of saying it is a species that probably never was common and whose current status is unknown. It is recorded from the lower Winooski and New Haven rivers, and known to use whitewater or riffles.

Six other species (the river carpsucker, northern hog sucker, and four species of redhorse) are also listed as species of special concern, and known to use whitewater or riffle areas at some time during their life cycle. At present we do not know their Vermont distribution and cannot associate them definitely with any of the rivers in this study.

14. It is unfortunate that we are not able to give a summary of rare stone flies and mayflies, two groups of insects that have many genera specialized for life in whitewater streams. Many records are certainly available in museums, but so far as we know there has been no compilation of Vermont records, and no substantial amounts of recent fieldwork on the adult mayflies and stoneflies in the state.

5.15 Rare Amphibians, Reptiles, Birds, and Mammals

No rare species of amphibians, reptiles, or mammals have any specific association with whitewater.

Two rare birds, the bald eagle and the osprey, are regular migrants along rivers. The bald eagle occurs mostly in the Connecticut River valley; the osprey occurs on both large and small rivers throughout the state. Both formerly bred in Vermont (though very rarely), suffered a period of greatly decreased numbers throughout the northeast, and have made substantial recoveries in the last decade. The osprey now is a frequent bird along many Vermont rivers from April to July, and is believed to breed at perhaps three sites in Vermont. The eagle is a rare migrant along rivers, and may have bred at Lake Memphremagog in the late 1970's.

None of the birds that nest along whitewater rivers are rare.

5.16 Lower Plants

Little is known of the algae species of Vermont whitewater streams, and what knowledge there is does not seem to have been compiled. Some examination of the moss species was made in connection with the Vermont Waterfall & Gorge Survey. A number of interesting species were found in gorges at levels above the normal height of spring run-off, but the areas that were regularly scoured by the river had for the most part a fairly simple moss and liverwort flora dominated by common species. Occasionally interesting (and taxonomically very difficult) species from the moss families *Bryaceae* and *Pottiaceae* occur on sandy soil or stones along smaller streams. We did not look for them in this study, and do not know if they occur along whitewater streams of the size we were interested in.

5.17 Higher Plants

Table 5-8 lists rare species known to be or to have been associated with the channel communities of Vermont whitewater rivers. It does not include the species that live higher up in rocky gorges. (For a treatment of these see the Vermont Waterfall and Gorge Report.) It is based on historical records, past research by the authors and others, and on surveys done for this study. It is by no means complete: the surveys of most rivers consisted of samples taken at scattered sites, and for 16 of the principal streams and the majority of the isolated rapids we do not have any field data at all. We feel that we have enough data to put together a reasonable picture of the main species that occur, but still do not know how frequent they are, and do not have either a complete enumeration of the rare river species or the rivers along which they occur.

There are 32 species on this list: two are currently missing, and a third is currently known from a swamp but not from river shores. The remaining 29 are extant along rivers in the state. Of these, 17 are rare and 12 uncommon. Currently there are 500 plants in Vermont (out of a native flora of

ca. 1500) that we list as rare or uncommon. Hence our current estimate is that we can find somewhere around 5% of the rare or uncommon species of the state in the river shore community. This is a reasonable figure, typical of many communities. (The richest communities in the state, dry limy woods and ledges, include some 50-60 rare or uncommon species or ca. 12% of the total native flora.) In comparison, in our gorge and waterfall study, which included more stable sites with a much wider ecological range, we found some 35 rare and uncommon species, or 7% of the flora. Bogs and alpine areas, commonly thought of as particularly rich habitats for uncommon plants have about 6% and 4% of our total list of rarities. Thus the whitewater river shores, which we do not usually think of as a place to look for unusual plants, are fully as good if not better than many more famous habitats, and at least half as good as the best habitats in the state. They definitely lack many of the species that specialize in stable, ecologically restrictive microsites, but make up for this by being able to draw from a large pool of species.

It is interesting that we have comparatively few historical records of missing species from river shores. This may in part be a result of our continuing botanical studies of rivers. But it may also indicate that with the exception of rock-walled gorges, river shores have not been perceived as a very interesting habitat and so received less botanical attention than some other communities.

Table 22: Rare and Uncommon Plants of Vermont Whitewater Rivers

This table includes only shore and channel plants; for plants of ledges and rock-walled gorges see the Vermont Gorge and Waterfall Report.

Missing = not seen since 1970
Uncommon = 11 to 50 known sites
Rare = 10 or fewer known sites
Historical Record = prior to 1970

Species	Status	River	Comments
Allium sibiricum var. schoenoprasum	rare (middle)	Connecticut	Wild chives; limy cobble shores
Alnus viride	uncommon	West	Green alder; also on mountain slopes in north Vermont
Alopecurus aequalis	rare	Connecticut	Foxtail grass; also found on (northern) muddy shores and in swamps
Aster tradescanti	uncommon	Connecticut (middle), Mad	Tradescant's aster; also found in gorges; not adequately distinct in structure from several other species, but has a distinct blooming time
Campanula aparinoides	uncommon	Huntington, New Haven Lamoille Williams Winooski, etc.	Marsh bellwort; also in swamps frequent elsewhere in NE

Carex annectens	uncommon	Huntington	occasional in limy meadows
Carex garberi	rare	White	Garber's Sedge; part of the limy seepage community
Carex lenticularis	uncommon	Connecticut (northern)	Lens Sedge; occasional on lake and river shores
Carex trichocarpa	rare	Browns	Furry-fruited Carex; also along non-whitewater rivers
Deschampsia caespitosa	uncommon	Connecticut (northern)	Hairgrass; northern river & lake shores
Eleocharis pauciflora	rare	White	Cheap-flowered Sedge; part of the limy-ledge community
Habenaria flava	rare	West	Yellow rein-orchid; formerly known from a number of habitats; currently only known from the West River
Halenia deflexa	missing	Ottauquechee E. Br. Passumpsic	Spurred gentian; formerly known from river banks, gorges, and wet woods; rare in NE
Hypericum pyramidatum	scarce	Missisquoi	Great St. Johnswort; in a rock-walled gorge
Juncus marginatus	rare	Huntington West	Marginate rush; common in Massachusetts
Lathyrus palustris	rare	Missisquoi	Marsh pea; currently known from a single riverside thicket
Petasites palmatus	rare	Lewis Creek	Sweet coltsfoot; normally a plant cold swamps; 1 historical record from a river shore
Penthorum sedoides	uncommon	Lewis Cr. Winooski	Ditch stonecrop; common
Podostemum cerato-phyllum	rare	West Lamoille Winooski Connecticut	Riverweed; rare in New England; grows attached to stones, completely submerged, in fast water
Polygala sanguinea	rare	West	Common milkwort; common southwards in New England
Polygala verticillata	uncommon	West	Slender Milkwort
Polygonum careyi	missing	West	Carey's smartweed; historical record, not necessarily in whitewater segments.
Prunus depressa	uncommon	West	Sand Cherry

		Connecticut	
Rhynchospora capillacea	rare	White	Slender Beakrush; part of the limy seepage community
Salix pellita	rare	Connecticut	Satin willow; locally common along northern Connecticut River; occasional in far northern New England
Sanguisorba canadensis	uncommon	West	Canadian burnet; also found in meadows & wetlands; occasional southwards in New England
Scirpus expansus	rare	Black (Cavendish)	Balloon bullrush; also found on pondshores and non-whitewater rivers
Scirpus pendulus	uncommon	Lewis	Dangling bullrush; mostly found in limy meadows and swamps
Tofieldia glutinosa	rare	Connecticut White	Whole-grain Asphodel; rare throughout New England; one of a number of species threatened by projected dams on the Connecticut
Vaccinium cespitosum	uncommon	Mad, West	Dwarf bilberry; occasional in rocky gorges and on mountain ledges

5.18 Further Notes on Rare Plants: The Regional Abundance & Ecological Fidelity of the Rare Species

The 29 extant plants listed in Table 5-8 differ greatly in overall rarity and ecological specificity, and can be divided into several groups on this basis.

Table 23. Geographical Summary of the Rare and Uncommon River Plants

Species rare or uncommon everywhere in New England, and, at least in Vermont, restricted to river shores and channels.

Allium sibiricum
*Aster foliaceus**
Aster tradescantii
Carex garberi
Halenia deflexa (M)
Lathyrus palustris
Podostemum ceratophyllum
Prunus depressa
Salix pellita
Thermopsis caroliniana

Hypericum pyramidatum
Tofieldia glutinosa

Species which are rare or uncommon everywhere in New England, for which river banks are an important Vermont habitat, but not the only Vermont habitat.

Alnus viride
Alopecurus aequalis
Carex lenticularis
Deschampsia caespitosa
Eleocharis pauciflora
Habenaria flava
Rhynchospora capillacea
Sanguisorba canadensis
Scirpus expansus
Vaccinium cespitosum

Species rare or uncommon everywhere in New England, but for which whitewater rivers are not the principal habitat.

Carex annectens
Carex trichocarpa
Petasites palmatus (M on rivers)
Polygonum careyi (M)
Scirpus pendulus.

Species that are reasonably common elsewhere in New England.

Campanula aparinoides
Juncus marginatus
Penthorum sedoides
Polygala sanguinea

* = a species which is poorly delimited and has related varieties or sibling species which are more common.

M = a missing species which is was formerly reported in Vermont but which has not been seen for 20 years or more.

The 12 species in the first group are (in our area at least) the most dedicated river plants. Riverbank conservation is critical to their survival.

The 10 species in the second group occur regularly on rivers, though they are found elsewhere as well. Riverbank conservation, while not essential to the survival of the Vermont populations, is definitely important for them.

The five species in the third group are only casually associated with whitewater rivers; they are interesting finds where they occur, but their survival is not dependent on the existence of riverbank communities. *Alnus viride*, *Alopecurus aequalis*, *Deschampsia caespitosa*, and *Carex lenticularis* may also fall into this category.

The four species in the last group are interesting to us since they are scarce or rare in our flora, but are sufficiently abundant elsewhere in New England that their regional survival is not in question.

All the rare species are interesting to us individually, but their importance as priority species for conservation differs greatly. The conservation of whitewater rivers and rivershores is essential to the species in the first group, important to those in the second, and of little or no importance to those in the last two groups.

5.19 Further Notes on Rare Plants: How Common are Rare Species

Rare species are those comprising comparatively few individuals. If, as is the case with birds, there are only a few rare species and if you can only examine a few hundred birds of all species in a day, then it is safe to assume that rare species will be rarely encountered. But this is not the case with plants. Since about 30-40% of the flora is either rare or scarce and since you can examine tens of thousands of plants in an hour, you in fact encounter single rare plants fairly frequently.

This is illustrated in Table 5-9. Out of 31 sites that were picked more or less randomly for survey, 22 had no rare or scarce species at all, and nine, or a little under one in three, had at least one rarity.

But on the other hand, sites with 3 or more rare plants are very uncommon. We found none in the 31 survey sites we picked at random, and know of only four in the state, after many years of historical research and field research.

Table 24: Number of Species of Rare and Uncommon Shore Plants Currently Known For Different Whitewater Streams

River	Segment	# Species
Black	below Whitesville	1
Browns	Fairfax	1
Connecticut	Lyman to Bloomfield	4
Connecticut	Sumner's Falls, Hart Is.	ca. 5*
Huntington	below Huntington	1
Lamoille	above Hardwick	1
Lewis Creek	Charlotte	2 Georgia 1
Mad	Moretown	2
Missisquoi	Sheldon to East Highgate	2
New Haven	Bristol	1
West	below Ball Mt.	3
West	below Townshend	4
White	Sharon Line	4
Williams	Rockingham	1
Winooski	lower	2

* A number rare gorge sp ecies occur here as well.

This is true in other plant communities as well. In the communities that are richest in rarities it is possible to find 3-5 rare species together, but this is only true in the richest communities. In 1983 we examined some 150 botanical sites with at least one rare or scarce species; 50% of these had no more than two rare or scarce species, and only 9% had 5 or more such species. We found a single previously unknown site with over 10 rare or scarce species, and estimate that we currently know only about a dozen sites in the whole state where 10 or more rare or scarce species occur together.

These numbers have two important consequences. The first is that places with 1-2 rare or scarce plant species -- what we call ordinary rare plant sites -- are not biologically important for that reason alone. We already know hundreds of such sites in Vermont, and can find more at a rate of one or two a day, which is far faster than anyone could think of protecting them, if protection was to be necessary. But it is not necessary: ordinary rare plant sites occur in unremarkable places, often where there is evidence of recent disturbance or vegetation change. We have every reason to believe that these rarities, like most species, move around a lot, and that new sites for them are constantly being created. Hence their populations, though small, are being maintained naturally, and their protection is not a priority.

The second consequence is that groups of four or more rare or scarce species are very unlikely[15], and it is reasonable to ask whether they are chance collocations of individually distributed species, or some sort of biological ensembles which are together for historical or environmental reasons. This is an important question for conservation. If they are chance gatherings then the site merits preservation only if the individual species are quite rare, or if it is more efficient practically to preserve them as a group than separately. But if they are a natural group then the site definitely merits preserving, because there is something unique about its ecology or its history, and hence it has scientific value apart from the individual species contained in it.

It is very hard to decide what is and what is not a natural group of rare species. To us the important criteria are the following:

- Whether similar groups are found elsewhere.

- Whether local examples of the group are fairly uniform.

- Whether there are independently demonstrable ecological or historical peculiarities to the site.

15. A crude way of estimating this is to use a Poisson distribution. In our sampling of 31 sites the mean number of rare and scarce species at a site is 0.36 If these occurrences are distributed independently then by the Poisson probability of finding 4 at one site is

$$(e^{-0.36}(0.36)^4)/4!,$$

or ca. 1/2000. This is small enough to suggest that the sites with 4 rarities are fairly special.

- Whether the co-occurrence of these species is statistically unlikely given their independent distributions.

- Whether there are geographical connections between various examples of this group.

In Vermont we have four river shore floras that might conceivably be natural groups of rarities. Without trying to decide the matter, we make the following comments.

- The plants of the northern Connecticut river are all large, sturdy species with northern affinities. It seems likely that this is the only penetration into Vermont of some of the members of a community that might be found commonly on rivers farther north. They may or may not be dependent on the presence of lime in the soils.

- The plants of the middle Connecticut and lower White rivers are small species which are definitely associated with limy areas, and at one site are found mixed with a limy gorge flora. They are restricted to the Connecticut river, and not known on smaller streams. Their affinities are also basically northern. Their small size raises some interesting questions about their ecological niche: they may need a shore with a particular amount of disturbance, or perhaps one that is regularly flooded in the early summer but low in mid-summer. Their association with the gorge flora suggests that they might have formerly occurred at a number of other whitewater sites on the Connecticut that have been destroyed by dams, and hence that they are the surviving relics of what may formerly have been a restricted but characteristic Connecticut River community. In any event, their current habits and habitats are abundantly peculiar, too much so, it seems to us, to be accidental.

- The plants of the Upper West River comprise 3 species of northern affinities, all of which tend to be somewhat more common on limy sites in Vermont. Their presence in a cold river valley with scattered limestone outcrops is quite reasonable, though it does not indicate that they are really a natural group, and indeed they do not co-occur anywhere else in Vermont. The interesting question is if the West is, as it appears, the only place in southern Vermont with these species, or if there were or are other rivers with similar floras.

- The lower West has four ecologically unrelated species with southern affinities. The authors differ in their thinking about this group. Jenkins notes that numerous southern New England and coastal plain species get into lower Windham County, and suspects that their association is accidental. Zika thinks that the sites and communities are peculiar in some way, and that something is going on.

Without trying to make a final judgment on any of these floras of species, it is clear that each group has one or more ecological or geographical distinctions, and at least some of them may turn out to be natural groups with a limited distribution in Vermont. This is an important conclusion for conservation. It indicates that there are some special river sites that are exceptions to the general interchangeability of river floras that we have spoken of above. The rarity of such sites, the possibility that some of them are relics of a formerly more widespread flora, and the scientific in-

terest attached to both the individual species and their habitats combine to make them extremely important. We recommend that the highest priority should be given to the conserving them, and to searching for other sites like them.

5.20 Whitewater Rapids & Water Quality

In this section we deal with the question of how important rapids are in oxygenating water, and so improving water quality.

The following brief explanation may be useful for readers who are not familiar with the connection between oxygenation and water quality.

When organic wastes are added to the streams they promote bacterial growth which eventually consumes the wastes. This is the main way that streams deal with organic wastes and is the reason that streams, up to a point, are self-cleaning. Bacterial growth requires and consumes dissolved oxygen[16]. If the oxygen is not replenished the stream becomes unfit for most of the clean-water species of fish and insects, and in addition the bacterial purification process itself stops or slows down. Rapids restore oxygen to the water and so facilitate the natural purification process, and in addition allow the stream to handle unnatural additions of organic material from human sources.

The effectiveness of a rapid in restoring oxygen depends on how thoroughly the air and the water are mixed, which in turn depends on the turbulence. Falls and intense rapids generally restore oxygen levels to saturation. Waves and riffles or mild rapids do not.[17] We have been unable to quantify this further, or to say how many yards of water of a certain intensity will bring the river to saturation. But it is worth noting that a single falls of 2' or more may do more, especially at low flows, than a mile of rocks and riffles.

Since we were unable to quantify the effects of individual rapids we took an alternate approach and tried to identify streams with high oxygen requirements where any substantial rapid or drop would be important.

Two groups of streams appear to fall into this category.

The first group are the rocky upland trout stream with moderately steep slope. Such streams (often Class II-III whitewater runs if they are large enough) tend to have low summer flows and to run thin and hence warm because of their slope. The total amount of oxygen that water can hold decreases with increasing temperature. In thin warm streams the amount of summer oxygenation can make the difference between a good trout fishery and none at all.

16. This is why a convenient measure of the amount of organic matter added to or carried by a stream is the BOD or biological oxygen demand, the amount of oxygen that will eventually be required to decompose these wastes.
17. "Saturation" is the maximum amount of oxygen that can dissolve in water of that temperature, typically ca. 13 milligrams/liter for water near freezing and ca. 7 mg./l. for water at 30 celsius (86 F.).

The second group are the large lowland stream thats have to deal with nutrients and organic wastes from settlements, industry, or agriculture. Such streams are often moderately fertile and hence have substantial algae populations. These add oxygen in the day but consume it at night, creating night-time oxygen deficits that are difficult for fish. If in addition such streams receive organic wastes, they will have large bacteria populations, which consume oxygen at all times.

Large lowland streams have for the most part comparatively few rapids, and thus those that they do have are of considerable importance. We made no attempt to decide just how important individual rapids were, but simply take the point of view that all falls and ledges, and any rapid that produces a substantial turbulence at low flows, is important for water quality.

Table 5-10 lists the rapids which we believe, on circumstantial grounds, to be important to the oxygen economy of lowland streams. They satisfy the following criteria:

- They occur on otherwise slow streams in agricultural or settled valleys.
- Either there are impoundments above the rapid, or there is evidence from land use or from the presence of channel algae or turbid water that the stream has to absorb substantial amounts of nutrients and organic wastes.

There is a third group of streams in which rapids may be of considerable importance for water quality. These are streams draining upland valleys where there are ski resorts. Examples are the Deerfield North branch below Dover, the Mad River below Warren, the Ottauquechee below Sherburne, and the Waterbury River below Stowe. Such streams often receive heavy seasonal loads of treated and sometimes untreated wastes. It is quite conceivable that the rapids on them are important for reoxygenating the streams, but the matter is more complicated than in the case of the lowland streams because much of the load comes in seasons when the streams are low and the rapids may not contribute much to oxygenation. In addition there is the technical question of how much bacterial growth and hence oxygen consumption occurs when the water temperature is near freezing. Because of these uncertainties we note in the text that the rapids in these streams may be important for water quality, but do not rate them as we do the rapids whose importance is more certain.

Table 25: Rapids and Drops on Major Streams Which May be Important for Water Quality

River	Rapid or segment	Remarks
Barton	drops & rapids N. of Barton	important trout stream in agricultural valley

Black	below Whitesville	impoundments & towns above
Clyde	below Salem Pond	good trout stream, impounded above
Connecticut	below Lyman	important trout stream in an agricultural valley
	Sumners Falls	impoundment & pollution above
Lamoille	drops & rapids near Johnson	important trout stream; settlements & heavy farming above
	below Fairfax	settlements, heavy farming in watershed
Lemon Fair	ledges & gorge near Shoreham	heavy farming in watershed
Missisquoi	below N. Sheldon	heavy farming in watershed
	Sheldon Gorge	potentially important for oxygena tion but now gets only very low flows in summer
Otter	S. Wallingford	agricultural valley
	Beldens Gorge	below an impoundment
	Carver Falls	" " "
	below dams in Middlebury	" " "
	Huntington Falls	" " "
	Weybridge	" " "
Poultney	Carver Falls	" " "
West	Dummerston	settlement & agriculture in watershed
Williams	ledges below Chester	" " "

5.21 Summary: Biological Importance of Stream Segments

In the preceding sections we have discussed five ways that a whitewater stream may be biologically important. It may be biologically diverse in comparison to its immediate surroundings. It may support a good fishery. It may be in a remote or undisturbed area and so be important to wildlife. It may have rare plants or animals. And it may be important to the oxygen balance of the stream on which it occurs.

As noted in the introductory sections of this chapter, we consider all of the whitewater streams we examined biologically important for one or more of the above reasons.

In this section we try to identify the stream segments of the highest importance. As in our discussion of recreational importance we preface our list with three warnings about the ratings:

- They are based on incomplete information and hence may change with better information.
- They are partially subjective and hence biased.
- And, despite our earlier cautions on this very point, they put an undue stress on the exceptional.

The criteria we use to pick the streams of high biological importance are similar in principle to those used to distinguish the most important recreational whitewater. In particular a stream segment of high biological importance is considered to be outstanding in the state or within a 50-mile region within the state, as shown by its meeting one or more of the following requirements:

- It has a major fishery that attracts much use, or
- It supports populations of one or more threatened or endangered species, or
- It supports good examples of a plant community that is rare within the state or the region, or
- Its banks are continuously wooded and it crosses a substantial area of unsettled woodland, or
- It has populations of four or more scarce or rare plant species.

None of these criteria deal with overall diversity, and none deal with oxygenation. Both of these are important components of biological importance. They are omitted here because we lack the information necessary for comparisons.

Table 5-11 summarizes the biological features of the stream segments included in this report. High importance streams are noted; all other streams are classified as moderately important.

Table 26: Biological Features of Whitewater Rivers

Key to Surveys: PZ = Peter Zika, JJ = Jerry Jenkins, JZ = Jenkins & Zika

River	Section	Botanical Data	Biological Importance	Importance Based On
Battenkill	Arlington - NYS line	JJ 1975-1985	High	famous as trout stream flood plain woods spectacular mayfly hatches 2 scarce plants

Black (1)	Irasburg - Coventry	none	High	good trout fishery, important runs of trout, salmon, and wall-eyed pike
Black (2)	Cavendish Gorge	JJ1983	High	exemplary moss flora
	Cavendish Gorge - Weathersfield	PZ1984		1 rare plant stocked fishery
Clarendon	Clarendon Spr. - E. Rutland	JJ 1983		
Clyde	Salem Pond - Clyde Pond	none	High	good trout fishery former salmon run, wild surroundings
Connecticut	Lyman to Bloomfield	J&Z 1983	High	3 rare plants 1 uncommon plant migratory route for osprey and eagle good trout fishery IMPORTANT for water quality
Connecticut	Sumners Falls	J&Z 1981-4	High	rare plants (NH & VT) migratory route for salmon, osprey & eagle 2 threatened invertebrates IMPORTANT for water quality
Deerfield West Branch	Somerset	JJ1975-85	High	wild stream in remote and continuously wooded area
Deerfield East Branch	Somerset	JJ1975-85	High	wild remote stream much used by wildlife unusual tidal marshes good trout stream
Deerfield North Branch	Dover - Wilmington	none		brook & brown trout quality unknown
Deerfield West Branch (2)	Heartwellville	none		brook & brown trout quality unknown
East Branch Passumpsic	E. Haven to E. Burke	PZ1984	High	brook trout fishery of unknown quality, adjacent to large areas of continuous forest
Green	Green River to MA. Line	none		needs botanical study good trout stream
Hancock Branch of White	below Robbins Branch	none		trout stream of unknown quality
Huntington	above Huntington	PZ1984		1 rare plant

	Gorge			2 uncommon plants good trout fishery
Lamoille	above Hardwick	PZ1984		1 uncommon plant good brook trout fishery
	Cadys Falls Cambridge	none		good trout stream IMPORTANT for water quality
	below Fairfax	PZ1984		1 uncommon plant bass & trout fishery of unknown quality IMPORTANT for water quality
Lewis Creek	between covered bridges	PZ1984	High	historical site for 2 or 3 rare plants 3 uncommon plants runs of steelhead trout landlocked salmon project good trout fishery
Mad	above Moretown	none		popular trout fishery, heavily stocked
	below Moretown	PZ1984		2 uncommon plants popular trout fishery, heavily stocked
Middlebury	Middlebury Gorge	JJ1983	High	exemplary moss flora, completely wild, bordered by large tracts of woodlands
Mill	E.Wallingford Clarendon Gorge	no data		unproductive trout stream; 1 segment borders large tract of continuous woods
	Clarendon Gorge	JJ 1983	High	exemplary moss flora
Moose	Victory to N. Concord	none	High	? poor trout fishery borders large wild areas
	below N. Concord	PZ1984		rainbow & brown trout fishery of unknown quality
Missisquoi	E. Richford Richford	none		1 range limit plant, good trout stream
	N. Sheldon Sheldon Springs	JZ1983 1983		extensive botanical survey in didn't find anything; reported to be a poor fishery IMPORTANT for water quality
	Sheldon Springs	PZ1984		1 rare plant

	Gorge			historical breeding grounds for sturgeon?
New Haven	above W. Lincoln	PZ1984		good brook trout fishery
	New Haven River Gorge	JZ1983 PZ1984		exemplary moss flora good trout fishery
	below Rocky Dale	PZ1985		excellent trout fishery
Nulhegan	Nulhegan Pond Bloomfield	JJ1986	High	surrounded by extensive woods and wetlands
Ompompanoosuc	below Strafford none			? poor trout stream
Ottauquechee	below W. Bridgewater	none		good trout stream historical site for a rare plant IMPORTANT for water quality
Saxtons	below Grafton	PZ1984		put & take trout fishery, some wild fish
Waits	below Waits River	none		trout fishery of unknown quality
Wardsboro	below Wardsboro	JJ1983 PZ1984		trout fishery of unknown quality
West	above Ball Mtn.	none		brown & brook trout fishery of unknown quality
	below Ball Mtn.	JZ1984	High	3-4 rare plants important trout fishery salmon restoration project 2 rare beetles
West	below Townshend	PZ1983	High	8 rare plants salmon and shad migration route important trout & bass fishery historical site for 2 rare plants IMPORTANT for water quality
White River	Stockbridge - Conn. River	none	High	salmon restoration project famous trout & bass stream historical site for 2 rare plants; rare plant community with 4 rare species
Wild Branch	N. Wolcott	PZ1984		? poor trout stream
Williams	above Chester	none		trout stream of unknown quality
	below Chester	PZ1984		1 uncommon plant good bass fishery

				IMPORTANT for water quality
Winhall	below Grahamville	PZ1984		trout fishery of unknown quality
Winooski	above Montpelier	none		good brown & rainbow trout fishery IMPORTANT for water quality
	Bolton Falls & vicinity	*PZ1984*	*High*	*historical site for Dryopteris* fragrans 2 uncommon plants important trout fishery osprey migration route historical breeding grounds for sturgeon? IMPORTANT for water quality

CHAPTER 6. CONSERVATION

This chapter is brief because this is principally a report on the existence and importance of whitewater streams and not on the threats to them. But we do wish to state the general argument for the conservation of whitewater streams, and comment on a few current threats.

The argument for the conservation of any resource depends on the resource's importance, scarcity, and vulnerability.

We hope that the preceding chapters have given the reader a sense of the importance of whitewater. In summary we would have the reader recall the variety of animals and plants for which it provides homes and food, the geological unusualness of intense whitewater, and the critical importance of whitewater to fisheries and recreation.

The scarcity of whitewater was dealt with at some length in Chapter 4, and implicitly in the discussions of Chapter 3 and Chapter 5. The following observations may put it into perspective:

- There are only some 200 miles of boatable whitewater in the whole state, out of 1300 miles or more of boatable streams. The amounts of any specific type of whitewater, Class III for example, are even less than this. (Table 6-1)

Table 27: Total Amounts of Whitewater of Various Types Currently Known

Type of Whitewater	Total Miles	% of Total Boatable River Miles in Vt.
Small Class II Streams	49	3.8
Medium Class II Streams	57	4.4
Medium-large and Large Class II	35	2.7
Small & Medium Class III streams	61	4.7
Large Class III streams	6	0.5
Class IV and higher	17	1.3

- There are appear to be only seven stream segments with high quality fisheries out of the 40 some segments we examined.

- There are only six whitewater segments with important populations of migrant trout or salmon.

- There is only a single whitewater stream in a remote and unsettled area.

- There are only two rivers and four segments where significant groups of rare plants occur together.

Our conclusion from these observations is that whitewater streams of boatable size are uncommon in the state as a whole, and occur at a frequency of somewhere around one mile out of every six miles of boatable channel. And further that the specific types of whitewater that are of importance for particular plants and animal or for particular recreational users are much rarer than that, occurring at frequencies of between one mile out of 20 and one mile out of 100.

The vulnerability of whitewater streams and their animal and plant populations to human activity is amply demonstrated by the last 200 years of human use. As examples we cite the following:

- The damming of every major stream in Vermont except one, with the consequent destruction of the original salmon and sturgeon populations.

- The direct destruction by flooding of all but one rapid on the Connecticut River and all but two on the other large streams of the state.

- The interruption of a number of long whitewater segments (Mad River, Winooski, West River, Connecticut) by dams.

- The cumulative interruption of the navigable rivers of the state by dams until at present there are only three places within the state where you can canoe for over 20 miles without encountering a dam.

- The consequent vulnerability of many rivers to local extinction of animal species, which can no longer migrate upstream and downstream and recolonize segments where populations have been destroyed by floods or droughts.

- The consequent heating of the water in impoundments, and the deoxygenation caused by the restriction of summer flows and the diversion of water around falls and rapids for hydroelectric generation.

- The extensive flooding of steep rocky sections of major rivers by impoundments, resulting in the destruction of habitat for ledge and cobble plants, and the subsequent extinction or endangerment of a number of rare plants.

- The extensive clearing of the banks of streams in agricultural areas, eliminating shade and possibly sources of terrestrial insects, both very important to fish.

- The unregulated logging of stream watersheds, leading to erosion and flooding with consequent damage to invertebrates and fish.

- The alteration and channelization of streams in connection with highway construction and flood control projects, with consequent damage to invertebrates and fish.

We stress this history, because we think that any discussion of conservation must begin with the realization that current threats to rivers are not questions of small alterations in an ample and basically unchanging resource, but part of a continuing process that has left us with a resource that is greatly diminished from what it once was. We would remind the reader, and especially the reader concerned professionally with the use and conservation of rivers, that the historical changes in rivers and river uses have happened gradually but have had an enormous cumulative effect. Thus it is no defense of a proposed alteration in a river to say that it will be small in relation to the whole of the state's rivers, or will only effect a few animals or a few users. Much the same defense could be have been offered for any of the past alterations whose cumulative effect, over 180 years or so, has been anything but small.

* * *

Having given that warning - in effect asked the reader not to forget that there were once fifteen-and twenty-mile whitewater runs on the West and Connecticut Rivers, and that salmon were once fished in many of the rivers of the state -- we can turn to some brief comments on current issues in river conservation.

Our first comment is that, in the years since 1965 when we first became interested in conservation issues, there have been considerable advances in river conservation in Vermont, including the following:

- Development of water quality and water basin plans for all the watersheds in the state.

- Very substantial improvements in water quality, mostly connected with the construction of new primary and secondary treatment facilities, and with higher standards for the treatment of industrial and agricultural wastes.

- General use of stream-protection belts in logging operations within the National Forest, and occasional signs of their use elsewhere.

- Extensive efforts by both government and private organizations to restore fisheries and improve stream habitats.

- Provision of minimum flows below all new impoundments, and negotiation of minimum flow agreements for some older impoundments.

- Increasing attention to the censusing and protection of rare animals and plants.

- Attempts to assess and control diffuse ('non-point source') pollution from agriculture and industry.

- The apparent abandonment of several proposed flood control dams (particularly Gaysville and Victory) originally planned for Connecticut River tributaries.

The advances in all these areas have been impressive, and in many cases considerably in excess of what we would have dared to predict when we first became interested in river conservation issues in 1968. They are a substantial demonstration that the degradation of rivers can not only be halted but reversed, and are a demonstration of just how much can be achieved, given time and continuous effort, by committed people, agencies, and organizations.

Our second comment is that, acknowledging the great improvement over the last two decades, there are still a number of continuing issues in river conservation that are critically important, and many of them directly concern whitewater streams. We list them here so the reader will be aware of them and their importance. We do not intend this as a criticism of the people and agencies who are already aware of these problems and working for their solution, but rather to add our concern to theirs, and call attention publicly to the importance of their work.

The current needs and issues in river conservation can be divided into two groups: those concerned with remedying previous damage, and those concerned with preventing new damage.

Under the first heading we have the following observations:

- There are many rapids below impoundments without adequate summer flows.

- There are many impoundments that are damaging fisheries by discharging poorly oxygenated, warm water from the surface of the reservoir.

- There are a number of segments where fish habitat could be improved by replacing, or allowing the natural replacement of, bank vegetation.

The second group of issues are concerned with the prevention of future damage to rivers, and to whitewater rivers in particular. In general the current situation seems good to us, especially as a number of the problems - for example the containment of agricultural wastes -- that are very important in lowland watersheds are of less importance to whitewater streams. Considering only the streams we looked at in this study, we would say that the following were the most important issues related to future damage:

- The possibility that new dams will be built on whitewater segments, and damage fisheries, plant and animal populations, and recreational whitewater.

- The continuing damage done by soil erosion during the logging of steep watersheds.

- The damage done by stream 'cleanup' and channelization in the wake of floods.

Dam construction is locally the most damaging of these. Most of the current proposals for new dams are for hydroelectric installations and most of these are at falls or on small steep streams, and do not effect the streams we looked at in this study.

There are, however, two proposals for major dams on the Connecticut River, one at Lyman and one at Sumner's Falls. Both places are of great value as whitewater segments. The area around Lyman has a number of rare plants and is considered to be a site of high biological importance: it also has an important fishery and the last extended whitewater run on the whole Connecticut River. Summner's Falls is a famous biological site with an extraordinary concentration of rare plants and a number of rare animals. It also is a popular isolated rapid and much used for whitewater practice. The damming of either of these sites would entail the loss of a river segment of the highest possible importance.

There is also a recent proposal for an ice-control dam at Richford. This is discussed on p. 277. The dam is only needed for the control of ice in the winter, but would still have a permanent pool. This would flood an attractive stretch of Class II rapids, place a dam and lake in the middle of the longest uninterrupted segment remaining on the Missisquoi, and possibly affect a significant trout fishery.

* * *

The effects of logging are only temporarily damaging, but are often of great concern to fisheries biologists. In our fieldwork we did not encounter any striking examples of bad streamside logging, but it was frequently mentioned in interviews as an important concern, and a number of people gave us examples of streams which had been damaged.

Finally we would note that a time-honored rural flood control technique is to put a bulldozer in the stream and push the stream bottom around until you get tired of doing this or use up what remains of your grant or budget. In the process you can do substantial damage to the biology of the stream. The engineering logic seems to have something to do with making a freer channel and preventing floods. Bulldozing streams into socially approved channels may work at times, but a century of experience with channel alterations has demonstrated that rearranged channels tend to shift flood damage downstream rather than prevent it altogether, and that rivers have a strong propensity to do what they want to do in floods anyway.

The biological effects of this sort of channel disturbance are often disastrous; rivers have a living soil that supports their biology just the way a forest or garden does, and are rendered sterile when the bottom is torn up and the interspersed animals and organic matter washed down stream.

Our purpose here is not to advise on these issues, or even to explore the facts and alternatives involved. The reader will certainly have no difficulty guessing our opinions, but they are not the concern of this report. But it is certainly important to note that the three problems just mentioned -- logging, dam building, and channel alterations -- are all capable of doing serious damage to the biology and uses of whitewater rapids, and that they appear to us to be the most pressing threats with which river conservation has to deal.

* * *

We might end this chapter by noting that how well we conserve any resource is critically related to how much we know about it. The knowledge is important not only because it tells us specifically what places need to be protected and which threats are most dangerous, but also because it persuades us that we have important things that are worth saving.

In this connection we return to a point made in the previous chapter, which is that we do not have any detailed knowledge of the distribution of the less common animals, in our streams. This puts us at a great disadvantage, in trying to assess the importance of many streams. Our lack of knowledge situation is intellectually unsatisfactory because we cannot establish clear priorities and definitions of importance, and politically dangerous because the geography of scarce animals is a very powerful argument for the preservation of streams, and one that is not at present available to the conservationist.

Thus, both as conservationists and as naturalists, we feel that it is a matter of some importance that we try to improve our knowledge of river zoology. We applaud the people in the environmental and academic communities who are doing this, and wish them more money and more colleagues. An adequate zoological survey of Vermont streams will not be easy, but it is an important job, and one we will all benefit from.

PART II: RIVER DESCRIPTIONS

General Information

Part II contains descriptions of all streams in Vermont currently known to have segments with runnable whitewater over two miles long and at least Class II in intensity. A few Class I streams are included when they have scattered rapids and are used for a mixture of flatwater and mild whitewater touring. Otherwise touring streams are not covered. For shorter rapids and isolated drops see the Appendix . For a list of some 20 additional small streams that appear to have sufficient slope and watershed to produce runnable whitewater see Table 3-3.

The descriptions are arranged by watershed, beginning with the Hudson River Basin in the southwest corner of the state and circling the state clockwise through the Champlain, Memphremagog and Connecticut Basins. In each basin the upstream areas are described before downstream, and the main river before the tributaries.

The descriptions are based on our own field work, and on descriptions from other boaters and the Appalachian Mountain Club River Guide for New Hampshire and Vermont. We have tried to indicate where the information is second hand, and in particular when we have not scouted or run a river at high water.

The intent of the descriptions is to indicate in general the boating conditions to be expected but not to offer rock by rock descriptions for boaters. BOATERS SHOULD REALIZE THAT THIS DOCUMENT IS NOT INTENDED AS A WORKING GUIDEBOOK TO WHITEWATER RUNS, AND SHOULD BE PREPARED TO RELY ON THEIR OWN SCOUTING OF ANY RUN UNFAMILIAR TO THEM.

The following notes and definitions may be useful when consulting the descriptions.

Lengths and slopes are approximations. Slopes often vary in different places within a segment.

If not noted otherwise the watershed is measured at the lower end of the run. Watersheds given as an approximate figure or a range of figures were estimated from topographic maps. Watersheds given as an exacted figure are quoted from published sources.

Sizes are given as follows: *small* streams are under 25' wide; *medium streams* 25-50', *medium-large* streams 50-75' wide, *large* streams 100' wide or more.

A stream suitable for *touring* is one that is not primarily a whitewater stream, but which may have isolated rapids.

A *quickwater stream* is one which has waves and riffles but no serious whitewater. *Mild whitewater* is whitewater from Class I to low or middle Class II. Heavy whitewater is Class III or higher whitewater.[1]

A reference to the VWG report means Vermont Waterfalls, Cascades and Gorges by Jenkins & Zika; to the AMC Guide means to the Appalachian Mountain Club River Guide.

In the general sections introducing each watershed, a * following a stream means that this stream is described in the main text. A + indicates a stream that, based on the hydrological criteria explained in Chapter 3, may be runnable but has not been field checked. See Table 3.3 for more information on these streams.

For some of the more obscure topographic names used to identify segments ("Prindle Corners," "East South Northfield") consult the topographic maps listed or the Vermont Atlas (DeLorme Publishers).

Full plant lists for sites with recent botanical surveys can be found in Appendix 4.

1. For a discussion of the different classes of whitewater see Chapter 2.

Map 6: Whitewater Segments Described in Part II

CHAPTER 7. HUDSON WATERSHED

The Vermont portions of this watershed include the following streams:

Battenkill*
Roaring Brook
Fayville Branch of Battenkill
Roaring Branch of Walloomsac
Green River
Roaring Branch of Battenkill
Hoosic
Walloomsac
North Branch of Hoosic

* = treated in text

Most of these streams have their headwaters on the western slope of the Green Mountains, and then work their way west or northwest through the 'Vermont Valley' and the Taconics and into the Hudson Valley.

This watershed contains two sorts of streams: steep mountain streams, mostly on quartzite and schist, and flat lowland streams on schist, dolomite and limestone. The transition from valley bottom to mountain slope is usually abrupt. Unfortunately this means that streams of intermediate slope, which might provide good white-water boating, are lacking.

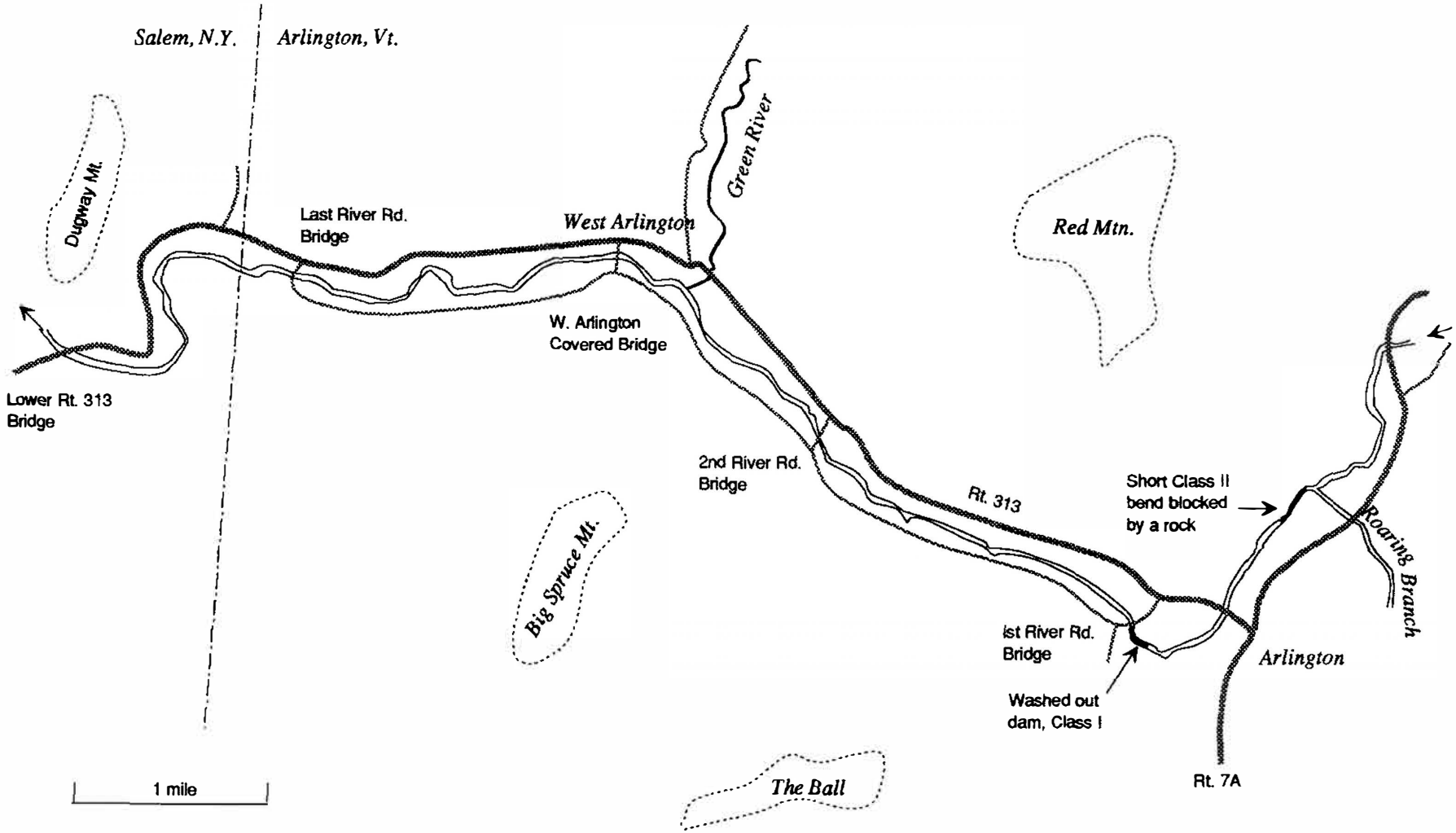
The Battenkill[2] is a famous and beautiful trout stream, much used for general canoeing, and with enough scattered Class I rapids to merit inclusion here.

The Green River is a small tributary of the Battenkill. The lower four miles of it are a tight Class II run in spring high water. The stream is shallow and often blocked by trees, and gets very little use.

The Hoosic and Walloomsac are medium-sized streams used for general summer touring. Both contain a few short Class II pitches at highwater, but are otherwise quickwater streams. The North Branch of the Hoosic is a small steep stream that might be runnable for a few miles.

Roaring Brook, the two Roaring Branches, and the Fayville Branch are all high-gradient, boulder-filled streams coming down the west slope of the Green Mountains; none of them are currently used recreationally, the general opinion being that you need flood conditions to get enough water in them to cover some of the rocks, and by this time they are too fast and dangerous to run. But several of them have lower stretches of more moderate slope, and given future exploration, especially by kayakers, some of them may eventually see some use.

2. In Dutch this is *Batten Kill*, Batten's Stream; I use, for convenience, the modernized form Battenkill here.



Map 7: Battenkill River, Showing the Quickwater Segment From the Rt. 7 Bridge to the Rt. 313 Bridge
River is quickwater or mild Class I except as shown. Access from all seven bridges.

7.1 BATTENKILL: Rt 7 Bridge in Sunderland to NY Line

Length	9-10 miles overall, 1/4 mile Class II rapids, many scattered Class I rapids
Towns	Sunderland, Arlington
Counties	Bennington
Quadrangle	Manchester 7.5', Arlington 7.5'
Access	five highway bridges
Elevation	660'-590'
Average Slope	ca. 10'/mile
Description	medium-sized stream in alluvial valley; mostly quickwater and Class I riffles; 1/4 mile of Class II water; very pretty river and valley
Surroundings	hemlock-hardwoods, floodplain woods, farm land; few buildings, no junk
Water Quality	good
Flow Regulation	none
Hydrology	gauging station in Arlington; watershed 394 sq. km, mean flow 9.7 m3/sec, max/mean 2.4, min/mean 0.36
Biology	nationally famous trout stream with naturally reproducing populations of brook and brown trout; significant alluvial woodlands; rare plants in New York but not in Vermont.
Known Use	very popular canoe stream for general touring & fishing
Season	spring, summer, fall
Suitable for	open boats, tires, rafts
Interruptions	none; this segment continues without interruption for approximately 25 miles to Greenwich, N.Y.

Importance *HIGHLY IMPORTANT* for fishing, biology, and general boating; also has an isolated rapid that is important for whitewater practice

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A beautiful and famous stream. Clean water, sand and stone bottom, mixed agricultural and wooded valley; many nice gravel bars and wooded banks; some alluvial woods, fine views of hills, great mayfly hatches, good for trout and birds, great swimming.

This part of the river is mostly quickwater; there is one 1/4 mile Class II rapid, just below the confluence with the Roaring Branch. The river is useful much of the year; it is fast but not dangerous at high water[3], and is runnable (at least below the Rt. 7 bridge two miles above Arlington) in all but the driest summers. It often stays open in the winter, and makes a very pleasant run on mild winter days. It is beautiful, satisfying river, and much loved by everyone.

The river is boatable below Manchester Center. The first 5 miles are narrow and winding, slow except when the river is in flood, and often blocked by fallen trees and dams of brush. The next 3 miles are wider; here the river runs deep and slow and the banks are very bushy. This is a fine place to see birds in the spring. Then, about 1 mile S. of the Rt. 7A bridge there a short Class II rapid, which is the most difficult part of the river. There is a shoal at the confluence with the Roaring Branch which forces you right into a steep pitch right up against a high eroding bank, which often has fallen trees that you have to dodge. At the bottom of this pitch there is a big boulder right in the middle of the channel, and you have to either back ferry left, or try to make a sharp turn in the pillow on the rock, or, in high water, take a cute sneak route to the right. After this there are several more rocks and eddies, but nothing very technical, and then fairly fast current for about 1/4 mile, and with three very short Class II rapids at the bends.

This segment, while not long enough or continuous enough to be an important whitewater run, is *tricky and causes many spills and sinks a few boats every year. Boaters without whitewater experience* should look it over before running it; the fast part is short but it is a genuine Class II rapid, and has the nasty feature that the tricky part -- where you come down the chute and end up aimed at the rock -- is quite fast and doesn't give you much time to experiment. The trick, as with so many steep passages, is to back-ferry or sideslip away from the outside bank at the top of the rapid, before it you get going too fast.

This rapid is useful for whitewater teaching and practice for much of the summer. It has several nice eddies, some small waves to balance on, and a good fast current for ferries. It is the best spot for summer fastwater practice in the county, and so valuable for that reason.

3. Note however that running any stream at highwater involves some danger, and that while the Battenkill is not dangerous *as a whole* there are always some fallen trees and undercut brushy banks which could trap and possibly kill a boater who didn't understand the danger and know how to avoid them. Also note that while the Battenkill may not be rough at high water it is at times faster than many streams with heavy water, and that the sheer speed of the current and the strong eddies it creates can upset boaters who are not used to strong current differentials. High-water paddling is a specialty, and should only be done by paddlers who understand the risks involved, and who can maneuver decisively in strong currents.

Below the Route 313 bridge in Arlington the river is mostly quickwater, with occasional mild Class I rapids. The rapids are all wide open and do not require maneuvering, but they are still cheerful and wet and very pleasant. This section and the adjacent parts of the river in New York State receive much use from recreational boaters, and are very popular for tubing as well.

The Battenkill runs in a valley with limestone bedrock and many postglacial terraces of sand and gravel. It has fairly steady flows and is less variable from month to month than many other streams. It stays high for a long time in the spring and early summer but does not rise suddenly in thaws or after rains. The even flows are the result of interchanges between the stream and reserves of water stored in the glacial terraces and in headwaters swamps, and are extremely important to both the fishery and the recreational uses of the stream.

* * *

Biologically it is a nationally famous trout stream, with naturally reproducing populations of brook and brown trout. Fishery reports say that the growth rate of trout in the main river is very good. This is probably a consequence of several things: good summer flows, cool summer temperatures (caused by groundwater entering the stream from glacial terraces), relative absence of sudden spates which disturb the bottom and the invertebrate populations, absence of pollution, and the general fertility of streams in limestone valleys. Some casual entomology by the author some years ago found large populations of a number of mayfly species, including several which I had not seen elsewhere in the area; serious investigation might turn up important insect records. The spring and early summer mayfly hatches can be quite spectacular, and are biological events of considerable excitement and beauty, quite apart from their importance to the fish and fishermen.

Botanically the stream is limited by the lack of rocks and extensive shoreline forests, but is more or less continuously bordered by trees, and is shady and private in the summer. There are several small but interesting alluvial woodlands, which are dominated by cottonwood, red maple, basswood and elm, and have dense understories of ferns and herbs. Bennington County has few alluvial woods, and these are among the best examples of alluvial woodlands in the county.

Only a few rare or scarce species are known from the Vermont segment of the stream. The alluvial woods contain the sedge *Carex amphibola* and the anise-root *Osmorhiza longistylis*, both scarce in Vermont and otherwise unknown in Bennington County.[4] One of the white aquatic buttercups occurs or used to occur in an oxbow south of the river. And several interesting species occur west of the New York border. Senna (*Cassia hebecarpa*), cuckoo-pint (*Cardamine pratensis var. palustris*), and great blue lobelia (*Lobelia siphilitica*) occur on marshy shores, and giant saint johnswort (*Hypericum pyramidatum*)and the tall cinquefoil (*Potentilla arguta*) on rock ledges. Two of these -- the lobelia and the senna -- are known only from historical records in Vermont. The other three are currently considered scarce plants in Vermont. It would be pleasant to discover any of them on the Vermont side of the border.

4. These plants are not associated with the stream channel and so are not listed in the table of rare river plants in Chapter 5.

In addition there is a historical record for false mermaid (*Floerkea proserpinacioides*) from an unknown locality in Shushan, again just across the New York border. This is a delicate, bright green annual that usually grows in alluvial woods. It is currently listed as a missing species in Vermont; we have looked for it in both Arlington and Shushan, but without success.

* * *

In the summer the Battenkill receives moderate to heavy weekend use by canoeists and tubers. Both Battenkill Canoe Livery in Arlington and the Battenkill Sportsquarter in Jackson, N.Y., have a rental fleet of 20-50 boats each. They use shuttle vehicles to carry boats to put-in points, and have arranged their weekend schedules so they spread their boats out over about 20 miles of river and thus try to avoid concentrated use of any segment. In addition the river attracts local users and visitors from all over with their own boats and tubes. This use tends to be particularly heavy between the River Road bridge in Arlington and the New York State line[5].

Some fishermen resent the use of the river by boaters. Statements that the amount of boating on the Battenkill is detrimental to fishing have appeared in the local press, and in the recent book *Vermont Trout Streams* by Allen, Antczak & Shea. A petition was submitted to the Water Resources Board (and then subsequently withdrawn) that would have restricted canoeing to a few miles of the river, and also restricted the hours that rental boats could be on the river.

The fishermen's feelings are understandable. Some canoeists are noisy, and whether or not they scare the fish they can certainly interrupt the quiet and concentration of the fishermen.

Our opinion, which is just one among many, is that the canoes are not damaging the river, and that the most popular times for canoeing and fishing don't overlap too much. Canoes and tubes (as opposed say to waterski boats on lakes or four-wheel drive vehicles in the woods) do not pollute the water, and, so far as we can tell, do not have any permanent effect on the fish. They definitely interrupt the fishermen, but are numerous only in the middle of the day, and mostly on summer weekends. In the spring you can have the river to yourself much of the time, and even on a summer weekend there are very few boats out in the morning or the evening, which are of course the best fishing times. If you want to fish the Battenkill at twelve noon on the 4th of July you are going to see a lot of boats and suffer a lot of non-Waltonish interruptions to your fishing, but this is to some extent a case of putting your toe out where it is sure to be stepped on.

5. The popularity of the Battenkill as a tubing stream was greatly increased in the 1970's by a Fourth of July tube race that drew thousands of spectators and participants, and generated crowds that were big enough and disorderly enough to scare both local residents and the race organizers, who discontinued the race in 1978. The race was written about in the New York Times Magazine, and made the Battenkill known to tubers from all over the northeast.

* * *

The Battenkill is rated HIGHLY IMPORTANT as a nationally famous fishing stream, and as one of the state's finest streams for summer boating. It also has important alluvial woodlands, and a good short rapid that can be used for whitewater practice in the summer.

* * *

Note added in proof:

Since the above was written controversies between fishermen and boaters have continued. At one point petitions were filed with the Water Resources board which would have restricted the hours that rental boats could be on the river, and limited them to about 25% of the boatable water in Vermont. This petition was withdrawn before it went to a hearing, and has been replaced by a process of negotiation between boaters and fishermen under the auspices of the Regional Planning Commission and several conservation groups

CHAPTER 8: CHAMPLAIN BASIN

The Champlain basin is the major watershed of western and northern Vermont, and includes the following rivers:

Big Branch +
Black Creek
Brewster River
Browns River
Clarendon River*
Cold River
Dead Creek
Dog River +
Furnace Brook
Gihon River
Huntington River*
Lamoille River*
Lemon Fair River
Lewis Creek*
Little Otter
Mad River*
Mendon Brook
Mettawee River +
Middlebury River*
Mill River*
Missisquoi River*
Neshobe River
New Haven River*
North Branch
North Branch of Lamoille +
Otter Creek
Poultney River +
Seymour River
Stevens Branch +
South Branch of Trout River
Trout River+
Tyler Branch
Waterbury River
Wild Branch*
Winooski River*

* = a river treated in text
+ = a possible whitewater run; see Table 3.3,

The Champlain basin is a geologically diverse watershed draining the west side of the Green Mountains. Geographically it includes five quite different groups of streams:

- The various streams of the Taconic Mountains, mostly with fairly small watersheds and no recreational whitewater.

- The Vermont Valley streams (including Otter Creek, Lewis Creek, and the Lemon Fair), mostly low-gradient streams in limestones and shale, with isolated gorges and falls but little continuous whitewater.

- The streams of the western scarp of the Green Mountains, all on quartzite and schist, many too steep to run but others with superb whitewater.

- The main stems of the three big northern rivers (Winooski, Lamoille and Missisquoi) typically low-gradient streams but with important gorges, falls, and a few major rapids.

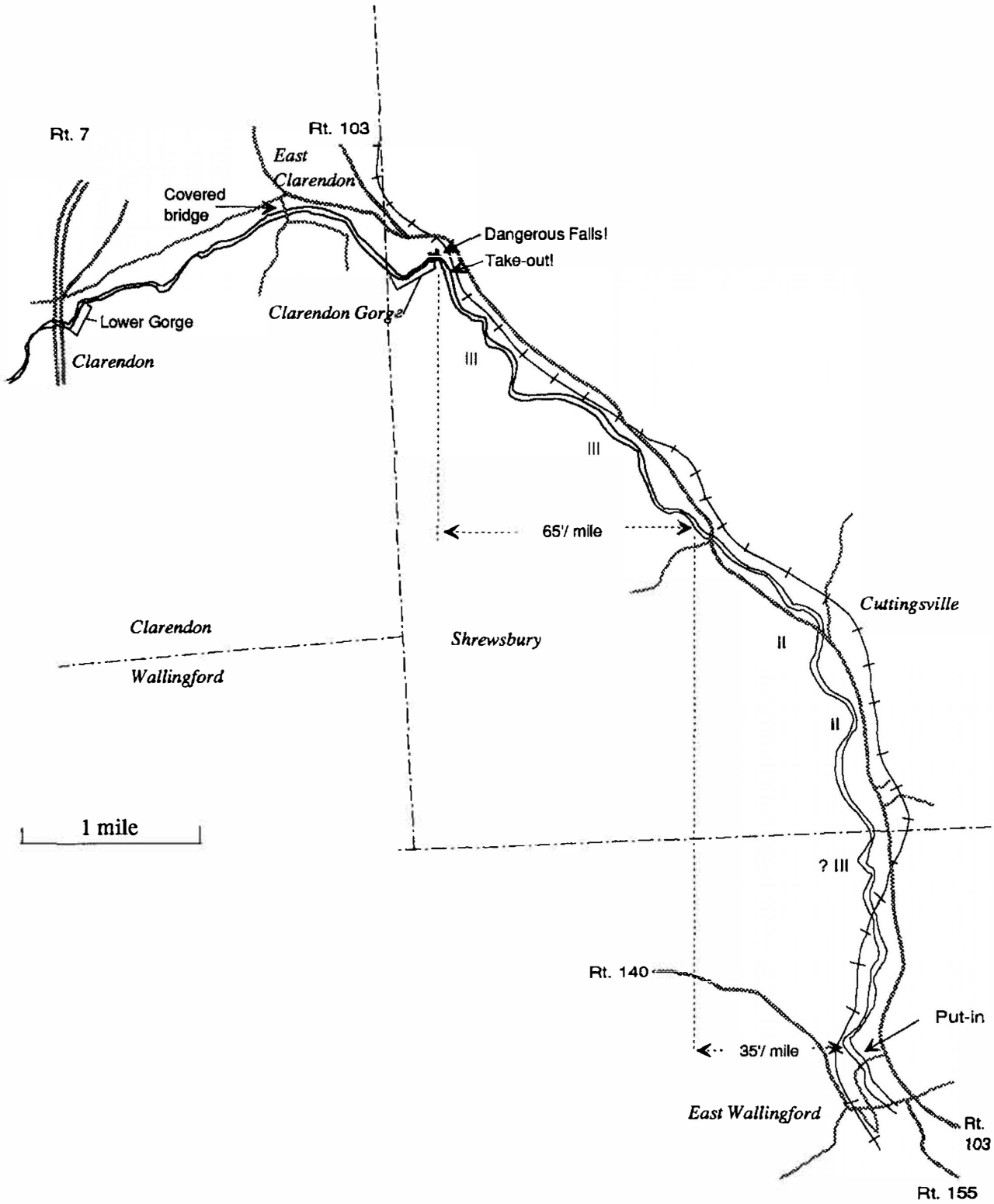
- The upland tributaries of these rivers, a geologically diverse group that contains a number of interesting small streams and a few major whitewater runs.

The whitewater in this basin is scattered, but there are excellent streams in every part of the watershed. The Mill River is a small steep mountain stream, probably Class III at flood, with a short season. The upper part is a good medium-level whitewater run. The lower part has two spectacular gorges which, so far as we know, haven't been run. The Middlebury and New Haven Rivers have steep rocky ravines, called gorges but largely without continuous rock walls, with Class IV-V closed-boat runs. The New Haven also has excellent Class III-IV water below the gorge and II-III water above it. Lewis Creek is a very pretty rural Class II. The Winooski proper has a number of isolated rapids, several of which are useful in the summer. The lower segments are fine for general touring and the upper segment has scattered rapids separated by dams. The Mad is a glorious stream has fine mild whitewater above and very serious Class III-IV gorges below. It is exceptionally beautiful, and gets heavy spring use. The Huntington is pretty rural Class II, and, like the Mad, is much used. It has a spectacular gorge, which is not runnable, and a lower ravine which might be runnable but, so far as I know, has not been tried. The Lamoille has big Class II-III rapids at the lower end, good general touring with isolated rapids in the middle, and north Vermont's favorite Class III run at the upper end. The Wild Branch is a fast, tricky, pasture stream, mostly Class II. The Missisquoi has several isolated Class II rapids, two Class III ledges, and a Class III-V gorge.

A number of other rivers in this watershed are not whitewater rivers. The Otter contains several nice isolated rapids (two short sets of ledges and a gorge) but is otherwise smooth. The Lemon Fair, Dead Creek, Little Otter, and Dog are not used for whitewater, though there is a gorge below Shoreham on the Lemon Fair that might be interesting. The Mettawee has a Class II upper part that is too small to be a useful whitewater run; otherwise it is not a whitewater stream. The Poultney is a beautiful stream for early summer touring, and contains two short Class III ledges and a giant falls, but no continuous whitewater. The Browns is a quickwater pasture stream, popular in the early spring, which has occasional Class I-II rapids but is not a whitewater run in our sense.

Finally, a number of the rivers in this watershed are either untried and unknown as boating streams, or at least unknown to us. The Big Branch is a giant mountain stream with immense boulders and a 200'/mile gradient, and there are stories of kayakers having tried it but no reports of anyone really running it. If it can be run at all it might be Vermont's most formidable wildwater run. There are a number of steep streams like Mendon Brook, small tributaries like the Stevens Branch, Trout River, and Winooski North Branch, perhaps other small pasture streams like the Brown's, all of which might have good water, or be fun given the right boater on the right day.[6]

6. Since this was written we have learned that a 'whitewater' race was formerly held on the Trout River, probably on the main stem, between Montgomery and Berkshire. The slopes here are under 15'/mile, and the drainage is fairly small, and so the stream probably has at most Class I water or mild Class II on the bends. The South Branch of the Trout, with a slope of ca. 75'/mile and a drainage of about 20 square miles, has a possible whitewater run of 3-4 miles. Note however that small steep streams like this can be scratchy and filled with dangerous obstacles, and be basically unpleasant places at high water. We have also found several interesting isolated rapids on the Dog, and heard that a segment above Northfield may be a Class II run.



Map 8: Mill River. Segment Between East Wallingford and Cuttingsville is mostly Class II but has scattered Class III. The falls at the head of the Clarendon Gorge are very dangerous and possibly deadly. The two gorges have, so far as we know, never been run, and appear quite dangerous and possibly unrunnable. The section between the gorges is runnable, but access is difficult.

8.1 MILL RIVER: East Wallingford to Clarendon Gorge

Length	6 miles
Towns	Wallingford, Shrewsbury
Counties	Rutland
Quadrangle	Wallingford 15', Rutland 15' or Rutland 7.5'
Access	continuous access from Rt. 103
Elevation	1180'-820'
Average Slope	60'/mile
Description	medium-sized, steep rocky upland stream, probably Class II at medium water and Class III at high water, with Class III drops
Surroundings	road side, houses, second-growth hardwoods forest
Water Quality	good
Flow Regulation	no
Hydrology	no gauge data; watershed 97 sq. km. at junction with Mt. Holly Brook, ca. 170 sq. km. at the Clarendon Gorge
Geology	Mostly highly metamorphosed quartzites & gneisses (Mt. Holly gneiss, Cheshire Quartzite); hence a steep slope with lots of boulders but no ledges or major drops.
Biology	Brook trout in upper parts, rainbows have been stocked below Clarendon but apparently with limited success. No botanical data for this segment. Clarendon gorge is an important botanical site and is covered in the waterfall and gorge report.
Known Use	occasional local use
Season	snowmelt, after rains
Suitable for	skilled open boats, kayaks

Interruptions	none; waterfall and dangerous or deadly gorge just below the take-out!
Importance	IMPORTANT for boating; a fairly long stretch of rapids and hence probably the best whitewater run in southern Rutland Co.

The Mill is a small to medium-sized stream paralleling Rt. 103, mostly in cleared land and close to the road, without particularly striking scenery but occasionally with nice views of adjacent hills. The channel has lots of bends and many rocks one to three feet high. From the road no ledges or drops were apparent.

At present we do not have detailed information on this stream. The AMC Guide says it is a Class II-III stream with "intermittent whitewater", but the description is not detailed and may not be firsthand. The gradient is similar to that of the Winhall, lower New Haven, and Ompompanoosuc West Branch, (all Class III streams) and the watershed slightly greater than any of these. The bed has a number of good-sized boulders. No gauge data is available from which to estimate variability, but the watershed has steep slopes and thin soils, and so we would expect it to be a highly variable, flashy stream. These observations suggest a fast stream with substantial volume, likely to have considerable amounts of Class III whitewater. Local boaters have run the lower segment from Cuttingsville to the Clarendon Gorge in kayaks and open boats. They say that there are several difficult places here (probably Class III), and that several open boats have turned over. We scouted the segment from East Wallingford to North Clarendon, and noted two or three tight steep places that were definitely Class III. ANYONE PLANNING TO RUN IT SHOULD SCOUT IT CAREFULLY, AND TREAT IT AS A DIFFICULT STREAM: IT IS ALMOST 2X AS STEEP AS MOST OF THE CLASS II RUNS THE STATE, AND HAS SEVERAL PLACES THAT MAY BE DANGEROUS AT HIGH WATER.

If it does get enough volume to make it a good run it could potentially be an important whitewater stream, especially since there are no other good whitewater runs of medium difficulty in this part of the state. Hence we rate it as IMPORTANT for recreation on the strength of its potential usefulness, with a note that if the whitewater proves continuous we may raise its rating to highly important.

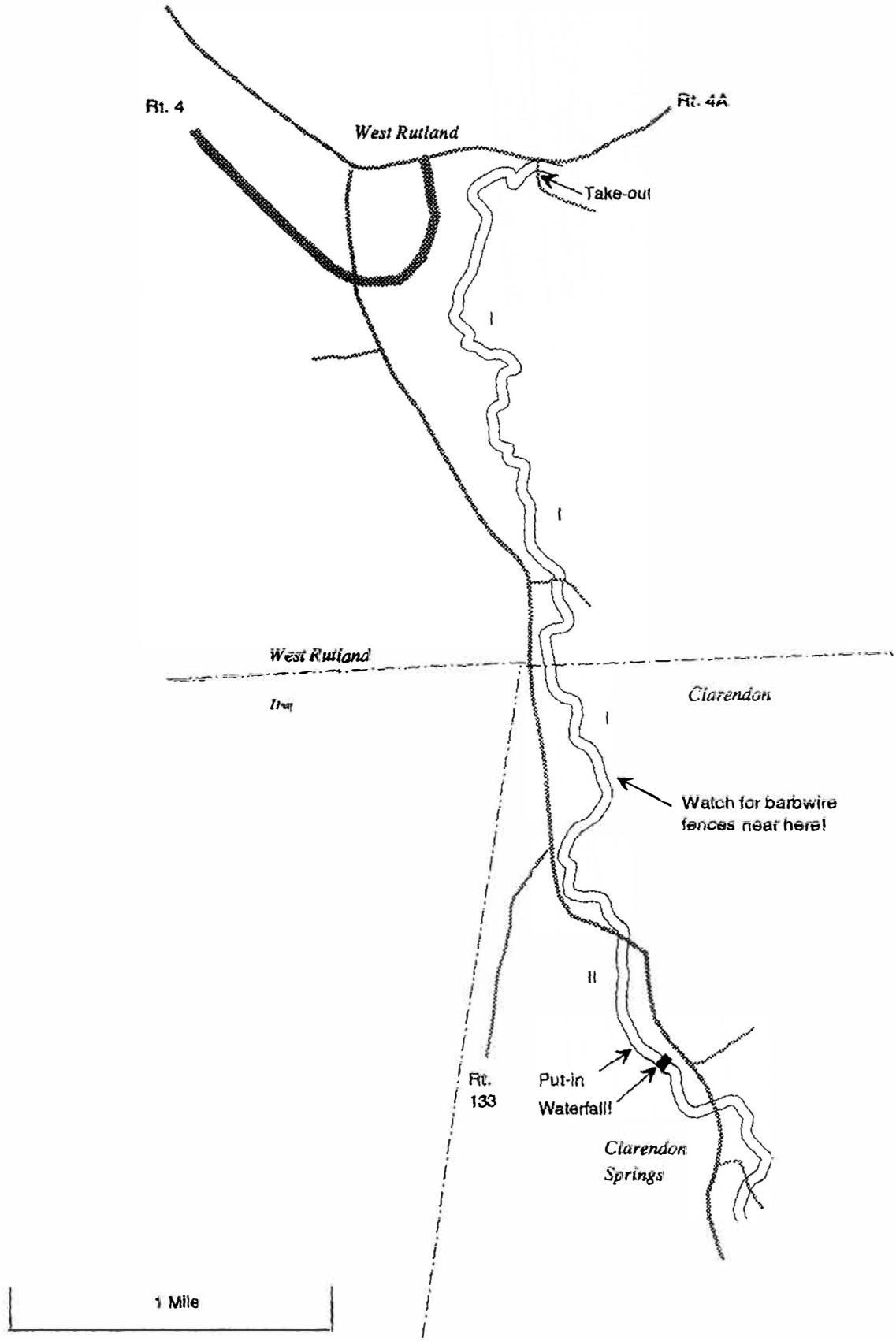
Not much biological information is available. It has quite clean water and supports a brook trout fishery, but has the reputation of not being a very productive stream. This would be expected: it is in a region of exceedingly infertile bedrock, has a steep slope and little groundwater recharge and so should run thin and hot in the summer, and is liable to destructive floods and spates. Rainbow trout are reported to have have been stocked all along the river but are only established below Cuttingsville.

We have no botanical data on the whitewater segment. There are no rare plant records from the area, and in general we do not find a varied flora in quartzite-gneiss watersheds.

* * *

The Clarendon Gorge, located just below this segment, is a spectacular gorge of high biological and recreational value. See the *Waterfalls, Cascades and Gorges of Vermont* for a full description. It is a very popular swimming area and also has a rich moss flora. It is also potentially a Class V whitewater run: the main part of the gorge is about 1000' long and drops 40' in that length (equivalent to 200'/mile). It is thus equivalent in steepness to the Middlebury Gorge, and since it has a slightly larger watershed (over 100 sq. km. as opposed to 80 sq. km.) it is, in theory, runnable. Like the Middlebury Gorge it would require careful study, exactly the right water levels, and a party of experts, probably with a rescue party on shore.

A second gorge, which we call the Clarendon Lower Gorge, is located one mile below the first and is much less well known. It is a beautiful sculptured marble gorge, which is deep and narrow in spots, and has several small cascades, long narrow pools, and a unique 'balanced' spire. The rare plant *Erigeron hyssopifolius* occurs there.



Map 9: Clarendon River. The Class II segment is quite short.

8.2 CLARENDON RIVER: Clarendon Springs to West Rutland

Length	3 miles
Towns	Clarendon, West Rutland
Counties	Rutland
Quadrangle	Castleton 15'
Access	dirt road between Clarendon Spring & West Rutland
Elevation	640'-500'
Average Slope	100'/ mile (lst mile); 20'/mile (next 2 miles)
Description	small stream descending over ledges, then in an alluvial valley; Class III above, Class I-II below
Surroundings	second-growth hemlock hardwoods above, meadows below; some houses, some junk
Water Quality	good
Flow Regulation	none
Hydrology	no gauge data; watershed 130 sq. km. at mouth, probably 80-100 sq. km. in whitewater segment.
Geology	Fairly complicated sequence of Taconic rocks: Cambrian & Ordovician dolomites, limestones, and phyllites. Some of the ledges and small gorges are in marble, others probably associated with changes in rock types.
Biology	listed as having brook, rainbow & brown trout but not generally rated high as a fishing stream. Limited botanical survey, no interesting records.
Known Use	reported to be used by Castleton State College Outing Club
Season	snowmelt and after rain
Suitable for	open boats, kayaks
Interruptions	steep ledges in Clarendon Springs, falls below lst bridge

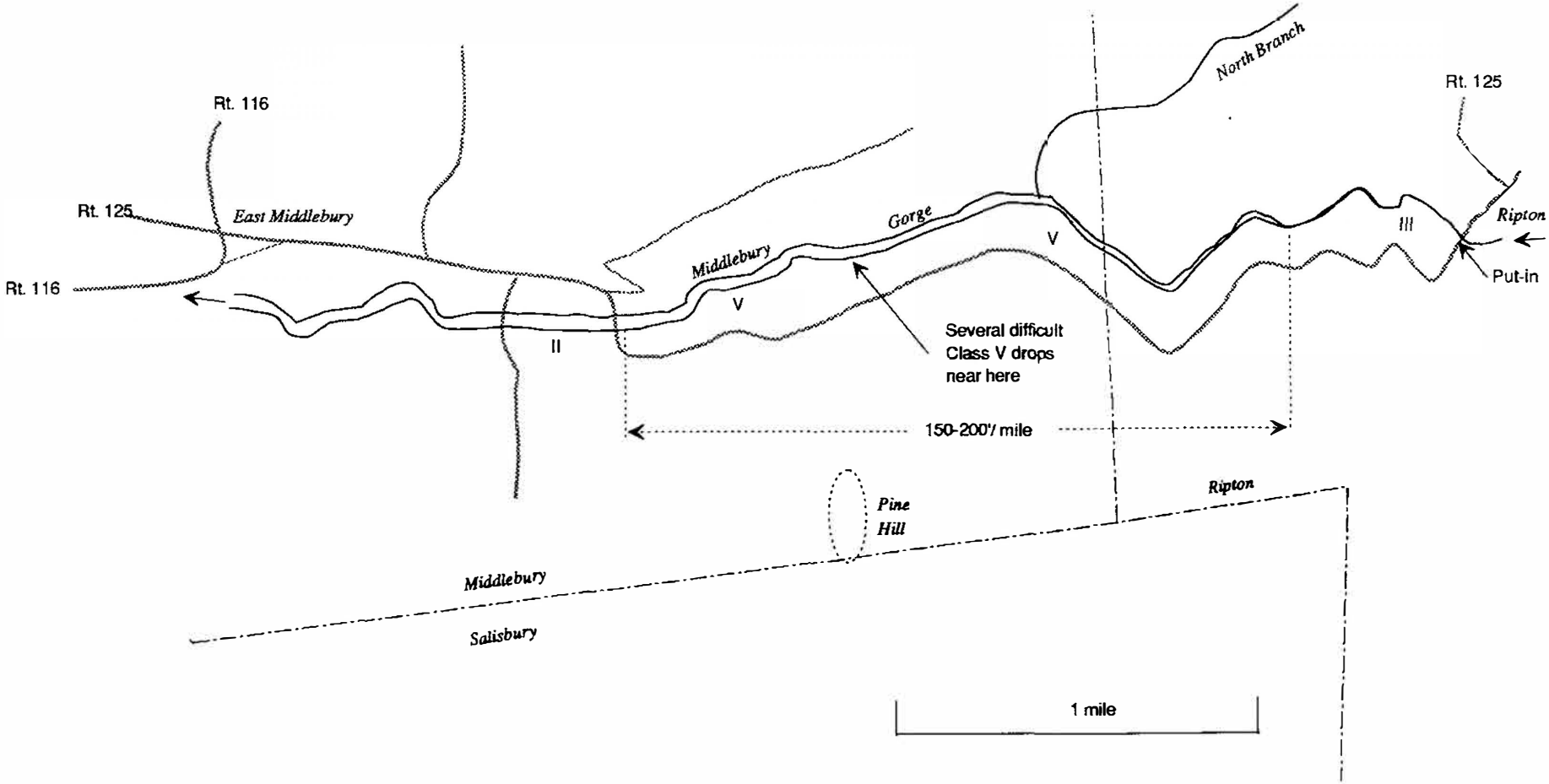
Importance IMPORTANT as a whitewater run

This is a small upland stream, which parallels the back road from Clarendon Springs to East Rutland. It has average scenery, no views. The best parts are some pretty wooded places. Starting from the road crossing a quarter mile below Clarendon Springs the stream is small, ledgy and quite steep, approximately Class III. It is pleasant boating for half a mile and then there is a 15' waterfall hidden around a sharp bend which you can't see when scouting from the road and which is not mentioned in the AMC Guide. The falls slope and might be runnable in a kayak of the crash-and-burn persuasion, but not in anything else[7]. Below that the stream stays fast and ledgy with several tight chutes and drops for about a half mile and then starts to flatten out, with mostly Class I-II rapids and at least three barbed wire fences in the next mile. After that it flattens still more, and is not a whitewater run for the last mile into West Rutland.

No detailed biological information is available. This part of the state has a rich and at present inadequately known flora, and it is quite possible that summer exploration of several of the small gorges and ledges might yield some valuable species. Trout are present but the Clarendon has an indifferent reputation as a fishing stream. Upstream of this segment the stream passes through the great wetlands of the Tinmouth Channel, a wetland complex of great importance.

This segment is considered mostly of local importance for whitewater. The steep parts are fun and tricky but they are not very long and are interrupted by the falls. The lower parts have about a mile of good mild whitewater, but again there is not that much of it. The gradient becomes too flat too soon, and there is just not enough of a watershed to make the lower segments interesting. The stream might by fun if you live nearby and can catch it on the right days but the combination of waterfalls and barbed wire above and unremarkable mild rapids below doesn't make for a choice whitewater run.

7. There are a lot of better things to do with a kayak in Vermont. I missed these falls when I was scouting the stream, saw them from about 30 feet away, and bailed out. My boat went over them and ended up upright and quite dry in a pool below.



Map 10: Middlebury River. The Middlebury Gorge is a very steep, difficult Class V run for closed boats. It requires careful scouting, expert technique, and exactly the right river level.

8.3 MIDDLEBURY: Ripton to East Middlebury

Length	3 miles
Towns	Ripton, Middlebury
Counties	Addison
Quadrangle	Brandon
Access	Rt. 125, bridge below Ripton
Elevation	1150'-450'
Average Slope	230'/mile
Description	a small stream in a steep, narrow-walled, mountain gorge; Class V, with cascades & falls and very tight technical channels
Surroundings	hemlock hardwoods forest, cliffs; no houses or trash
Water Quality	good
Flow Regulation	none
Hydrology	no gauge data: watershed at the bottom of the gorge approximately 110 sq. km.
Geology	spectacular deep gorge in Cambrian & Precambrian quartzite; some greywacke present, and some sculpturing of the walls occurs.
Biology	good brook trout reproduction in upper stream and tributaries; brown trout below this segment. Explored botanically in 1983; no rare vascular plants but an excellent site for mosses. See VWG report for details.
Known Use	very bold kayakers; one known descent
Season	snowmelt
Suitable for	expert wildwater kayakers
Interruptions	8' waterfall in middle; and one other major drop
Importance	HIGH IMPORTANCE as an extremely difficult closed-boat run, and also as a fine rock-walled gorge with an exemplary moss flora. Also important as a fishery.

The Middlebury is one of the premier small mountain rivers of the state, with a beautiful setting, very clean water, and some dramatic whitewater.

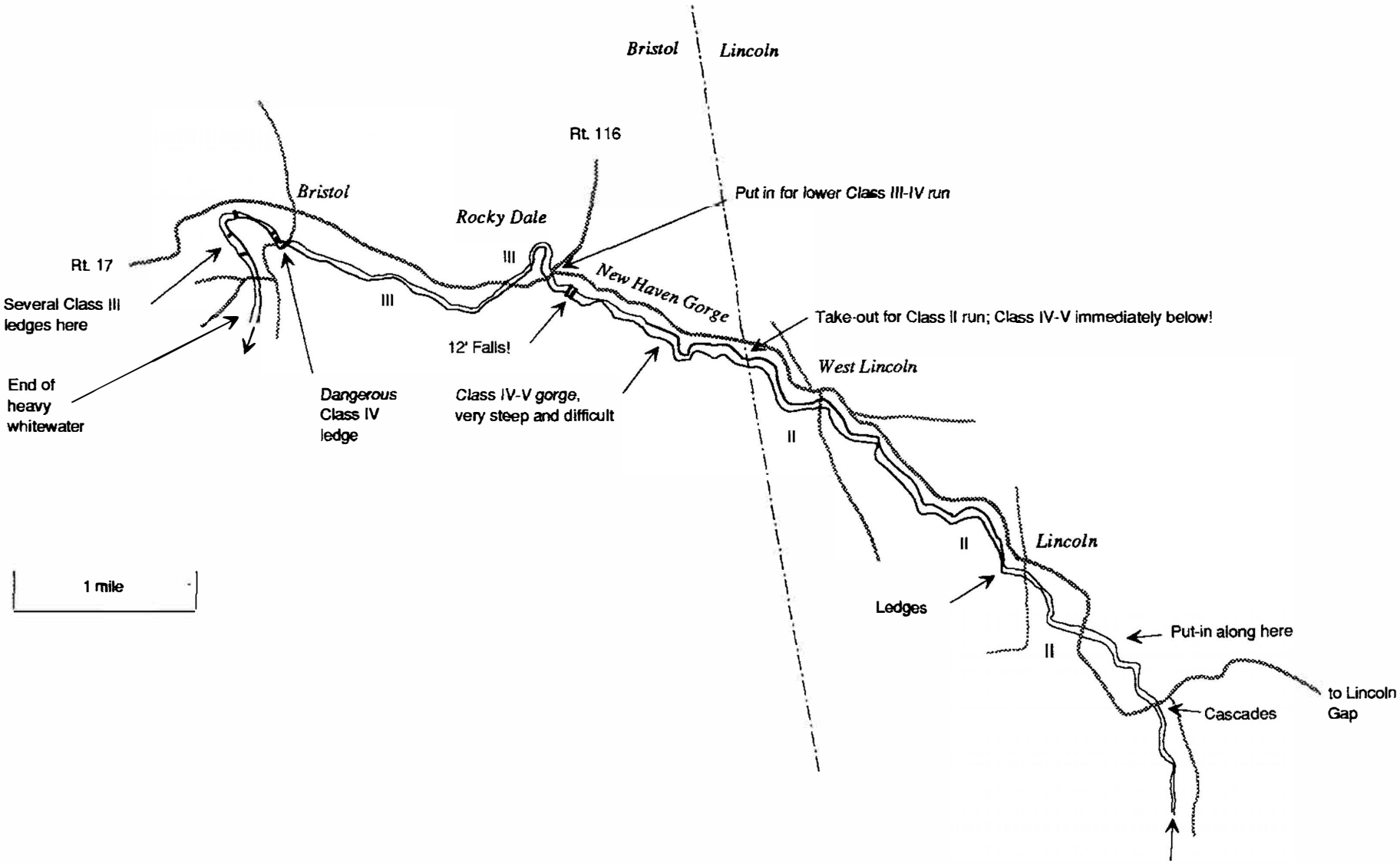
Below Ripton the Middlebury runs in a deep, spectacular, wooded ravine with carved rock walls 20-40 high along the stream. It has big boulders, cascades and chutes and pools, a formidable gradient, and is one of our most beautiful and unusual places. The boating is extremely difficult, and is suitable only for expert closed boaters with experience on very steep streams. It has twice the gradient of the steepest streams in normal use in the state, and so at present is considered an "expeditionary run", meaning that it is suitable only for highly qualified boaters with careful preparation.

It has been run at least once, in the early 1980's, by a party of kayakers that included Jim Northup of Rutland. He said it was a very exciting descent, and that the water level has to be just right -- if the upper river near Ripton is not a bit thin the lower gorge will be suicidal. He says that the two major drops are potentially runnable, but are difficult enough that you would need to have a party with ropes on shore. At one of the drops there is no shore, only a 40' high wall, but rescue might be possible below this.

Biologically this is a clean coldwater stream which is reported to have fairly small trout (as would be expected from a quartzite watershed) but excellent natural reproduction and stable or growing populations over the last 25 years. The gorge is not known to support any vascular plants of interest, but has a diverse and interesting moss and liverwort flora, perhaps owing to small traces of lime in the rock. See the VWG report for botanical details.

* * *

This is one of Vermont's finest gorges, rated of HIGH IMPORTANCE as a natural area and as a uniquely difficult whitewater run.



Map 11: New Haven River. The gorge segment is steep and extremely rocky, with narrow, intricate passages between large boulders and many drops. The Class IV drop below Bristol is quite nasty and at high water could pin a boat and cause a fatal accident.

8.4 NEW HAVEN RIVER 1: Lincoln Gap Road to West Lincoln

Length	4 miles
Towns	Lincoln
Counties	Addison
Quadrangle	Lincoln 15' or 7.5', South Mountain 7.7'
Access	from road to Lincoln Gap
Elevation	1080'-860'
Average Slope	ca. 55'/mile
Description	small stream with rocks and ledges; Class II with Class III drops
Surroundings	hemlock-hardwoods forest, road, houses
Water Quality	good
Hydrology	no gauge data; watershed above W.Lincoln approximately 75 sq. km.
Geology	Cambrian greywacke & schist
Biology	good brook trout fishery, many deep pools; 1 uncommon plant.
Flow Regulation	none
Known Use	local canoeists
Season	snowmelt & early spring
Suitable for	open canoes
Interruptions	several small constrictions; 2 ledges near the stone bridge at the Lincoln Gap Road; small ledges and two tight steep passages by an island above the bridge; sloping ledges with 3'-4' drop 1/2 mile north of Lincoln at the West Lincoln Swimming Hole.
Importance	IMPORTANT for boating (though apparently not much used at present); pretty stream, continuous rapids, good steep gradient. Also IMPORTANT as a natural brook trout fishery.

This segment was proposed as a possible run by Ray Gonda of South Burlington; we scouted it but did not run it.

About 1/2 mile above the road to Lincoln Gap there are several small cascades or falls. The stream appears runnable from here on down. You will have two small drops (1', 2') at the stone bridge (Garland's Bridge) by the Lincoln Gap Road[8], or you may start below this road.

The first part of the run is fairly narrow and, at moderate water levels, basically Class II. The stream is small, pretty and rocky. It has a rural setting, hemlocks and ledges and farm houses, tight bends and shallow water.

Between the Lincoln School and the next bridge there are ledges and two tight steep passages on either side of an island. These passages will be hard at high water and could easily be blocked by fallen trees or debris; if you are going to boat this segment remember that for all we know you may be the first person ever to do it, and scout carefully.

After Lincoln there is an open meadow left and Beaver Brook entering right. About 1/2 mile below this there are some sloping Class III ledges (The West Lincoln II swimming hole) which should be scouted.

The next mile below this appears to be a great Class II run and moderate water, with lots of woods and rocks. You will pass West Lincoln and make a gradual left turn, and notice the river steepening and (again at moderate levels) becoming high Class II or low Class III. Four tenths of a mile past the gradual left turn the river will make a sharp left turn away from the road. You are now at the top of the Class V New Haven Gorge, which is only suitable for experts in closed boats.

We estimate that at moderate water most of this run is Class II: it has the slope of the small Class III streams like the the Winhall or Ompompanoosuc West Branch, but only about half the watershed. Some of the ledges may be be full Class III at moderate water. And like any steep stream it will run very fast and tight when the water is high, and judging from streams of similar slope is likely to become a full Class III, with the difficulties increased by the small size and the danger of obstructions. AS WITH ANY SMALL STEEP STREAM IT MUST BE CAREFULLY SCOUTED BY ANYONE PLANNING TO RUN IT, AND BOATERS SHOULD RECOGNIZE THAT IT IS POTENTIALLY DANGEROUS AT HIGH WATER.

A single uncommon plant, the marsh bellwort *Campanula aparinoides* was found along the shores. The fishery is not highly productive, but there are reported to be good natural populations of brook trout.

8. This is the Garlands Bridge Swimming Hole, which is the most popular swimming hole in Lincoln, and that is saying something.

* * *

We rate this stream IMPORTANT as a small, very attractive Class II-III run.

8.5 NEW HAVEN RIVER 2: 1 mile below West Lincoln to Rocky Dale; the New Haven Gorge

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Length	1.1 miles
Towns	West Lincoln, Bristol
Counties	Addison
Access	from road to Lincoln Gap

Elevation	820'-630'
Average Slope	ca. 170'/mile, beginning at ca. 130' per mile and steepening to over 200'/mile at the end
Description	steep bouldery stream that descends over a series of ledges and small falls; Class IV above, ? Class V below
Surroundings	hemlock-hardwoods forest in ravine; few houses near West Lincoln; remnants of old dam sites; no trash
Water Quality	good
Flow Regulation	none
Hydrology	no gauge data; watershed above Rocky Dale ca. 130 sq. km.
Geology	mostly Cambrian Cheshire Quartzite
Biology	good brook trout stream; no important vascular plants; good bryophyte flora at New Haven River Gorge.
Known Use	used by a few expert boaters
Season	snowmelt and early spring
Suitable for	expert kayakers, might be possible in open boats at just the right water level

Interruptions dam and 15' drop (Bartletts Falls) about a mile above Rocky Dale

Importance HIGH IMPORTANCE for whitewater; one of the most challenging kayak streams in the state. Also IMPORTANT for biology.

This segment of the New Haven, 'New Haven Gorge', is a very impressive & very difficult small upland stream. It has wooded, narrow valley, moderately wild setting, few clearings or buildings, handsome woods and views. The stream bed is steep and bouldery, with lots of sharp drops. The white water is continuous and very complicated, suitable for experts only.

Average gradient 170'/ mile, three times that of the West and twice that of the Wardsboro, making it one of the steepest boatable streams in the state. Watershed at bottom of the run a third larger than the Wardsboro and hence we can expect this to be a very fast and dangerous stream, potentially deadly when in flood.

A great piece of water. Most of the other streams that come down the west slope of the Green Mountains have more or less planed smooth by all the boulders coming down them and have few ledges. They are steep and very rocky and never let up, but do not have drops and pools. The New Haven on the other hand is a classical staircase stream, with many drops and chutes and pools. It is used as a high-level kayak run, definitely Class IV and possibly higher at high water. (Crash- and-bash style boaters thinking about running please note that the segment below this, which is considered substantially easier, scares experts.) It is probably the most difficult ledge run in the state. As is the case with the Middlebury Gorge and other steep streams the water level has to be just right -- the too rocky threshold and the too dangerous limit are very close together.

Because of its great difficulty and limited season it is only rarely used, but is none the less considered of high value both for difficulty and beauty. It may well get more use as more boaters learn about it.

Biologically it is considered an excellent brook trout stream, valued for the deep pools. It is not a fertile watershed and the trout are said to be small, be it is reported to be an excellent place to fish.

The botany of the area is potentially interesting since there are apparently small traces of lime associated with the bedrock. The authors investigated the lower half mile of the segment in 1983: no interesting vascular plants were found, but the moss flora was moderately diverse, and the site rated of moderate biological importance for that reason. See the VWG report for details. Several more sites were checked for vascular plants in 1984. No rare plants were found, and with the exception of the grass *Sphenopholis intermedia* the flora was typically of acid sites with low fertility bedrock, and neither differentiated nor particularly interesting.

* * *

The segment is rated as HIGHLY IMPORTANT for boating, and IMPORTANT for fish and mosses.

8.6 NEW HAVEN RIVER 3: Rocky Dale to below Sawmill Bridge

Length	3.1 miles
Towns	Bristol
Counties	Addison
Quadrangle	Middlebury 15' or Bristol 7.5'
Access	Rt. 116 in Rocky Dale; normal take out is 1/2 mile below the bridge in New Haven Mills
Elevation	620'-400'
Average Slope	ca. 75'/mile (lst 0.8 mile = 80'/mile, next mile ca. 65'/mile, last mile ca. 85'/mile)
Description	medium-sized stream with rocks and ledges; Class II-III at medium water and III-IV at high water.
Surroundings	hemlock hardwoods forest; second growth, some houses, town of Bristol, sawmill, etc.
Water Quality	good
Flow Regulation	none
Hydrology	no gauge data; drainage area at Bristol is 180 sq. km. and at New Haven Mills 227 sq. km.
Geology	upper part in Cambrian quartzite; lower, flatter part in dolomite.
Biology	excellent brown & rainbow trout fishery below Bristol; no rare plants found.
Known Use	popular and demanding run.
Season	snowmelt and after rain
Suitable for	skilled open boats & kayaks

Interruptions	difficult and potentially dangerous Class IV drop at the Mill Hill bridge just S. of Bristol
Importance	HIGH IMPORTANCE: the advanced run most prized by west Vermont boaters; also IMPORTANT as a trout stream.

This this segment begins just below the formidable New Haven River Gorge. It is a medium-sized stream, steep and rocky, with a number of ledges. The run is difficult and potentially dangerous run, suitable for intermediate boaters at low river levels and experts at high water.

The hydrology makes it clear why this is a demanding stream. With an average gradient of 75'/mile and the watershed of 230 sq. km. it is both a steep stream and a moderately large one. Only one other Vermont stream with a gradient anywhere near this steep, the famous segment of the West from Ball Mountain to Jamaica, has a larger watershed. The Winhall, of comparable steepness, has half the watershed. The upper Lamoille, with a similar watershed has a substantially lower gradient. Taken together, the combination of volume and steepness make it one of the state's best whitewater streams.

The upper parts of this segment are very pretty, with nice views of the cliffs at Rocky Dale. The last mile is enclosed between steep banks, and there are houses and a big sawmill on the banks. This portion is not particularly pretty, but it is so difficult that I suspect no one has much time to notice.

The following description has been compiled from several boaters and checked by scouting at moderate water.

The run starts with a Class II-III drop at the confluence of Baldwin Brook and the New Haven; below this there are Class II-III rapids to the first bridge in Bristol. These rapids are tight and rocky but not particularly difficult.

At the Mill Hill bridge in Bristol there is a series of about 5 drops, the largest 3-4' high. There are rocks blocking some of the drops, and substantial holes and heavy waves. There are no pools, and if you upset here and do not have a rescue party to throw you a rope you may swim for some distance in Class III rapids. These drops require considerable maneuvering, particularly in open boats. They are Class III at medium water and Class IV at high water. Many good boaters will not run this place when the water is high.

Below the drops at the Mill Hill bridge there are 0.7 miles of continuous rapids to the next bridge. These rapids are typically Class III (heavy Class III in high water), and have a number of holes and drops of 1-2', but are not as difficult as the rapids at the bridge. The heaviest water in this segment is just beyond the apex of the big left turn at the sawmill. Recently the outer parts of this turn have been lined with stones; the river seems to have responded by creating a high water cut-off channel on the inside of the bend. Just how this will affect the rapids is not known.

The rapids decrease in intensity below the second bridge, and the river becomes Class I about 1/4 mile below the bridge and remains that way to New Haven Mills. There are good takeouts to the left below the bridge.

Western Vermont boaters value this river highly. At high water it is near the limit of what an expert open boat can do, and at moderate water it is still quite challenging. (Steve Sease: "Not an easy river; just reading about it makes my blood run cold.") No other open boat run on the west side of the mountains is this consistently difficult. Boaters rate it as harder than the Lamoille and equivalent to the upper West River. It is considered one of the state's finest pieces of water. In the past it was almost unknown, but is now increasingly talked about and used. It is still largely unknown outside of Vermont, we encountered no visiting boaters who knew of it.

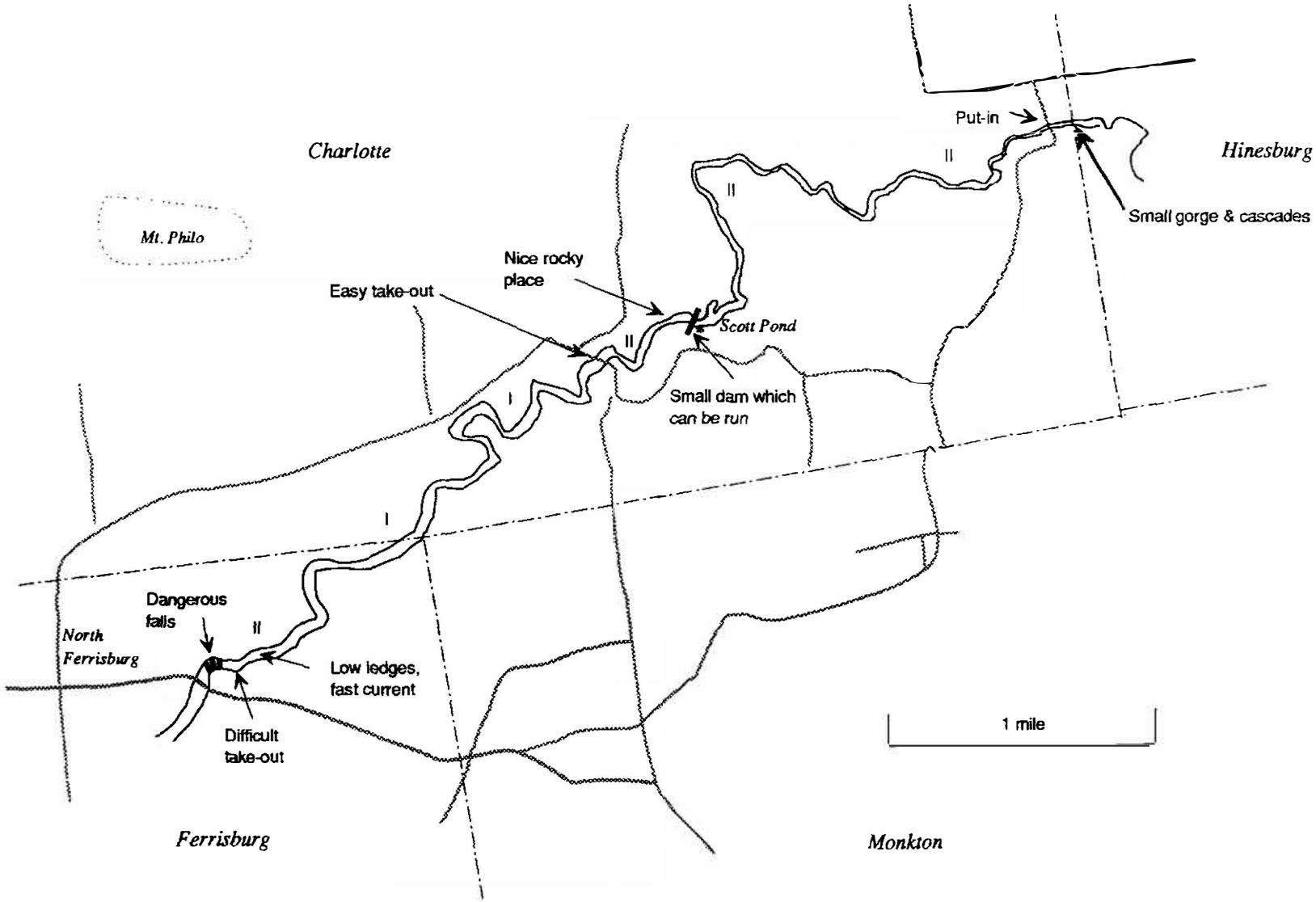
Not much is known about biology. It is reported to have "trophy size" rainbow and brown trout. No rare plants are known from the area.

* * *

Rated as HIGHLY IMPORTANT as a whitewater run, and IMPORTANT as a trout stream.

* * *

The next 3.7 miles to the bridge at New Haven Mills have a slope of about 20'/mile, and are mostly quickwater and Class I with a few short Class II rapids at bends; we do not have detailed information on it, but it is apparently a popular touring river. There are one or more drops and short rapids near the bridge at New Haven Mills. We have received contradictory information about these rapids: to us they looked like Class II rapids at moderate water, but one boater thought that they were substantially harder than that at high water, and warned that the middle of the river could be impassable because of waves and that boats would have to sneak along the sides.



Map 12: Lewis Creek. The segment above Scott Pond is largely Class II, the lower segment largely Class I. Quickwater and flatwater continue from North Ferrisburg to Lake Champlain.

8.7 LEWIS CREEK: Prindle Corners to the Covered Bridge below Scott Pond

Length	3 miles
Towns	Charlotte, Ferrisburg
Counties	Chittenden, Addison
Quadrangle	Burlington 15' or Hinesburg & Mt. Philo 7.5'
Access	covered bridge near Prindle Corners
Elevation	300'-220'
Average Slope	ca. 25'/mile, maximum 60'/mile
Description	medium-sized rocky stream with wooded shores; Class II above Scott Pond, Class I-II below
Surroundings	hemlock hardwoods forest, farmland below; almost no houses; no trash
Water Quality	good
Flow Regulation	none
Hydrology	no gauge data; watershed ca. 180 sq. km. at North Ferrisburg.
Geology	Ordovician shales and phyllites with some interbedded limestones
Biology	spring and fall runs of steelhead rainbows; good brown trout fishery but probably limited by temperature in the summer; work in progress towards establishing landlocked salmon here. Two scarce plants, but no rare ones; historical records of several interesting species.
Known Use	no information
Season	snowmelt, after rains
Suitable for	open boats
Interruptions	dam at Scott Pond with ledge below; 3' ledge 1 mile below Scott Pond.

Importance IMPORTANT both for whitewater and fishing; small pretty stream, fairly remote from roads and houses, pleasant mild whitewater, steelhead and bass fishery; potentially a landlocked salmon fishery.

Lewis Creek begins in the long swampy valley between Monkton and Starksboro, flows north for several miles, and then turns west and works its way down to Lake Champlain. It crosses several bands of hard rocks, and has three interesting small gorges which are excellent swimming holes. Parts of the upper segment might be an attractive flat-water run in spring.

The whitewater is mild Class II, except perhaps in the steep part at high water. The run starts at the upper covered bridge. Lewis Creek is a small stream here, with clean water. It is twisty and tight for the first mile or so. The banks are mostly wooded, with a few shoreline ledges and some sandy bluffs. It is rugged, though more in appearance than the whitewater. There many boulders to five feet high, the stream is separated from the road and in a shallow ravine and so seems remote, and it is very enjoyable to boat and a generally pretty place to be. The lower part of the run is in abandoned farmland reverting to woods. There are some fine views of Camels Hump here.

Hydrologically Lewis Creek is comparable to the East Branch of the Passumpsic or the main stem of the Ompompanoosuc below Post Mills. From the slope and watershed we would expect it to have on the average intermittent Class II water, with possibly a few more intense pitches.

The run begins below the Prindle Corners bridge. It lies in a wooded ravine, away from all roads and very attractive. The water here, at moderate levels, is a fast but untechnical Class I mixed with Class II. There are a few nice rocks for eddy turns and a lot of current and waves and don't have, but nothing very difficult. The boating resembles that of the upper Ottauquechee near West Bridgewater, or that of the easier parts of the Green River or Waits River.

After 1 mile the gradient increases to about 60'/mile, and the river gets a lot faster though not much rockier. At an island you have the choice of two passages. The left one is small and goes fast as a freight train, and may have down trees or logs to dodge. The right one appears to be easier, at least if you are in the left one. This section is high Class II at medium water, and probably a solid Class III at high water. At medium water it requires concentration but is not difficult; at high water it will require caution, and maybe a guardian angel.

The current then moderates for the next mile, and the boating is a relaxed Class II, without notable features. You come into the backwater of the dam at Scott Pond, and can carry around it to the left, or can scout it and run it. Just below the dam is a quarter mile of fine Class II water, with some nice places to ferry, a few low drops and good rocks and waves. This is an excellent practice and play place.

At an abrupt right hand turn 0.3 miles below the dam there is some riprap and a low Class II drop across a ledge or piece of concrete extending across the channel. Beginning boaters may want to look this over. The take-out if you are not continuing on down is at the covered bridge below this.

Between this covered bridge and North Ferrisburg the stream drops about 20'/mile for the next 3 miles, and is a pleasant and undemanding run. There there is a substantial waterfall just above the bridge at North Ferrisburg, and you must take out safely above. This segment is away from the road, quite pretty, and has mostly Class I and mild Class II water. There is a good-sized ledge about halfway down the segment; I think that I have run it but am not sure. The takeout is difficult; the stream is in a ravine and there are no good places to take out or portage, and to make things worse you have to land in the middle of a rapid with a dangerous falls just around the corner.

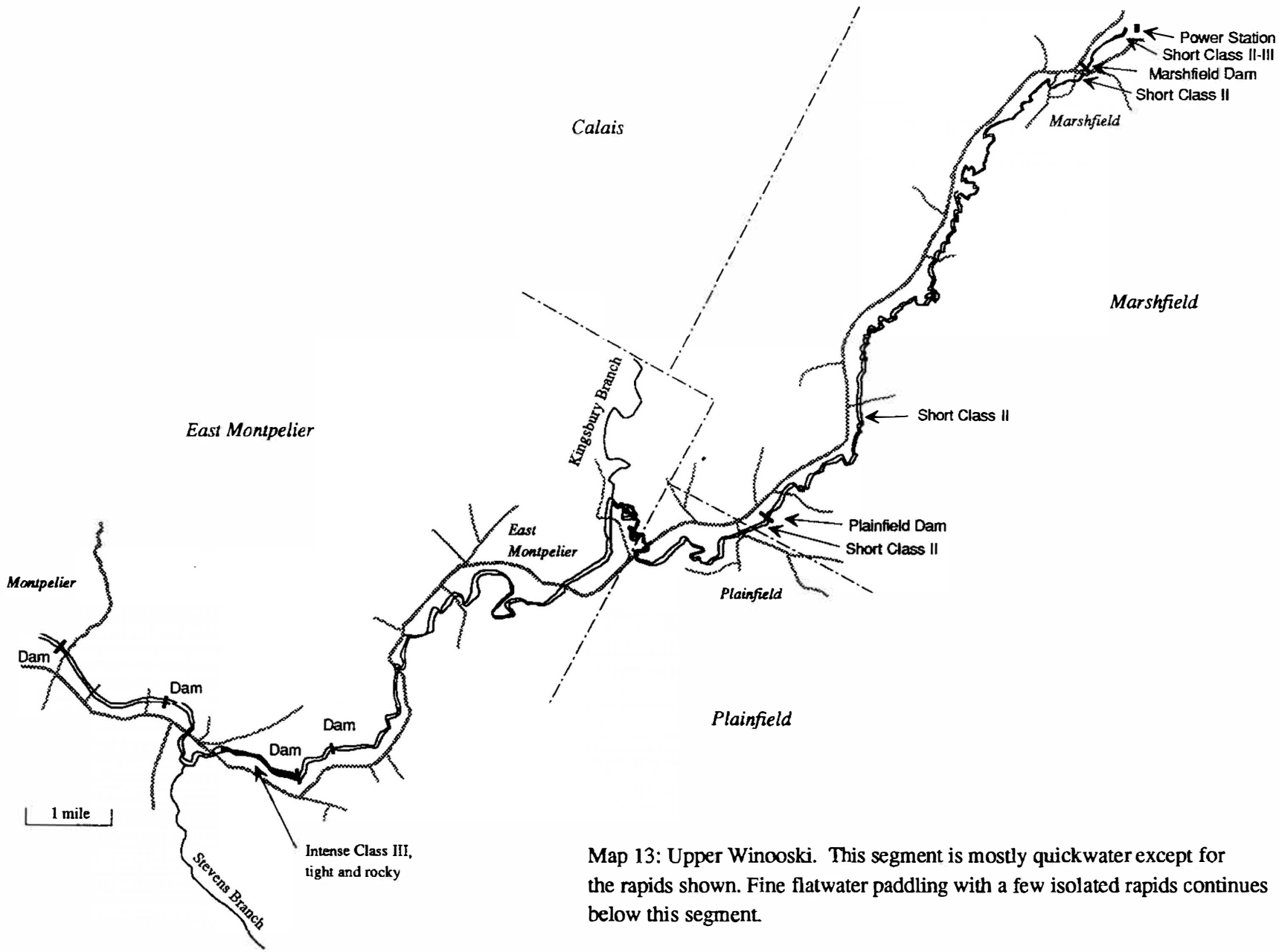
Boaters wishing a spring tour can carry the falls and continue 6 miles to Lake Champlain, but they should be warned that the North Ferrisburg portage is difficult. This run is largely quickwater and flatwater except for two major ledges by the Rt. 7 bridge.

Biologically Lewis Creek is a fertile Champlain Basin stream. Steelhead rainbows have been introduced and special fishing regulations are in effect. Efforts have been made to establish a salmon run, and there are supposed to be good brown trout.

This segment is located in an area of some considerable botanical interest, but so far not botanically noteworthy. Surveys to date have produced two species (*Scirpus pendulus* and *Penthorum sedioides*) that occur irregularly but fairly reliably in limestone areas of the state, and no rarities or interesting communities.

There are several interesting historical records of rare plants from along the creek or from nearby woods. The pine drops *Pterospora andromeda*, a giant relative of the indian-pipe which is currently known from a single site (and apparently a single plant) in Vermont, once occurred in woods near the creek. The sweet coltsfoot *Petasites palmatus*, normally a plant of conifer swamps and currently very rare in Vermont, once occurred on a riverbank here. We have searched for both of them along the creek, but so far unsuccessfully.

Rated IMPORTANT for recreation since it is a pretty stream and since whitewater of any kind is scarce in the Champlain Basin, and also IMPORTANT for fishing because of the steelheads and potential for landlocked salmon.



Map 13: Upper Winooski. This segment is mostly quickwater except for the rapids shown. Fine flatwater paddling with a few isolated rapids continues below this segment.

8.8 WINOOSKI RIVER: Marshfield to Montpelier

Length	24 miles
Towns	Marshfield, Plainfield, East Montpelier, Montpelier
Counties	Washington
Access	many crossings on Rt.2 and side roads
Elevation	780'-520'
Average Slope	11'/mile overall; 8'/mile Plainfield-Marshfield; 25'/mile East Montpelier- Montpelier
Description	medium-large quickwater stream with isolated rapids above; whitewater stream with numerous dams below.
Surroundings	woods, towns, highway, some farmlands.
Water Quality	fair (effluent limitation segment), receives treated and probably some untreated wastes
Flow Regulation	many small mill and power dams.
Hydrology	gauging station in Montpelier: watershed 1028 sq. km., mean flow 16.7 m3/sec, max/mean 3.0; watershed at the bottom of this segment ca. 500 sq. km.
Geology	Devonian limestone & phyllite; upper segment in deep alluvium
Biology	reportedly a good brown and rainbow trout fishery but damaged by June 1984 floods
Known Use	spring and early summer touring on the upper segment; local whitewater use below the Winooski 8 dam in East Montpelier.
Season	spring run-off, high water
Suitable for	touring above; mixed whitewater, flatwater, and lots of healthy portaging below

Interruptions	isolated rapid below power station above Marshfield; dam in Marshfield with short Class II rapid below it; 1/2 mile Class II rapid near King School; dam just above Plainfield with 1/4 mile Class III rapid below it; 4 dams below East Montpelier, the first two with Class III rapids below them, the third with a Class II. Importance IMPORTANT for boating and as a trout stream; also IMPORTANT for water quality

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This is a river that several boaters we talked to expressed interest in, but for which we could find no first hand information. WE HAVE ONLY RUN PARTS OF IT AND HAVE NOT SCOUTED IT AT HIGHWATER, and so the following information is provisional.

Hydrologically the upper parts are typical of flatwater streams with big watersheds, comparable to the Williams or Lower West. The lower parts are somewhat steeper, and, were the grade uniform, would be a solid Class II run, or perhaps (allowing for the large watershed) Class III at high water.

The upper parts from Marshfield to East Montpelier appear to be a flatwater run with the exception of the 4 rapids noted above. The rapid above Marshfield has not been examined at high water. The rapid right below the Marshfield Dam is short and not particularly interesting. The King School Rapids are about 1/2 mile long and have a number of medium-sized boulders. We judge them Class II at medium level and a scratchy I at summer levels. The Plainfield dam has a short Class II rapid below it.

From Plainfield to East Montpelier the river is largely flatwater. The river then drops into a wooded ravine with a string of dams. The first and second dams below Plainfield are short but substantial Class III rapids. I have scouted the second of these (below the Winooski 8 Hydroplant); it is about a half mile long, has a slope of about 60-80' per mile, and is narrow, fast, rocky, and quite heavy at high water. There are essentially no eddies. At medium water it looks easy for kayaks and tight but do-able for open boats. At high water it looks hard, especially just below the dam where it divides into two chutes. One kayakist told me that he and another boater tried it, and spilled in the upper part.

Below the Winooski 8 rapids there is some flat water, then another dam with some short Class II rapids below it, and then flatwater to the last dam.

So far as we can determine none of these rapids get much use at present, but they are in a populated area and might come to be important.

The biological information on this segment is limited. The river has moderate sediment loads from a number of areas with eroding banks. There is supposed to be a self-supporting population of rainbow & brown trout, and some excellent fishing, especially in the tributary streams which are colder than the main stem. We have no historical records of important plants from this segment, and no contemporary survey information.

Parts of the stream below Montpelier and Plainfield are listed as Class C water by the Department of Environmental Conservation. The upper Winooski as a whole is a moderately fertile stream that receives both treated wastes and considerable agricultural runoff. Hence we consider the rapids important for water quality.

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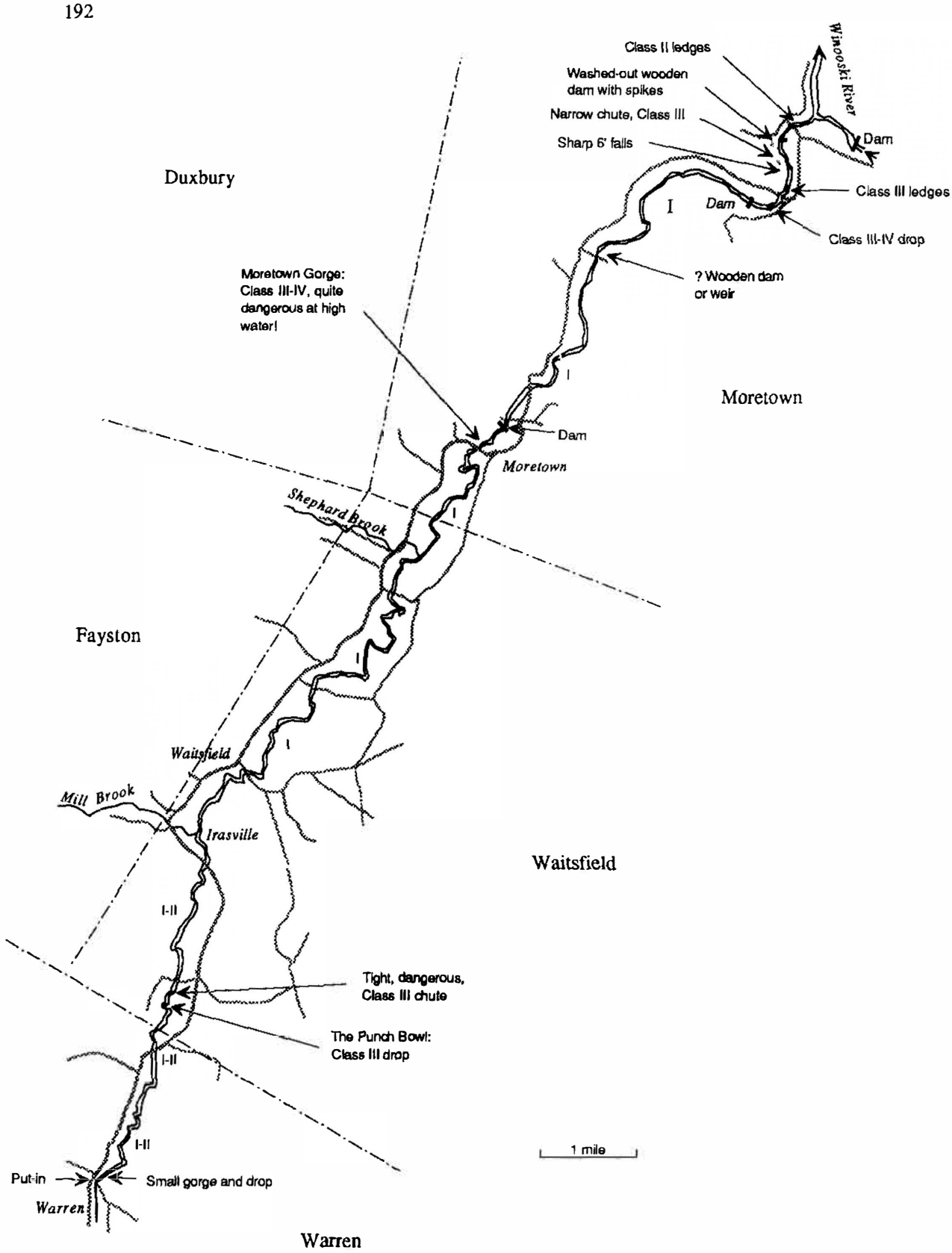
This segment is rated IMPORTANT for general boating, as a fishery, and for water quality. The whitewater is at most of local value.



Map 14: The Mad River. Much of the river is Class I, but with a number of ledges and gorges, The two main gorges, at Moretown and just above the mouth, are excellent boating at medium water, but quite difficult and dangerous at high water.

8.9 MAD RIVER 1: Warren-Moretown

Length	ca. 12 miles
Towns	Warren, Waitsfield, Moretown
Counties	Washington
Quadrangle	Lincoln 15' or Warren 7.5' & Waitsfield 7.5'
Access	Rt. 100 in Warren
Elevation	890'-620'
Average Slope	ca. 20'/mile (30-35'/mile for lst 4 miles)
Description	medium-sized rocky upland stream; Class II with drops to Waitsfield; then Class I with a few places that are Class II to Moretown
Surroundings	hemlock-hardwoods forest, farms, some houses.
Water Quality	good
Flow Regulation	none
Hydrology	gauge at Moretown: watershed 360 sq. km., mean flow 7.3 m3/sec, mean/max 3.0.
Geology	Ordovician schists with some phyllite and amphibolite; bedding very complicated, resulting in the ledges and small gorges.
Biology	populations of brown, brook, and rainbow trout; heavily fished and stocked. No records of interesting plants.
Known Use	very popular with local boaters; also receives some use by visitors; a popular downriver race (one of the legs of a triathlon) is held here in early April.
Season	snowmelt and after rain
Suitable for	open boats
Interruptions	Class III ledges where the river crosses the Waitsfield-Warren town line; dangerous Class III-IV ledge 1/2 mile below this. DANGEROUS (Class

IV) GORGE just below this segment, as you enter the village of Moretown.

Importance HIGH IMPORTANCE for boating and fishing; pretty, clean, rural stream, 4 miles of continuous light rapids; popular for fishing & boating, and receives much use. Possibly important for water quality.

The Mad River is one of the great streams of the state. It has clean water, fine views, great swimming, some fine spring touring with scattered rapids, and two gorges with intense and difficult rapids.

The upper Mad is a medium-sized rocky stream, paralleling Rt. 100. The valley was formerly agricultural and now has a mixture of agriculture, settlement, and ski-related development. The river is moderately easy, and really more of a tour with scattered rapids than an intense whitewater run. But it is fine water, and no one complains. The first 4 miles are mixed Class I-Class II with several difficult drops (which should be portaged except by skilled whitewater boaters) to make it interesting; the lower part is pleasant canoeing but basically not a whitewater run.

The average gradient of 20'/ mile is too low to provide solid whitewater, but makes a lively touring stream. The combination of the moderate watershed (equivalent say to the Battenkill and hence larger than most of our whitewater streams) and a 30'/mile gradient in the upper four miles makes this a very sporty run, probably of the same approximate difficult as the Class II portions of the Black River below Cavendish.

The run begins just below a bridge in Warren. You start in a wooded ravine (the bottom of the Warren Gorge) and run a small ledge and then through a rocky segment in the woods. The first half mile has some beautiful woodland pools and is exceptionally fine. After that you come into more open country, and the river is less rocky overall but still has many fine pools and sculptured rocks and ledges. At medium flows the water, like that of the Huntington, is deep green, and the pools and rocks are very handsome and inviting. Even in March it makes you think of swimming. There are a number of fine views, and the river is enjoyed as much for its beauty as for its whitewater.

The two sets of ledges just below the Waitsfield-Warren line need special comment. The first, the Punch Bowl, occurs where the river is swinging away from the road on the far side of a large meadow. The river turns right and then there is a big rock in the middle with a 3' drop left and a narrow chute on the right. Both sides are runnable; the left is steep and abrupt and the right has a substantial hole. (We took an open canoe down the right side, got half way out of the hole, and then were pulled backwards into it and sank stern first; it felt a little like being torpedoed.) Look these drops over before running them, and go into them with plenty of power.

The second set of ledges is by a side road off Rt. 100 north of the Waitsfield-Warren line, about 1/4 mile north of the Punchbowl. The first ledge of this pair is a straightforward 2' drop, Class II-III depending on the water. The second ledge here is very nasty. At medium water the river is blocked on the left and you have to go right, down some low ledges and then turn quickly into a narrow chute, with a real chance of getting pinned in your boat if you spill. At high water you can keep left, but the drop will be more severe and there will be a substantial hydraulic at the bottom. Either way this is a dangerous place, and should only be run by experts. We recommend carrying here.

The lower 6-8 miles of the run are more quickwater and Class I than whitewater, but they have some nice rocks and places to eddy, and are a very pretty tour.

Take out safely above the Route 100 bridge south of Moretown. The current is fast underneath this bridge and leads to a difficult Class III-IV gorge.

We have only a little biological data on this segment. The Mad is reported to have brook, brown and rainbow trout, to be heavily fished and to receive heavy stocking. It warms up more in the summer than some of the other less steep tributaries of the Winooski and so produce fewer and smaller fish. No rare plants have been reported from the river, our single survey did not produce anything noteworthy.

The valley between Warren and Waitsfield has been heavily developed, and it is conceivable the the rapids on the streams are, or may someday become, important for water quality. We have no definite evidence either way.

Rated as HIGHLY IMPORTANT as a popular recreational whitewater stream and popular fishery.

8.10 MAD RIVER 2: Moretown to the Winooski River

Length	ca. 7 miles
Towns	Moretown
Counties	Washington
Quadrangles	Lincoln 15' or Waitsfield 7.5', Camels Hump 15' or Waterbury 7.5', Montpelier 15' or Middlesex 7.5'
Access	Route 100 in Moretown
Elevation	620' to 420'
Average Slope	ca. 25'-30'/mile, but concentrated in short steep rapids and drops. Slope in Moretown Gorge ? 60'/mile. Lower gorge ca. 60'/mile.
Description	medium-large upland stream in steep valley; 2 Class IV gorges, 4 miles of scattered Class I-II rapids; lovely valley, and some very scenic places.
Surroundings	hardwoods, road, farmland, several dams, no trash
Water Quality	good
Flow Regulation	yes
Hydrology	see above for gauge data; watershed at Moretown 360 sq. km.; watershed at mouth ca. 375 sq. km.
Geology	see above
Biology	fishery as above; 2 records of uncommon plants.
Known Use	very popular stream with expert boaters
Season	snowmelt and after rains
Suitable for	kayaks and expert open boats inthe gorges, general touring in the middle segment
Interruptions	dangerous dam in Moretown; weir at gauging station; high power dam; waterfall at head of lower gorge; old dam in lower gorge.

Importance HIGH IMPORTANCE for boating; varied water, used by both open and closed boats, good playing places for closed boats, lower rapid which runs in summer. IMPORTANT as a popular fishery.

A fascinating and difficult piece of water. Unlike most Vermont streams it has a number of short ledges and gorges with sharp drops and difficult waves. The difficulty of these segments varies with the water level. At moderate levels it is a good solid CLass III and a wonderful practice stream. At high water it is one of the most technical and challenging small streams in the state.

Hydrologically the overall gradient is not formidable, but what makes this a demanding stream is that you have individual drops that are quite difficult, and a large watershed equivalent to that of the West at Jamaica.

The run begins at the Rt. 100 bridge just above Moretown. There is a nice hole under the bridge, and then the river narrows abruptly and you enter the Moretown Gorge, which is about 1/4 mile long. The gorge can be scouted from either bank. Or you can just run down the middle and swim when you come to the diagonal wave. The upper part of the gorge has a fast chute just below the bridge, and then some big rocks and eddies which are not too hard. Then the river turns to the left and there are two sets of ledges and holes, with a diagonal wave from the left at the lower hole. At medium water the gorge is Class II-III and good for intermediate level open boaters and kayakists, provided that it is scouted carefully. At high water it is Class III-IV, and for experts only.

Below the gorge there is a short stretch of flatwater, then a dam. The dam is dangerous and must be carried. Below this there are about 4 miles of quickwater, with a few short Class II rapids; this is a very pretty part of the river, and boaters speak with great affection of this run. This segment is often used for classes by the Northern Vermont Canoe Cruisers.

Below this there is a mile of flatwater and a high dam. The lower gorge begins below the dam.

What is called the lower gorge begins as a wooded ravine, and later becomes a low rock-walled gorge . The river drops about 100' in 1 1/2 miles through here. The gradient is not uniform but is concentrated in a number of abrupt drops. If you start just below the dam you begin almost immediately with several Class II-IV drops between the dam and the Rt. 100' bridge. At medium water none of these drops are more than Class III, but at high water one of them is Class IV and has a deep recirculating hole that extends three quarters of the way across the river and is potentially deadly[9]. Below this there is a nice chute and some fine eddies and play places. At medium water this is a superb practice place.

9. In all the scouting I did for this book I only saw two places in Vermont where it looked very easy to get killed. One was this hole at high water, and the other was the Londonderry Ledges during a major flood.

You then go under the Rt. 100 bridge, and down a set of fairly broad sloping ledges which aren't very hard. The river is easier for about 0.4 miles, and then bends to the left, narrows , and enters the rocky part of the lower gorge. This starts with a sharp, folded 6' waterfall which I have never wanted to run. Below the waterfall is a short pool, and then some broad flat ledges on the left which are only submerged at high water, and an interesting 15' wide rock chute on the left. This is a fun ride at medium levels. Below it, at an old mill site, is a partly washed-out dam with dangerous spikes. It is safest (though perhaps not safe) to run this on the far right, against the rock wall. I remember that something interesting happens when you do, but I don't remember exactly what. Then you go under the Lover's Lane bridge, run one fairly difficult ledge right below the bridge, and then just have quickwater to the confluence with the Winooski.

Steve Sease said that at high water: "The lower gorge is very scary ... anyone less than an expert trying it could get himself killed. It should be thoroughly scouted by any party of boaters thinking of trying it. I wouldn't want to do it without someone on shore with a throw rope."

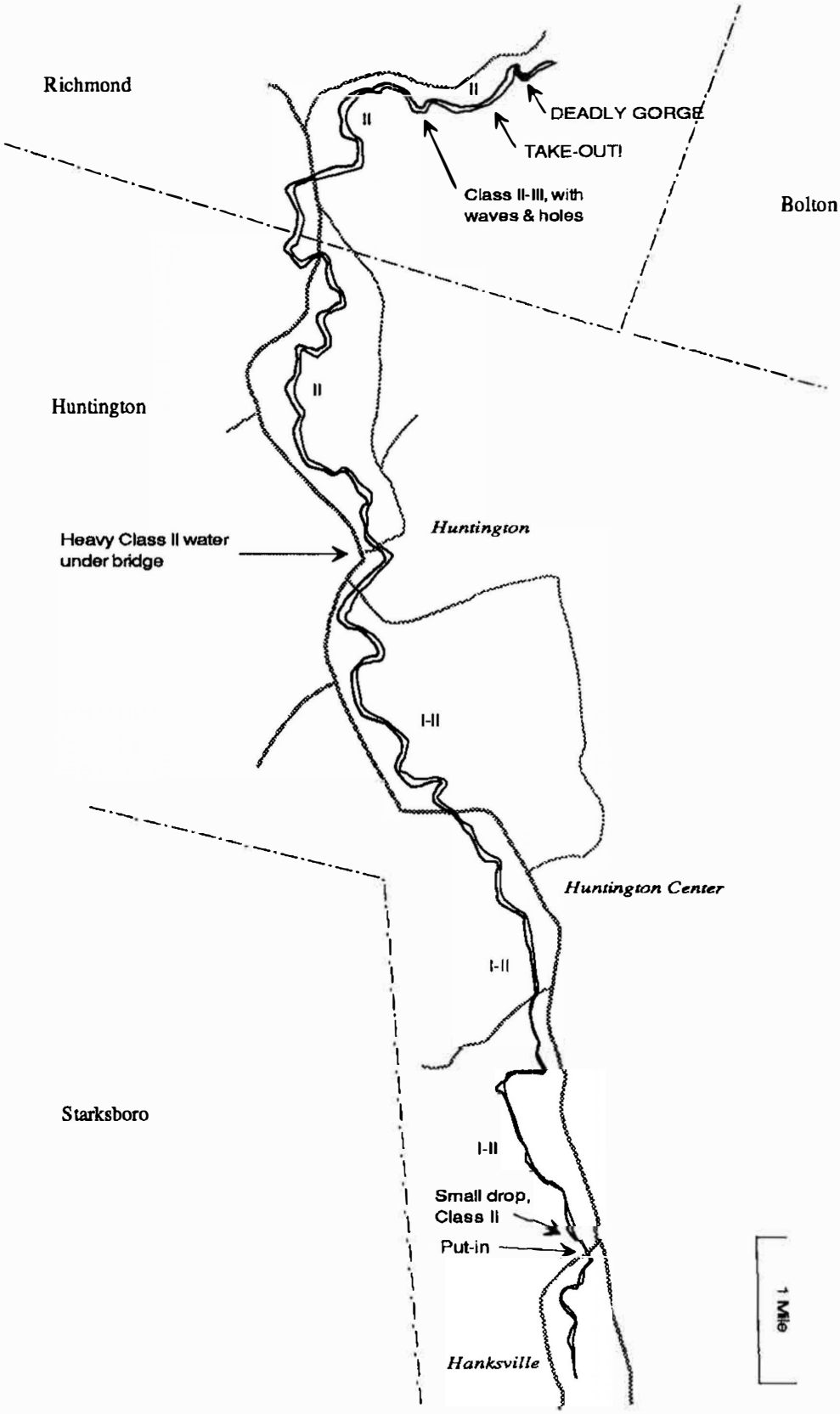
I would add that while this is true at high water the drops are interesting but not formidable at medium water. Provided that you carry the waterfall and avoid the spikes at the old dam there is some wonderful water here, with excellent eddies for practice and teaching. Parts of this gorge can be run late in the spring, or in wet days in the fall and the summer.

As with the upper river our biological information is scanty. Brown, rainbow, and brook trout occur, are heavily fished, and are in part naturally reproducing and in part maintained by stocking. Summer flows are fairly low and the stream probably gets warm. Development has created some problems with sediment loads and bacterial contamination, especially after summer rains. But whatever the actual status of the fishery the Mad looks like the perfect trout stream.

Two moderately rare plants -- Tradescant's aster (*Aster tradescantii*) and dwarf bilberry (*Vaccinium cespitosum*) -- from the lower gorge. Neither is a common species, but both have turned up fairly frequently on ledges along steep whitewater rivers.

The Mad is one of our prettiest and most scenic whitewater rivers, and along with the West probably the only one of our difficult whitewater runs whose scenery can compare with that of some of the fine streams of the Adirondacks.

Rated as HIGHLY IMPORTANT for boating: a beautiful and difficult piece of technical whitewater, usable for much more of the season than any other Class III or IV stream in the state. Also IMPORTANT as a popular fishery.



Map 15: Huntington River. The take-out is in fast water and must be carefully scouted. The gorge below is deadly.

8.11 HUNTINGTON RIVER: *Hanksville to the Huntington Gorge*

Length	ca. 10 miles
Towns	Huntington, Richmond
Counties	Chittenden
Quadrangle	Camels Hump 15' or Huntington 7.5'
Access	from road through Hanksville
Elevation	800'-480'
Average Slope	ca. 30'/mile
Description	small rocky rural stream, mixed Class I-II rapids, with a Class III pitch near the lower end.
Surroundings	hemlock-hardwoods, farmland, few houses, no junk
Water Quality	good
Flow Regulation	none
Hydrology	no gauge data; drainage area above Huntington Gorge approximately 150 sq. km.
Geology	Cambrian Underhill schist, one of the commonest rocks of the central Green Mountains, very variable in folding and bedding and often producing river ledges and small gorges.
Biology	good populations of brown, brook, rainbow trout; few recent records for 3 uncommon plants.
Known Use	popular for general touring; pleasant whitewater in spring
Season	snowmelt, after rains
Suitable for	open boats
Interruptions	4' ledge near start

Importance HIGHLY IMPORTANT for boating and fishing; very pretty pleasant stream for touring and whitewater; nearest whitewater stream to Burlington

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The Huntington and the Mad are the two gems of the Winooski watershed. The Huntington is much more rural than the Mad, lacks the Mads gorges and difficult water, but is swift and has more continuous Class II water. It is a great stream for learning or teaching Class II boating. And on an early spring day when the blackbirds have just come and the skiing is all turning to slush, it is as perfect a place to be as I can imagine.

The Huntington is a small stream in a rural but not remote area. It has very clean green water, some hemlock-hardwoods forest, much farmland or old farmland, and two small villages. The channel is not ledgy like the Mad, but has pools and low streambank ledges at the bends with good swimming holes.

Hydrologically the Huntington has a moderate watershed and slope. This with mostly middle Class II rapids, which, because the channel is mostly broad, are easy and pleasant to run. It is comparable in slope and volume to the Green River and just a little steeper and smaller than Lewis Creek.

At low water it is mostly Class I, at medium or high water a mixture of Class II and some Class I. It is a very safe stream, fast enough to be fun, but not tight or pushy or demanding. Boaters say it is a relaxing stream that gives you good practice and makes you feel good but doesn't scare you. It is a little tame for experienced boaters, but makes up for this by liveliness and attractiveness.

The run can be started at Hanksville; the first mile is fairly steep and narrow and twisty. Many boaters start further down, at any of the next 3 bridges.

The run ends at the Huntington Gorge. The gorge is deadly and its entrance is hidden behind a bend; boaters should scout the takeout carefully from the shore. Probably the only sure way to get killed on a Vermont River would be to miss the takeout at high water and go into the gorge.

Below the first bridge there is a short set of ledges (the Hanksville Swimming Hole), high Class II at medium water, about 100 yards north of the road. Intermediate level boaters may want to look them over.

From there to the bridge below Huntington Center the river remains small and the boating straightforward.

The river steepens somewhat at the bend east of Huntington, and there is some comparatively heavy water (still Class II) at a side-road bridge here.

The next few miles are lovely paddling, with fine views.

One mile above the gorge the river bends east; this mile has some slightly heavier rapids than the preceding ones, rising to Class III at high water. If you have had difficulties above here you should take out here.

After the bend there is a steep straight pitch along side the road, with an interesting dry-stone retaining wall. At high water the current is very fast here, and it can be a bit scary, but remind yourself that the gorge is really not around the next bend. This pitch leads to a sharp left turn. Just around the turn are several big holes, which approach Class III at high water. From this turn it is 1/2 mile to the gorge, and you must take out safely above the gorge. Pardon us for saying it again, but a swim here could kill you. A rock wall on the right bank where the river bends left marks the entrance to the gorge. Take out at least 100 yards above this, and allow more if the water is high.

The Huntington Gorge, which is immediately below this segment, is a very narrow, twisty, sculptured gorge, unique in the state, extremely pretty, and not remotely boatable. For details see the VWG report.

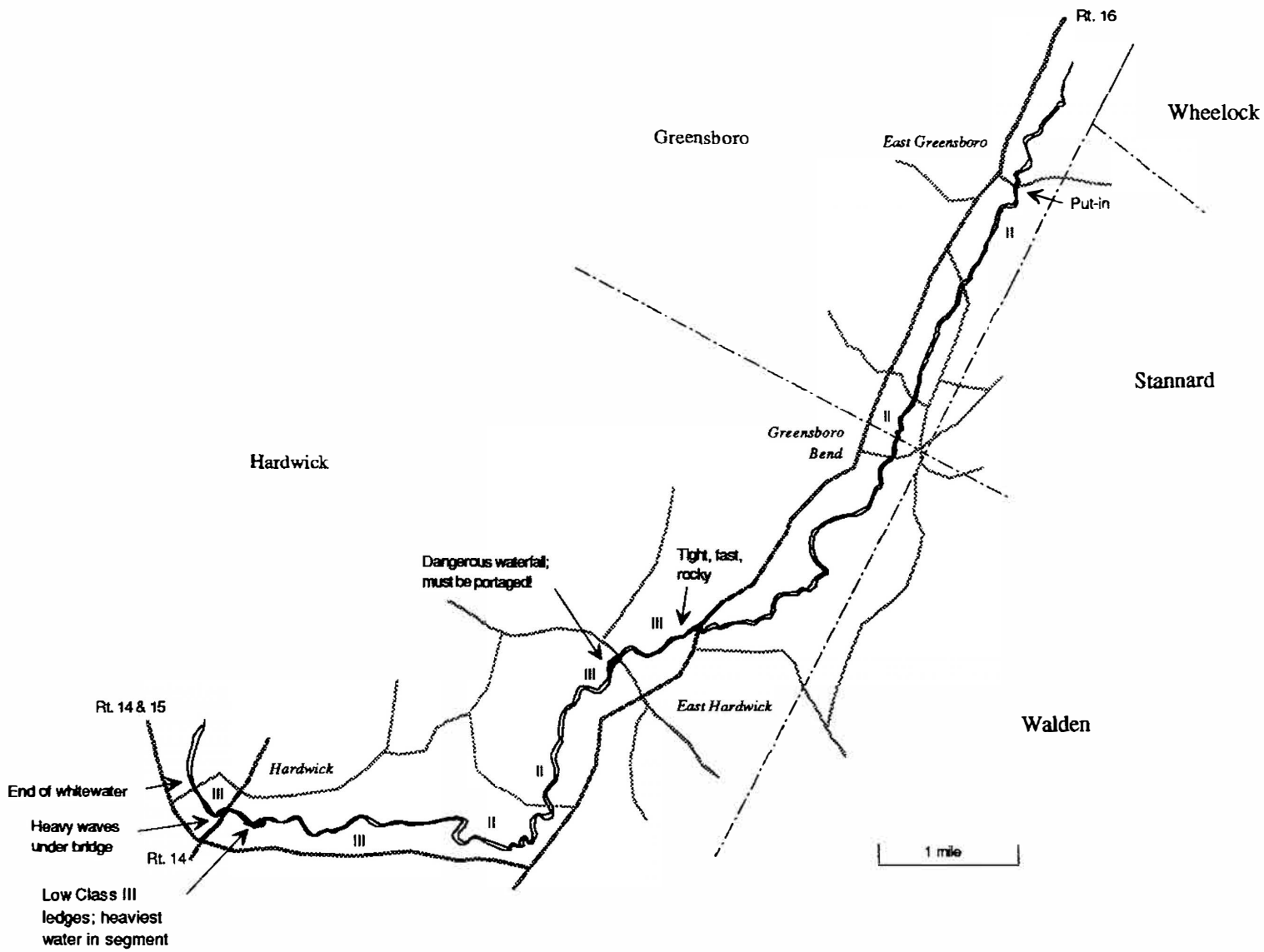
The stream below the gorge is steep (50-75'/mile) with chutes and drops and pools. At least part of it is definitely runnable, and looks like high-level kayak run. We know of no one who has used it. It may have too many unrunnable drops to be a useful whitewater run, but it might repay exploration.

The Huntington is reported to have moderately good cold-water fishing . Like the Mad it gets fairly thin and warm in the summer and so is not as productive a trout stream as some of the other tributaries of the Winooski, particularly the Dog and Little Rivers. It is stocked heavily, and gets heavy use.

We have three records of scarce plants from the Huntington: the bellwort *Campanula aparinoides*, a sedge *Carex annectens* and a rush *Juncus marginatus*. All are uncommon or rare in Vermont but common elsewhere in New England. All occur on rivers but in other habitats as well. Like a number of river shore species they have scattered and rather unpredictable ecological and geographical distributions, and are what we call scarce native vagrants.

* * *

We rate the Huntington as HIGHLY IMPORTANT as a boating and a fishing stream. It has fine water, extended segments that are undeveloped or lightly developed, and fine scenery. It is also very accessible: it is within a half hour of Burlington, and so gets used on weekday evenings by many boaters and fishermen from the city. While not as famous as the Mad it is still a very popular stream, and deserves its popularity.



Map 16: Upper Lamoille. Much of this segment averages Class II, but the hard parts are solid Class III at high water.

8.12 LAMOILLE 1: Greensboro Bend to Hardwick

Length	7-8 miles
Towns	Greensboro, Hardwick
Counties	Orleans, Caledonia
Access	from Rt. 16, Greensboro Bend
Elevation	1160'-820'
Average Slope	ca. 40'/mile; fast stretches are ca. 50-60'/mile
Description	medium-sized stream with small ledges and tight bends; Class II & III at medium water, much Class III at high water
Surroundings	second growth hardwoods, some farmland, road, few houses, occasional junk
Water Quality	good
Flow Regulation	none
Hydrology	no gauge data for this segment; watershed above Hardwick 220 sq. km.
Geology	Devonian Barton River limestones & schists
Biology	good brook trout fishery; survey did not find any interesting plants on this segment
Known Use	very popular with Vermont boaters, occasionally used by individuals or groups from elsewhere
Season	snowmelt and after rain
Suitable for	intermediate kayaks, intermediate to advanced open boats
Interruptions	large cascade in East Hardwick
Importance	HIGH IMPORTANCE for boating; the longest stretch of Class III water in the north part of the state; also IMPORTANT for fishing.

This is a great stream with tough but not extremely technical water. Unfortunately it has a short season, but it sinks enough boats in a week or two every spring to make up for it.

The upper Lamoille is a small stream in an alluvial valley, mostly farm country, with meadows, a few houses, tight turns, steep banks, and lots of rocks and waves but few ledges or drops. It parallels Rts. 15 & 16 and the St. Johnsbury-Lake Champlain Railroad. The upper part is pretty and has some nice woods and meadows. The lower part has steep banks and you don't see much at all, though considering the water you often don't have much time to notice.

The gradient is 40'/mile with locally steeper stretches, comparable in slope to the Wild Branch or the West Branch of the Ompompanoosuc. But the watershed is twice that of either of those streams, and hence the upper Lamoille is the hydrological equal of the Moose. The substantial watershed in a fairly narrow channel makes for big waves without too much space between them. Since there are no major drops or intricate places it is a fairly easy stream in a closed boat since you can paddle down the middle and go right through the waves. But it is mean in an open canoe. You and the water are going quite fast, and between the rocks and the narrow channel you don't have a lot of time or space to work with. The individual waves and holes would not be particularly difficult on a larger river, but strung tight together they are a different matter.

The run begins above Greensboro Bend. The first two miles are in the open and are basically fast, bouldery, Class II water with some tight turns. Then you enter a wooded portion where there is a hill on the left and the river turns right and crosses under Route 12. This is the start of about a mile of continuous rapids that are high Class II at medium water and Class III at high water. The most difficult pitch is below the Route 12 bridge: there are no drops but the waves are continuous and because the stream is narrow and rocky you have to plow right through them. An open boat can take on a lot of water here.

At East Hardwick there is a steep cascade which must be portaged; below it is a 1/2 mile Class III rapid with dense cedar woods on either side. There are some low ledges and substantial holes here, and at high water this pitch has a reputation for sinking and breaking boats.

As you leave the cedars there are 1.5 miles of easy Class I-II rapids to the corner where Rt. 15 meets Rt. 16. Below this the stream gets abruptly steeper, and the next next two miles contain the most difficult rapids of the run. At high water the rapids are continuous Class III; at low water they are mostly Class II with several Class III pitches. There are a number of tight rocky corners here, and you must watch carefully for logs and fallen trees. There are also several small drops, most notably behind the motel just east of Hardwick and below the bridge in the middle of town. The drops are not particularly high but the waves are substantial and irregular and extend across much of the stream, and it is notoriously difficult to get an open tandem boat through them without taking on a lot of water.

This segment of the Lamoille has the most continuous and difficult rapids in northern Vermont. At medium water it is exciting and challenging in open boats, and at high water may be at or

beyond the limits of what an open boat can handle, both because of the speed and the impossibility of avoiding some of the waves. None of the individual rapids are exceptionally hard, but the whitewater is continuous, particularly in the last mile, and there is a lot of volume in a small channel, and very few good eddies. This is one of those streams where the run as a whole is harder than you would suspect from scouting individual rapids: hence it should be approached with caution, particularly at high water and by open canoes.

A number of experienced north Vermont boaters told us it was their favorite stream and that it was the most interesting extended stretch of whitewater in the northern part of the state. It is not very well known outside of the state or southwards, but our impression is that it is at least the equal of many streams that have wider reputations.

In the last few years there has been some concern among canoeists about various plans by the Town of Hardwick to put some sort of strainer or boom into the river to catch chunks of ice and prevent ice-jam floods. At present ice accumulates just west of town where the river flattens out and this occasionally floods the lower part of town. The town has felt that they could prevent this by stopping the ice before it gets to the town, effectively moving the build-up of ice eastwards and upstream. For a while they proposed a permanent strainer of steel bars set in concrete, but now have abandoned that idea in favor of a removable boom of truck tires strung on a cable.

It is not our concern here to comment on the soundness of the idea, or, assuming that the boom can do what it is supposed to, on the wisdom of replacing an ice jam below the town with one above the town. But we do need to comment on the threat that such structures present to boaters. If they can trap ice flows they can trap canoes or canoeists, and this is quite capable of causing a fatal accident.

There are two reasons why this sort of obstacle is so threatening. First it extends completely across the river, and so very is difficult to escape, especially because you are in a place where the river is fast and eddies infrequent. Second, the water is not diverted around it but rather passes through or under it so that a boat -- or a swimming person -- will be forced against it or pulled under the water. The force of the water against such an obstacle is very great and at high water can easily drown a swimmer.

We would recommend that several things be done to minimize the chance of a fatal accident: first there should be a warning sign upstream of the boom whenever the boom is in place; second the town should notify the regional canoe clubs (AMC, North Vermont Canoe Cruisers, Johnson College Outing Club, Sterling College Bounder Program) when the boom is going to be put in place and when it will be removed; and third that there be a single person in the town who understands the dangers to boaters, and who is is responsible for getting the boom out as soon as the river starts to break up.[10]

10. Since this was written we have learned from Ray Gonda that an arrangement has been worked out between the town and the North Vermont Canoe Cruisers that provides that the ice boom will be removed once the river is open, and that canoe organizations and conservation groups will be consulted about any future plans to place structures in the river.

Biologically the upper Lamoille is moderately fertile because of the limy bedrock. It supports a good population of brook trout, and they are reported to grow larger here than in many streams of this size, presumably because of the fertile water. Because of the lime and the northern location it was also reasonable to expect that some interesting plants might occur here and so a number of sites along the river were field checked, but without interesting results.

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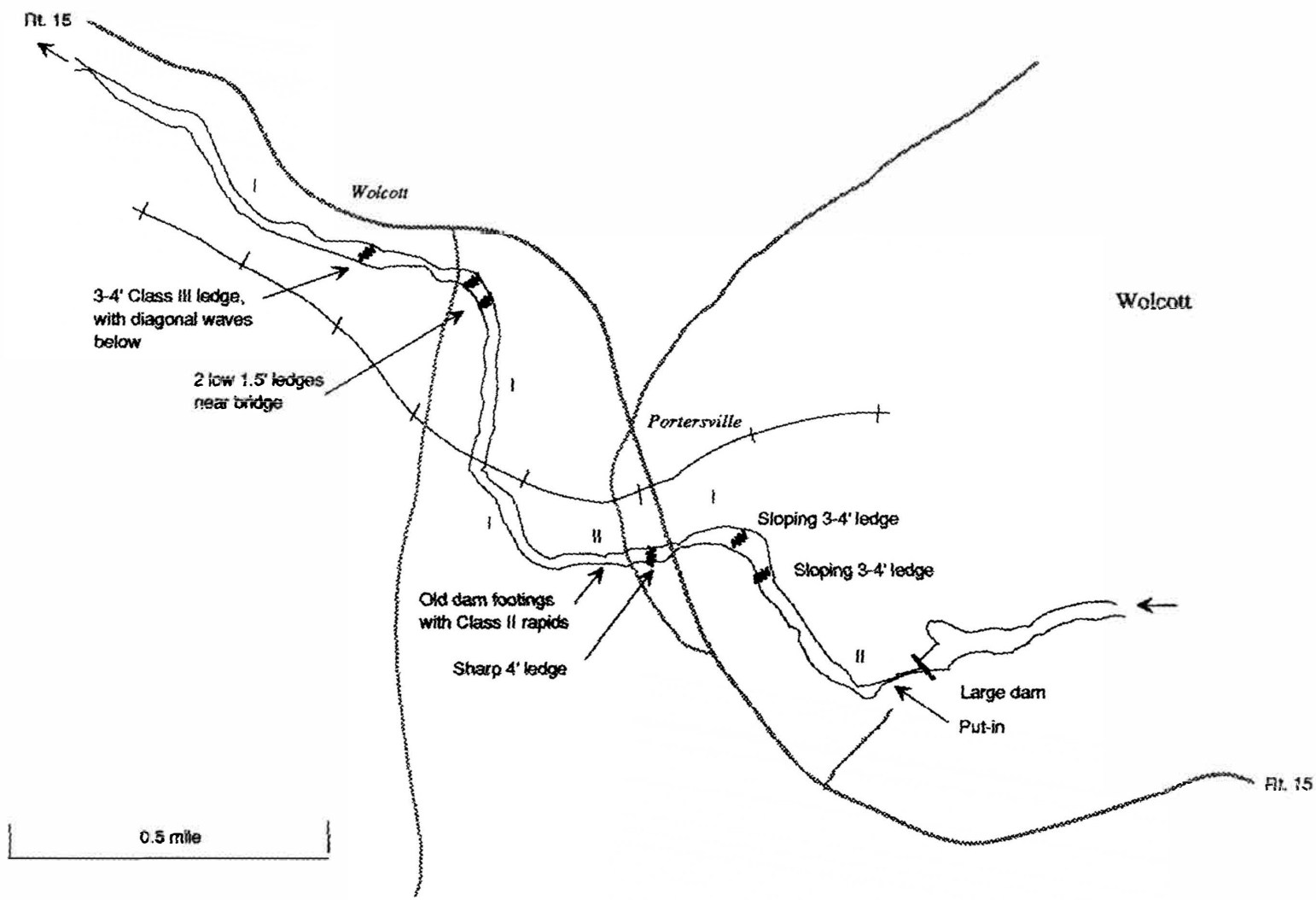
Rated HIGHLY IMPORTANT as the most demanding piece of continuous whitewater in northern Vermont, also IMPORTANT as a brook trout fishery.



Map 17: Wolcott Ledges on the Lamoille. The ledges vary from Class II to Class III with the water level. At medium to high water the last ledge (behind the stone in Wolcott) can sink an open boat. Except where shown the river is Class I.

8.13 LAMOILLE RIVER 2: Pottersville to Wolcott (The Wolcott Ledges)

Length	1.4 mile
Towns	Wolcott
Counties	Lamoille
Quadrangle	Hardwick 15'
Access	from below the dam at Potterville
Elevation	ca. 820'-780'
Average Slope	ca. 30'/mile
Description	medium-sized alluvial river with ledges
Surroundings	wooded ravine, road, old mill site, town
Water Quality	mostly good
Flow Regulation	dam at Pottersville but comparatively little storage
Hydrology	no data
Geology	Ordovician Moretown Quartzite-granulite
Biology	good brown trout fishery, no botanical records
Known Use	fine Class III drops and practice rapids, many runnable in the summer
Season	spring, wet summers and falls
Suitable for	open and closed boats
Interruptions	see text
Importance	HIGHLY IMPORTANT for whitewater; a unique run which is often usable in the summer. Also IMPORTANT as a fishery.

This is a fine and comparatively unknown[11] segment of the Lamoille which is very valuable for whitewater practice. It is a short run but the ledges afford a number of interesting play places, and you can easily spend an hour or more on this segment.

All the ledges are runnable at medium water, and probably at high water. Some become very bony at low water. Many of them require setting up your position carefully, and hence should be scouted before you try them. The possible routes vary a lot with the water level; we ran them four days in a row one September and found that we were forced to take different routes through the drops each day.

The run begins at the dam above Pottersville. Boaters coming down from Hardwick should land on the left bank, and carry down to the powerhouse. The put-in is behind the powerhouse. There is a 1/4 mile rapid directly below the put-in which is Class II at medium water and has several nice eddies and waves.

A little below this is an island with a sloping 3-4' Class III ledge immediately below it. This is the hardest drop, and you should scout it carefully. We normally run left of the island, and start to the right of the center and angle left. There is a big rock that splits the current halfway down the main drop, and you don't want to get stuck there.

Below this the river bends left and there is a rocky knoll on the left with another 3-4' ledge below it. At medium water there are several possible routes. We favor a tongue of water to the left. In the summer this is a nice place to swim. Boaters swim here too, sometimes suddenly.

A quarter mile below this is the bridge at Pottersville. Below it is some fast water ending in a sharp 3' ledge extending across the stream. Several routes are possible: we have been running to the extreme left, with enough speed on to get the boats out over a hole at the base of the ledge. The setup here is particularly tricky, and a foot one way or the other can make the difference between an easy ride and a spill.

Below this ledge, by the footings of an old dam, is a short Class II rapid with a sloping drop and some nice waves in the center. This rapid runs in wet times in the summer and is a good place to play. It is safe and doesn't require scouting.

Below this rapid there is flatwater for about 1/2 mile to Wolcott. There are two small Class II ledges about 1.5' high by the highway bridge. Both are easy to run straight on, but have small but vigorous hydraulics that are fun to experiment with. We found that at medium water they could hold a canoe sideways quite effectively, and that it took some determined downstream bracing to get out.

The final drop is behind the general store in Wolcott. It is a sloping Class III drop of 3-4', with some rocks and diagonal waves to think about. The approach here is a bit tricky, and requires scouting. It can be quite heavy at high water, and it is not uncommon to finish the run with a lot of water in you boat.

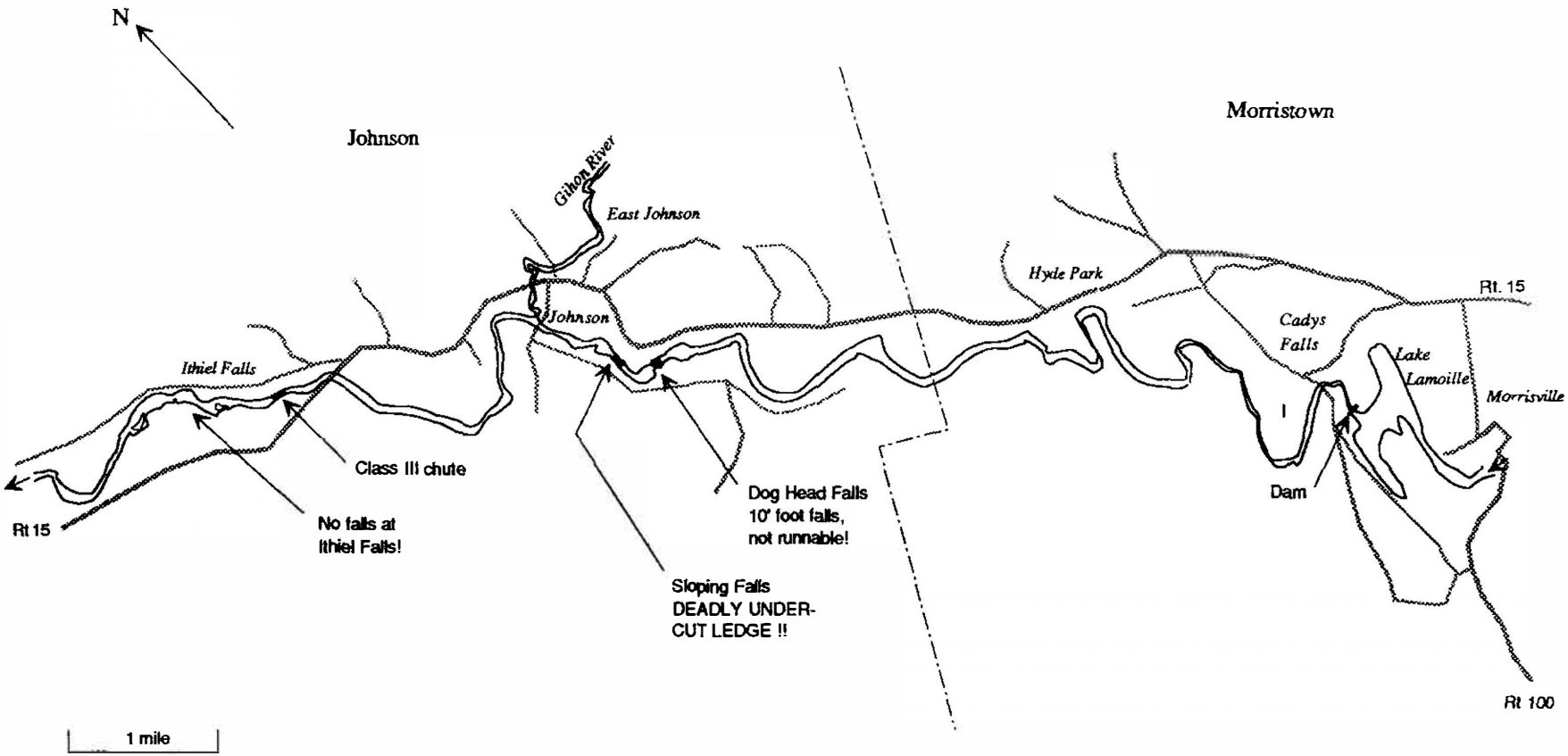
11. The AMC guide suggests portaging the whole segment by car.

ANYONE BOATING THIS SEGMENT AT HIGHWATER SHOULD SCOUT CAREFULLY AND BE PREPARED FOR GREATLY INCREASED DIFFICULTY.

You can take out here or continue down the river to Morristown. There are no more drops but at high water there are some nice (though short) Class I-II rapids and a few good rocks for eddying about 3 miles further down.

* * *

Rated HIGHLY IMPORTANT as one of the few segments with Class III drop usable in summer and fall.



Map 18: Middle Lamoille, Morrisville to Ithiel Falls. This segment continues un-interrupted to Fairfax falls. Dogs Head Falls is a folded drop with a bad hole and a rock in the chute. Sloping Falls has much of the flow going under an undercut ledge. If you run it you will probably die.

8.14 LAMOILLE RIVER 3: *Cadys Falls to Cambridge*

Length	ca. 34 miles
Towns	Morristown, Johnson, Cambridge, Fairfax
Counties	Lamoille, Franklin
Quadrangle	Hyde Park 15', Mount Mansfield 15'or Jeffersonville 7.5'& Gilson Mountain 7.5'
Access	from the road by the dam at Cady's Falls, or from the 1st bridge below the dam
Elevation	540'-360'
Average Slope	ca. 5'/ mile
Description	large alluvial river; several isolated rapids and drops; not really a whitewater run, but whitewater technique required to run it
Surroundings	varied; mostly farm land, some towns, some hardwoods
Water Quality	mostly good; treated waste in Hardwick, class C segments below Hyde Park & Johnson; much agricultural runoff
Flow Regulation	dams at Lake Lamoille and Hardwick
Hydrology	gauge at Johnson: watershed 803 sq. km., mean flow 15.2 m3/sec, max/mean 2.8
Geology	Variously Ordovician or Devonian schists, with some quartzite; locally small gorges & ledges occur at places with vertical bedding
Biology	rainbow and brown trout fishery, some smallmouth bass below Jeffersonville; summer temperatures kept low by some regulated tributaries and hence a good summer trout stream; some areas recently degraded by floods and construction; no botanical information
Known Use	very popular for general touring; whitewater race in the vicinity of Johnson each spring.
Season	much of the year

Suitable for	general touring; local whitewater practice
Interruptions	Dog's Head Falls, 1/2 mile above Johnson; Sloping Falls, just below Dog's Head Falls; possible dangerous rapid below Gihon River, Johnson; ledge & short rapid, Class IV at high water, 1/4 mile below the Rt. 15 bridge below Johnson; Ithiel Falls, short rapid, Class III-IV in high water, 3/4 mile below the Rt. 15 bridge below Johnson; dam at Fairfax Falls
Importance	whole segment: HIGH IMPORTANCE for general touring IMPORTANT as a trout stream; isolated rapids: IMPORTANT for whitewater practice IMPORTANT for water quality

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The Lamoille here is a large river in a farmed valley, paralleling Rts. 15 & 104; open rolling country, fields and rocks and wooded banks and big farms and long views to the mountains; generally a wide lazy river, but occasionally dropping abruptly or confined by rocks. Like the Battenkill it is not really a whitewater stream but merits inclusion as a quickwater stream that is very important for touring, and because the individual fast places and rapids are important to local boaters.

While not a whitewater run as such, it none the less contains some interesting short rapids and drops, and is used by local boaters for practice and by Johnson College for an annual race. It is also one of the state's premier streams for river touring. This segment of the Lamoille and the segment of the Otter between Proctor and Middlebury are the two longest unbroken stretches available for summer canoeing in the state.

The run begins below Lake Lamoille; there are about one half mile of ledges and Class II rapids below the dam, which might be an interesting kayak run at flood; alternately you can start below the ledges. The river is slow for about 8 miles to Dogs Head Falls, which is a pretty small falls about 6-8' high which can't, repeat can't, be run by open boats, and may or may not be runnable by closed boats.[12] The falls are narrow and angled and a boat could easily be trapped below them. Boaters should approach them with caution and take out safely above them.

About one quarter mile below Dogs Head Falls is Sloping Falls, which are a difficult and dangerous drop. At medium water they appear to be Class III-IV. The water is not that difficult,

12. At low water most of the flow over the falls is confined to a tongue that is blocked by several rocks, and looks very unattractive. At high water the falls are clear, but are what is called a 'folded' drop. The lip of the falls is a horizontal V with the apex upstream. The flows from both sides fold together and make a deep recirculating hole. The tongue coming out of the hole piles up against the Dogs Head, a high transverse ledge about 30-40' downstream from the falls, and makes an unstable exploding wave where it piles up. Assuming that you get through the hole and ride off the exploding wave there is then a very mean oblique breaking wave that extends across much of the river about 50 yards below. Skilled closed boaters can run some amazing and pretty dangerous stuff, and all this may be runnable. But it is not for the average paddler, or even for a good average paddler.

but the problem is that most of the river funnels to the right, straight at an undercut ledge which is is potentially deadly. We were told that on at least one instance a boat was trapped here and the boaters were very lucky that help was available.

At high water the water splits into two tongues. The right one, which heads for the undercut ledge, tumbles into a trough and makes just about the meanest and most dangerous looking hole we have ever seen in Vermont. The left tongue is a cleaner run, but leads to a pair of very mean diagonal waves with no clear tongue between them. I rate the whole drop as Class V and potentially deadly. If you are the one boater in a thousand that is competent at running extremely difficult water with no margin for error you may want to go and have a look. Everyone else should carry this place and not think twice about it.

Two miles below Johnson (and immediately below the Rt. 15 bridge) is a sharp ledge and short rapid. This is often called a Class IV, but in fact it washes out at high water. Our impression is that it is Class II at low medium water, rises to a solid Class III at medium water and then drops back down to Class II at high water. Possibly there is one particular level where it goes to Class IV before it starts to drop, but we doubt it.

One half mile below this is Ithiel Falls, which was formerly a falls but was dynamited. At medium water this is now a light Class II rapid which ends in some large rock islands that four generations of canoe books, copying from each other, say are granite but aren't. The river splits abruptly around these islands, and at medium levels some confident maneuvering will be necessary. The AMC guide rates this rapid as 'up to Class IV' at high water. The most we have ever encountered here is mild Class II, but we have not seen them at really high water. But they are definitely barely a rapid at average water levels. In any event this segment is beautiful, and affords some interesting paddling, and a few spots that can be used for summer practice.

Below this the river is smooth all the way to the dam at Fairfax Falls.

Touring boaters using the river at should note that several of these rapids, while short, are real whitewater. THEY SHOULD BE SCOUTED CAREFULLY, AND WHEN THE WATER IS HIGH THEY SHOULD ONLY BE ATTEMPTED BY EXPERIENCED WHITEWATER BOATERS WITH ADEQUATELY EQUIPPED BOATS.

Biologically the middle Lamoille is a fertile river, receiving nutrients from limy bedrock in the headwaters, and treated sewage and farm wastes in the lower watershed. The fertility makes it potentially productive, but also threatens the oxygen supply, especially in the slower and warmer stretches.

The quality of the fishing apparently varies a lot from place to place. The following general picture has been compiled from several sources.

Above Hardwick the steep portions of the river are quite warm in summer, but still, apparently atypically, support a good brook trout fishery.

From Hardwick to Morrisville there are brown and rainbow trout, and the fishery was, at least formerly, good enough to attract national attention. Several fishermen suggested that the fishing many have deteriorated recently. Summer flows below the dam at Hardwick Lake can be very low, and there has been recent highway construction, which creates sediment and can disturb spawning. There are no rapids here, and apparently a good deal of agricultural runoff, and the combination of low flow, high temperatures and no opportunities for reoxygenation may be harming the fishery.

From Morrisville to Jeffersonville the dominant species continue to be brown and rainbow trout; the river here has better flows and is better oxygenated, and there are supposed to be stretches with large fish and excellent fishing, especially below some of the colder tributaries like the Green and Gihon Rivers.

Between Jeffersonville and Fairfax the river is warmer and supports both bass and trout. Reportedly it has local stretches with good fishing but is neither as well known nor as heavily used as the upper parts of the river.

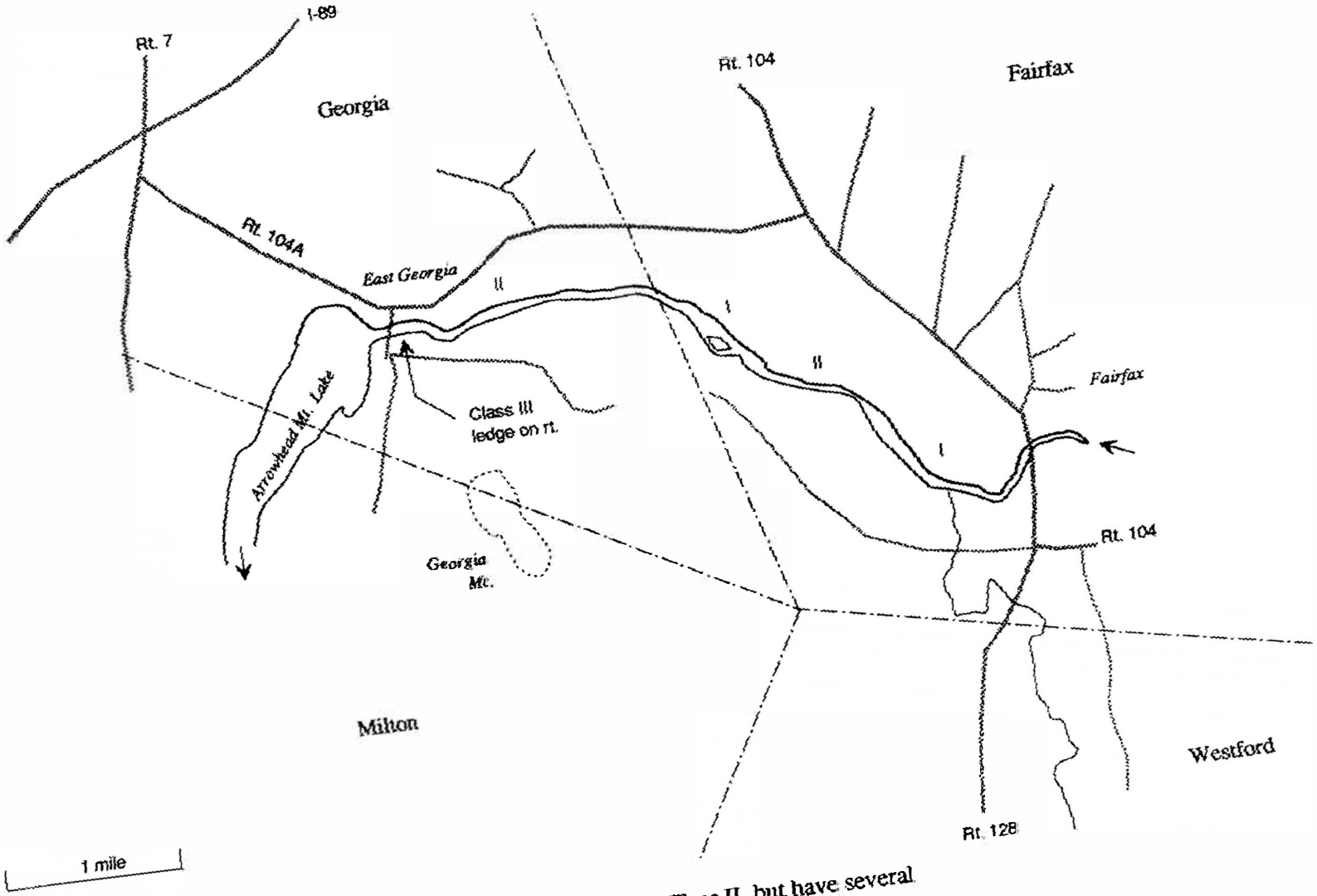
Botanical studies, so far, have largely been negative. The Lamoille lacks the sort of habitats (limy cobble shores, large gorges, limestone ledges) that produce interesting species, and so far we have found no plant species of note along it.

This segment of the river is naturally fertile, and receives substantial nutrient inputs from agriculture and settlement. Hence we rate the isolated rapids as important for water quality.

* * *

We rate this segment as HIGHLY IMPORTANT for river touring because of its length, variety and beauty; and IMPORTANT as a trout stream.

We rate the isolated rapids as IMPORTANT for whitewater practice (and for the spring race sponsored by Johnson College) and IMPORTANT for reoxygenating the river and so helping it handle the nutrient load.



Map 19: Lamoille River, Below Fairfax. The rapids are generally Class II, but have several holes that can be Class III.

8.15 LAMOILLE RIVER 4: Fairfax to Arrowhead Mountain Lake (Arrowhead Mountain Rapids)

Length	4.6 miles
Towns	Fairfax, Georgia
Counties	Franklin
Quadrangle	Milton 15'
Access	Take the side road going southwest from the center of Fairfax and go as far as you can
Elevation	320' to ca. 280'
Average Slope	ca. 10'/mile
Description	large river with big rocks and small ledges; Class II at medium water, to solid Class III at high water
Surroundings	hardwoods & alluvial forest, farmland, some houses
Water Quality	good
Flow Regulation	dams at Hardwick & Fairfax Falls
Hydrology	gauge at Georgia: watershed 1777 sq. km., mean flow 35.0 m3/sec, max/mean 2.8
Geology	Cambrian schists and quartzite; the main area of rapids is where the river leaves the schist and crosses the quartzite.
Biology	reported to be a poor brown trout fishery and to have bass; no plant records from this area.
Known Use	very popular with boaters from the Burlington area
Season	runnable as winter in winter thaws, during spring runoff and after heavy rains; can be run as a touring stream throughout the year
Suitable for	open boats, kayaks in high water

Interruptions none

Importance *HIGH IMPORTANCE AS A WHITEWATER RUN*; one of the very very few rapids on a large river that has not been dammed; the most accessible whitewater in the Burlington area, and usable in winter and early summer when most other rapids are too low. Also IMPORTANT for water quality.

This is a a very valuable piece of water; it is one of the only places in Vermont where you can paddle whitewater on a large, undeveloped river.

This segment of the Lamoille starts in a broad alluvial valley and then drops into a broad wooded ravine. There are no roads or buildings anywhere near the river, and the landscape is exceptionally pretty. The slope is gentle, and the rapids are created by low ledges and large boulders, and possibly by local increases in steepness that do not show up on the topographic map. At moderate water the rapids are light intermittent Class II, good for practice but not very difficult. At high water there are much larger waves and some holes; the rapids are more continuous and the most difficult parts reach Class III. At high water the largest waves are about three feet high and some of the holes are big enough to give an open boat serious problems. But because the river is broad and the current not particularly fast it is easy to miss the holes, and we would rate the rapids as generally Class II, even in high water.

The rapids start about 1 or 1.5 miles below Fairfax. The first rapid has scattered rocks and a lot of waves. They continue, more or less continuously, to below a pair of islands.

The AMC Guide says that the rapids at these islands are Class III at medium water, that there are two drops of 2'-3' here, and that the rapids get harder at high water. We have not seen the rapids at medium water, but at high water the drops are washed out and there are mostly big waves, and the rapids appear to be largely Class II rather than Class III.

These rapids are followed by a Class I segment with scattered rocks and a few waves. Below this is another Class II rapid about 3/4 miles long, which ends in some Class III ledges. These are just below the gauging station, and marked by a power-line crossing the river. There are a number of good passages over these ledges, and some fine waves and holes to play in below them. This is by far the best practice and play place in this segment.

This and the Sheldon rapids on the lower Missisquoi are the only remaining rapids on big rivers in the state. These rapids are interesting because there are big rocks and eddies out in the middle of the river, and because they offer many alternate routes and hence much variety. They are also valuable because, being segments of mostly low gradient, the river increases in depth rapidly with increasing discharge. Hence these rapids become runnable after summer and fall storms, unlike most of the steeper rapids in the state.

Biological information is meager. There are reported to be brown trout, though the river has, by this point, become warm and perhaps too turbid to be a good trout stream. There are some bass. We have done some botanical work in the area but have no records of interest.

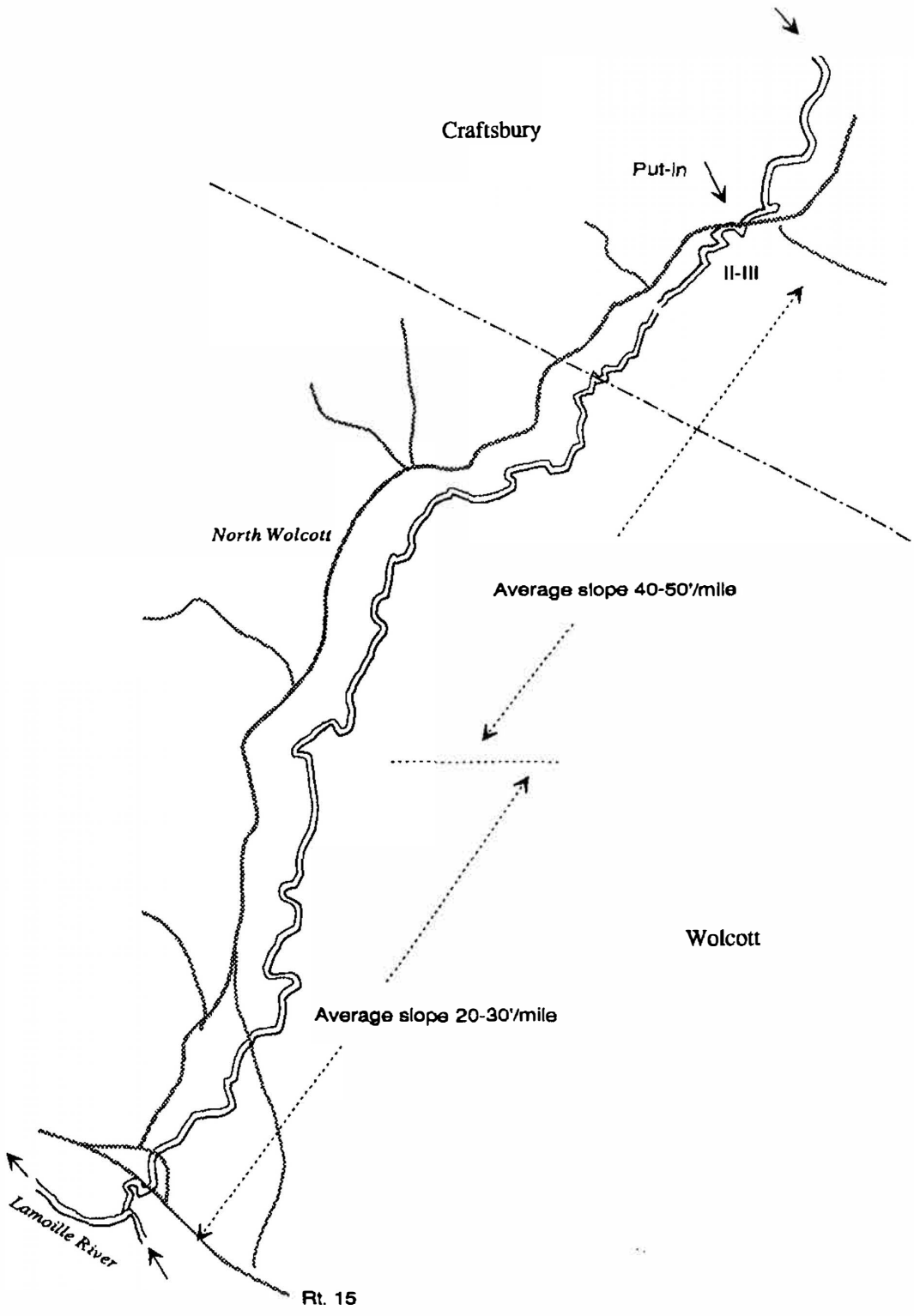
The rapids here are considered important for water quality, because the river receives considerable amounts of nutrients and some organic pollution upstream.

* * *

Rated as HIGHLY IMPORTANT for whitewater boating, as a unique site which gets much use and has a longer season than most other Vermont rapids. Also IMPORTANT for water quality.

* * *

Below this segment there are no major rapids on the Lamoille. There is a handsome limestone gorge in Milton, and a short Class II rapid, ca. 50-100 yards long, below the Peterson Dam, 3 miles below Milton. This rapid runs at moderate water levels, and might be useful for practice.



Map 20: The Wild Branch. At high water the stream is Class III at the bends and Class II between them. Note that it is mostly bends. Fallen trees are common and can be very dangerous.

8.16 WILD BRANCH: Wolcott Road Crossing to the Mouth

Length	ca. 7 miles
Towns	Craftsbury, Wolcott
Counties	Orleans
Quadrangle	Albany, Wolcott 7.5'
Access	from North Wolcott Road
Elevation	1040'-700'
Average Slope	ca. 50'/mile; upper 3 miles 70'/mile
Description	small upland stream; Class II at moderate water, Class III at high water
Surroundings	farms, 2nd-growth spruce & hardwoods; no trash
Water Quality	good
Flow Regulation	none
Geology	Moretown Ordovician quartzite-granulite
Hydrology	no gauge data; watershed ca. 100 sq. km
Biology	no rare plant species, and reported to be a poor fishing stream, with very few trout
Known Use	used and enjoyed by local boaters; not in AMC Guide; Sterling College uses it to teach whitewater.
Season	snowmelt
Suitable for	open boats
Interruptions	watch for trees and barbed wire
Importance	IMPORTANT for boating; not rocky or technical but still a grand high-speed ride.

The Wild Branch deserves its name. It is small stream in an open, narrow, barely alluvial valley. It has some rocks and boulders (but is basically not very rocky), comes up very fast in the spring, makes a quick, unpredictable, twisty, highly technical run, is Class II-III, and is not safe at full flood. It is an endearing stream, but with a dangerous streak. It has an attractive agricultural valley, nice and open and rural, and some nice views of the surrounding hills.

Hydrologically the Wild Branch is a steep stream with a small watershed. This means that it has a narrow channel, but very fast water when it floods. In slope it compares to the New Haven and other difficult runs, but it lacks their volume and has no drops or difficult pitches or holes and waves. But what is does have is right-angle bends, very pushy water, and unexpected obstacles. This means that it is quite hard work to paddle at high water. When you start out you say 'Well that corner is tricky and I'm glad I missed the ice-shelf and the alders, but it isn't really Class III.' But it adds up. After about forty-five minutes of non-stop rapids and what starts to seem like 200 more blind corners, you don't begrudge the Branch its Class III rating a bit.

The gradient is a substantial 70' per mile, but because the Branch is not very rocky and has a low volume it does not produce drops or holes or complicated waves, and is not comparable to streams like the Winhall and Ompompanoosuc West Branch. They have similar slopes but are heavier and a lot meaner. But is a definitely technical run, and one that requires a lot of defensive paddling because of the bends and obstacles. This means that you want to be comfortable handling a boat fast in tight places, and have be able to paddle backwards up anything short of a waterfall. It is also potentially a dangerous stream: ANY STREAM THIS SMALL CAN EASILY BE BLOCKED BY ICE OR DEBRIS OR FALLEN TRESS, AND THE GREAT STEEPNESS AND CONSEQUENT SPEED CAN MAKE IT DIFFICULT TO AVOID SUCH OBSTRUCTIONS UNLESS YOU KNOW WHERE THEY ARE IN ADVANCE. Careful scouting is mandatory.

Like all steep streams there is a great deal of difference in speed between medium water and high water. At medium water it is a pleasant Class II, at high water a clear III.

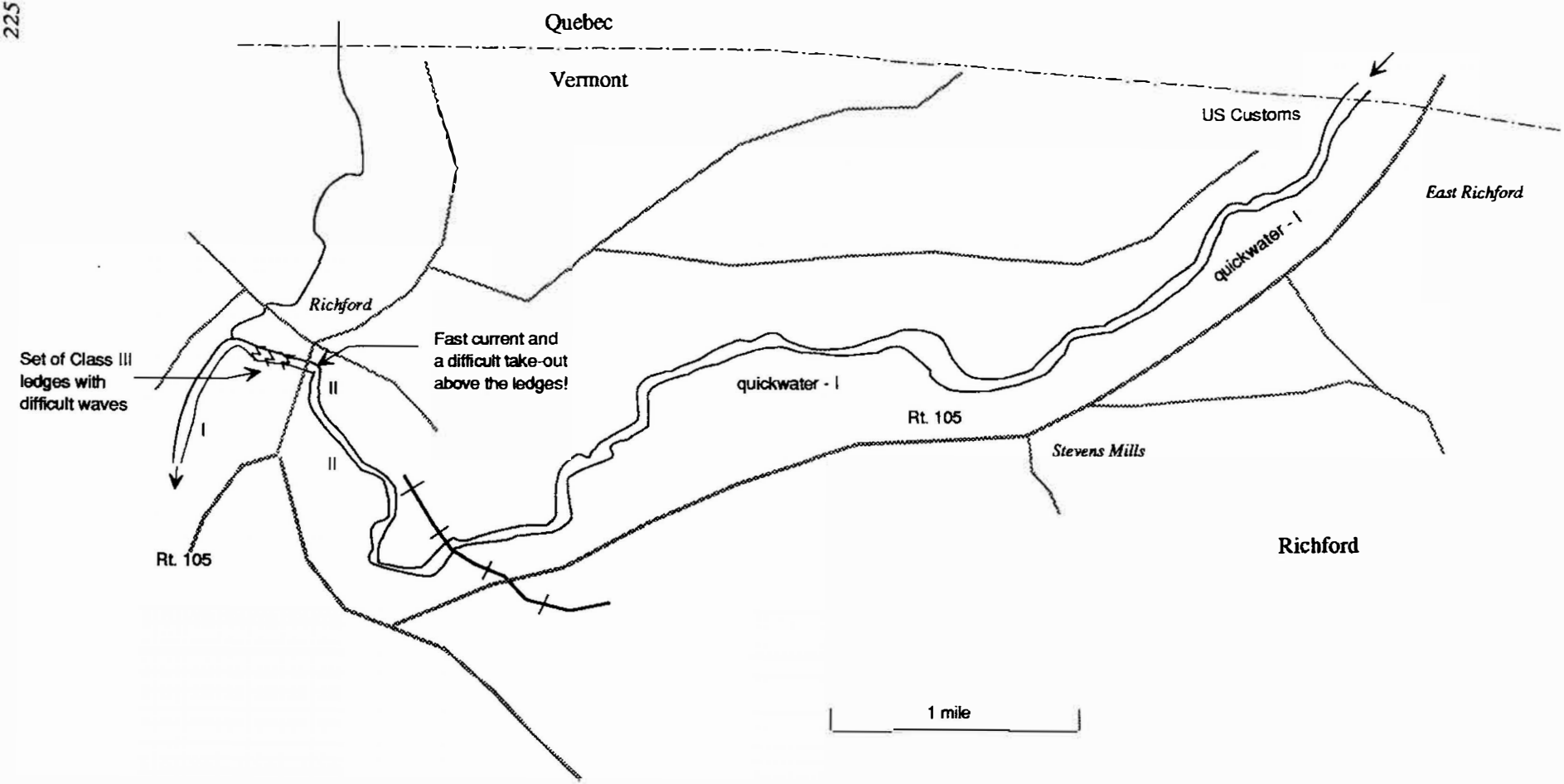
It is mostly used by local boaters, and is the kind of run we call a pasture steeplechase -- very fast and tight, nothing big, but no room to get out either, and no telling what is around the next bend. This is not the sort of rocky, awesome whitewater that the experts travel hundreds of miles to run, but that doesn't mean you don't need to be pretty quick with a paddle to get down it, or that it does not have enough power or potential danger to punish carelessness. It is, however, one of the smallest streams regularly used in Vermont, and this, combined with a rocky watershed where stream levels rise and fall rapidly, means that it has a short season and is mostly used by local boaters who can catch it when it is up.

Biologically it is a stream on quartzitic bedrock (and so low in nutrients), and is fairly steep and very inclined to flood, and runs shallow and warm in the summer. Many of the banks are cleared.

None of this makes for good trout habitat, and the fishing is reported to be poor. As near as we can tell the bank vegetation is what you would expect from a stream in farm country, and we have no records of rare or specialized plants.

* * *

Rated IMPORTANT for boating. We note that although because of its short season and unpredictable habits it really doesn't have regional importance, in many ways it is a perfect small stream of its kind, and can offer you a very memorable run.



Map 21: Missisquoi Near Richford This segment is mostly quickwater or Class I with the exception a shortClass II rapid above Richford and the set of ledges in Richford. The ledges have a series of diagonal waves and are quite heavy at high water. There are tongues, but they are offset. If you set up carefully and catch all the tongues it is easy. If not you sink.

8.17 MISSISQUOI RIVER 1: *East Richford to Richford*

Length	6 miles
Towns	Richford
Counties	Franklin
Quadrangle	Jay 15'
Access	customs station in East Richford
Elevation	500'-420'
Average Slope	ca. 13'/mile
Description	medium-sized river, pretty woods and rural setting, mostly quickwater but with 1 mile of intermittent Class II rapids and an excellent Class III drop
Surroundings	woods, farmland, village of Richford
Water Quality	good
Geology	Cambrian Underhill schist
Hydrology	gauge at Richford: watershed 1241 sq. km., mean 26.3 m3/sec, max/mean 3.4
Biology	reported to have good rainbow & brown trout fisheries; no rare plants
Flow Regulation	none
Known Use	probably moderate use
Season	probably much of the year
Suitable for	open boats
Interruptions	large Class III ledge in Richford
Importance	HIGH IMPORTANCE as a touring stream with a short section of whitewater that runs after rains; IMPORTANT as a fishery

This segment is mostly quickwater but includes an important short rapid that can be run in the summer. It is a very pretty portion of the river with fairly fast current, nice views, and some handsome woods and bars along the river. The area is rural and sparsely settled, and at least half the run is completely away from houses and roads.

The run begins where the Missisquoi re-enters the United States at East Richford. The first 5 miles are quickwater, and in our estimation are one of the most varied and enjoyable parts of the middle Missisquoi. Light Class II rapids start a mile or so above Richford; there are some nice eddies and places to ferry and practice. The rapids increase in intensity just above the town; the river runs between two retaining walls, and the rapids become Class II-III depending on water level. There is a sharp left turn and immediately below this the Route 105 bridge. A substantial Class III ledge extends across the river below the bridge, and boaters will need to make a moderately difficult landing here to scout the ledge. The ledge is actually a series of drops, the steepest of which has some heavy rollers, a hole, and some diagonal waves. At medium water this can be run fairly easily to the right of center, but boat placement is critical, and you should scout carefully. At high water it may be very difficult and possibly becomes Class IV.

There are some excellent play places below the ledge; the whole rapid can be used at medium-low water and so is a valuable summer rapid and place to practice.

The section from the retaining walls to the ledge is Class II even at medium water; BOATERS WITHOUT WHITEWATER EXPERIENCE SHOULD TAKE OUT ABOVE THE RETAINING WALLS; ALL BOATERS SHOULD SCOUT FROM THE ROUTE 105 BRIDGE AND PLAN THEIR TAKEOUT.

We have little biological information about this segment. It is reported to have fairly good brown and rainbow trout, and certainly looks like what a good trout stream is supposed to look like. Vermont Trout Streams says that there is good trout fishing in the lower rapids and around the bridge in Richford. We have no records of rare plants but did find the sandbar willow (*Salix exigua*, formerly *Salix interior*) on several sandbars here. This is a species long known from Lake Champlain that has only recently been discovered in the middle segments of the Lamoille and Missisquoi Rivers.

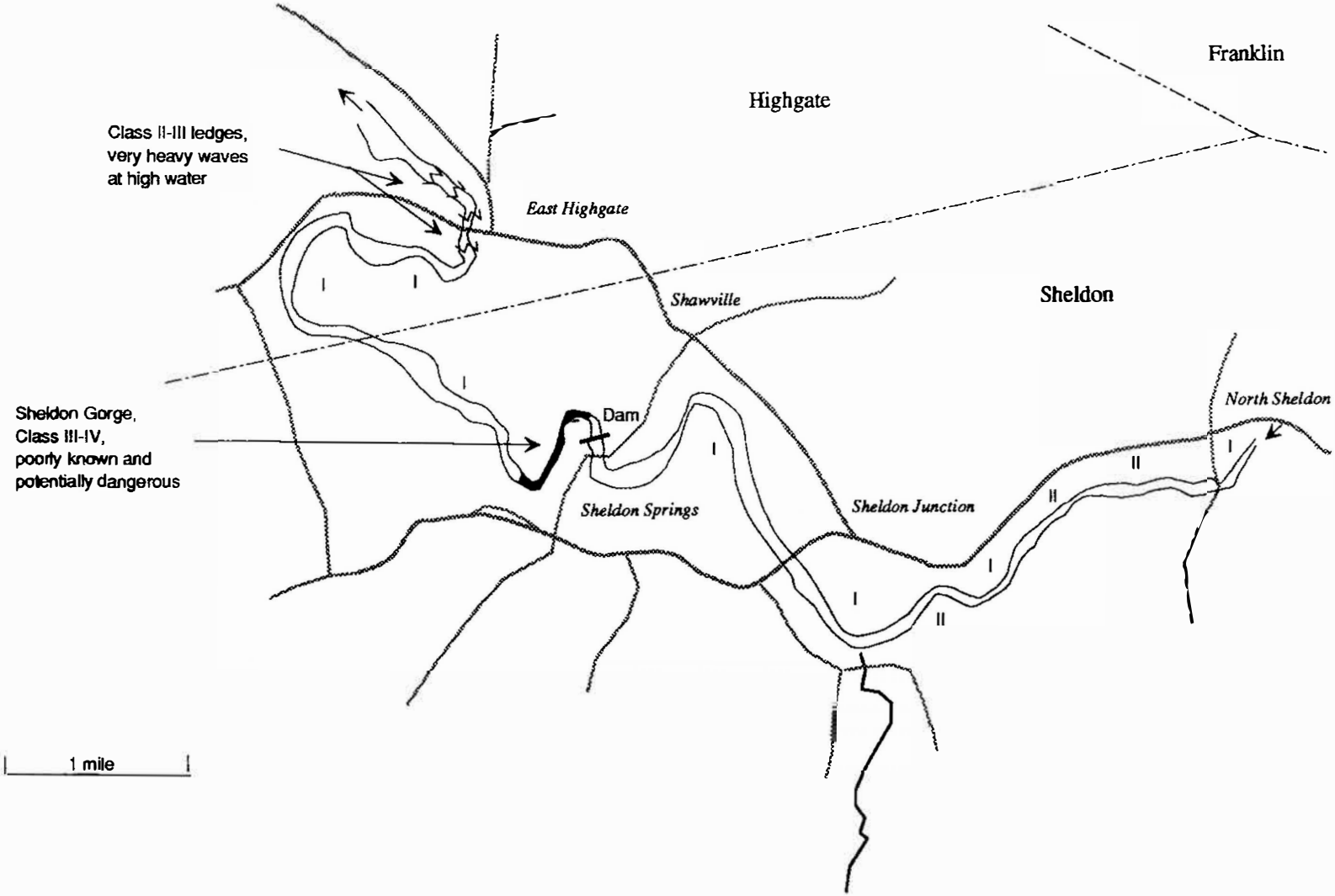
The Corps of Engineers is currently preparing an impact statement on an ice-control dam that would be placed a little ways above the bridge in Richford. The dam would have a permanent pool about a mile long, and so would eliminate the whitewater segment above Richford, and would seemingly damage the trout fishing in this segment. They were originally considering a 'stop-logged' dam which could be opened after the ice went out and would not impede fishing or boating in the spring and summer; this was abandoned in favor of a design with a permanent pool.

WE STRONGLY OPPOSE ANY DAM WITH A PERMANENT POOL HERE, ARGUING THAT THE RAPIDS AND FISHING ARE VALUABLE AND THAT WATER ICE-CONTROL

CAN BE ACHIEVED WITHOUT SACRIFICING THE PRESENT SPRING AND SUMMER USES OF THE RIVER. We note that the lower Missisquoi has 4 dams (Enosberg Falls, Sheldon, Highgate Falls and Swanton) and the segment from East Richford to Enosberg Falls is the only place on the middle and lower river where you can make a full day's canoe run without encountering a dam.

* * *

Rated HIGHLY IMPORTANT a fine touring stream with more natural beauty than the segment immediately below it, and a fine short set of rapids that can be run in wet periods in the summer and fall. The big ledge at Richford is rated IMPORTANT for whitewater practice.



Map 22: Missisquoi Near Sheldon. Most of the river is quickwater, except as marked. The gorge at Sheldon Springs is not much used. It has sharp, undercut rocks and appears dangerous. At medium levels it appears to be Class III-IV. It may be harder at high levels.

8.18 MISSISQUOI RIVER 2: North Sheldon to Sheldon Springs

Length	5 miles
Towns	Sheldon
Counties	Franklin
Quadrangle	Enosberg 15'
Access	bridge in North Sheldon
Elevation	340'-320'
Average Slope	ca. 10'/mile
Description	large river with big rocks in bed; intermittent Class II rapids for one mile, then quickwater and flatwater to the dam at Sheldon Springs.
Surroundings	farmland, road and railroad, village of Sheldon Junction
Water Quality	good; receives some treated wastes and much agricultural runoff
Geology	Quartzite and schist, passing into limestone and shale at the gorge in Sheldon Springs.
Hydrology	gauge at Richford, ca. 20 miles above this segment: watershed 1241 sq. km., mean 26.3 m3/sec, max/mean 3.4
Biology	reported to be too warm for a good brown trout fishery; botanical survey of much of this segment in 1983 did not find any rare plants here. We do have a few interesting species elsewhere on the Missisquoi.
Flow Regulation	dam in Enosburg Falls
Known Use	? moderate local use, some touring boaters
Season	high water
Suitable for	open boats
Interruptions	none

Importance IMPORTANT for boating; interesting rapid on a large river, good potential for use when other rapids are not available. IMPORTANT for oxygenation; low gradient river with impoundments and substantial nutrient input.

This segment of the Missisquoi is a large flat river in a broad, heavily farmed, alluvial valley. The country is attractive with some nice river views, but not wild. The river is away from the road for much of this segment and, like the Fairfax rapids on the Lamoille, gives you the welcome experience of being on a big river but seeing mostly woods and open land. Altogether this is an attractive paddle, and quite important for scenery.

The first half mile below North Sheldon is flatwater. Rapids begin as the river turns left, and extend for a mile. The rapids are basically Class II and consist of scattered rocks, a low broad ledge, and big waves. Halfway down there are two ledges with holes below them the first on the left and the second on the right. These are Class III at medium water, but can be avoided. Thus we judge these rapids Class II or II+ at medium water, but note that they may go to Class III at high water.

These rapids, like those of the Lamoille below Fairfax which they resemble, are interesting because they occur on a broad segment of a large river. Hence when you paddle them you can be some distance from the shore, and have considerable choice of where to go, and of whether to run the most difficult places or avoid them. To our knowledge these two segments are the only rapids of this sort left in Vermont; others that formerly occurred have been destroyed by dams. For this reason we regard them as particularly noteworthy, and rate both as important.

Botanical surveys found a few interesting species in the Sheldon Springs Gorge (see below) and one (*Lathyrus palustris*, a wild pea) on the shore near East Highgate, but none in this segment. According to to Vermont Trout Streams the water is warm here and the fishery is poor.

The Missisquoi receives considerable nutrient input from farms and treated wastes, and is a low gradient stream with few rapids. Hence we regard these rapids as very important for oxygenation and water quality.

* * *

Rated IMPORTANT for boating. It is an interesting rapid on a large river which ought to be usable late in the spring and after rains, and hence be available when most other rapids are not. Not given a higher rating because the rapids are intermittent, and so not as important as those on the lower Lamoille. Rated HIGHLY IMPORTANT for water quality and oxygenation: warm fertile streams like the Missisquoi need all the oxygen they can get.

* * *

The Sheldon Springs Gorge, just below this segment is a 3/4 mile long, Class IV-V gorge. The gorge is potentially a short and challenging covered-boat run. The dam at the head of the gorge was recently rebuilt, and there has been talk of whitewater release here, though thus far there have not been any. We talked to several paddlers who had thought about running the gorge, but have not met anyone who has actually done it. There are a lot of sharp edged, irregular rocks in the gorge, and it could conceivably be a dangerous piece of water.

Formerly the gorge was a breeding site for sturgeon. Currently a scarce plant, the great St. Johnswort *Hypericum pyramidatum*, occurs here. At present most of the flow is cut off by a dam and diversion, and the water quality is poor in the summer. It would definitely be benefited by improved summer flows.

* * *

The Missiquoi has a number of isolated ledges and short rapids, some of which may be interesting for practice, and all of consequence to touring boats. See the Appendix for a list.

CHAPTER 9. LAKE MEMPHREMAGOG WATERSHED

The Memphremagog Basin is a a small watershed in northern Vermont, with mostly lowland streams without heavy whitewater. It includes four main streams:

Barton River	Clyde River*
Black River*	Willoughby River +

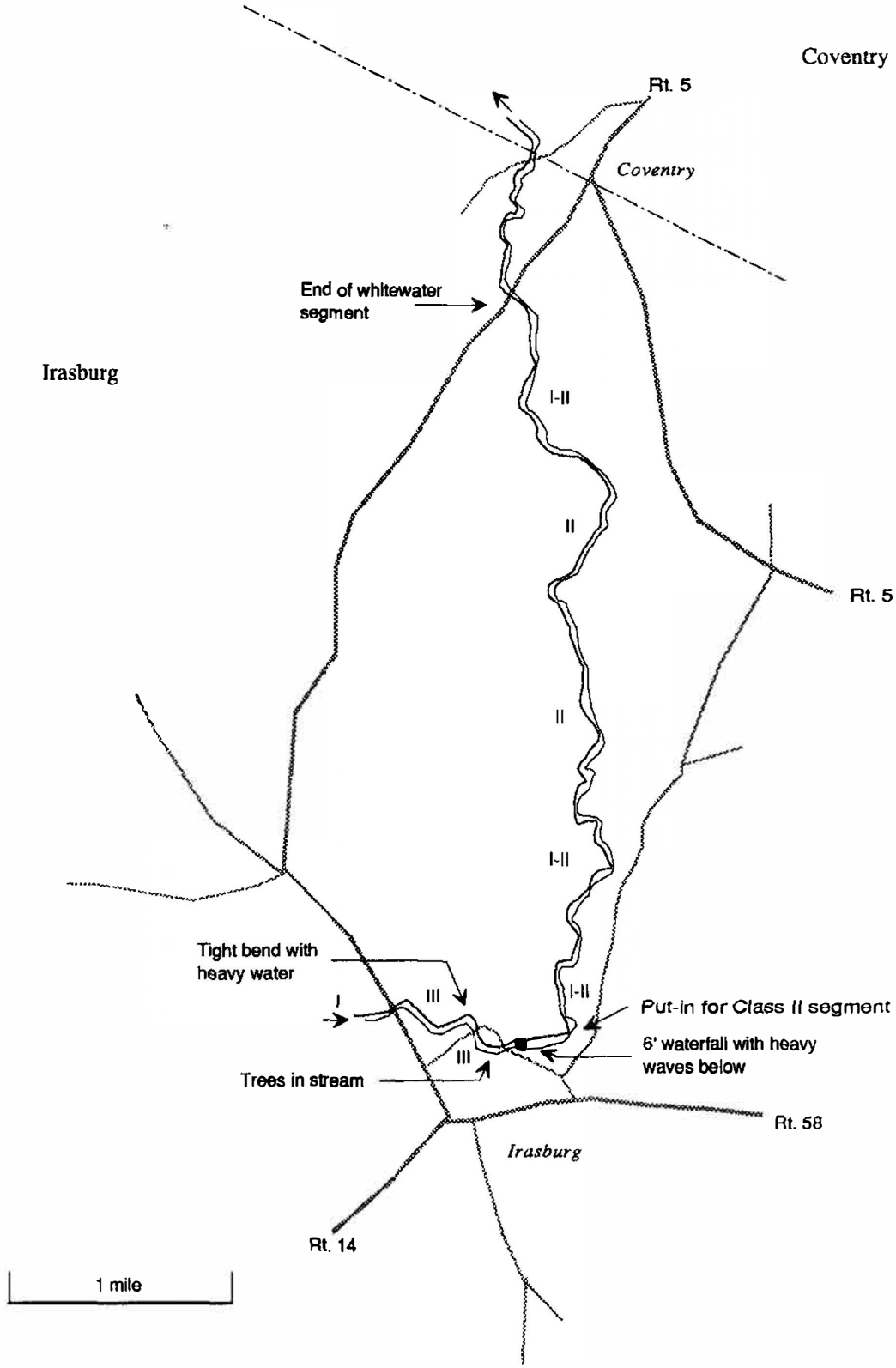
* = a river treated in text
+ = a possible whitewater run; see Table 3.3, p. XX

It is a rolling, sparsely populated, handsome part of the state. Many of the valleys are limy, and there are a number of botanically important marshes and cedar swamps in the watershed. The streams as a whole are fertile (except for a few headwaters segments on granite) and a number have fine fisheries. Migrating fish that ascend the streams from Lake Memphremagog are important throughout the watershed and the Barton and Willoughby River in particular are famous for their spring runs of rainbow trout.

The Black and Clyde are medium-sized streams with swampy headwaters and fine Class II or low Class III rapids in their middle sections.

The Barton is largely a flatwater river, small and alder-lined above Barton and medium-sized and winding and very secluded and handsome below Orleans. A short segment one mile north of Barton has Class II-III rapids and is listed in the section on isolated rapids.

The Willoughby is a small stream, originating in Lake Willoughby and joining the Barton in Orleans. Its most famous feature is a sloping falls just east of the center of Orleans where people come by the hundreds in spring to fish or watch the trout jump the falls. A three mile segment of the Willoughby from Evansville to the falls at Orleans may be runnable. It is tight and steep (ca. 60-80'/mile), has a number of small drops and ledges, and, if runnable at all, will be a technical Class III. We have not scouted the whole segment and have no direct information from anyone who has tried it. It may well be one of those streams that is unpleasantly thin and rocky at medium water and fast and dangerous at high water.



Map 23: Black River. There are approximately 20 miles of flatwater paddling above this segment and 5-7 miles of flatwater below it. The falls at Irasburg are runnable but need careful scouting. The section immediately above them runs among trees at high water and is dangerous.

9.1 BLACK RIVER: *Irasburg to Coventry*

Length	ca. 5 miles
Towns	Irasburg, Coventry
Counties	Orleans
Quadrangle	Irasburg 15'
Access	from Rt. 58
Elevation	800'-700'
Average Slope	20'/mile (maximum slope ca. 30'/mile, steep pitch at Irasburg ca. 60'/mile)
Description	medium-sized stream, continuous Class II rapids, with short Class III rapids and a Class III-IV drop at Irasburg
Surroundings	no data
Water Quality	good
Flow Regulation	none
Geology	Devonian limestone with interbedded slate and phyllite
Hydrology	gauge in Coventry: watershed 316 sq. km., mean flow 5.8 m3/sec, max/mean 3.1
Biology	excellent resident population of brown trout; seasonal runs of rainbows, land-locked salmon, brown trout and wall-eyed pike from Lake Memphremagog; no botanical records
Known Use	locally popular with whitewater canoeists, popular fishing stream
Season	snowmelt and after rain
Suitable for	open boats
Interruptions	difficult rapids and drop right at Irasburg

Importance IMPORTANT as a whitewater run; HIGHLY IMPORTANT for fishing

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Hydrologically this is a stream with a good-sized watershed; at Coventry the watershed is about three-quarters of that of the West at Jamaica. Above Irasburg the stream is winding and slow, and has some fine swamps. It is an excellent stream for birdwatching, and is often used for practice by flatwater canoe racers because it opens early in the spring and is slow enough that in a racing boat you can paddle both upstream and downstream and so avoid setting up a shuttle. A flatwater race, which is one leg of a ski-run-bike-paddle quadrathalon sponsored by Craftsbury Center, is held here in March.

Below the Route 14 crossing north of Irasburg there is a short steep segment with a gradient of approximately 60' per mile. It begins with a straight run of Class III waves, then a steep turn at a mill, then a series of low Class III ledges where there are, somewhat curiously, trees in the middle of the rapids, then a bridge, and then a 5' waterfall, runnable to the right and Class III-IV depending on the level[13]. After this the river flattens and the rapids become Class II. This steep segment is occasionally run by expert boaters, but it is considered tricky and a little dangerous.

The Class II whitewater run on the Black begins just below this segment, where the river turns north from Route 58. There is a convenient put-in right off the dirt road. The gradient is between 20 and 30 feet per mile, the river is rocky and interesting and pleasant, with fairly uniform rapids and no ledges or difficult spots. After a short run through farmland the river turns into the woods for two miles, then into farmland again and enters Coventry. There are two waterfalls in Coventry, and below them 5 miles of quickwater to Lake Memphremagog.

The total run from Route 58 to the covered bridge at Coventry is about 5 miles, of which 2-3 miles are good medium Class II whitewater. The run is excellent for beginning boaters and is often used by whitewater classes from Sterling College. It does not challenge experienced boaters, but both the wooded and the open portions of the stream are exceptionally pretty, and highly regarded by the people that know it. Dave and Ann Brown of Craftsbury say that it is an excellent place to see wildlife, and that in recent years deer, bear, otter, and fishers have been seen along it.

Most of the Class II water ends above the Rt. 14 bridge south of Coventry; the normal takeout is at the covered bridge.

The waterfalls in Coventry are about 6-8' high. They have not been scouted at high water and we do not know whether they are runnable or not, or whether there might be good play places below them.

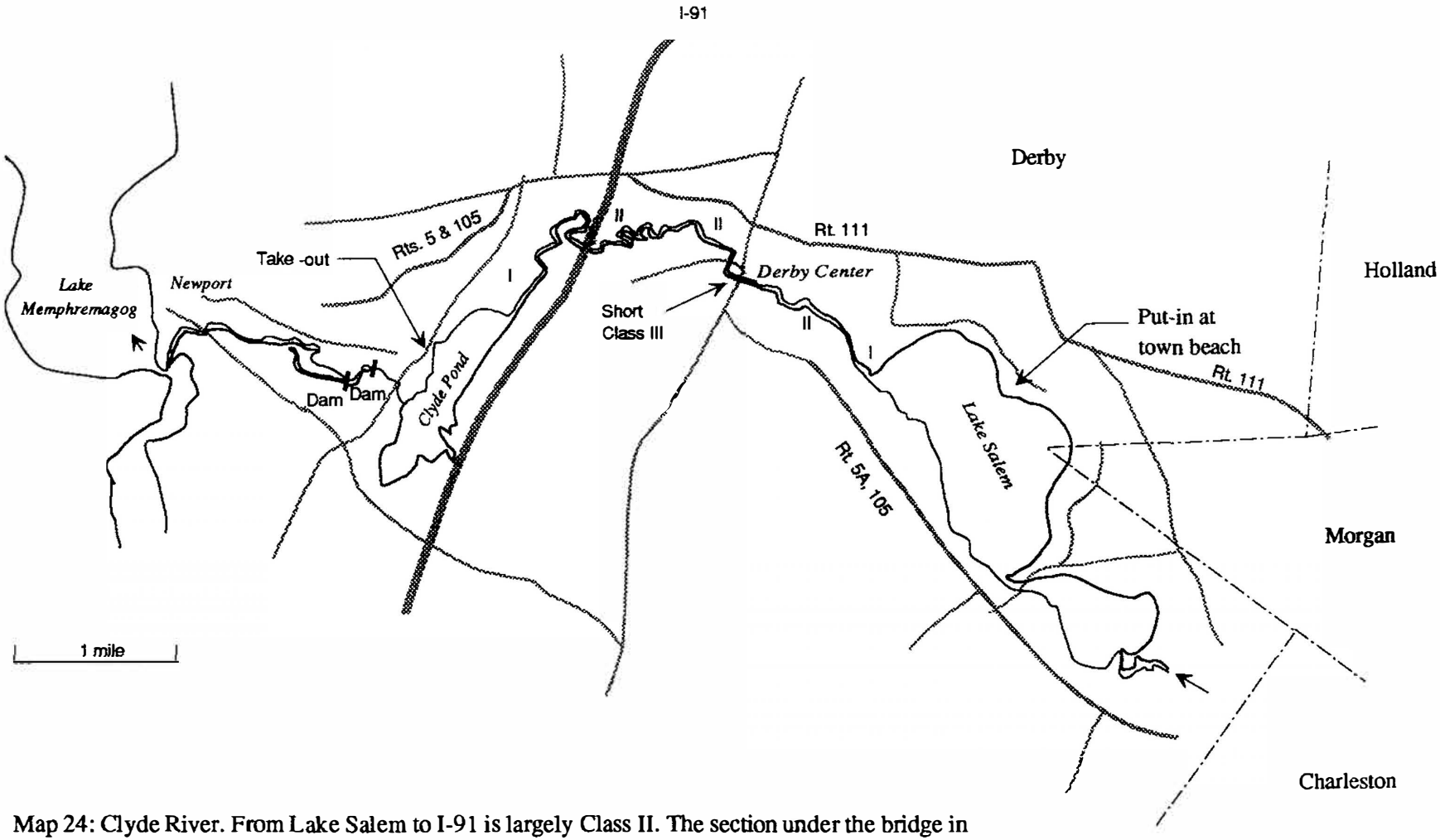
Biologically the Black is well-known locally as an excellent fishing stream. The watershed has limestone bedrock and so growth rates are good. There are resident populations of brown trout

13. This is one of those drops where the back of the boat gets buried in mush and it is up to the front paddler in a tandem boat to put the power on and pull the boat through.

which reach good sizes, and spawning runs of rainbows, browns, wall-eyed pike and occasional land-locked salmon from Lake Memphremagog. Some ascend the river all the way to Irasburg while others don't go further than the falls at Coventry.

We have no botanical information on this segment. Small populations of the rare orchid *Calypso bulbosa* are found in cedar swamps near the headwaters of this river. With the limy bedrock and northern location this segment could well yield some interesting species.

Rated IMPORTANT for boating, and HIGHLY IMPORTANT for fishing.



Map 24: Clyde River. From Lake Salem to I-91 is largely Class II. The section under the bridge in Derby Center is II-III or III depending on level. Open boats sometimes sink here.

9.2 CLYDE RIVER: Salem Pond to Clyde Pond

Length	ca. 3 1/2 miles
Towns	Derby
Counties	Orleans
Quadrangle	Memphremagog 15'
Access	somewhat restricted; either put in at the south end of Salem Pond and paddle about 1.5 miles across of the pond, or get permission to use the road to the YMCA camp at the north end of the lake.
Elevation	960'-780'
Average Slope	20-25'/mile
Description	pretty stream, much of it in cedar woods; Class II, with a little Class III at high water
Known Use	popular with local boaters; annual downriver race
Geology	Devonian limestone interbedded with phyllite and schist
Hydrology	gauge at Newport: watershed 368 sq. km., mean flow 7.3 m3/sec, mean/max 2.3; watershed at Salem Pond ca. 355 sq. km.
Biology	good populations of brown trout in this segment; some wall-eyed pike in and below Salem Pond; small-mouth bass in the lower stream; former land-locked salmon run. No botanical data.
Season	snowmelt, after rain, water releases
Suitable for	open boats
Interruptions	none
Importance	HIGHLY IMPORTANT both for boating and fishing; a pretty and exciting run in a unique setting, much enjoyed by local boaters, in an area where there is not much whitewater. Good fisheries but isolated from the lake by dams and not getting the spawning runs of other rivers in the watershed. IMPORTANT for water quality because of the fertile watershed and impoundments above and below.

A medium-sized stream, similar in slope and volume to the Black, and with water of about the same difficulty.

This is a unique whitewater segment. It begins on one lake, descends into a cedar forest, makes a quick passage under the main street of Derby, goes back into the cedars, and finally emerges in another lake. It is a short run but combines fine water, a beautiful setting, and a remarkable sense of isolation.

The Clyde and its small tributaries the Pherrins and Oswegatchie Rivers begin in the uplands around Island Pond. The Clyde becomes paddleable about 2 miles below Island Pond. The next 13 miles, to Pensioner Pond, go though a large tract of wetlands called the Buck Flat Swamp and are a great flatwater paddle at high water.

Starting at Pensioner Pond the Clyde descends through a chain of 4 ponds and then a short steep wooded ravine, entering Lake Memphremagog at Newport. The whitewater segment, between Salem Pond and Clyde Pond, is the only part that is normally paddled. Because of access problems you need to paddle across Lake Salem to get onto this segment, and across Clyde Pond to get off it. The ponds keep their ice fairly late, and it is often late April or even early May before they are open. Fortunately, because of the large headwaters swamps and the natural lakes in the drainage, the Clyde rises and goes down later than other streams in the area and is often runnable long after the Black and upper Lamoille are too low.

The run begins at Salem Lake. The only public access is from the Derby beach on the NE corner. From there you paddle 0.8 miles west to the the lake outlet. The river is lined by cedars; the gradient gradually increases, rocks appear, and soon you are running a full Class II rapid -- with a lot of volume -- down what appears to be the middle of a cedar swamp. It is very beautiful and private and secluded here. Boaters say it is a good place for birds and wildlife. It is definitely a good place for whitewater technique, staying Class II or at most II+, but with a lot of nice big rocks and waves to practice on.

After a little over 1 mile you leave the swamp and go under the Route 105 bridge south of Derby Center. The river steepens slightly here and there are several holes and big waves, Class II+ at medium water and possibly Class III at high water. This is a delightful rapid, difficult enough to be challenging but still straightforward and safe.

Then the river goes into a ravine, crosses under I-91, enters another cedar swamp, and gradually flattens and widens into Clyde Pond, which is undeveloped and very pretty. The rapids in this section are all Class II at medium water.

There is no public access on Clyde Pond. Boaters usually paddle the length of the pond and take out by a farm road on the SW end.

There has recently been some heavy logging in the upper part of this segment. The logging comes right down to the stream and several people we talked to questioned whether this was legal. The answer is that it is legal, but is still regrettable.

An annual open canoe race is held here, starting at the south end of Salem Pond and paddling across the pond and down the river. It is a hybrid sort of a race: flat water for about 2 miles, rapids for 5 miles, and flatwater to the finish. Like many small races it was formerly a local event but now draws competitors from some distance, including some of national caliber. The whitewater is not particularly difficult or dangerous. A lot of competitors use flat-water racing boats, paddle as fast as they can across the lakes, and hope that they make it through the waves. All sorts of boaters and boats turn out for it, and there are always lots of stories of spills and sinkings.

Like the Black, this is a limestone stream. It is fed from cedar swamps in its headwaters and so has fairly steady summer flows and cool temperatures. This segment has a good resident population of brown trout; elsewhere there are brook trout, rainbows, and land-locked salmon. Salmon were introduced into the Clyde some 80 years ago, and a good salmon run was established. Subsequently the run died out, reportedly because the hydroelectric plants switched to saving water and generating only at peak demand, and this created highly variable flows. At present the state is attempting to arrange for minimum flows and fish movement over the lower dams, preparatory to an attempt to restore the salmon.

No botanical records from this segment. The 'Great Falls' of the Clyde, just above Lubber Lake, are an interesting but somewhat degraded limestone gorge, and are described in the VWG report.

* * *

Rated HIGHLY IMPORTANT for boating, IMPORTANT for fishing, and IMPORTANT for water quality.

CHAPTER 10. CONNECTICUT RIVER WATERSHED

The Connecticut River Basin is the largest watershed in the state, running the whole length of eastern Vermont from Canada to Massachusetts, and draining the eastern slopes of the Green Mountains and their associated uplands. The watershed has much whitewater, which tends to occur in predictable geographic settings. Many of the rivers run southwards for some distance in inter-montane valleys, and then, having accumulated watersheds of considerable size, turn eastwards toward the Connecticut River. As they do so they encounter rocks of high metamorphic grade and considerable structural complexity, and steepen their slopes. The resulting whitewater segments are typically 4-8 miles long, with slopes anywhere from 20-50'/mile. They are never as steep as the mountain streams on quartzite and gneiss on the western slope of the Green Mountains, but because they often have larger watersheds and more reliable flows they are on the whole more important for boating.

The watershed includes the following streams:

Connecticut River*
Nulhegan River *
Passumpsic River
East Branch of Passumpsic*
Wheelock Branch of Passumpsic
Miller Run +
Sleepers River +
Moose River*
Stevens River +
Wells River
Waits River*
Tabor Branch of Waits +
South Branch of Waits +
Ompompanoosuc River*
West Branch of Ompompanoosuc*
White River*
1st-3rd Branches of White*
West Branch of White +
Tweed River +
Brandon Brook
Ottauquechee*
West Branch II of Deerfield*
N. Br. of Ottauquechee +
Bernard Brook +
Lulls Brook +
Mill Brook +
Black River*
Williams River*
Saxtons River*
West River*
Winhall River*
Wardsboro Brook*
Mill Brook
Wardsboro Brook II
Grassy Brook
Rock River #
Whetstone Brook +
Green River*
North River #
Deerfield River
West Branch I of Deerfield*
East Branch of Deerfield*
North Branch of Deerfield*

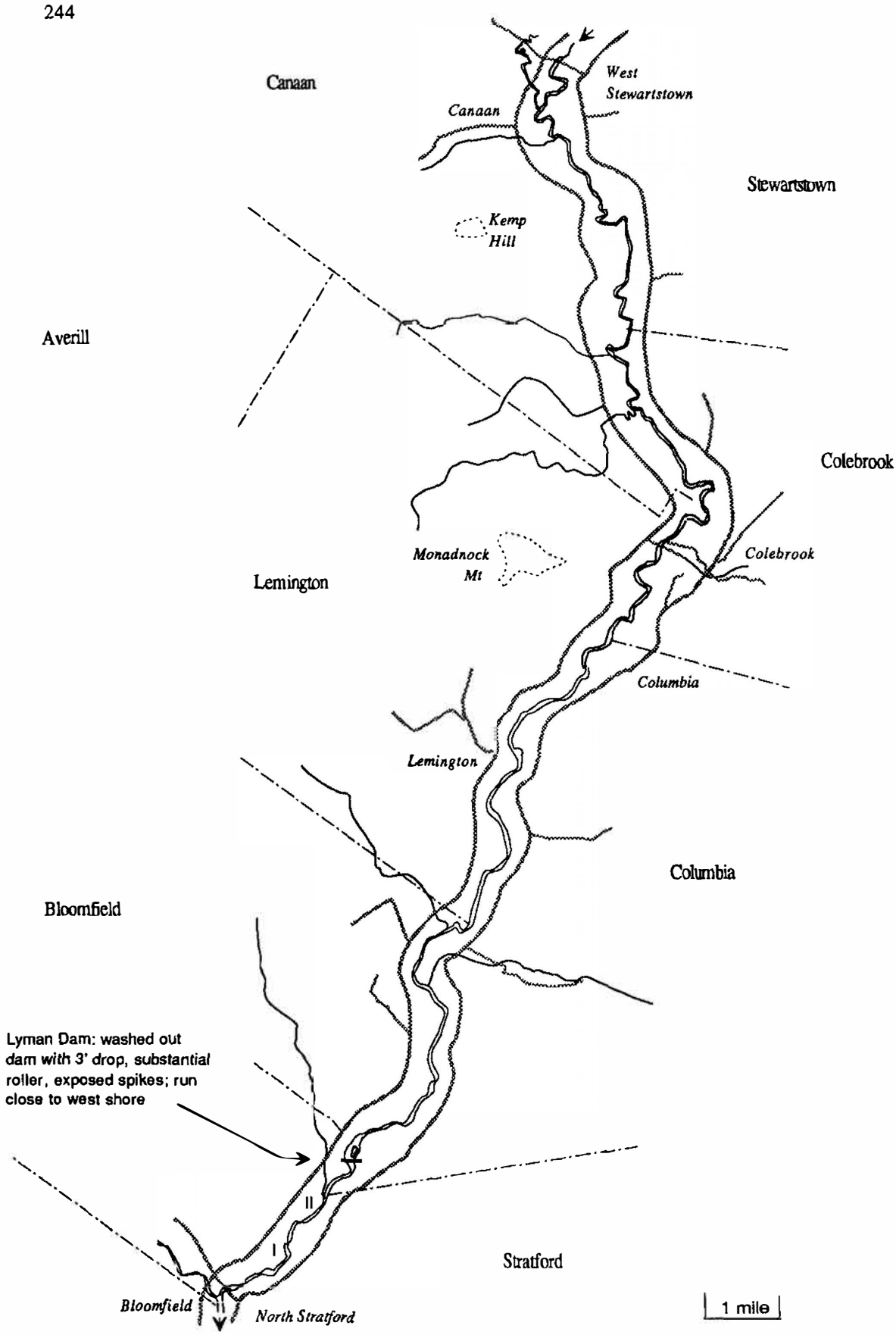
* a whitewater run described in text
\# a stream known to have whitewater, described in theAppendix
\+ an unknown stream that appears hydrologically to be a possible whitewater run; see Table 3.

The major rivers in this watershed divide in the following way with respect to boating. The Connecticut, Williams, Wells & lower West are excellent touring rivers with occasional white water. The Passumpsic, Waits, White, Ottauquechee, middle West, Green and Deerfield West Branch are good Class II runs. The Moose, Ompompanoosuc, Black, Saxtons, upper West, and Winhall have Class III sections, and are demanding runs at high water. The portion of the West below the Ball Mountain Dam is the biggest Class III river in Vermont, and one of the best loved in all of New England. The Wardsboro is a tricky Class III-IV run that becomes dangerous at high water. It is runnable only a few days a year, but is valued for its difficulty.

As in other watersheds, a number of small streams, indicated by a + above, have the proper combination of slope and watershed to be potential whitewater runs, but have not been explored. See Table 3-3 for details.

Two streams, the Rock River and the East Branch of the North River definitely have whitewater runs, but were overlooked during the fieldwork for this report. They are briefly noted in Appendix 1.

Besides the major whitewater runs, this basin also contains a number of isolated rapids which are summarized in the Appendix, and much good water for general touring, particularly on the Connecticut, Wells and White Rivers.



Map 25: Upper Connecticut. The river is mostly quickwater or Class I except for the Class II below Lyman Dam. Lyman Dam is easy to run but potentially dangerous because of the spikes and roller.

10.1 CONNECTICUT RIVER: Lyman Dam to Bloomfield

Length	ca. 3 miles
Towns	Bloomfield
Counties	Essex
Quadrangle	Averill 15'
Access	From Rt. 102
Elevation	1000'-900'
Average Slope	ca. 30'/mile
Description	Medium-sized river with rocky banks; mostly quickwater, with 2 miles of Class II rapids; handsome rural valley
Surroundings	hemlock-hardwoods forest, some meadows, occasional houses; no trash
Water Quality	good
Flow Regulation	none
Hydrology	watershed at rapids estimated at 300 sq. km.
Geology	Devonian schist and phyllite, with occasional limy areas
Biology	excellent populations of rainbow & brown trout; designated a no-kill section: fish must be taken on flies or lures, and released immediately; botanically interesting, several rare species occur
Known Use	general canoe touring; probably rarely visited specifically for whitewater
Season	can be run all year; good whitewater in spring and after heavy rains
Suitable for	open boats
Interruptions	remnants of old dam at Lyman

Importance HIGHLY IMPORTANT for boating, fishing and botany; the last remaining rapid of any length on the Connecticut River

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The Connecticut here is a medium-sized river, with the banks partially open and partially wooded. The intervale is narrow in most places, but there will occasionally be a big terrace. The channel and shores are rocky, and there are occasionally small ledges on the banks.

The whitewater segment, which begins at Lyman Dam, has an average slope of about 30'/mile. The watershed is substantial and the river is hydrologically similar to the West below Jamaica.[14] There are many rocks, and the river is quite pretty and wild.

The whitewater extends for about 2 miles downstream from Lyman Dam. The dam is breached and largely gone. The remnants of the dam provide a drop of ca. 3' with a substantial roller below. In the summer the dam is Class II and the rapids below Class I; in medium water the dam is Class III and the the rapids below Class II. There are some steel spikes in the footings of the dam that make it dangerous to play or spill here: the safest passage is to the far right.[15]

We have not seen the rapids at high water, and cannot estimate how difficult they become. LYMAN DAM IS POTENTIALLY A DANGEROUS DROP, WHICH MIGHT TRAP A BOATER; IT SHOULD BE SCOUTED CAREFULLY AT HIGH WATER.

The rapids continue for 1.5 to 2 miles, and are followed by quickwater to Bloomfield.

The Lyman-Bloomfield rapids are very pleasant on a summer trip. They are mild but invigorating and make a lovely change from the smoothwater elsewhere. Since so much Vermont whitewater can only be run early in the spring it is a great pleasure to run even mild rapids on a hot sunny day. They appear to be one of our best summer rapids, and had this segment no other virtues it would still be important for this reason alone.

* * *

This segment has considerable biological importance. The river is cool, clean, and fairly large, and has good summer flows and some lime in the bedrock; it is an excellent trout stream, and fairly large fish have been reported. Like all of the main stem of the Connecticut it is managed by the New Hampshire Fish and Game Department, and can be fished with either a Vermont or New Hampshire license. This section is reserved for fly-fishing and a no-kill policy is in effect.

We made a brief botanical survey of about 20 miles of the upper Connecticut in 1983. We were looking for some of the rare limestone river-ledge plants. We did not find any of them but did note a number of interesting species on limy cobble shores and river bars. These included *Salix*

14. It does not, however, have the short steep passages that the West does, and so the whitewater is not as intense.
15. If you run the dam on river right there are some good safe surfing waves below the main drop. Just be careful of the spikes and the recirculating waves near the dam.

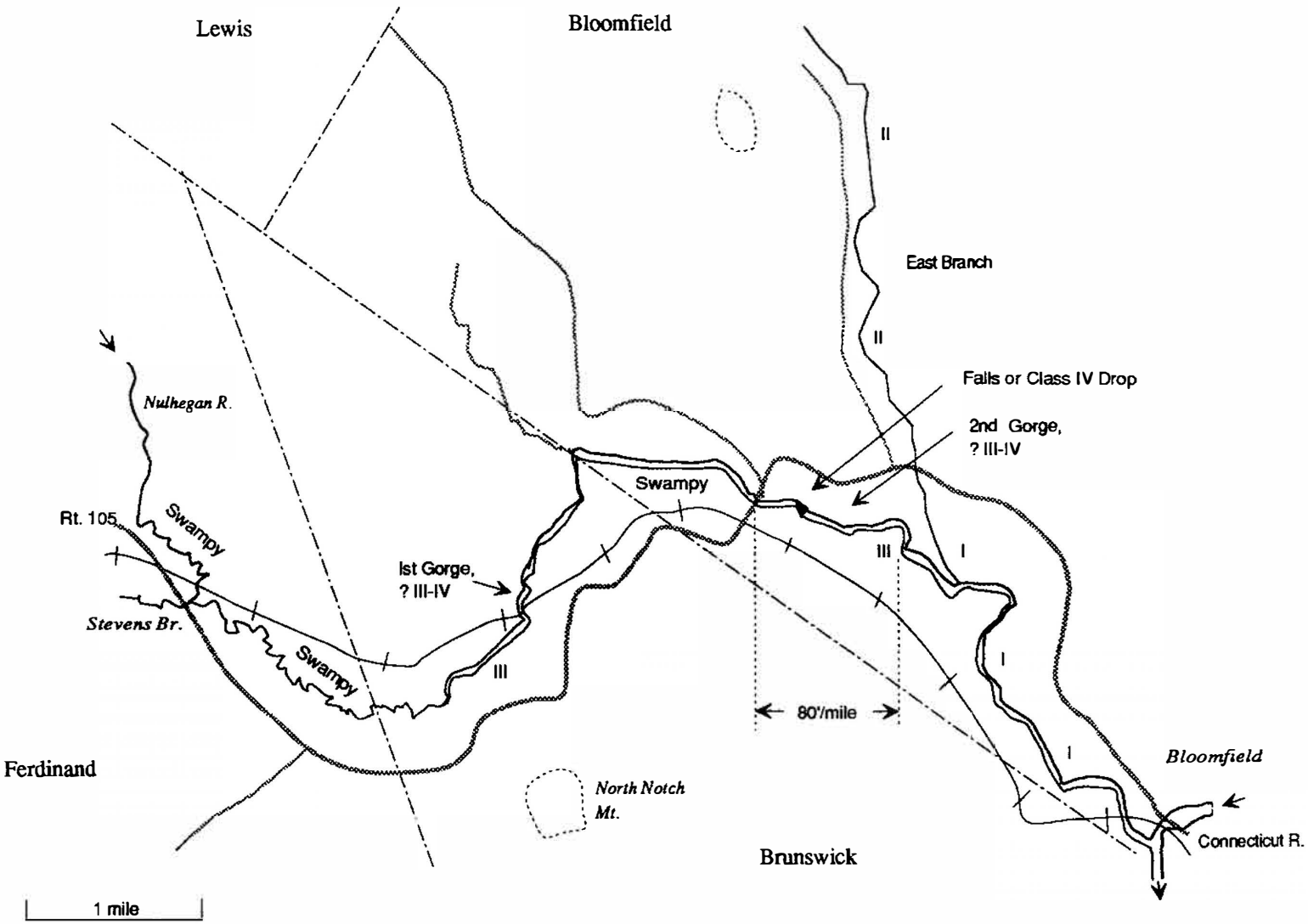
pellita, satin willow; *Carex lenticularis*, a sedge; *Deschampsia caespitosa*, hairgrass; and *Elymus wiegandii*, Wiegand's Wild Rye.

All of these species either occurred in this segment or quite near to it. Two are rare in the Ver mont and the other two scarce. We regard it as likely that other interesting species exist and feel that a more thorough survey would be valuable.

In addition to these species there occurred a number of populations of a plant that has been called *Aster foliaceus*, but which we and other botanists regard as a leafy-bracted form of *Aster novi-belgii*.

* * *

We rate this segment as HIGHLY IMPORTANT for the combination of fishing, rare plants, and as the longest remaining rapid on the main stem of the Connecticut, and one of the only summer rapids in the state.



Map 26: Nulhegan River. This segment is a mixture of swamps and quite difficult rapids. We do not know if the gorges have ever been run.

10.2 NULHEGAN: Rt. 100 Crossing in Ferdinand to Bloomfield

Length	ca. 9 miles
Towns	Ferdinand, Brunswick, Bloomfield
Counties	Essex
Quadrangle	Averill 15'
Access	Rt. 105
Elevation	1150'-900'
Average Slope	varies greatly; less than 5'/mile to ca. 100'/mile
Description	wild river with swamps and two gorges, partly flatwater, partly Class III-IV
Surroundings	alder swamp, cedar-spruce-fir forest, some open land
Water Quality	good
Flow Regulation	flows influenced by large wetlands in the watershed
Geology	granite intrusives, Devonian Giles Mountain limestone
Hydrology	no gauge data; watershed ca. 330 sq. km. at mouth
Biology	brook and brown trout fishery, no botanical records
Known Use	no users known
Season	high water and after heavy rains
Suitable for	expert open or closed boats
Interruptions	several drops in upper and lower gorge
Importance	HIGHLY IMPORTANT as a wild stream. Boating cannot be rated yet.

This is a unique stream, unlike any other in the state. It is mentioned in the AMC guide but we have not encountered anyone who has run it. The information below is based on scouting on foot. Our impression is that it is a difficult and very striking stream, and that it might make an exciting trip for a skillful party.

The Nulhegan originates near Island Pond and flows east through a large tract of alder-sedge swamp on granite bedrock. It then leaves the granite and enters the first of two gorges, then another swamp, then the second gorge, and finally runs through some open farmland to join the Connecticut River in Bloomfield. Much of the time it is away from the road and so either you must run it in long segments or make difficult carries through the brush to get on and off of it.

The upper segment, from Nulhegan Pond to the Rt. 105 bridge in Ferdinand, is a flatwater run that lies entirely in swampland, and is an exceptionally fine paddle for wildlife and birds. It may be one of the best places in the state to try to see moose from a canoe.

The lower segment alternates swamps and difficult whitewater. It begins with two miles of swamps; then half a mile of rocky, tight, technical water which is probably Class III at medium water; then a railroad bridge at which you should pull out and scout. Below the bridge there is a short, steep gorge perhaps 75 yards long, with three drops of several feet each. The drops come quickly one after another and there is no getting out between them, but they look like they might be runnable. Remember however that we have not seen this segment at medium or high water.

After this gorge there are some Class II rapids followed by about 1.5 miles of alder swamp, and then the second Rt. 105 bridge. Immediately below this bridge the river drops into the second gorge. This gorge is really a steep wooded ravine about a mile long with a slope of 100'/mile. At high water the stream has a lot of volume -- more say than the upper Lamoille or the New Haven at Bristol -- and this combined with the slope makes it a fearsome river. We scouted this section at high water. The roar was deafening as we went down the gorge, and the water was fast and wild but not unimaginably difficult. We were torn between wishing that we were paddling down it, and being very glad we were on shore and had trees to hold onto.

The rapids here seem mostly Class III, with two drops in the middle that are high Class III or Class IV.

Below the gorge the river rapidly flattens out, becoming Class II and then quickwater and Class I to the confluence with the Connecticut.

As mentioned above, we have no recent information from anyone who has run this. It is a spectacular looking run, and anyone who does it when the water is up and comes out in one piece is going to have something to be proud of.

* * *

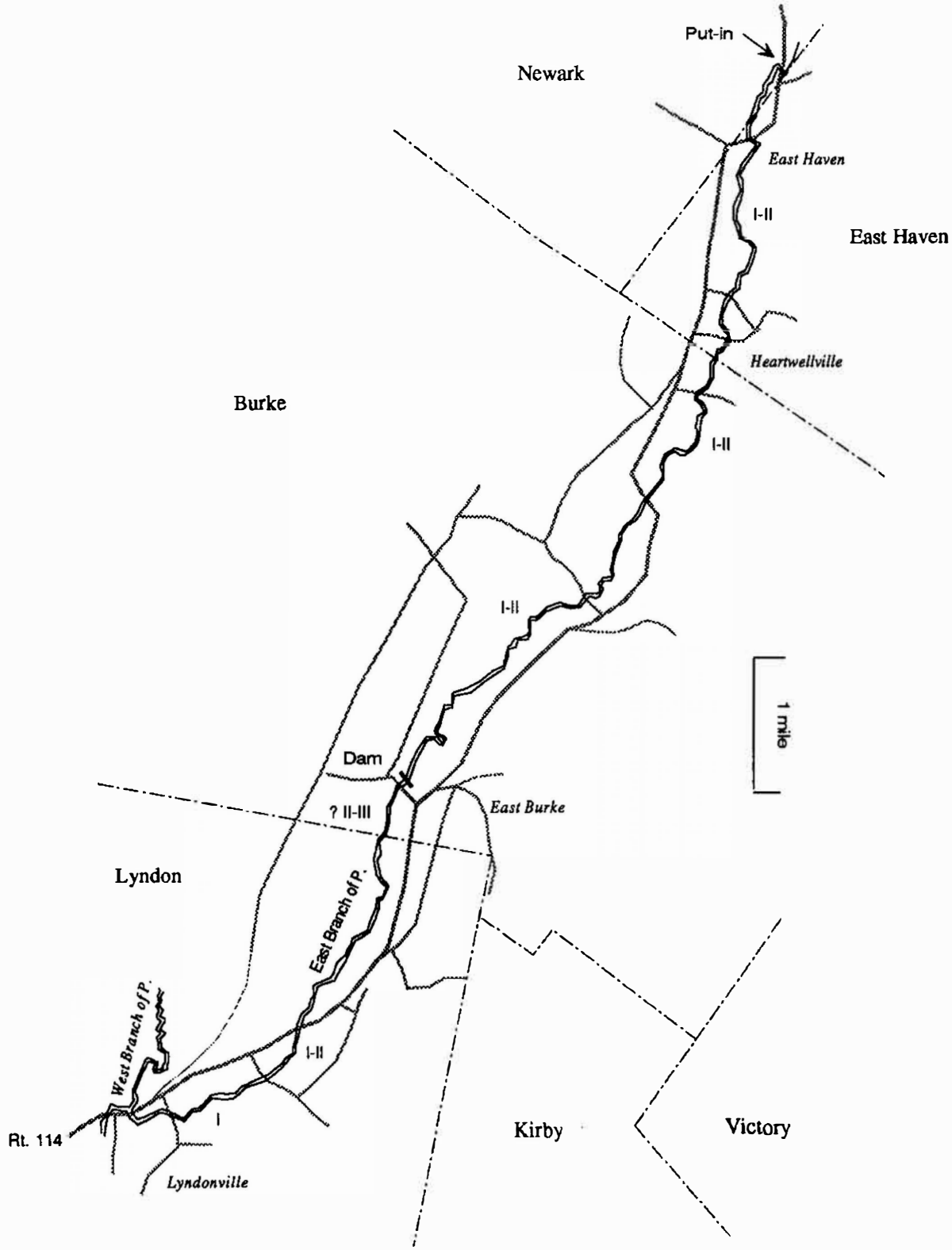
We have done some botanical survey work in both the upper marshes and the lower gorges, but do not have much to report. Nulhegan Pond, at the headwaters of the mainstem of the Nulhegan, is an important bog pond with a number of scarce boreal species. But the marshes and streambanks, while very attractive and undisturbed communities and quite important as wildlife habitat, are low in plant diversity and do not appear to have rare or scarce species. This is about what we would expect on the granite bedrock.

* * *

We rate this stream HIGHLY IMPORTANT as a beautiful and wild stream, but are waiting to rate the boating until we know that it has been run. It is potentially of high importance as a unique run in a very wild setting.

* * *

The East Branch of the Nulhegan is a small stream that joins the mainstem about two miles above Bloomfield. From the maps and hydrology it appears that it might have 4-6 miles of Class II rapids in a wilderness setting. We scouted the lower mile at highwater, and found that it did indeed have good rapids, but that it is on paper company land and that the road is closed to vehicles in mud season. If special permission could be arranged to take a four-wheel drive vehicle in this might turn out to be a lovely run.



Map 27: East Branch of the Passumpsic. There are several miles of flatwater paddling below this segment, followed by a series of dams.

10.3 EAST BRANCH, PASSUMPSIC RIVER: East Haven to Confluence with West Branch of Passumpsic

Length	11 miles
Towns	Burke, Lyndon
Counties	Caledonia
Quadrangle	Burke 15'
Access	from Rt. 114
Elevation	1000'-700'
Average Slope	ave. 27'/mile; upper segment ca. 30-35'/mile, lower segment ca. 20'/mile
Description	medium-sized alluvial stream; Class II in high water
Surroundings	second-growth hardwoods, farmland, road, some houses, no junk
Water Quality	good
Geology	Devonian limestone interbedded with phyllite and schist
Hydrology	gauge at East Haven, watershed 139 sq. km., mean flow 3.0 m3/sec, mean/max 2.4; watershed at confluence with West Branch ca. 200 sq. km.
Biology	brook trout fishery of unknown quality; botanical reconnaissance found no rare species
Flow Regulation	none
Known Use	local use for mild whitewater; annual race
Season	snowmelt, after rain
Suitable for	beginning open boats, flatwater boats
Interruptions	dam at East Burke with a ledge and ? Class II+-III rapids immediately below.

Importance IMPORTANT as a whitewater run; biological importance UNKNOWN.

The East Branch is a small to medium-sized stream with some rocks but no drops or ledges. It runs in an alluvial valley, paralleling Rt. 114, and has a mixture of woods, and open meadows. The wooded parts are very attractive and wild feeling, though not remote. There is some fine rural scenery, and some nice views of surrounding hills.

The East Branch has a fairly small watershed with only moderate slope, analogous to the upper Williams or the Ompompanoosuc below Post Mills. The upper seven miles need medium to high water to be runnable and are generally easy rapids, Class I to middle Class II. They are a pleasant sporty run; we found the woods and the setting very interesting, saw ducks and a mink and an otter, and enjoyed being in a part of the state that was unfamiliar to us.

Directly below the dam at East Burke is a ledge and some heavier water, apparently high Class II at medium water and perhaps Class III at high water. The last four are once again mixed Class I and Class II. The slope decreases to about 20'/mile for the last two miles and the rapids here are somewhat lighter than those above. This segment is more in the open than the upper one, and has some nice views but was less interesting biologically.

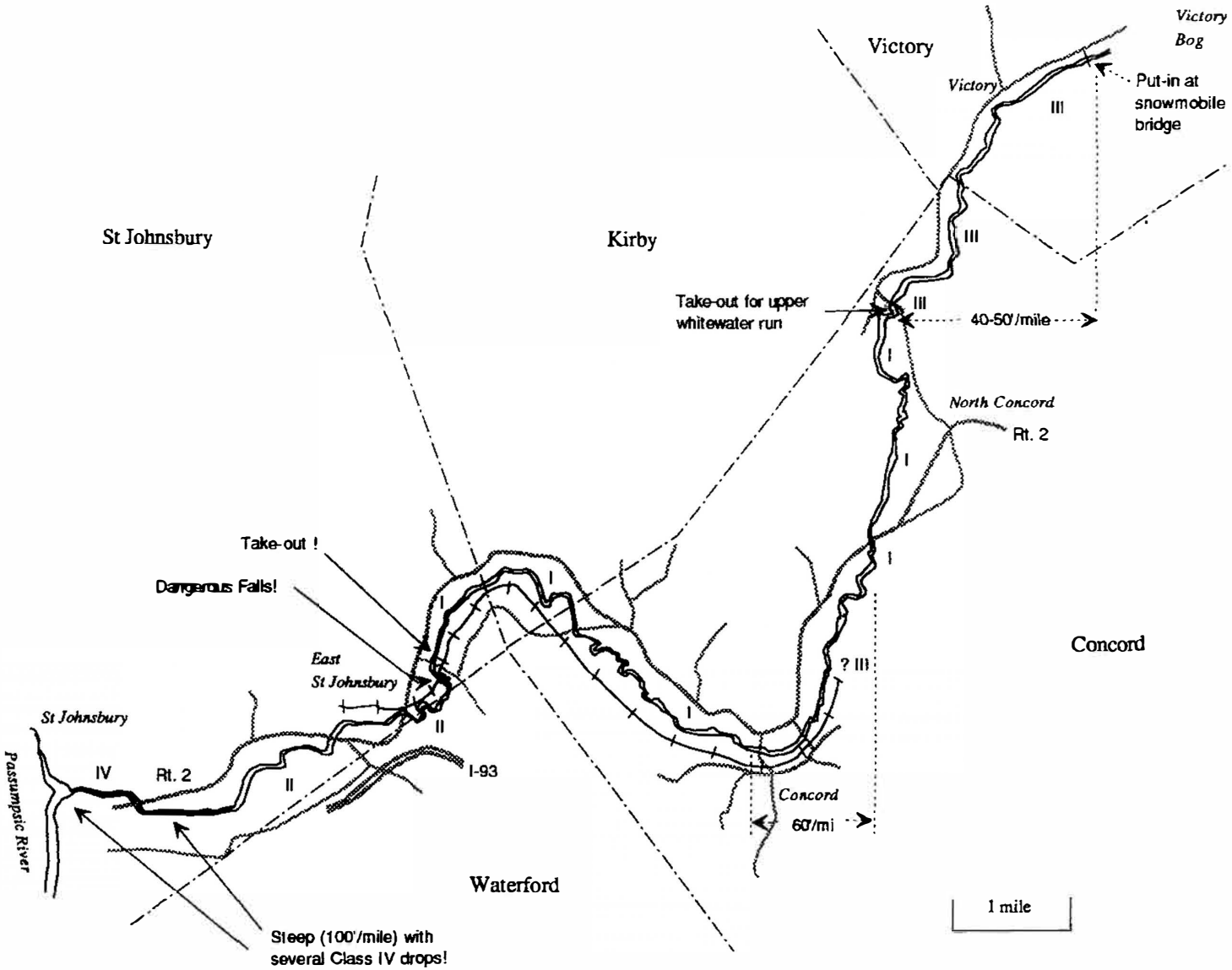
There is a downriver race here in the spring, which was described to us as being "fun to see because there are a lot of people in it who don't have any idea what they are doing." This may be changing. With the growth of interest in triathlons a lot more people are getting seriously interested in down-river racing, and even small races like this one now get a lot of good paddlers and specialized racing canoes.

* * *

We have very little biological data: brook trout are present, and we have botanical data from a single site, which did not yield any interesting species.

* * *

Rated IMPORTANT; the East Branch probably doesn't draw many boaters from long distances but it is a pretty and interesting stream with a feeling all its own, and affords the longest whitewater run in northeastern Vermont. If the whitewater were a little more intense and continuous it would rate highly important.



Map 28: Whitewater Segments of the Moose River. There is a fine flatwater segment in Victory Bog, above the segment shown here. Note the dangerous falls below the railroad trestle at East Concord, and the Class IV drops near the mouth.

10.4 MOOSE RIVER 1: Victory Snowmobile Bridge to North Concord

Length	ca. 3 miles
Towns	Victory, Concord
Counties	Caledonia, Essex
Quadrangle	Burke 15', Littleton 15'
Access	from dirt road to Victory Bog

Elevation	1120'-1000'
Average Slope	40'/mile
Description	small stream in remote area; Class II with Class III pitches at medium water, probably Class III with Class IV pitches at high water
Surroundings	hardwoods-fir forest; no views, but wild and very pretty place; only 1-2 houses, no trash, some nice rocks and ledges, good for birds & animals
Water Quality	good (brown water from Victory Bog, with much organic material)
Flow Regulation	none
Geology	granite, assumed to be mid-Devonian or later
Hydrology	gauging station at Victory: watershed 195 sq. km., mean flow 4.0 m3/sec, mean/max flows 3.2; watershed North Concord ca. 210 sq. km.
Biology	this segment is just below Victory Bog, an extensive complex of wetlands that is famous for wildlife. Brook and brown trout are present but the stream here is fairly warm in summer and reported to be a poor trout stream. No interesting plants known.
Known Use	seemingly known only in Northern Vermont; more people have heard of it than have run it
Season	snowmelt, after rains

Suitable for	advanced open boats, kayaks
Interruptions	none
Importance	HIGHLY IMPORTANT for boating: challenging water, wild and exciting setting; HIGHLY IMPORTANT for wildlife, as an undisturbed stream in a remote area.

The Moose is a small river in a wild and unsettled part of the state. It parallels the dirt road to Victory Bog and Gallup Mills, has a steep rocky channel with some abrupt chutes and ledges, and quite serious whitewater. The rivershore vegetation is mostly a mixture of spruce and birch and alder. There are occasional ledges on the shoreline, and almost no settlement. It is a good stream from which to see wildlife, and to enjoy being by yourself, and also a fine whitewater stream. It is exciting at moderate water and a handful and more at flood.

The hydrology is substantial. The slope and watershed areequivalent to the upper Lamoille, or, in southern Vermont terms, the Moose is a little bigger than the Saxtons and almost as steep. Like these streams it has small ledges, sudden corners, and abrupt, tight steep places with bad waves.

It is difficult not to love this stream. It passes through Victory Bog -- the largest continuous tract of wetlands in northern Vermont -- and is a steep, exciting, powerful stream with fine whitewater. It is the only Vermont whitewater stream that we know that has a granite bed, and this gives it the abruptness, big rocks, and short sudden drops and bends common in New Hampshire and Adirondack streams.

The upper part of the Moose, through the bog itself, is slow and windy. It is great moose country, has much beaver work, and definitely is not whitewater. The fast part starts at the snowmobile bridge below the bog, which probably is a zone of contact metamorphism at the edge of a big granite pluton that created the Victory Basin. Some of the most difficult rapids are just below the put-in. At medium water there are several steep chutes which are Class III, then continuous Class II rapids for about two miles, then three steep Class III places near the bridge at North Concord, then one last short steep place with big waves, then flatwater and alders for half mile. There is a good take-out point where the river swings back to the road.

We have not found anyone who has run it at high water. Quite possibly it becomes a solid Class III and the beginning and end parts might be near or at the limits for an open boat. THE FIRST DROP BELOW THE SNOWMOBILE BRIDGE AND THE STEEP PLACES NEAR THE NORTH CONCORD BRIDGE SHOULD BE SCOUTED CAREFULLY BY ANYONE TRYING IT WHEN THE WATER IS HIGH.

* * *

Considering the general importance of the Victory Bog region, the stream is a little disappointing biologically, but this is perhaps to be expected from the granite bedrock, which favors neither fish

nor plants. Brook and brown trout are present, but reported to be small and confined to the deepest and coldest holes. Richard Langdon, one of the reviewers of the manuscript, noted that Burbot occur in the Moose River and that they may be uncommon in Vermont. Botanical reconnaissance in 1968 produced only common species. The surrounding areas are very wild and the stream itself is almost entirely natural. Hence we judge it important for wildlife.

* * *

Rated HIGHLY IMPORTANT for boating: it has the best continuous whitewater in this part of the state, and a beautiful wild setting. Most Vermont whitewater is in moderately settled areas; this is one of the two wildest streams we have seen. Also HIGHLY IMPORTANT as a remote undisturbed stream used by wildlife.

10.5 MOOSE RIVER 2: North Concord to East St. Johnsbury

Length	7-8 miles
Towns	Concord, St. Johnsbury
Counties	Caledonia
Quadrangle	St. Johnsbury 15'
Access	from Victory Road or Rt. 2
Elevation	970'-760'
Average Slope	ca. 10' a mile in flatwater, 40-60'/mile in whitewater
Description	medium-sized river in settled valley; 2.5 miles of flatwater, 2 miles of Class II-III rapids, 2.5 miles of flatwater
Surroundings	2nd-growth woods, alders, some cleared land, houses etc.
Water Quality	good
Flow Regulation	none, but flow maintained to some extent by large wetlands in the watershed
Geology	Devonian phyllite & schist
Hydrology	gauge in St. Johnsbury: watershed 332 sq. km., mean flow 6.3 m3/sec, max/mean 3.2
Biology	rainbow and brown trout fishery of unknown quality; no botanical data
Known Use	apparently an interesting run that is rarely used
Season	snowmelt, early May, after rains
Suitable for	open boats, kayacks
Interruptions	none.
Importance	IMPORTANT for boating; interesting stretch of rapids and a pretty run connecting with other good whitewater runs above and below

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Ray Gonda called this section to our attention. There are some 2 miles of flatwater extending from North Concord to the Route 2 bridge. This is a windy stretch with lots of alders, and might be good for wildlife. Then below the Rt. 2 bridge the gradient increases to some 60' per mile, and there are steep rocky rapids that are probably Class II or Class III depending on the water level. These rapids decrease rapidly in the first mile below Concord and are followed by about 2 miles of flatwater to East St. Johnsbury.

At East St. Johnsbury there is a moderate current and some standing waves under the bridge. All boaters should take out here: there is a dangerous, possibly deadly, ledge just out of sight downstream. The ledge may be scouted from the railroad bridge; we don't think it can be safely run, but others may disagree.

* * *

Rated IMPORTANT as an intense and little known whitewater segment.

10.6 MOOSE RIVER 3: East St. Johnsbury to Passumpsic River

Length	4 miles
Towns	St. Johnsbury
Counties	Caledonia
Quadrangle	Littleton 15', Saint Johnsbury 15'
Access	from Rt. 2
Elevation	760'-540
Average Slope	ca. 40'/ mile for 3 miles; ca. 100'/mile for 1 mile
Description	medium-sized river in settled valley; Class II for 3 miles, Class III-IV for 1 mile
Surroundings	2nd-growth woods, alders, some cleared land, houses etc.
Water Quality	fair; about 1 mile of class C water with municipal sewage below East Saint Johnsbury
Flow Regulation	none, but flow maintained to some extent by large wetlands in the watershed
Geology	Devonian phyllite & schist
Hydrology	gauge in St. Johnsbury: watershed 332 sq. km., mean flow 6.3 m3/sec, max/mean 3.2
Biology	rainbow and brown trout fishery of unknown quality; single botanical visit did not locate any rare plants
Known Use	nice water which must be used; but we haven't located any users yet
Season	snowmelt, early May, after rains
Suitable for	open boats above; kayaks or expert open boats below
Interruptions	big ledge, possibly runnable, possibly deadly, at the put-in in East Concord; a number of drops and a 5 foot waterfall in the last mile.

Importance IMPORTANT for boating; appears to be very nice water. Last mile rated HIGHLY IMPORTANT as a uniquely difficult expert run. Also IMPORTANT for oxygenation.

The last segment of the Moose is a medium-sized river that begins by paralleling Rt. 2 in East St. Johnsbury and then enters a steep ravine near the railroad track in St. Johnsbury. The first three miles have easy, open Class II water; the last mile is steep and technical, with several Class III-IV drops and some big rocks and eddies.

The run begins below the big ledge at East St. Johnsbury. At medium-high water it is a fast Class II with a lot of waves but no holes or ledges. On paper the drainage area of 300 sq. km. and the slope of 40'/mile should produce Class III water, but the stream has comparatively few rocks and an unobstructed channel and so is likely to remain Class II even at fairly high levels.

One mile east of Saint Johnsbury the stream turns to the right (from south to west) and begins to steepen. A good landmark is the Fairbanks-Morse plant. Intermediate level boaters should take out here. The current is fast and care is required at the takeout.

The last mile is a very demanding Class III-IV run, suitable for experts only. The average gradient is 100'/mile, and there are several ledges and a 5' waterfall. It is not well known, but is probably one of the most difficult ledge runs in Vermont, comparable to parts of the New Haven Gorge or the lower gorge on the Mad River.

The following description of the lower rapids was supplied by Ray Gonda, who was one of several boaters that ran this segment at medium-low water, paddling solo in open boats. He says there are three ledges in the first half mile. They ran the first left and the second two right. The river then bends left and in about 200' there is a narrow, 100' long chute with a lot of waves and a hydraulic behind the Vermont Maple plant, followed by bends and irregular ledges to the Rt. 2 bridge.

About 100 yards below the Route 2 bridge there is a left turn followed by a 5' waterfall which can be carried or run on the left. At medium or high water the falls probably cannot be run in open boats, and may be dangerous in closed boats.

Below the falls the river runs straight to the Passumpsic. There are several more ledges; the last has a dangerous hydraulic on the left and should be run on the right.

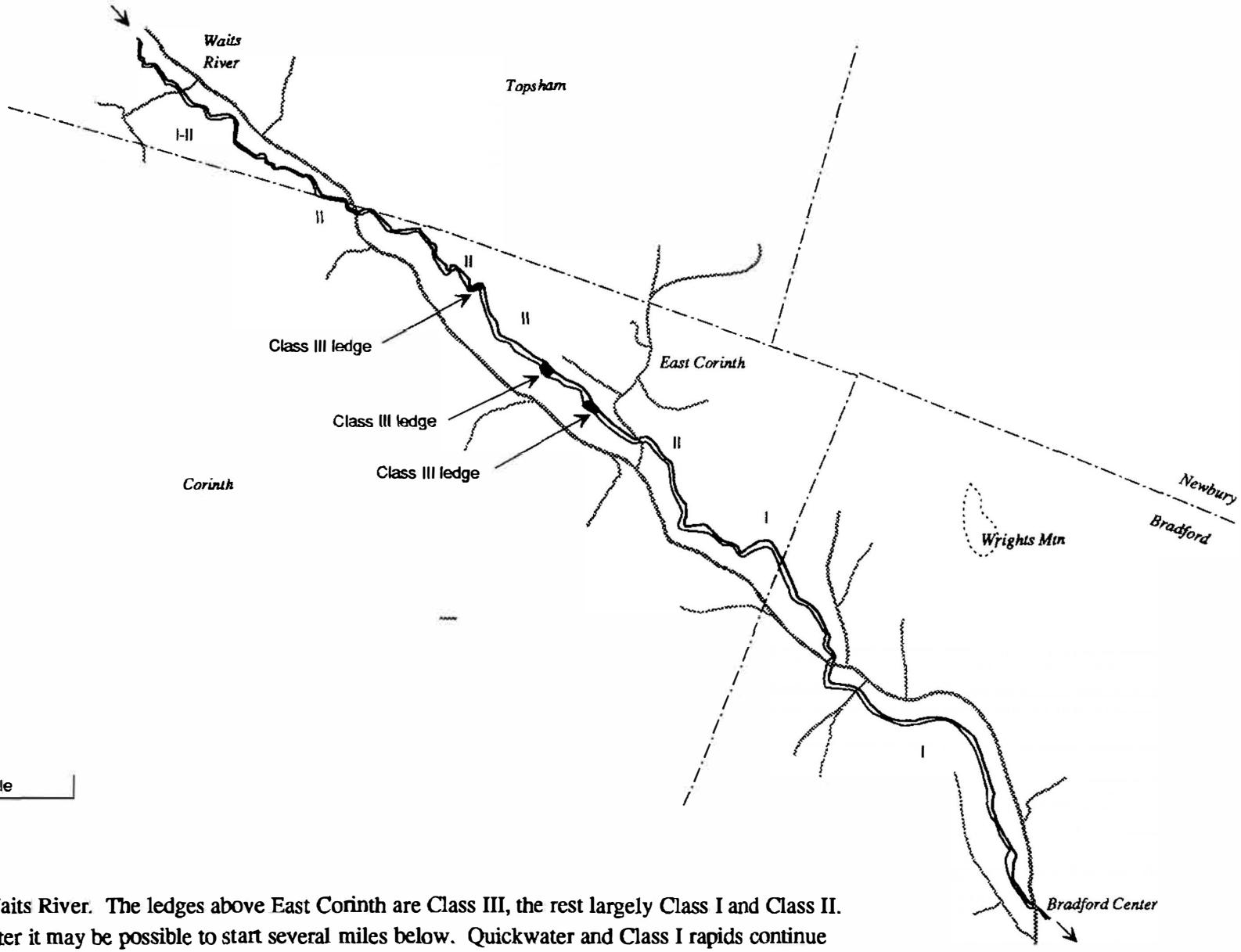
We have scouted portions of these lower rapids at medium-high water and judge them to be Class IV water, requiring careful scouting and expert technique.

* * *

Little biological information was available for this segment: the river is supposed to be warm and have only limited brown and rainbow trout populations. It receives municipal wastes in East St. Johnsbury, and at least formerly did not meet water quality standards for the first mile of this segment. Because of the wastes we regard the rapids as important for oxygenation and water quality. No botanical data were available.

* * *

Upper rapids rated IMPORTANT for boating and oxygenation. Lower rapids HIGHLY IMPORTANT as a unique expert run.



Map 29: Waits River. The ledges above East Corinth are Class III, the rest largely Class I and Class II. At high water it may be possible to start several miles below. Quickwater and Class I rapids continue below this segment to the power dam at Bradford, followed by flatwater to the Connecticut.

10.7 WAITS RIVER: Waits River to Bradford Center

Length	ca. 9 miles
Towns	Topsham, Corinth, Bradford
Counties	Orange
Quadrangle	East Barre 15', Woodsville 15' or East Corinth 7.5'
Access	from Rt. 25
Elevation	880' to 520'
Average Slope	ca. 40'/ mile (50'/ mile for lst 4 miles)
Description	small rocky fast stream; Class II-III
Surroundings	farmland, some houses, alluvial woods, hemlock-hardwoods and second-growth, no trash
Water Quality	good (secondary treatment plant discharge in Bradford)
Flow Regulation	none
Geology	upper part Devonian limestone intergrading with schists; lower part Devonian phyllite and schist
Hydrology	no gauge data; watershed ca. 340 sq. km. at Bradford Center
Biology	rainbow and brown trout fishery of unknown quality; no botanical data.
Known Use	well known to Vt. boaters and gets moderate use
Season	snowmelt, after rain
Suitable for	open boats, mild kayaking
Interruptions	three substantial Class III ledges
Importance	HIGH IMPORTANCE for boating; very pretty stream, good continuous rapids

This is an interesting stream. The watershed and the slope are typical of some heavy Class III streams like the Moose and upper Lamoille but the the channel is much less constricted and rocky and so at medium water it is largely Class II rather than Class III.

The run starts behind the center of Waits River. The first two miles, to the Route 25 bridge, have a slope of about 30'/mile and at medium water are easy, pleasant Class II. The next 2.5 miles, to the bridge at East Corinth, are steeper, with an average slope of 60'/mile and a maximum slope of ca. 80'/mile. This section is considerably more demanding -- Class II at low water but a tight and technical Class III at medium and high water.

The section between the Route 25 Bridge and the East Corinth bridge has three sloping drops 3-4' high, which are a bumpy Class II at low water and serious Class III at medium water. All three should be scouted carefully. The first is moderately steep and can be run in the middle. The second ledge is the largest, and descends in stages: the route will depend on the water level. The third also slopes and, depending on conditions, can be run on the sides.

The last 4.7 miles have an average slope of 27'/mile and a maximum slope of about 35'/mile. We have not seen them at medium or high water but suspect that they are a mixture of Class I and middle Class II. The most continuous rapids appear to be adjacent to Wrights Mountain, below the confluence with the South Branch, and there is supposed to be a 2' ledge somewhere just above the confluence.

It is also possible to start higher up in West Topsham, 3.5 miles above Waits River. The upper run is quite steep on the map, but appears to be pebbly rather than rocky, and may be of less interest.

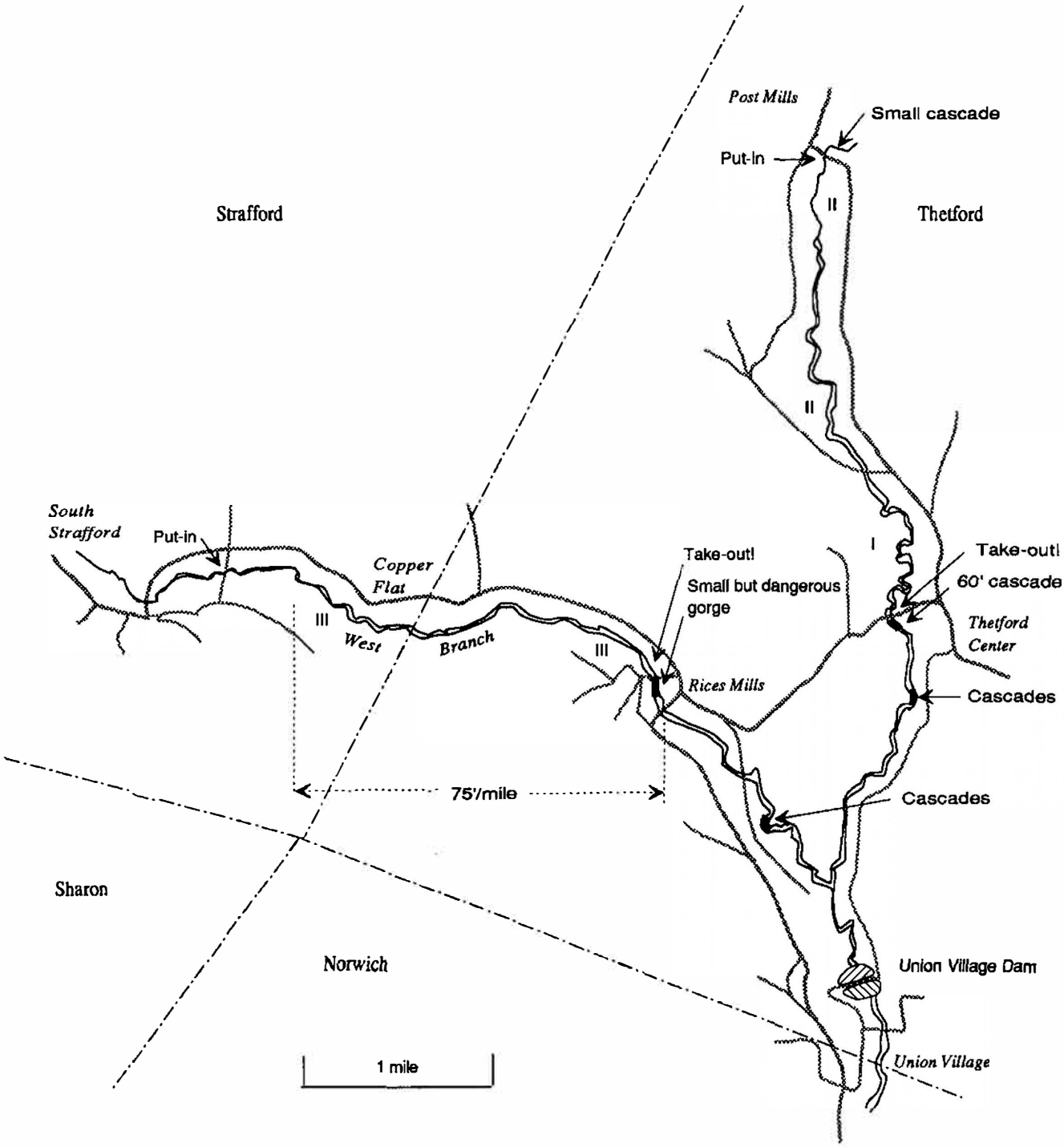
Several people remarked on the beauty of this stream and said that it was one of the nicest small rivers in the area. I ran it in May and and more than agree. The whole stream is nice, and the ledgy part east of Rt. 25 especially sweet and handsome -- one of the most memorable small streams we encountered in this survey.

* * *

There is only limited biological information on this segment. Vermont Trout Streams says that rainbow trout are somewhat more common in this watershed than elsewhere in the immediate area, that there are good spring spawning runs of rainbows in some of the branches, and that temperatures in the main stream fluctuate a lot in summer and hence summer fishing is spotty. No botanical information is available.

* * *

The Waits is rated HIGHLY IMPORTANT because it is a good continuous stretch of whitewater, and a clean and pretty river in a handsome rural valley.



Map 30: Ompompanoosuc and River and West Branches. The pool behind the Union Village flood control dam extends to the bridges at Rices Mills and Thetford Village at high water. The gorge at Rices Mills is runnable but dangerous; the high cascade at Thetford Center is unrunnable and could be deadly. The segments below Thetford Center and Rices Mills might be runnable at the right water levels, but are ledgy and have several small cascades, not all of which are shown here.

10.8 OMPOMPANOOSUC RIVER, WEST BRANCH: Strafford to Rices Mills

Length	ca. 5 miles
Towns	South Strafford, Thetford
Counties	Orange
Quadrangle	Strafford 15'
Access	from Rt. 132
Elevation	880'-580'
Average Slope	60'/mile
Description	small steep stream with lots of boulders, Class II at medium water and solid Class III at high water
Surroundings	second-growth hemlock hardwoods, no houses, no junk
Water Quality	superficially ok but with toxic and ph problems from copper mine drainage.
Flow Regulation	none
Geology	Devonian limestone and schist above South Strafford; Devonian phyllite and schist further down
Hydrology	no gauge data: watershed ca. 140 sq. km. at Rice's Mills
Biology	no botanical data: brown and brook trout present but fishing said to be poor owing to high temperatures and pollution of lower reaches from old copper mines
Known Use	experienced local boaters; known to a few out-of-staters and so receives occasional use by visitors
Season	snowmelt, after rains
Suitable for	kayaks, intermediate to advanced open boats
Interruptions	none; run ends at a pretty little falls and gorge at Rices Mills

Importance HIGH IMPORTANCE for boating: the most consistently difficult stream in this part of the state. Nice forests, no houses except at the bottom.

This is a difficult little stream in a pretty valley, very sporty and not as well known as it deserves to be.

The West Branch runs in a steep-sided, narrow, wooded valley, parallel to Rt. 132, mostly lower than the road and somewhat separated from it, but not really remote.

It is a small, very rocky, stream with serious water. The watershed is small but the gradient quite steep and hydrologically the stream resembles the Winhall and Williams Middle Branch. Like them it is probably a stream which is easy enough at medium water but increases dramatically in speed and difficulty at high water.

Like other streams of this steepness it is going to be flashy: the water level will rise fast and go down fast and so is hard to catch at the right stage. We estimate that it is probably runnable less than a dozen days each year.

The AMC Guide suggests starting this run 2.5 miles further up at Strafford rather than South Strafford. This is is certainly possible, but the segment above South Strafford has a maximum gradient of about 20'/mile and is not really a whitewater run. It might be a pleasant paddle, but is not likely to be interesting to anyone who is prepared to run the lower segment.

Below South Strafford the stream is very rocky, fairly narrow, and moderately steep. On paper it has the same steepness and watershed as the Winhall, but boaters we talked to say that it is not as demanding as the Winhall. We are not so sure: it has moved some fairly sizable boulders, and we wonder if they have seen it at its peak.

We were not able to run it or field check it when the water was high. By reputation it is a fast, non-stop run, Class II or II+ at medium water, and a demanding Class III at high water. There are very few eddies and good quick technical paddling is required. A kayakist said it was fun and bubbly. A number of canoeists said it was a pretty and exciting run, and that it was non-stop and required a lot of concentration. We expect that the boaters who think of it as a playful stream ran it at medium level, and that at high level it is going to need a lot of respect. Our experience is that streams this steep and rocky are taxing at high levels because the holes and waves are packed so tightly together and because you can't see what is coming around the corners.

At the end of the run at Rices Mills there is a narrow gorge perhaps 50 yards long and a minimum of 10' wide, with some small drops and rocks at the middle. This can definitely be run but we don't recommend it: you have to come over a small ledge and then turn sharply to enter the gorge, and if you spill here or in the gorge you will be swimming with your boat in a situation where it would be very easy to get pinned.

* * *

We have no botanical information about this watershed. As with most streams this steep it is supposed to get quite warm in the summer and hence have poor fishing. There is a lagoon with copper-mine waste in South Strafford which pollutes the lower parts of this segment.

* * *

We rate this HIGHLY IMPORTANT for boating: it is a continuous, exciting run, the most difficult water in this part of the state.

10.9 OMPOMPANOOSUC: *Post Mills to Mud Pond Bridge or Thetford Covered Bridge*

Length	3 miles or 5 miles
Towns	Thetford
Counties	Orange
Quadrangle	Strafford 15' or Strafford 7.5' and Vershire 7.5'
Access	Rt. 113 in Post Mills
Elevation	660'-540'
Average Slope	ca. 25'/mile (ca. 30-35'/ mile maximum, 15'/mile for last mile)
Description	narrow stream in steep ravine with a lot of boulders; Class II (?III) whitewater
Surroundings	hemlock-hardwoods forest in ravine; no houses, no junk
Water Quality	some drainage from the Ely copper mine
Flow Regulation	none
Geology	Devonian phyllites & schists
Hydrology	gauge at Union Village: watershed 337 sq.km., mean flow 5.5 m3/sec, max/mean 3.4; watershed at bottom of run ca. 130 sq. km.
Biology	no botanical data; fishing supposed to be poor except for a stocked segment above the Union Village Dam that has rainbows and brown trout
Known Use	intermediate level open canoes, kayaks
Season	snowmelt, after rains
Suitable for	open boats, kayaks
Interruptions	none; waterfalls just above and below this segment
Importance	IMPORTANT for boating

A small pretty stream in a wooded ravine, with fairly easy water.

Hydrologically this segment of the Ompompanoosuc is similar to Lewis Creek or the Huntington. It has a substantial watershed but the gradient near the low end for Class II streams and the stream lacks ledges and is not very rocky overall. As a result the most difficult places are sharp bends and occasional steep corners, and my suspicion is that it remains basically a Class II stream, even at moderately high water.

The stream is in a ravine between two roads but considerably below either one of them. In consequence the run is wooded, very pretty, and private. We ran this late in the season when the leaves were out, and were delighted by the handsome woods, fine streamside ledges, nice pools, and overall quiet and privacy. The middle two miles remain in our memory as one of the prettiest and most secluded segments of a small stream we have been on.

The run begins at Post Mills, where there is a lumber mill and a steep bank and you have the choice of a long walk through the mill yard or sliding your boat down the steep bank.

You enter the woods immediately, and for the next three miles are away from the road and in continuous rapids. The AMC Guide says there are three or four 'difficult' Class III drops here. We ran it at low water and found no ledges over 1' high, though we did find a few tight places with rocks and small drops. We think that some of these places may become a technical Class III at highwater, but saw nothing that we would describe as a difficult drop, and are reasonable certain, as noted above, that this is a Class II stream.

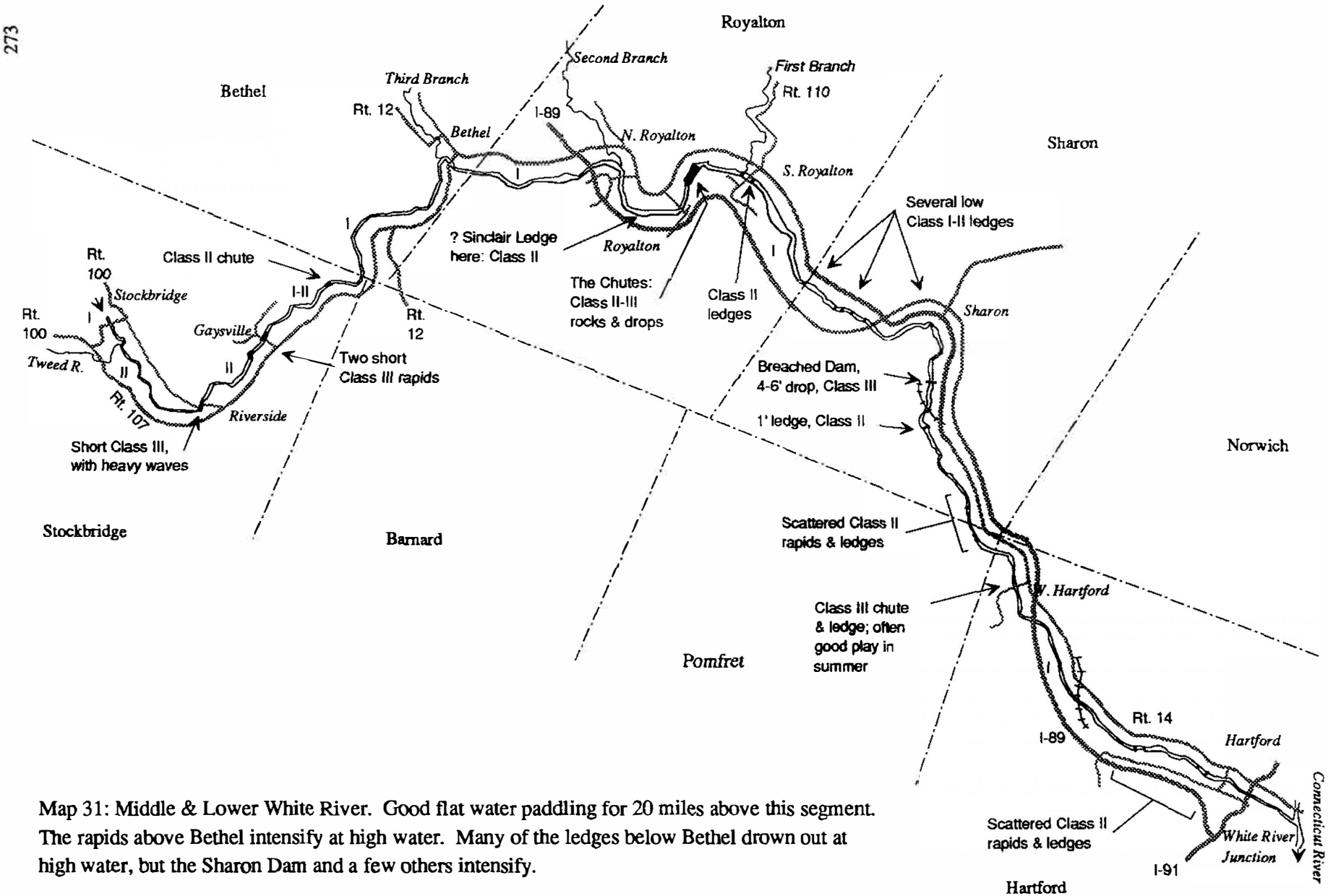
Below the Mud Pond bridge the gradient decreases and there are alluvial banks and a lot of fallen trees and stranded debris. This section is somewhat trying to get through, and could be avoided by taking out at the Mud Pond bridge.

The takeout is at the covered bridge at Thetford Center. There is a broken dam and a dangerous 40' cascade just beyond this bridge, and boaters should be careful at the takeout.

This run does not seem to be widely known to Vermont boaters in comparison to the more difficult Waits and West Branch runs nearby. It deserves to be better known: it is exceptionally attractive, and is probably both safe and sporty when the water is up.

* * *

Rated IMPORTANT as a pleasant Class II run in nice surroundings.



Map 31: Middle & Lower White River. Good flat water paddling for 20 miles above this segment. The rapids above Bethel intensify at high water. Many of the ledges below Bethel drown out at high water, but the Sharon Dam and a few others intensify.

10.10 WHITE RIVER 1: Stockbridge to Bethel

Towns	Stockbridge, Bethel
Counties	Windsor
Length	11 miles
Quadrangles	Rochester 7.5', Randolph 15'
Access	Rt. 14 or Rt. 100
Elevation	740'-530'
Average Gradient	ca. 20'/mile
Description	medium-sized river in a sparsely settled agricultural valley; mostly continuous class II rapids for the first 5 miles, then scattered class I-II rapids and quickwater to Bethel. Surroundings farmland, steep hills, occasional houses, hemlock-hardwoods forest, some riverside ledges.
Water Quality	good
Geology	mostly Ordovician quartzite-granulite; small amounts of Ordovician phyllite; Ordovician gneiss for last 2 miles
Hydrology	gauge at Bethel: watershed 624 sq. km., mean flow 14.0 m3/sec, max/mean 4.0
Biology	no botanical data; famous trout stream, with good populations of brown and rainbow trout; formerly had large runs of Atlantic Salmon, and now a major focus of the salmon restoration project.
Flow Regulation	none
Suitable For	whitewater touring, especially beginning & intermediate open boats.
Season	winter thaws, early and middle spring and after rains
Interruptions	none
IMPORTANCE	HIGHLY IMPORTANT both for boating and fishing: beautiful, fairly easy run; famous trout stream; major role in salmon restoration project

The White River is a big, clean, stony river. The valley is agricultural, but in this segment of the river the areas that are used for farming and settlement are only about 1/2 mile wide, and most of the hill slopes that border them are wooded. Thus when you are boating you see mostly woods and feel that you are right in the mountains.

Hydrologically this stream has a big watershed and mild gradient of 20'/mile (probably somewhat greater for the first 3 miles) which is near the lower end of the range of slopes of Vermont Class II runs. It derives its interest from the individual rapids that are associated with ledges and short steep pitches. None of these are very long, but because of the large size of the stream they can get quite intense at high water.

The river mostly has a boulder-bottom channel, without ledges and drops. But there are a number of sharp bends with rock walls (which we call 'half-gorges') and in several places the rocks extend into the edges of the channel.

The run from Stockbridge to Bethel is one of the classic Vermont whitewater runs, and is the one that out-of-state boaters mention most often after the West. It is really a very handsome tour with some whitewater rather than an intense descent in continuous whitewater. The valley and river are exceptionally beautiful, and there are some fine individual rapids.

Starting at Stockbridge there are about 3 miles of intermittent Class II rapids, followed by a bridge pier in the middle of the river which should be scouted at high water.

The first major rapid is about 1/4 mile below the bridge pier. The river makes a sharp left turn and there are some big waves here. This is followed by about 1/2 mile of Class II rapids, and then another sharp left turn.

Just below this second sharp left turn the river narrows and there is a short rapid with fast current and heavy standing waves. There are no rocks in the waves and a good pool below so it is basically a safe rapid, but the waves are high enough to sink an open canoe and it should be approached with caution. At high water this is a solid Class III rapid.

Below the pool the river turns to the right and there is a short steep rapid with a big hole on the right and big standing waves with a rock in them to the left.

Both of these rapids are Class II at medium water but go to Class III at high water, and should be scouted by boaters attempting the river at high water.

Below this rapid is the bridge at Gaysville. It has a sharp left turn above it, with considerable current and some good standing waves, and also should be scouted at high water.

Two skilled boaters with much experience in Class III water told us that they ran this section of the river when it was nearly in flood, and found exceptionally strong currents and eddies, and decided to take out. This illustrates what we have said in the section on safety: RIVERS IN FLOOD ARE CONSIDERABLY ABOVE WHAT IS CONSIDERED NORMAL HIGHWATER FOR BOATING, AND OFTEN HAVE DIFFICULT CURRENTS AND TURBULENCE.

Below the Gaysville Bridge the river is mostly quickwater with occasional short Class I-II rapids. There is a full Class II rapid on the Bethel-Stockbridge line. The gradient moderates as you approach Bethel, and the last 3 miles are mostly quickwater.

Throughout the run there are a number of big rocks and nice places to practice ferries and eddy turns. The rapids are not continuous, the current is not dangerously fast, and there are good pools below all the difficult rapids. It is an excellent river for teaching whitewater, and, at moderate water levels, a very good run for beginning whitewater boaters.

* * *

The White River system as a whole is nationally famous as a trout stream. The water is clear and for the most part quite clean, and summer temperatures low enough for trout are found all the way to the Connecticut River. There are no dams on the main stream (it is in fact the only major river in Vermont without dams) and hence fish are free to move up and down, and there are some good runs in the spring. It is especially well known for its rainbow trout and said to be some of the best water for them in the state.

There is also a good small-mouth bass fishery in the main stem, mostly below Bethel.

The White River had major salmon runs in the 18th century, which were eliminated about 1803 by the construction of dams on the Connecticut River. Starting in 1971 the U.S. Fish & Wildlife Service and the Vt. Fish and Wildlife Department began to experiment with stocking juvenal salmon in this watershed as part of a project to restore salmon to the Connecticut system. As of 1984 something like a million salmon had been released in the White River, and fish ladders have been constructed on all the Connecticut River dams so that there are now no physical barriers to salmon migration. Growth rates of juvenal fish in the White River have been good, and adult fish are now starting to make spawning runs up the Connecticut from the sea. The project has generated great enthusiasm among sportsmen and fisheries biologists, and rightly so. If it succeeds it will be a unique example of species restored to a region from which it has been absent for over 150 years.

* * *

We have no botanical information at all from the upper White River. By analogy with the West River it might potentially be very interesting, and it deserves more field study than it has received.

* * *

Rated HIGHLY IMPORTANT both for boating and fishing.

10.11 WHITE RIVER 2: *Bethel to Connecticut River*

Length	ca. 25 miles
Towns	Bethel, Royalton, Sharon, Pomfret, Hartford
Counties	Windsor
Quadrangles	Randolph 15', Strafford 15', Bethel 7.5', South Royalton 7.5', Sharon 7.5', Quechee 7.5', Hanover 7.5'
Access	Rt. 14 or Rt. 100
Elevation	530'-320'
Average Slope	ca. 10'/mile
Description	large river in agricultural valley; mostly quick water with scattered Class I-II drops or short rapids; one place may be Class III at high water.
Surroundings	farmland, occasional houses, alluvial woods, hemlock-hardwoods forest
Water Quality	generally good; some municipal wastes and high coliform counts, at least previously, for the first few miles below Bethel
Geology	variously limestone-phyllite and phyllite-schist, both of Devonian age
Hydrology	gauge at Bethel listed for previous segment; gauge at West Hartford: watershed 1790 sq. km. mean flow 33.6 m3/sec, max/mean 3.2
Biology	mixed rainbow trout & bass fishery; very important for the salmon restoration project; extremely important botanical site at the Sharon-Pomfret line
Flow Regulation	none
Known Use	very popular for flatwater touring and mild whitewater
Season	runnable all summer except in dry years
Suitable for	open boats
Interruptions	a number of low ledges, as described in text; 3-4' drop over the footings of an old dam in Sharon

Importance HIGHLY IMPORTANT for boating & fishing; one of the longest uninterrupted runs on a major river in the state and so very popular for long trips, canoe camping, and so on. HIGHLY IMPORTANT fishery, known nationally, critical for salmon restoration project. A HIGHLY IMPORTANT botanical site. Also IMPORTANT for oxygenation at low water levels.

The Lower White is a big, clean, stony river, mostly in an agricultural valley. There is some handsome open country and many good views of the hills. The river is a quickwater stream with a variety of short drops and short Class II rapids. In one or two places there are ledges that constrict the river and create chutes and abrupt turns. It is not a whitewater run as such, but rather a fine touring stream which has some exciting places. It is widely used by local and visiting boaters, and a number of clubs and several guide services run trips here annually.

The river has no extended rapids. What whitewater there is comes from the ledges and several fine short rapids. Our notes, which are not necessarily complete, record ledges above and below the bridge at South Royalton, above the I-89 bridge west of Sharon, at the bend at Sharon, at the footings of an old dam 1.5 miles below Sharon, below a gravel pit one mile below this, scattered in the next two miles to the Pomfret-Hartford line, at the West Hartford Bridge, and at the Hartford Bridge.

At medium water none of the ledges and rapids are more than Class II with the exception of the dam footing 1.5 miles below Sharon and the chute at the West Hartford bridge. Both of these are are Class III, even at medium low water, and are important play and practice places in the summer. The other ledges will all be easy for intermediate level whitewater boaters. But none the less they are still real whitewater and could easily swamp or sink a badly handled or badly equipped boat.

We have not scouted or run this section of the river at high water. Most of the small ledges probably wash out at high water, but some of the steeper ones, like the drop at West Hartford, and some of the obstructed passages, like the chutes at Royalton, may become quite heavy and could conceivably be high Class III or higher.

WE RECOMMEND THAT RECREATIONAL PADDLERS WITHOUT STRONG WHITEWATER SKILLS SHOULD SCOUT ALL THE RAPIDS IN THIS SECTION AND THAT ALL PADDLERS SHOULD BE VERY CAUTIOUS AT HIGH WATER.

* * *

The biology of this segment is very similar to the preceding, and the reader is referred there for details. Essentially there is excellent trout and bass fishing here and considerable hopes for the restoration of Atlantic Salmon.

Several important botanical sites occur in the lower part of this segment. At the Sharon-Pomfret line there is a set of flat ledges, extending for about 200 yards along the south bank of the stream. The ledges have a thin cover of peaty soil, are kept wet by limy groundwater, and are apparently kept open by scouring by ice or floods. They have a number of rare species, including the asphodel *Tofieldia glutinosa*, the vexatious sedge *Carex garberi*, and two more reputable sedges *Eleocharis pauciflora* and *Rhynchospora capillacea*.[16] With them occur a number of common but specialized species such as *Carex lanuginosa*, *Spiranthes lucida*, and *Eleocharis erythropoda*, making a distinctive community of great botanical interest. We call this community the limy rivershore seepage community. Other smaller examples of the community occur downstream from the Sharon site, and also below West Hartford.

This community is rare in New England at a whole, and the White River may have the best examples south of northern Maine. Another fine example occurs on the Connecticut River at the Hartland Rapids, some 15 miles from this site. There the habitat is less extensive, and the rarest plants, unaccountably, have chosen to grow on the New Hampshire side.

We believe that this habitat and the plants associated with it may have been more widely distributed in the Connecticut Valley formerly, but has been lost owing to the extensive damming of the whitewater segments of the Connecticut and its tributaries. Hence this site, like the one at the Hartland Rapids on the Connecticut, may be a remnant of great importance.

Because the river gets fairly low and warm in the summer, and also receives treated and untreated wastes at a few points the oxygen levels are critical for the fishery, and hence we regard the rapids in this segment as very important for water quality.

* * *

Rated HIGHLY IMPORTANT for boating and fishing: clean, beautiful, interesting, and the only major river in the state without dams. Its continuity is a major attraction, both to boaters and fish, and makes it rank as one of the most important streams for canoe touring in the state, and in fact to New England as a whole. It also has two IMPORTANT isolated rapids that provide good summer whitewater practice. The ledges at Sharon are of HIGH IMPORTANCE for rare plants and a rare plant community. And the individual rapids on this segment are HIGHLY IMPORTANT for maintaining summer oxygen levels.

16. The problem with *Carex garberi* is that it seems to appear and disappear in places making it hard to be very sure about. It addition some botanists suspect, perhaps unkindly, that *Carex garberi* is really just a name that gets mistakenly applied to immature *Carex aurea*. Someday we may know.

10.12 FIRST BRANCH OF WHITE RIVER: Chelsea to Tunbridge

Length	ca. 9 miles
Towns	Chelsea, Tunbridge
Counties	Orange
Quadrangle	Chelsea 7.5'
Access	from Rt. 110
Elevation	800'-540'
Average Slope	45'/mile in upper segment, 20-30'/mile in lower segment
Description	small stream in rural valley, Class II above, quickwater below
Surroundings	woods, farmland, occasional houses
Water Quality	good
Flow Regulation	none
Geology	Devonian Waits River limestone
Hydrology	no gauge data; watershed ca. 90 km.sq. at Chelsea.
Biology	reportedly a good rainbow trout fishery; no botanical data
Known Use	no known
Season	snowmelt and after rains; lower segment may be runnable much of the spring
Suitable for	open boats, kayaks
Interruptions	3' ledge 1/4 mile below Chelsea; five ledges below the first and second covered bridges; 5' dam above the third bridge; low ledge at North Tunbridge; dam above Tunbridge.
Importance	IMPORTANT as a short but nice whitewater run above, for a mile of interesting ledges in the middle, and as a touring stream below.

This stream is described incorrectly in the AMC Guide as a Class III-IV ledge run, highly dependent on water level, and suitable only for the 'expert ledge enthusiast.' In fact it is a Class II stream (with a low Class III segment) which can be run by a variety of boaters at a variety of levels, and most of the ledges are in a single 3/4 mile stretch that can be avoided if desired.

The First Branch is a fairly small stream at Chelsea, running in a wooded valley. The first 2.5 miles are moderately steep (45'/mile average, 60-80'/mile maximum) but have a small watershed and so are interesting rather than formidable whitewater. There is one 3' ledge with hole below it just below Chelsea that is a Class III drop; otherwise the stream is mostly rocky rather than really ledgy, and has interesting Class II water that probably is Class III in a few spots at high water.

This first segment is back in the woods, with delightful water and very pretty surroundings. It is quick and technical, but still suitable for intermediate level boaters. It would be even better if it were longer, but it is still nice.

After the first covered bridge the gradient of the stream decreases and it is basically quickwater (with a few short Class II places) from here to Tunbridge. The stream is mostly in the open from here on, and there are a number of excellent views.

The first mile below the first covered bridge contains a number of ledges, and boaters not interested in ledge-running can start about 1.5 miles downstream, where there are sandpits on the far bank.

This section contains a total of five ledges from 2-4' high. There are two relatively easy ones just below the first covered bridge, and two harder ones above and below the second bridge. The final one is about 200 yards below the second covered bridge, and is actually a set of three 1' ledges that combine to make a sloping drop.

At medium water the easy ledges looked like Class II drops and the hardest one a Class III. Boat placement will be very important here, and they should be scouted carefully. At high water the largest ones are probably high Class III, possibly Class IV.

The last 5 miles, from the last major ledge to Tunbridge, have only 2 important interruptions, and make an excellent quickwater tour, noteworthy for the unspoiled valley and fine rural scenery. The first interruption is at the third covered bridge, where there is an old, partially broken dam 4-5' high. Below this there are a few scattered Class II rapids, a 2', Class II ledge in North Tunbridge, and a 4' dam just above Tunbridge.

* * *

Rated IMPORTANT for a good short whitewater run, and nice touring below.

10.13 HANCOCK BRANCH OF THE WHITE RIVER: Confluence with Robbins Branch to White River

Length	3 miles
Towns	*Hancock*
County	Addison
Quadrangle	Rochester 15'
Access	road to Texas Falls
Elevation	1100'-900'
Average slope	ca. 65'/mile
Description	small upland stream, lots of rocks, Class II-III at moderate water
Surroundings	hemlock-hardwoods, occasional houses, occasional clearings, road, no junk
Water Quality	good
Hydrology	no gauge data: watershed ca. 50 sq. km.
Geology	Cambrian schists
Biology	no botanical records; rainbow, brook, brown trout fishery of unknown quality
Known Use	? occasional use by Vermont boaters (not in AMC Guide)
Flow Regulation	none
Season	snowmelt, early spring
Suitable for	open boats, kayaks
Interruptions	none
Importance	IMPORTANT for boating: a nice, small, technical run

A steep mountain stream, hydrologically distinguished by being the smallest stream in the state known to be used as a whitewater run.

Our information was contributed by Louise McCarren, who is a skilled whitewater paddler. She said the Hancock Branch was a fast small stream in the mountains, in a pretty valley, and that it had lots of rocks and current. At moderate water at least, it did not have enough volume to be threatening and was a good Class II with some Class III spots, and a lot of fun.

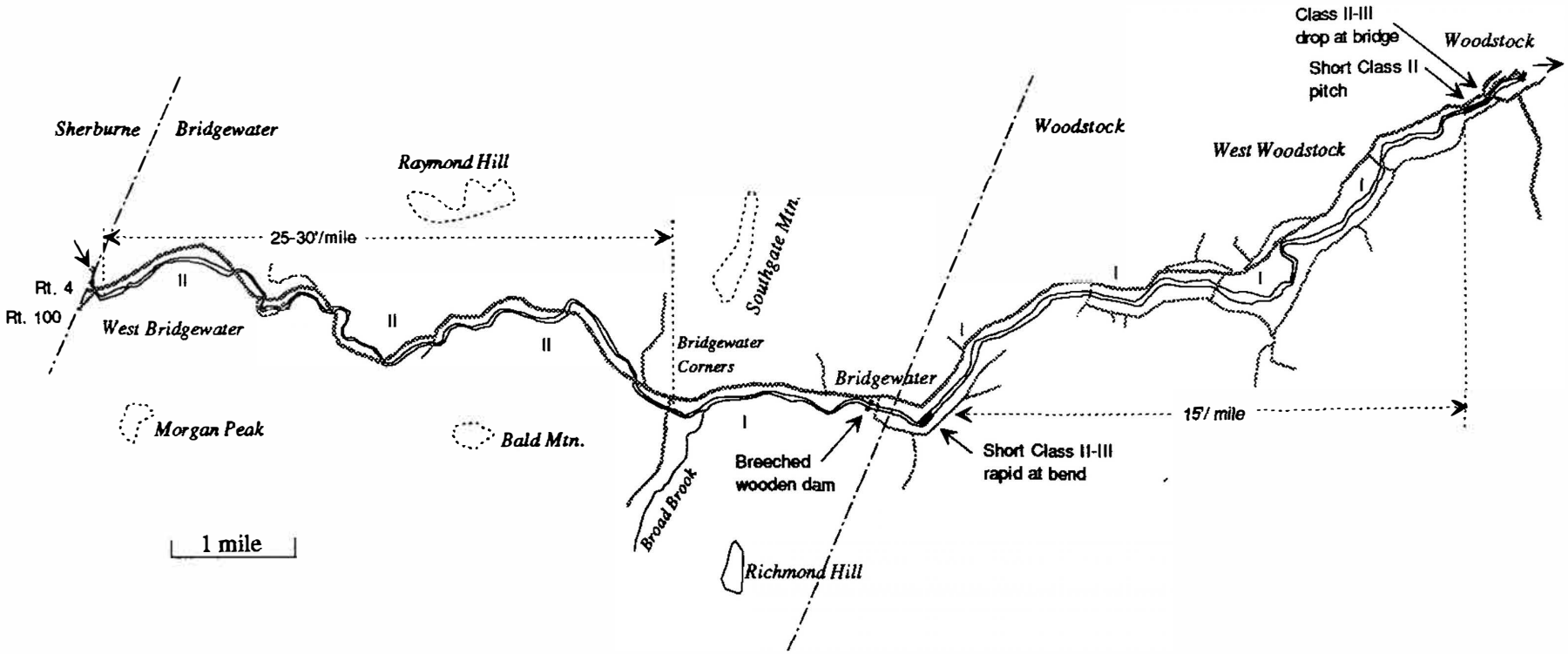
* * *

We have not examined it for whitewater but remember it from botanizing as an attractive stream, with two nice waterfalls (Texas Falls on this branch and Bailey Falls on the Robins Branch) and some good moss collecting upstream. It is quite a small stream indeed, and probably most fun for a kayak or short single canoe. Louise McCarren is the only person we talked to who has boated it. Her enthusiasm for it raised the interesting question of how many other small steep streams of this sort there might be, and led us to the survey of potential whitewater streams described in Chapter 3.

We have no detailed biological information. A previous botanical reconnaissance turned up a diverse but basically predictable moss flora at Texas Falls, and no vascular plants of interest. Like essentially all the tributaries of the White River it is listed as a good trout stream. It is however steep and the bedrock is quite acidic so the fishing is probably not exceptional.

* * *

Rated IMPORTANT as a whitewater stream.



Map 32: Ottauquechee River. River may be paddled for 4-6 miles above this eigment, and at least to the dam in Taftsville below. Access from all bridges.

10.14 OTTAUQUECHEE RIVER: West Bridgewater to Woodstock

Length	15 miles
Towns	Bridgewater, Woodstock
Counties	Windsor
Quadrangle	Woodstock 15' or Killington Peak, Plymouth & Woodstock South 7.5'
Access	Rt. 4
Elevation	1050'-680'
Average Slope	1st 6 miles, 31'/mile; lower river ca. 16'/mile
Description	small to medium-sized river, continuous light Class II rapids in the upper segment, Class I with scattered Class II rapids in the lower segment
Surroundings	second-growth woods, some open land, highway, houses, some junk
Water Quality	good to fair: domestic waste from the Killington area, treated waste in Bridgewater, municipal sewage in Woodstock
Flow Regulation	none
Geology	upper 5 miles, Ordovician quartzite-granulite & phyllite; lower 9 miles, Devonian limestone with some schist
Hydrology	gauge at North Hartland: watershed 572 sq. km., mean flow 11.3 m3/sec, max/mean 3.6; watershed at Woodstock 500 sq. km.
Biology	no current botanical data; historical record for the missing species *Halenia deflexa* from along the river near Woodstock; brown, rainbow and brook trout with reproduction mostly limited to tributaries and the main stream above Bridgewater.
Known Use	moderately popular whitewater run, mostly used by Vermont boaters
Season	snowmelt, early spring, after rains
Suitable for	open boats

Interruptions	Class II-III drop under the first bridge in Woodstock; Class III drop under the third bridge in Woodstock.
Importance	HIGHLY IMPORTANT both for boating; good continuous whitewater. Also IMPORTANT as a fishery and IMPORTANT for oxygenation and water quality since the stream receives both treated and untreated wastes.

The Ottauquechee, like several other important east-slope streams, is largely an upland river. It begins in Sherburne and descends through Bridgewater to the Woodstock valley. The segment of the river considered here parallels Rt. 4 and in many places has rip-rapped banks and altered bends. It is an attractive but partially compromised river. There is nice scenery in places but there are also a lot houses, bridges, and highway embankments. At least formerly it was moderately to badly polluted in the summer, though apparently much cleaner in spring. It would be a wonderful stream if it was wild, but it definitely is not.

The Ottauquechee has a moderately large watershed and is a good-sized stream, but the portions that are normally run have only moderate slopes and are not extremely rocky. Hence the whitewater never gets above middle Class II, and the run is suitable for novice and intermediate boaters.

The run begins at West Bridgewater. The first 6-7 miles are moderately steep and have more or less continuous middle Class II rapids. There are not many large rocks, and no ledges or holes. At medium water most of the rapids consist of waves at the bends, and an open boat can run this whole segment straight downriver without any ferries or defensive maneuvers. We have not seen it at high water, but suspect that it doesn't go beyond high Class II or low Class III. This segment has some very pretty stretches where it is back in the woods. Unfortunately these alternate with places where you are along side the highway and looking at guardrails and rip-rap and culverts. The highway has heavy traffic, especially on weekends, and the noise is distracting. The river is still quite attractive, but it is impossible to avoid the the thought that were the highway and the traffic not here it would be spectacular.

In Bridgewater there is a breached wooden dam above the bridge which does not create any waves or holes. One quarter mile below the bridge there is a left turn, and just around the turn there is a short but heavy Class II rapid with two holes and some large waves. It is easy to avoid the waves if you backpaddle on the corner and set up correctly, but a an open boat with the notion that it could just plow straight through them could easily swamp.

The next 7 miles to Woodstock are mostly Class I with scattered short Class II rapids at the bends. The valley has opened out and there are some nice views and pretty places with woods and flood plains, but like the upper stretch you still have a lot of road noise and rip-rap and distraction.

About 1/4 mile above the first bridge in Woodstock the river suddenly steepens and there are some big rocks, and a few holes and waves, making a nice Class II rapid that ends with a short Class II drop under the bridge. A pipe runs under the bridge and makes an artificial ledge with some standing waves. This rapid is harder than any of the others in the run, though still at most Class II at medium water. It is an excellent place to ferry and ride waves and practice (in fact the only good practice place on the river), but novice whitewater boaters may want to take out above it.

It is a little hard to find a place to take out in Woodstock since there are embankments and a lot of private houses along the river. One possible spot is behind the Federal Building, a big brick building on the right before the covered bridge.

If you paddle under the covered bridge and through town you should note that there is a substantial 2' Class III drop under the third bridge: this can be run but should be scouted.

* * *

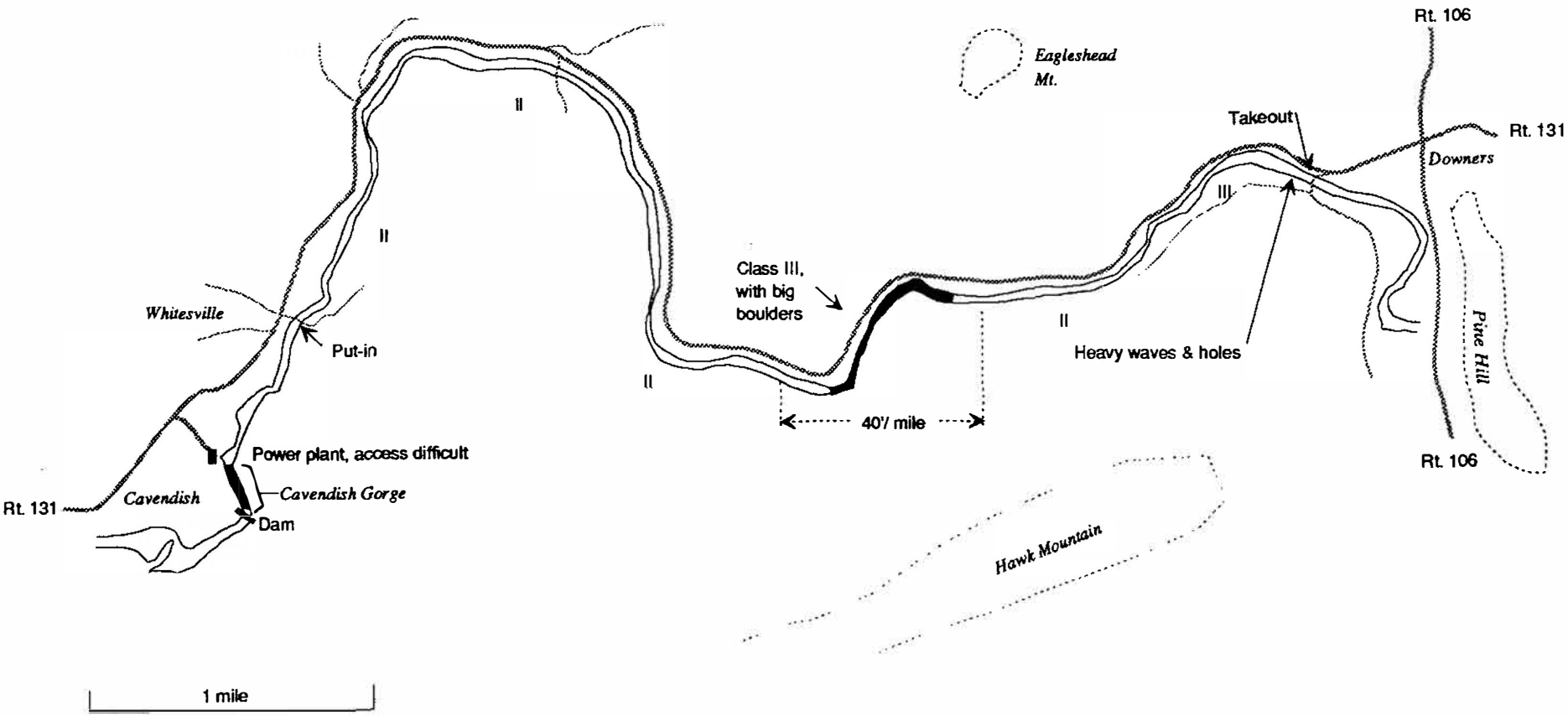
The main stream becomes moderately polluted in the Woodstock area, and has also been altered by recent highway construction and channelization; the best trout reproduction is reported to be above Bridgewater, but rainbow and brown trout are still found all the way to the mouth. The fishing is reported to be spotty, but the stream is in a area of the state that gets many visitors, and we rate it as a moderately important fishery both because of the amount of use, and because it does have pockets with good-sized native fish.

Botanical reconnaissance so far has not produced any interesting species. The spurred gentian *Halenia deflexa*, currently a missing species in Vermont, was formerly collected along the river near Woodstock; we have tried but failed to relocate it.

* * *

Rated HIGHLY IMPORTANT as a long Class II whitewater run suitable for novice and intermediate boaters; also considered IMPORTANT for water quality and oxygenation, and IMPORTANT for fishing.

Cavendish



Map 33: Black River From Whitesville to Downer. Lake and flatwater segments occur above and below this segment. Cavendish Gorge is very steep and obstructed, and probably has never been run.

10.15 BLACK RIVER: Whitesville to Perkinsville

Towns	Cavendish to Weathersfield
Counties	Windsor
Quadrangle	Ludlow 7.7'
Length	7 miles
Elevation	760'-520'
Average Gradient	35-40'/mile (1st 6 miles) 10-15'/mile (last mile)
Description	medium-sized bouldery upland river, with ledges and holes and waves; mostly Class II with one 1/2 mile stretch of Class III
Surroundings	big, steep-walled valley with hemlock-hardwoods forest and some pretty ledges; very little settlement along the road
Water Quality	good; receives treated wastes
Flow	Regulation by power dam above the Cavendish Gorge
Geology	mostly Cambrian quartz-mica schist; Cambrian dolomite near the covered bridge and below
Hydrology	gauge at North Springfield (below this segment): area 409 sq. km., mean flow 8.2 m3/sec, mean/max 3.5; watershed at Cavendish 295 sq. km., at Downers ca. 350 sq. km.
Biology	no natural trout reproduction; brook & brown trout stocked
Suitable For	intermediate open boats and kayaks
Season	snowmelt and after rains
Interruptions	none (ledges immediately above the put-in; dam at Perkinsville, below the take-out)
Importance	HIGHLY IMPORTANT for boating; fine, varied, exciting run.

This is the more southerly of Vermont's two Black Rivers; the northern one, near Newport, is also a whitewater run.

The whitewater, like that of many eastern Vermont streams, occurs as the stream cuts through the eastern edge of the mountains and drops into the Connecticut Valley. The setting is quite lovely. There is a narrow, mountainous valley, with fine ledges and forests and views and a bouldery, pleasant river. Route 131 parallels the stream and affords reasonably easy access and scouting. The road is mostly separated from the stream by wooded banks and the valley is largely without settlement. In consequence the run seems much wilder than it it actually is.

Hydrologically this segment of the Black has about the same slope and watershed as the rapids in the upper Connecticut at Lyman, or the Class II section of the West below Jamaica. In that section of the West, the combination of a medium slope and a substantial watershed have produced a solid Class II stream that rises to Class III where there are constrictions, steep pitches, or drops.

Much the same is the case here. The run is mostly Class II, but with enough Class III to give it a nice flavor. part. It has lots of rocks and holes and some interesting ledges and waves. It is not a tricky stream and not overly pushy or technical, but there is plenty of water and plenty to do. The top of the stream is wide and gentle and not very demanding. The middle part is narrower but not too much steeper. It has some big rocks and drops and pillows and eddies and is definitely three-dimensional water, and will sink a mis-paddled open boat without hesitation. The lower part is fast and full of waves but not as tight or three-dimensional as the upper. It has a couple of holes that you never see in time.

Put in near the bridge by Atherton's Mill in Whitesville. The ledge here may or may not be runnable, but it is easy to carry around it. Alternately you can come in 1/4 mile down stream by putting in where Twenty-mile stream crosses Rt. 131.

The first 3 miles are a standard Vermont Class II run -- boulders, waves, bends, and holes -- and present no difficulties. The water starts easy and gets gradually harder, and then abruptly a lot harder. About a mile below an iron bridge you start to see big rocks in the channel. The Class III part begins here and unless you have a very agile boat it is time to get out and scout. (Since one rock looks pretty much like another it is best to scout this part from the road and pick your warning marks beforehand. The picnic area 2 miles east of Whitesville is a good place to scout from.)

The next three quarters of a mile has a series of big rocks and drops and waves, and some technical maneuvering is necessary. Boat placement is important in several of the drops. If you have a quick boat and are quick with it you can improvise and enjoy it, but otherwise you may want to eddy hop and do some planning. If the water is high (or cold) open boat paddlers may want to carry up the north bank and portage along the road.

The two miles from the bottom of these rapids to the covered bridge are mostly middle Class II, but there are occasional drops and holes, and you have to be alert going around bends. There is a

hole and a big wave under the covered bridge, right when you think you are all done with the rapids; stay to the right here or have a stern paddler who bails fast.

The rapids end slightly beyond the Whitesville covered bridge; you can take out at here, or paddle about 1 1/2 miles further to where the river meets Rt. 108 in Perkinsville. There are no good takeouts in between. The last mile is all flatwater.

This river is a favorite, and gets a lot of use. The valley is clean and unspoiled, and the run is basically easy but just challenging enough to be exciting. The heavy sections are deep and have big rocks for eddying and enough space to maneuver easily, and so are satisfying in the same way that other 'big-rock' rivers like the West and Mad are.

* * *

There are a series of dams above this segment, and a hydro-electric plant. The water discharged from the dams is mostly surface water and hence quite warm in the summer. In addition there are no provisions for guaranteeing adequate minimum summer flows, and the water level can be very low in summer. The combination of high temperatures and low flows largely eliminates natural trout reproduction and growth in this segment. Brook and rainbow trout are stocked, and there is a small put-and-take fishery.

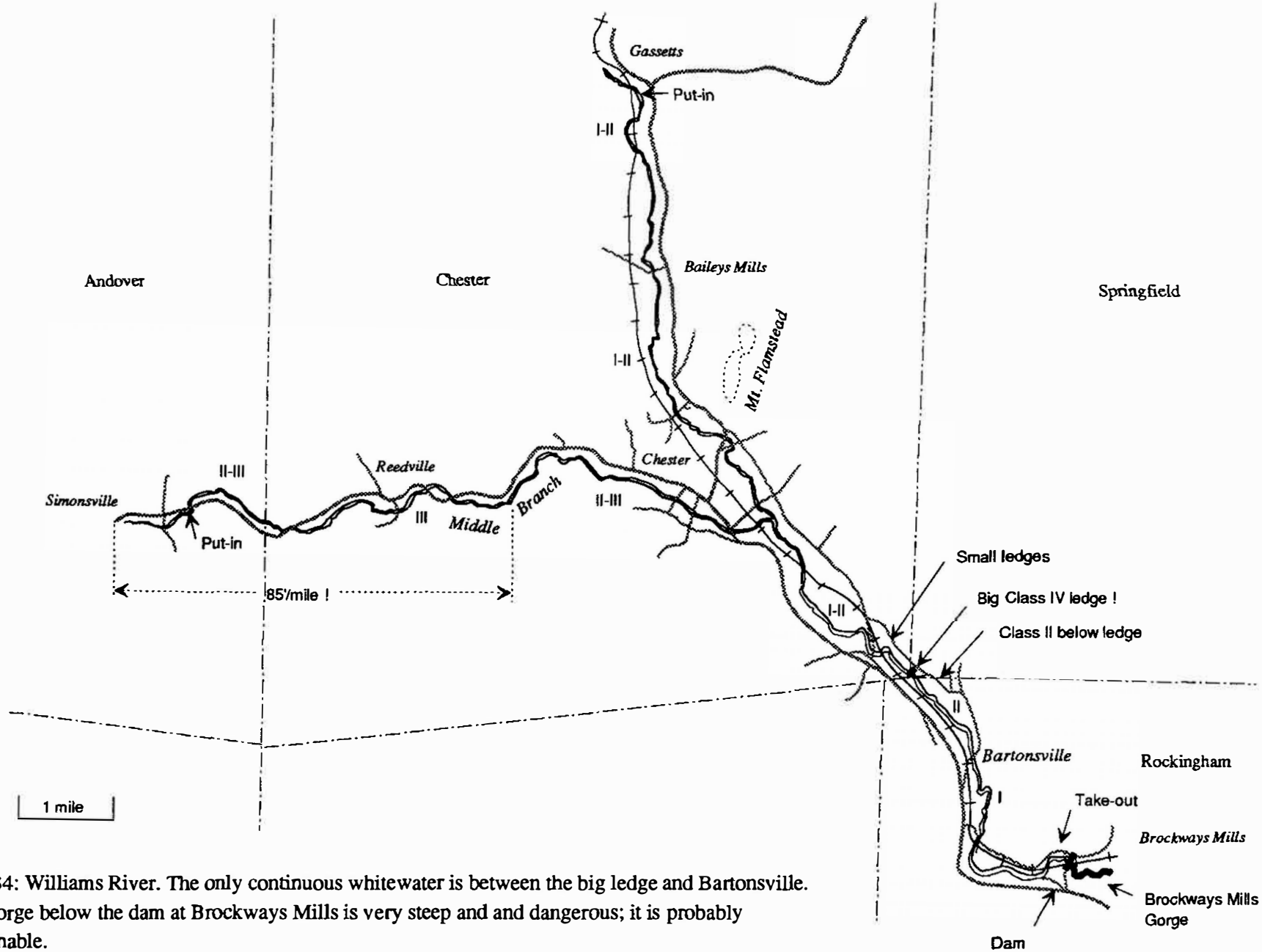
We have little botanical information. The Cavendish gorge, above this segment, is an important locality for mosses; botanical reconnaissance along the river itself has so far yielded only a single plant of interest, the sedge *Scirpus expansus*. This is currently known only from a few river and lake shores in the state, but grows in unremarkable places and may in fact be more common than the records suggest.

* * *

Rated HIGHLY IMPORTANT for boating: a fine, varied, beautiful whitewater run of medium difficulty, widely known to boaters and receiving considerable use.

* * *

Directly upstream from this segment is the Cavendish Gorge, a beautiful sculptured gorge with a number of cascades and pools. The gradient in the gorge is about 400'/mile, and there are drops and undercut ledges and big eddies and waterfalls and obstructions. At present it is regarded as unrunnable, and it is certainly an extremely dangerous place which could easily kill a boater.



Map 34: Williams River. The only continuous whitewater is between the big ledge and Bartonsville. The gorge below the dam at Brockways Mills is very steep and and dangerous; it is probably unrunnable.

10.16 WILLIAMS RIVER, MIDDLE BRANCH: Chester-Andover Town Line to Chester

Length	ca. 5 miles
Towns	Andover, Chester
Counties	Windsor
Quadrangle	Ludlow 15'
Access	Rt. 11
Elevation	940'-600'
Average Slope	ca. 70'/mile
Description	small rocky stream; Class II at medium water, Class III at high water
Surroundings	hemlock-hardwoods, farmland, houses, bridges & road
Water Quality	good
Flow Regulation	none
Geology	complicated sequence of Cambrian and Precambrian schists
Hydrology	no gauge data; watershed at Chester ca. 90 sq. km.
Biology	supports brook & brown trout; quality of the fishery is not known; no botanical data
Known Use	not known
Season	snowmelt
Suitable for	? kayak and advanced open boats
Importance	HIGHLY IMPORTANT for boating; small, technical stream with difficult, continuous whitewater

This segment of the Williams is a small, steep rocky stream paralleling Vt. Rt. 11 with tight turns, boulders 1-3' high, some steep pitches, and a few low ledges. The valley is farmed and settled , and the stream lies fairly close to the road and has pleasant but not striking scenery.

This is a very interesting small stream, with a small watershed and a steep slope. It is runnable from about five miles above Chester to Chester, and presumably (this has not been scouted) another mile from Chester to the confluence with the Williams River. The channel is rocky, with numerous boulders large enough to create waves and holes. There are also a number of low ledges or chutes that make heavy waves, especially on bends. And the average slope of 70' per mile means that it will be shallow and scratchy most of the time, and then suddenly become fast and pushy at medium to high levels.

At medium water this is probably mostly Class II, with perhaps some Class III water at the steepest places. At high water it is at least half Class III, with a lot of big holes and standing waves.

We ran it at very high water, and found it surprisingly demanding. The upper parts were shallow and mostly Class II, but below the confluence with the Andover Branch in Reedville it got considerable bigger. The slope there was nearly 100'/mile, and we found that there were sharp three-foot standing waves and holes and rollers half the width of the stream, and very little room to maneuver. In several places the stream was blocked by fallen trees. In other places there were debris jams or overhanging logs at difficult corners where much of the stream was funneling under them. Hence it was both an exciting run and a somewhat dangerous one. We came around one corner out of position, went up on a big pillow on a projecting ledge and saw a substantial hole directly below us and a strainer below the hole. Our boat, which in this instance had more good sense than its driver, grazed a rock and went into a eddy all of its own accord while we were still trying to figure out what to do. The general turbulence was such that it was hard to pick routes, and we found ourselves following the current over drops, bracing hard, picking our way through the standing waves, and then sneaking a glance behind us to see just what it was we had just come down.

The going became generally easier below the big corner 2 miles west of Chester, but there were still a number of difficult individual places, particularly a steep pitch or set of low ledges behind the first church in Chester.

We did not encounter anything that seemed harder than middle Class III, but we encountered a lot of that, and encountered it at a remarkable rate of speed. We want to stress that this is one of those small pushy streams -- like the Wardsboro or Ompompanoosuc West Branch to which the steepest sections are hydrologically comparable -- whose difficulty rises very fast with rising water level.

If you are preparing to run a stream like this, be aware that the stream will have very different sets of problems at medium and at high levels, and that you will have to be prepared for different things. At medium levels the stream will feel fast and rocky and require a lot on maneuvering but will not feel very dangerous. At high levels the rocks will be submerged and you will actually maneuver less, but the stream will be very pushy, and you will spend a lot of time back-paddling, steadying the boat in waves that you can't dodge, and worrying a lot about what may be around the corners.

* * *

We have no botanical data. Brown and brook trout occur; the stream is well shaded and has a number of pools, and so might be a good trout stream despite its steepness and consequent shallowness in the summer. It is pretty stream in a sparsely developed valley, and must be very attractive if run under conditions when you can take your eye off of the rocks and waves.

* * *

We rate it HIGHLY IMPORTANT for whitewater; it is a little known Class III run with excellent potential.

10.17 WILLIAMS RIVER 1: Gassetts to Chester

Length	5 miles
Towns	Chester
Counties	Windsor
Quadrangle	Ludlow 15'
Access	Rt. 103
Elevation	700'-560'
Average Slope	ca. 25'/mile
Description	narrow stream in farmland; ? intermittent Class II
Surroundings	farmlands, some second-growth woods
Water Quality	good
Flow Regulation	none
Geology	Precambrian schist & gneiss
Hydrology	no gauge data: watershed at Chester ca. 95 sq. km.
Biology	no botanical data; brook and rainbow trout fishery of unknown quality
Known Use	in AMC Guide; we did not encounter any users
Season	snowmelt, early May, after rains
Suitable for	open boats
Interruptions	very low dam at North Chester
Importance	not rated; not enough information

A small stream in an alluvial valley. A pretty, open, sparsely populated part of the state, barns and Jerseys and some classic farmhouses. The upper part of the Williams is very much a pasture stream: low banks, tight bends, only a few rocks, some fences and down trees. The floodplain is largely open with a few isolated woodlands, and there are some nice views.

Hydrologically the upper Wiliams is a stream with a small watershed (under 100 sq. km.), moderate slope and few channel boulders. This predicts that it will have only mild whitewater.

From what we have seen this seems to be the case. At medium water it had only occasional Class I rapids. At high water we imagine that it will be faster, but still be more of a Class I than a Class II stream. We would expect it to provide a twisty ride with intermittent Class II waves at the bends but no sustained whitewater.

The dam at North Chester mentioned in the AMC guide appears to be only 1' high, and probably easy to run at high water: scout to be sure.

* * *

We have little biological information: brook and brown trout are reported, but the quality of the fishery is unknown. Considering that this is a shallow stream that runs through a lot of open farmland we would not expect it to be exceptional.

Apparently no botanical work has been done along the stream, but our experience with agricultural streams on acid bedrock suggests that unusual plants or plant communities are very unlikely.

* * *

Not rated, pending observation at high water.

10.18 WILLIAMS RIVER 2: Chester to Brockways Mills

Length	ca. 7 miles
Towns	Chester, Springfield, Rockingham
Counties	Windsor
Quadrangle	Ludlow 15', Saxtons River 15'
Access	Rt. 11 bridge
Elevation	560'-460'
Average Slope	ca 15'/mile
Description	medium-sized stream in alluvial valley; mostly quickwater with scattered Class II rapids and one Class IV drop
Surroundings	farmland, hemlock-hardwoods, RR grade, occasional alluvial woods, occasional junk cars.
Water Quality	good; treated waste in Chester.
Flow Regulation	none
Geology	Precambrian schist & gneiss; then a compressed sequence including Cambrian gneiss, Cambrian chlorite schist, Ordovician chlorite schist, Ordovician quartzite granulite, and Ordovician gneiss: rocks which, for all their diverse names, look alike even to geologists
Hydrology	gauge at Brockways Mills: watershed 267 sq. km., mean flow 4.9 m3/sec, max/mean 3.8
Biology	fairly warm in summer, but still supports some rainbow & brook trout; good bass fishery; preliminary botanical survey did not find any rare species.
Known Use	popular for touring and whitewater
Season	snowmelt, early May, after rain
Suitable for	novice & non-whitewater touring

Interruptions major Class IV drop ca. 1/2 mile below 2nd RR bridge

Importance HIGHLY IMPORTANT for touring, mild whitewater, and fishing. Pretty stream and pleasant paddling. Individual rapids IMPORTANT for water quality.

This part of the Williams is much larger than the preceding segment. It has a broad agricultural valley with alluvial banks & woods and some nice views. The stream is separated by farmland and woods from the road and so is moderately private and undeveloped though definitely not wild. The railroad embankment and a bridge and a few houses at Bartonsville are essentially the only structures you see once you leave the road just below Chester. The river is sizable, clean, and handsome, and the valley pleasant to be in. It is, in our opinion, an underrated stream, and one we look forward to going back to.

The average slope of 15'/mile is too small to provide continuous whitewater, but there are a number of interesting individual rapids, and some excellent practice places. The combination of moderate slope and deep alluvium in the valley provide good flows when other steeper rivers are dry, and the rapids can often be run in wet periods in the summer.

The run begins at the Route 11 bridge in Chester. The first two miles are mostly Class I or easy Class II. As you turn left and cross under a bridge there is a Class II chute with some good waves and eddies. Then the river goes under a railroad bridge and turns right, and around this bend are a set of 1' Class II ledges, which are an excellent place for play. The ledges are locally called the Rainbow Rocks, and the pool below them is a nice swimming hole in the summer. Then the river runs straight with mild Class I-II rapids for three quarters of a mile, and there are some rocks on the left and a 5', Class IV ledge that extends across the river.

Everyone should scout this ledge and only expert boaters should run it. There is a dangerous hole below it, blocked by several rocks, where a boat can easily get pinned. Following this there is a difficult angled wave and another sloping drop of 3'. Even at low water an open boat can easily sink here.

Below this ledge there are some fine rapids, beginning with about half a mile of continuous Class II-III water, and ending with several sets of low ledges. The last ledge has a nice set of waves below it to surf on. These rapids have a lot of pretty blue rocks and nice pools, and have good eddies and interesting water. It is the kind of place where you can take your time and try every wave and learn a lot. Many of these rapids run after rains and in wet summers, adding greatly to the value of the river.

The rapids end above the bridge at Bartonsville, and the river runs Class I and quickwater for the 2 miles to Brockways Mills. Even though the rapids end at Bartonsville the last two miles have some interesting and pretty places, and are well worth running.

The run ends above Brockways Mills Gorge. There is a large waterfall at the head of the gorge immediately below the bridge. For details see our VWG report. Boaters should take out safely above the bridge. The gorge below the falls might be runnable in a closed boat. WE HAVE NOT ENCOUNTERED ANYONE WHO HAS TRIED THIS, AND CAREFUL SCOUTING WOULD BE REQUIRED BEFORE HAND.

The gorge is about 3/4 mile long and has a drop of ca. 100 feet so it would certainly be an expert run, but not prohibitively steep.

This segment is basically a quickwater tour rather than a whitewater run, but there are some difficult places, and boaters should to be careful with them. We have not seen it at high water and do not know which rapids wash out and which intensify.

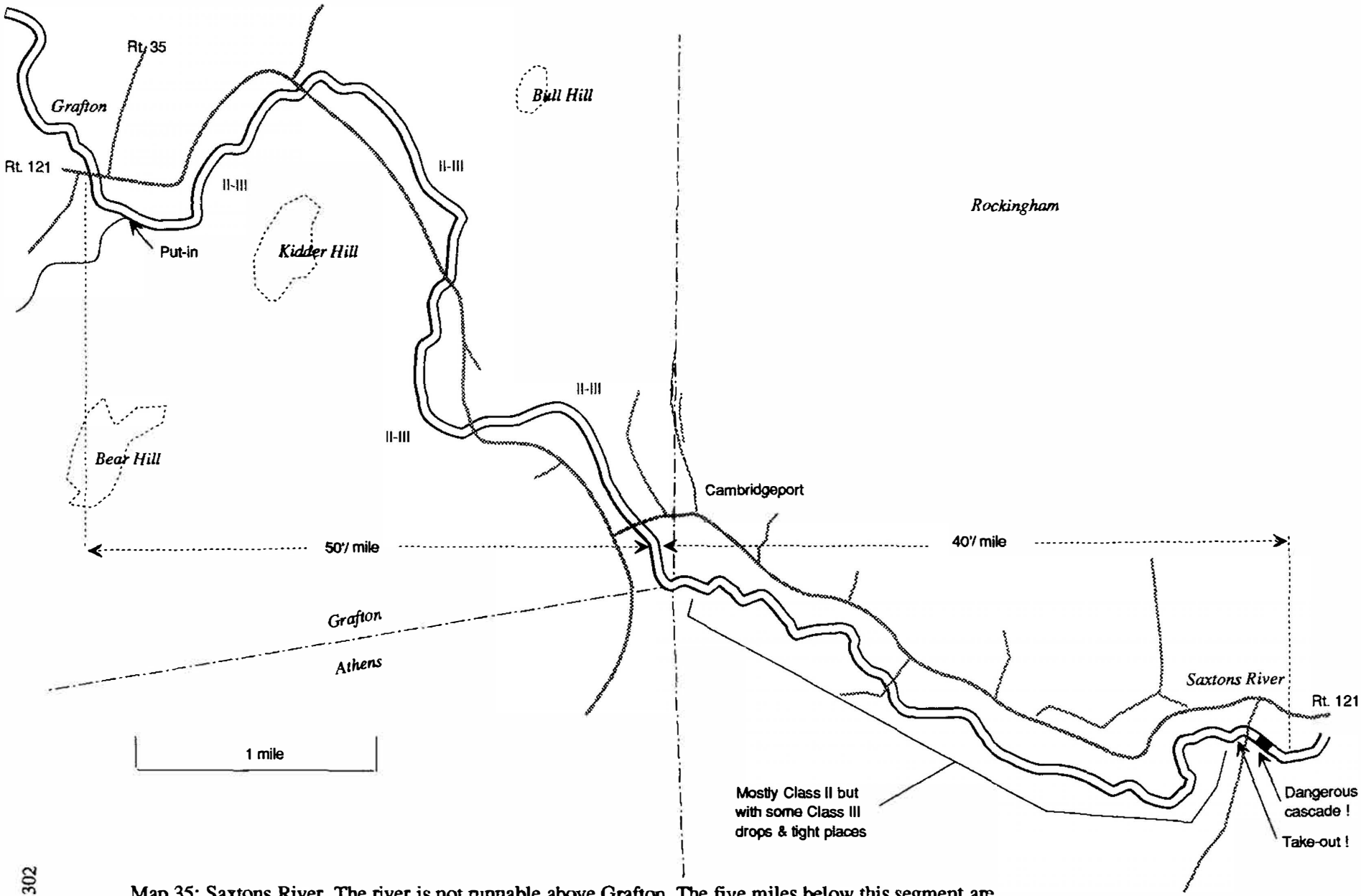
* * *

The main stream here is reported to get fairly warm in the summer, and to have some trout and a good population of bass. The water is basically clean, but because of the high temperatures, low gradient, and discharge of treated wastes in Chester, we regard the individual rapids as moderately important for water quality.

We have little botanical information from this area: field checks have so far yielded only common plants and unremarkable communities, with the exception of a single record for the marsh bellwort *Campanula aparinoides*, which is scarce in Vermont but has turned up a number of times along streams.

* * *

Rated HIGHLY IMPORTANT for boating both because of its beauty and quality as an undeveloped touring stream and because it has rapids which can be run after the normal whitewater season is over. Also IMPORTANT as a warm-water fishery, and with individual rapids that are IMPORTANT for water quality.



Map 35: Saxtons River. The river is not runnable above Grafton. The five miles below this segment are runnable but have three dams and a high waterfall.

10.19 SAXTONS RIVER: *Grafton to Saxtons River*

Length	ca. 8 miles
Towns	Grafton, Athens, Saxtons River
Counties	Windham
Quadrangle	Saxtons River 15'
Access	Rt. 121
Elevation	820'-480'
Average Slope	40-50'/mile
Description	small stream in narrow valley, Class II rapids and lots of Class III corners and drops.
Surroundings	second-growth hardwoods, hemlock-hardwoods, some farm land, some houses, no junk
Water Quality	good
Flow Regulation	none
Geology	complicated succession of Precambrian, Cambrian, and Ordovician gneisses and schists above Cambridgeport. Devonian limestone and schist below Cambridgeport
Hydrology	gauge at Saxton's River: watershed 187 sq. km., mean flow 3.4 m3/sec, max/mean 3.7
Biology	no rare plants; put-and-take fishery for brown and brook trout, with reportedly a few native fish
Known Use	popular with local kayakers and experienced open boat paddlers, also mentioned by a number of out of state boaters
Season	snowmelt and after rains
Suitable for	intermediate to advanced open boats, intermediate kayaks

Interruptions none

Importance HIGHLY IMPORTANT for boating; one of the best small technical rivers in the southern part of the state. Also IMPORTANT as a fishery.

A small, steep, windy stream with lots of boulders and small ledges, paralleling Rt. 121 and easily accessible from the road. The country is mostly average young woods, neither strikingly pretty nor disagreeable. There are not many views, but in this sort of a river you are looking at the water every moment anyway.

The Saxtons is a substantial whitewater run. The average steepness is a little higher than that of the Moose or Lamoille and the watershed a bit smaller. It apparently does not have quite as heavy water as either of these, but is thoroughly technical and demands careful, alert paddling.

It needs medium or high water to be runnable, and has a short spring season. At low water you dodge rocks and get stuck, and bump over ledges. At higher water the rocks are less important but you have a lot of tight corners with abrupt drops and groups of waves. Boaters who have run it when the water is good say that it is a pleasant but not difficult kayak run and a tricky and technical open boat run.

We did not see it with high water. From the slope and watershed and what we saw at medium water it seems to be a little less severe then the Winhall but to have more ledges and tighter corners. It looks to be a marvelous river and is certainly highly regarded by everyone who has canoed it.

At medium water the river is mostly Class II. At high water it is probably about half Class III and half Class II. It is a tight and tricky stream, and could be very difficult at flood. According to the AMC Guide the best range for open canoes is between readings of 3.5' and 4.5' at the gauge 1 1/4 miles below Saxtons River.

The normal run begins in Grafton and goes to Saxtons River. It is possible, but not necessarily desirable, to go farther, but the water is not as interesting and there are a number of obstacles. There is a dangerous drop just below the first bridge in Saxtons River. This is not usually run but might be possible (? Class IV) by an expert in a closed boat. Below it there are 3 miles of lighter rapids, then a dam, then a waterfall, then another dam. So far as I have been able to determine the stretch below Saxtons River doesn't get much if any use.

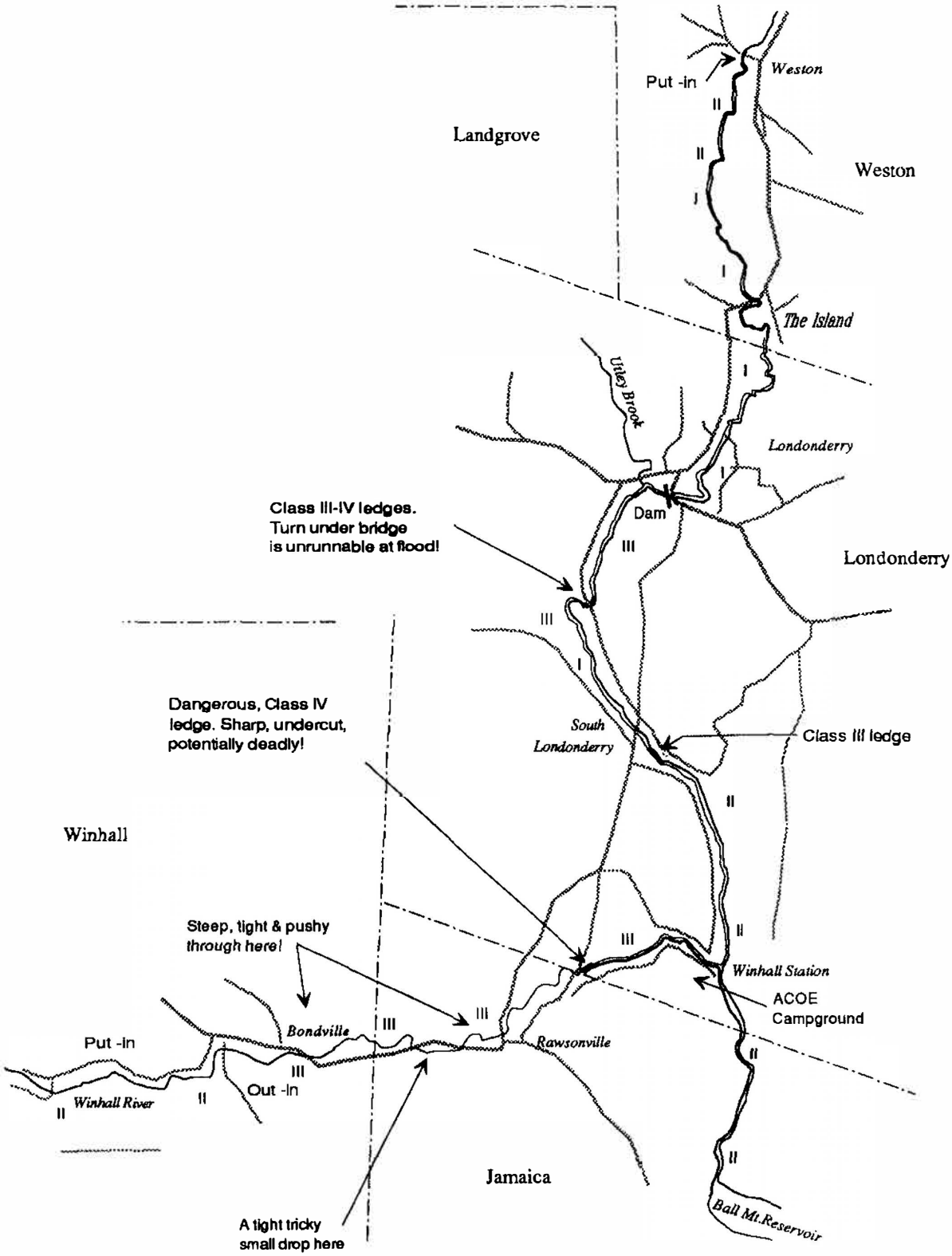
* * *

The main stream below Grafton is reportedly fairly warm in the summer, and hence marginal as trout habitat. Brown and brook trout are stocked here for a put-and-take fishery, and there are said to be some medium-sized native fish as well. The area is poorly known botanically. We have no

important historical records from the river, and our own surveys have not produced any plants of interest.

* * *

Rated HIGHLY IMPORTANT as a fine technical whitewater run, and IMPORTANT as a fishery.



Map 36A: Upper West River, Weston to Ball Mt. Reservoir; Winhall River. The ledge at South Londonderry is wet but not too difficult. The ledges below Londonderry are runnable at medium water, impossible at high water. The ledges and small gorge on the Winhall below Rawsonville are very dangerous, and probably should not be run.

10.20 WEST RIVER 1: Weston to Londonderry

Length	ca. 7 miles
Towns	Weston, Londonderry
Counties	Windsor, Windham
Quadrangle	Wallingford 15', Londonderry 15'
Access	Rt. 100
Elevation	1290'-1140
Average Slope	lst 2 miles slope 40'-45'/mile, last 5 miles ca. 15'/mile
Description	small upland stream, Class II-III above, Class I below
Surroundings	farmland, second growth woods, occasional houses
Water Quality	good
Flow Regulation	none
Geology	Precambrian gneiss
Hydrology	no gauge data: watershed at Londonderry ca. 180 sq. km.
Biology	no rare plants known; brook and brown trout
Known Use	? occasional use by open boats
Season	? snowmelt & after storms
Suitable for	open boats
Interruptions	none; ends at a dam in Londonderry
Importance	IMPORTANT for boating and fishing

This, the uppermost section of the West, is a small winding stream with scattered rocks and tight bends in an agricultural valley. The countryside is pretty, there are some nice views down the valley, and the parts you see from the road appear pleasant and not very difficult.

The run divides into two sections. The first two miles are are in a moderately steep, very rocky wooded ravine. This is the part you don't see from the road, and it is more difficult than the part you do. This section is difficult and scratchy at low water, with a lot of tight places to bump through. We have not seen it at high water, but think it will be a fast, technical Class II-III run. It is entirely away from the road, and can't be scouted easily. At medium levels competent boaters are probably justified in running it without scouting. But be aware that the steepest part of this segment is tight and rocky and ends at a potentially difficult corner. We would advise that it be scouted at high water, and that you expect continuous Class III rapids here.

The river flattens abruptly as it leaves the woods and for the next 5 miles is basically quickwater with a few scattered light Class II rapids. The section below the Route 155 bridge could be run when the upper section was too low.

This is a beautiful, peaceful run: no houses, nice views down to Glebe Mountain, swampy banks, excellent country for seeing birds and animals. We ran it in twilight one night when the woodcock were out.

About a mile above Londonderry the river turns right and there is a side-road bridge with two short Class II rapids. Then you enter the backwater of a mill dam and paddle between grassy banks the rest of the way to Londonderry.

* * *

We have no botanical information from this part of the West River. This segment has native brown and brook trout. the fish are reported to be small but the fishing generally good.

* * *

Rated IMPORTANT as a short whitewater run.

10.21 WEST RIVER 2: Londonderry to backwater of Ball Mountain Dam (The Londonderry Ledges)

Length	ca. 7 miles to backwater of Ball Mountain Dam
Towns	Londonderry, Jamaica
Counties	Windham
Quadrangle	Londonderry 15'
Access	from Rt. 11
Elevation	1150'-850'
Average Slope	40'/mile; maximum 100'/mile
Description	small to medium-sized upland stream; mostly Class III water with a difficult Class IV pitch at high water
Surroundings	second-growth woods, road, occasional houses
Water Quality	good; some domestic waste in Londonderry
Flow Regulation	none
Geology	Precambrian gneiss & schist
Hydrology	no gauge data: watershed in South Londonderry ca. 200 sq. km., and at the confluence with the pool of the Ball Mountain ca. 360 sq. km.
Biology	brook & brown trout of unknown quality fishery; no botanical data from this segment
Known Use	moderate use by local and visiting boaters
Season	snowmelt and after rain
Suitable for	advanced open boats, intermediate kayaks
Interruptions	ledges at Route 100 bridge, ledges in S. Londonderry
Importance	HIGHLY IMPORTANT for boating; a difficult, and reasonably well known high-level run.

This section of the West is a small to medium stream with lots of boulders and several substantial ledges. It parallels Rt. 100 as from South Londonderry to Londonderry, then follows a dirt road into the valley south of Shatterack Mountain and meets the backwater from the Ball Mountain flood control dam. The countryside is mostly second-growth woods, with some nice views of the mountains. Between S. Londonderry and Winhall Station the river corridor is isolated and undisturbed, and the views of Shatterack and Ball Mountain as you enter the backwater of the dam are very fine.

This portion of the river is steep and tricky, with some quick pushy water and two sets of very serious ledges. Hydrologically it is similar in slope to the Moose, Saxtons and upper Lamoille but with a somewhat larger watershed than any of these. The run is generally Class III, but made additionally difficult by sets of closely spaced small drops and their associated waves, and by the ledges in South Londonderry. It is wet but not too demanding for kayaks at medium water, and considerably more difficult for open boats. Many of the waves can't be avoided, and an open boat can easily take too much water and swamp. At high water it is very fearsome, and the drop under the Rt. 100 bridge is somewhere between Class V and impossible.

The first mile below Londonderry is Class II. About 1/2 mile above above the Rt. 100 bridge the gradient steepens to about 60'/mile and the stream comes Class III. Just above and below this bridge there is a difficult set of ledges, which are an intricate Class III at medium water and a Class IV at high water. The stream makes a right angle turn under the bridge, and at very high water -- near flood -- the water hits the bridge abutments and then explodes, and there may be no way to get under the bridge.

Below this ledge comes a short stretch of Class II-III rapids above the former South Londonderry dam, and then easy rapids to the second Rt. 100 bridge. One quarter mile below the bridge there is another a set of Class III ledges. These ledges are most difficult at medium water. At high water they tend to wash out, and can be run as a Class II set of standing waves by keeping to the left.

The stream then enters the woods, and, depending on how much water is ponded behind the flood-control dam, you have one to two miles of rapids to the backwater of the Ball Mountain Dam. This portion of the run is very beautiful. The stream is wide and rocky, the woods are handsome and wild, and there are continuous Class II-Class III rapids. There are few streams in Vermont that equal it for demanding water in an undeveloped setting. It is not well known, but certainly deserves to be.

As far as whitewater goes, the two ledges are the crux of this run. Scout them carefully. Both are tricky and require careful boat placement at medium water but are not particularly dangerous. But at high water the ledges at the Route 100 bridge become dangerous, and at very high water they are terrifying.

Rick Davis, a skilled closed-boat paddler, looked at the upper ledges when the river was in flood in April 1987. He said that the turbulence was awesome. He thought an expert could manage the

drops below the bridge, but that so much water was coming sideways onto the abutments of the bridge that he saw no way that he thought a boat could get under the bridge. We saw them in the same storm and agree fully.

There is road access to the Ball Mountain Park at the confluence with the Winhall, and through the park perhaps half a mile below this. The roads are small and can be impossibly muddy at snowmelt.

The segment from the Winhall to the Ball Mountain dam is very pretty but makes for a difficult takeout. If you run to the dam you have the choice of a steep portage up to the access road by the dam or a very hard portage over the dam and down again to the next section of the river.

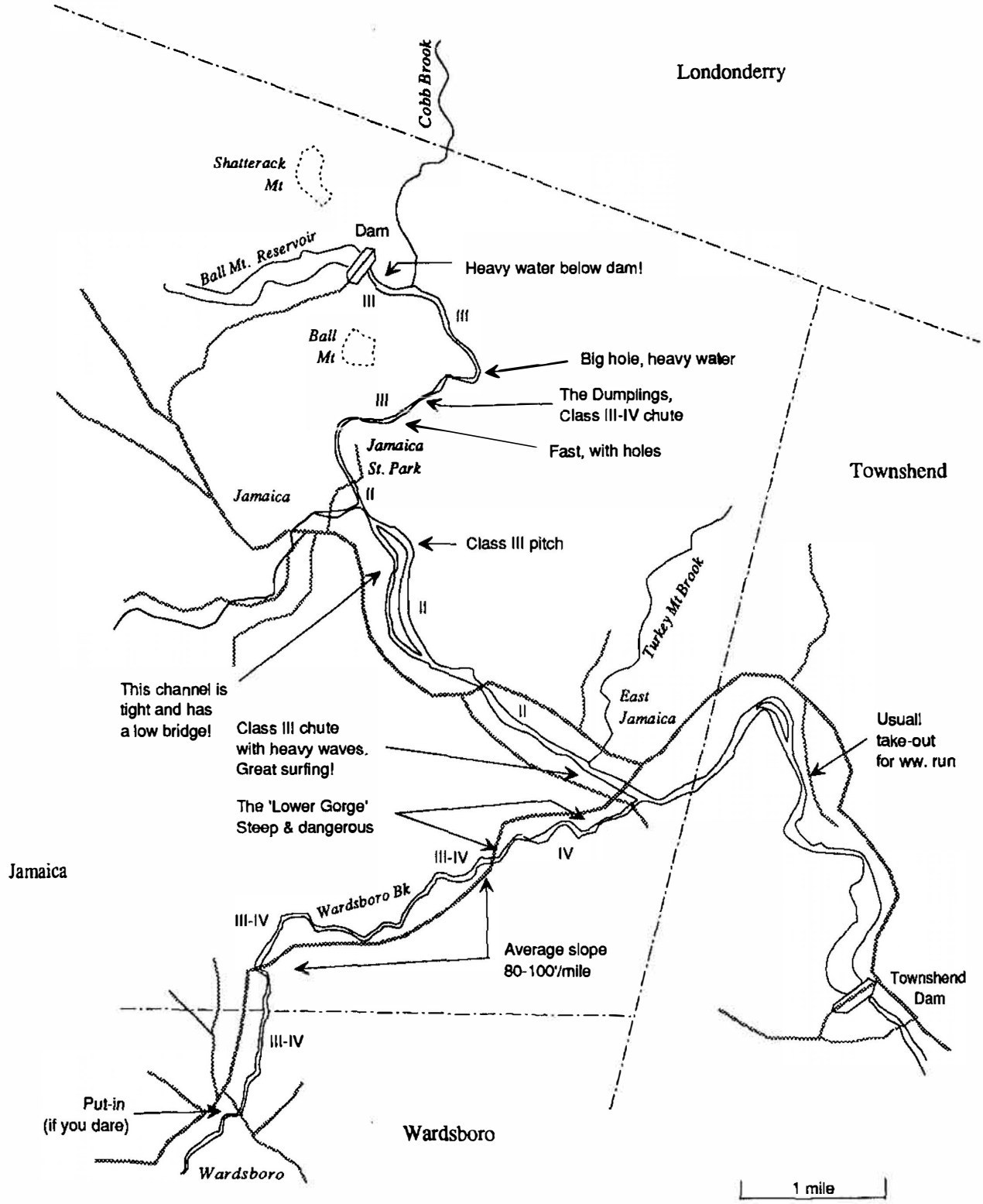
Before the Ball Mountain and Townshend Dams were built you could run continuously from Londonderry to Townshend and have nearly 20 miles of class II-IV white water, surely the finest run in Vermont. The Ball Mountain Dam interrupts the run and makes it difficult to run continuously, while at the same time providing the water releases that have made the section of the West below the dam nationally famous. The section above the dam is less popular, but it is still used, and people find it a demanding run. Ledgey runs are unusual in Vermont, and for this reason the Upper West, like the Saxton's, is especially popular with kayakers and boaters who enjoy staircases and drops.

* * *

No rare plants are known here, and we have no recent botanical information from this segment. Brook & brown trout occur. The quality of the fishery is unknown.

* * *

Rated HIGHLY IMPORTANT for boating because it is a popular and interesting run of a type that is not common in Vermont, and because it has a significant, three-mile long segment that is undeveloped and natural.



Map 36B: Upper West River, Ball Mt. Dam to Townshend Dam; Wardsboro Brook. The last half mile of Wardsboro Brook has a slope of 120'/mile and many large boulders; it is very dangerous, and possibly suicidal, at high water.

10.22 WEST RIVER 3: Ball Mountain Dam to Route 100 Bridge

Length	ca. 6 miles
Towns	Jamaica, Townshend
Counties	Windham
Quadrangle	Londonderry 15', Saxton's River 15'
Access	1) difficult carry from parking lot at Ball Mountain Dam 2) dirt access road up north side of the river through Jamaica State Park; normally closed to vehicles; park department provides shuttles during water releases
Elevation	800'-480'
Average Slope	ca. 50'/mile above Jamaica, 30'/mile below.
Description	medium to large river, in a narrow valley above and then developing a floodplain below; superb Class III-IV water above the bridge in Jamaica and Class II-III below the bridge
Surroundings	upper part: hemlock hardwoods in steep mountain ravine, some ledges. Lower part: low wooded banks, some houses, some alluvial woods, finally swampy woods or flooded woods at flood control pool.
Water Quality	good
Flow Regulation	Ball Mountain Dam, immediately above this segment
Geology	Precambrian gneiss & schist; small amounts of lime occur locally near the foot of Ball Mountain
Hydrology	gauge at Jamaica State park: watershed 464 sq. km., mean flow 17.9 m3/sec, max/mean 3.4; watershed at Townshend dam ca. 700 sq. km.
Biology	good brown trout fishing reported below the dam; formerly had runs of Atlantic salmon; salmon restoration project currently underway; records of several rare plants
Known Use	upper segment used heavily during whitewater releases, both for recreation and competition, rarely used otherwise; lower segment gets much use throughout season.

Season	snowmelt, sometimes after rains, and during water releases, which are currently held on 2 weekends in April and May, and one in September or October.
Suitable for	upper section, intermediate to expert open and closed boats; lower section, novice to intermediate open and closed boats
Interruptions	none
Importance	HIGHLY IMPORTANT for boating: famous race course that has been used for national team trials and championships; superb water suitable both for intermediate and expert boaters; annual water releases popular with boaters from all over the Northeast; possibility of a world championship here. HIGHLY IMPORTANT for biology: good existing fishery, important for the salmon restoration project, several rare plants

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This is the famous part of the West that is known nationwide for races and water releases. It is a big deep stream. The upper part, above Jamaica Bridge is in a steep, and very rocky wooded valley, with small waterfalls coming in on the sides, and many large rocks in the stream bed. The lower part is wider and partly alluvial. Here the hills are set back farther from the stream, and there are fine views, many bars and chutes and islands, and a few big rocks. The surroundings are beautiful all along. My two favorite places are the large pool above the dumplings where there are beautiful ledges along the south shore, and the backwater of the Townshend Dam where the views of Rattlesnake and Bald Mountain are breathtaking.

Hydrologically this segment of the river is unique in Vermont. Both the upper and lower parts of this segment have twice the watershed of other Vermont streams of comparable slope. The large watersheds give them big waves and very exciting water, and also make them more roomy (and hence safer) than smaller streams of similar intensity.

The upper part of this segment is from Ball Mountain to the Jamaica Bridge. Access is through Jamaica State Park. A dirt road (the grade of the former West River Railroad) extends up the north bank from the bridge to just below the dam. The road is closed to vehicles except during water releases when the Vermont Department of Forests and Parks runs a shuttle service. It is possible to carry boats up the road on foot, or to carry them down from the Ball Mountain Dam.

At moderate levels the run is fast and exciting but basically quite safe. It begins with a mile of big waves and holes. You are going very fast and there are a lot of rocks and holes, but there are no major problems and you can paddle defensively and be fine. Then there are two sharp bends with

very big holes where you have to either ferry to the inside or be prepared for a wet ride. After this there is a steep quick drop to a nice pool where you can rest. Below the pool are three great big rocks that almost block the channel. Closed boats can run to the right into a big hole. Open boats usually make an S-turn here, passing the first rock to the left, turning to the right above the second rock, and then turning back to the left to miss a big hole which, on release days, has more kayaks than water in it. The S-turn is not really that difficult, especially compared with the pushy water higher up, but there is a rock and a big wave waiting for you if you don't turn in time and usually a mess of spectators on the banks, and everyone regards it as the climax of the run.

Below the Dumplings there is a very quick section with several holes and some more big waves and then 3/4 of a mile of easier water from there to the bridge at Jamaica.

The lower five miles of this segment, from Jamaica to West Townshend, are milder but can be mean when the river is in flood. There are only a few rocks and holes, but the river has some steep pitches that develop big waves, and there are two channels around islands that have tight bends and strong rips where they rejoin the main channel.

People either put in at the Salmon Hole in the state park or at Jamaica Bridge for this portion. The run begins with fast water right below the bridge, then some nice eddies with difficult waves on the left, and then a chance to run right or left around an island. The right channel is narrow and fast and goes under a low bridge which you may need to look at a high water. The left channel has a fine pitch with some Class III rocks and waves half way down. After this the water gets milder for a while and is basically Class II till you come to a steep pitch above the second Rt. 100 bridge, where the river narrows into a chute and there are several big waves and a nice pool and some eddies. This is a favorite surfing place, though the current is quite fast and it is hard, for us at least, to get on the waves. This chute is a solid Class III at medium levels and requires either that you be prepared to paddle aggressively through some steep breaking waves or that you be defensive and run a sneak route to either side.

Below the Route 100 bridge the river flattens out and alternates between quickwater and nice Class II rapids on the bends. There are some nice eddies and practice places here, and even if the whitewater is not as continuous as on the upper river the setting is very attractive and well worth paddling.

The normal takeout for this section is on a 20' high bank to the left where a dirt road comes down to the river. The current is fast here and many boaters turn into a little creek entering from the left and pull out there. If you want a longer tour with great scenery you can paddle another XX miles to the West Townshend Dam. If you do this you will have a long carry up to the road on top of the dam.

During snowmelt the Ball Mountain dam releases 2500-4000 cubic feet per second (ca. 72-130 m3/sec). At these levels the upper segment of the West is probably mostly Class III-IV and the lower segment mixed II and III. For races and recreational releases the dam releases 1500-1800 cubic feet per second (43-52 m3/sec) and the upper segment is mostly Class III with the Dumplings perhaps Class IV. At these levels the lower segment is mostly Class II, though with the

Class III pitches noted above. BOATERS SHOULD NOTE THAT THE MEAN APRIL FLOW (66 m3/sec = 2300 cfs) IS CONSIDERABLY HIGHER THAN THAT ENCOUNTERED DURING RACES OR WATER RELEASES, AND PLAN THEIR SCOUTING AND PRECAUTIONS ACCORDINGLY.

Both of the parts of this segment are almost perfect whitewater runs. The West is compared to other Vermont streams of similar intensity. The upper segment has difficult water but enough room to maneuver and enough time to think, and it has lots of eddies to rest in and safe places to roll or recover below the difficult places. Hence it doesn't hurry you and you can work down it gradually and enjoy the water and experiment with it, unlike some of our smaller and more pushy streams.

The lower part has substantial rapids but few drops and holes, and is very sunny and wide and open and scenic. At medium water levels it is a good place for learning about waves and current without having to battle rocks, and is a wonderfully relaxing run after you have been in the upper part. At high water -- 3000 cfs and above -- it is a substantial run in its own right: fast current and big waves, especially where side streams come in, two wild cutoffs behind islands. The senior author was thrown out of his boat here one day in early April when Ball Mountain dam was releasing 2800 cfs, or twice the level of a recreational release. He remembers that for a moment or two all he could see around him were waves, and that he had the momentary sense of being overboard at sea. He also remembers that the hole that sunk him looked fully capable of swallowing a pickup truck, or perhaps several.

Races and water releases on the West are a New England institution.[17] There may be anywhere from 100 to 500 boaters, and total crowds may be over 1000. People come from all over the East, and come back year after year. They say they love the river and the clean water and clean park, and excellent facilities and service. Many of them say that though there are bigger and more demanding streams elsewhere the West River weekends are the most fun and most satisfying of any, and their favorites of the whole whitewater season.

Considering the rivers with which the West must compete, this is remarkable praise, and there can be no doubt that the West is one of the state's whitewater treasures: a beautiful river with varied, safe and extremely exciting water in a beautiful setting. Equally the Vermont Park Department (who arrange the releases and handle the crowds and camping and shuttles) should share in the praise. They provide excellent facilities and service, handle large crowds with a minimum of restrictions and delays, and have impressed virtually every boater I have talked to by their friendliness and hospitality.

17. Since this was written the West River races have been discontinued, owing in part to conflicts with fishermen about the wires across the river used to suspend the gates for the race course, and in part to liability problems that arose when the Town of Jamaica attempted to bill the race organizers over $10,000 for a fatality that occurred during a race weekend, but which was not connected with the race and occurred in the lower river, a mile or so away from where the race was being held. We feel that the races are a great loss to Vermont boating, as there are now no whitewater slalom races of any sort held in Vermont, and now no opportunity to see national and international caliber boating. We realize that there were legitimate grounds for conflict between race organizers, fishermen, and the town, but think it quite unfortunate that these could not have been resolved by negotiation.

* * *

The upper part of this segment is of considerable biological importance. Because of the small amounts of lime in the soil it is botanically interesting. It has two species (green alder, *Alnus viride;* dwarf bilberry, *Vaccinium cespitosum)* that are rare in southern Vermont. It also probably has the yellow rein orchid, *Habenaria flava*, which is discussed in the next section.

In addition to the plant records there are two records of rare beetles from this section. See the discussion on rare insects in Chapter 5 for details.

This portion of the river is also quite important for fish. It supports a good brown trout population and was formerly an important spawning stream for the Atlantic salmon. In many respects it is a choice place for fish, being cooler and deeper and more shady than much of the rest of the West, and so is particularly favorable to trout and other coldwater species.

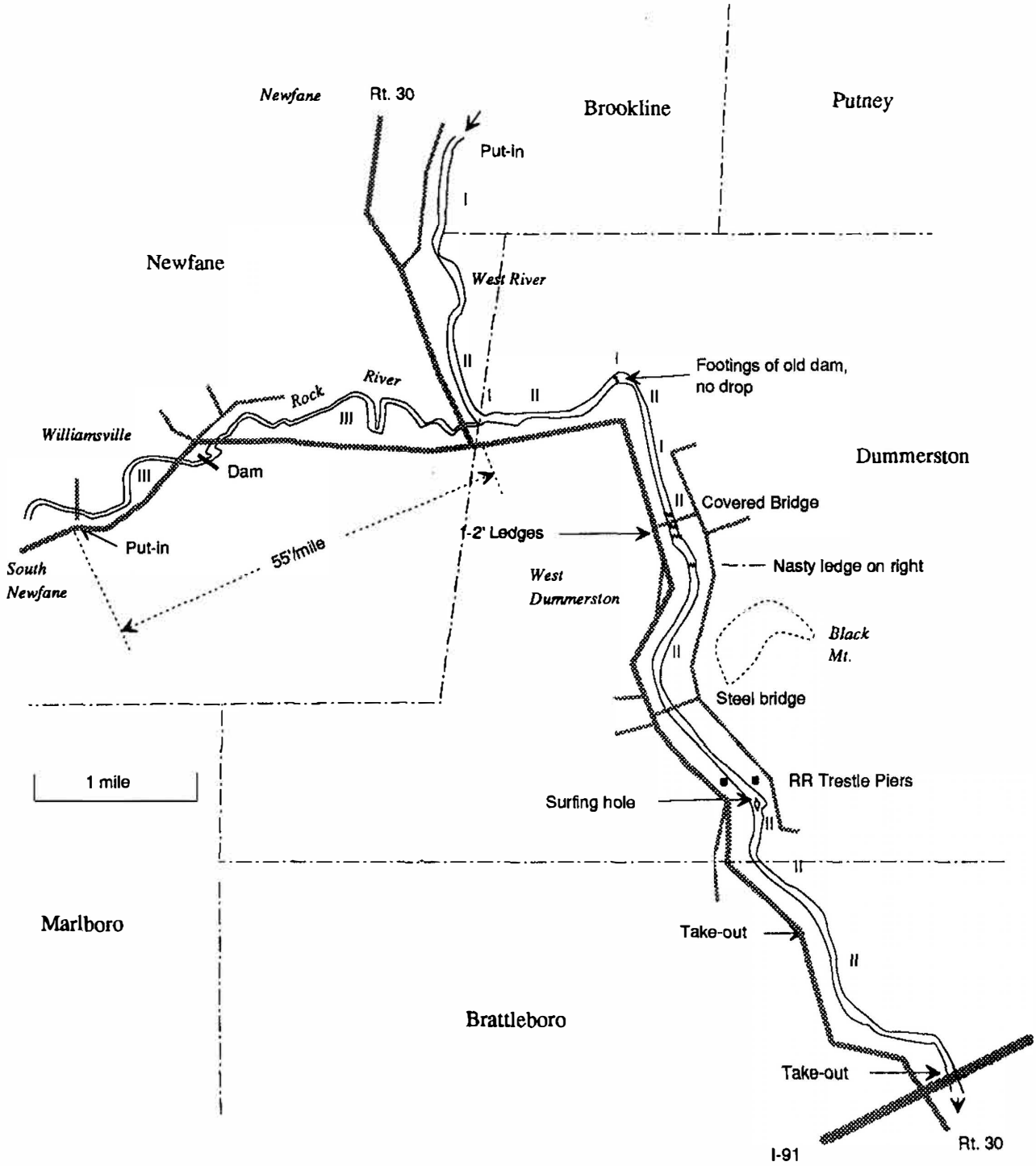
Since 1981 young Atlantic salmon have been stocked in the West with the hope of establishing salmon runs here. (This is part of a salmon restoration project jointly undertaken by the federal government, Vermont, New Hampshire, Massachusetts, and Connecticut. The project began in the early 1970's, and has involved growth studies in a number of watersheds, the stocking of a number of million young salmon, and the construction of bypasses or fish ladders on all the dams on the Connecticut from Bellows Falls to Long Island Sound.) The high flood control dam at West Townshend is a difficult obstacle; current plans call for netting returning fish in the spring run and carrying them over the dam.

There has been considerable discussion by boaters and fishermen about potential conflicts between whitewater releases and the salmon project. Fisheries biologists feel that late spring, summer, or fall releases endanger adult fish (which are not feeding and hence are weakened), disturb spawning grounds by siltation or scouring, and kill young fish. Boaters feel that salmon breed by their own choice in streams liable to spates, and are smart enough to choose spawning sites that aren't disturbed by short periods of high water. They also feel that because of the obstacle presented by the Townshend dam the upper parts of the West are never going to be a major salmon stream, and that perhaps the upper West should be devoted to whitewater use and the salmon restoration focus on the lower West, and on undammed streams like the White.

This is both a technical argument and a partisan one, and we have neither the space here to do justice to the issues involved, nor the expertise to decide between conflicting factual claims. But we might mention two observations which bear on the discussion. The first, somewhat in favor of the boaters, is that the river levels used for water releases are actually considerably lower than the average levels encountered in April, and so the releases are, in natural terms, not very dramatic or unusual events. The second, in favor of the biologist's concerns, is that natural high water of any kind is rare in September and October. Thus it seems possible to us that even medium high water in the fall might causes a lot of mortality among young fish. This may not be important because high fall flows don't occur every year, and also because natural populations tend to be organized into cohorts because of predator-prey cycles. (And thus the loss of a single year's cohort of fry in high water may not be very important.) If this was the case annual fall releases, even if fairly mild, could be an unnatural and damaging stress.

* * *

The middle West River is rated HIGHLY IMPORTANT as a fishery, for rare plants, and as a regionally and nationally known whitewater run.



Map 37: Lower West River and Rock River

10.23 WEST RIVER 4: Townshend Dam to Connecticut River

Length	ca. 18 miles
Towns	Townshend, Newfane, Brookline, Dummerston, Brattleboro
Counties	Windham
Quadrangle	Saxton's River 15', Brattleboro 15'
Access	Rt. 30
Elevation	440'-220'
Average Slope	ca. 12'/mile
Description	large alluvial river; mixed quickwater and Class II rapids
Surroundings	varied; hardwoods forest, some farms, occasional houses; no trash, nice views
Water Quality	good
Flow Regulation	Ball Mountain Dam and Townshend Dam
Geology	Cambrian quartzite granulite, gneisses, and schists; Ordovician gneiss & schist; Devonian slate-phyllite; Devonian limestone; granite pluton (near West Dummerston)
Hydrology	gauge at Newfane: watershed 798 sq. km., mean flow 17.9 m3/sec, max/mean 3.7; watershed at mouth 1100 sq. km.
Biology	good bass fishery, mostly too warm for trout; several records of rare plants.
Known Use	very popular for general touring; popular whitewater run in spring, important whitewater teaching area
Season	good whitewater in spring and after rain; other parts can be run much of the year
Suitable for	general open boat use, closed boat teaching and practice

Interruptions	*none*
Importance	HIGHLY IMPORTANT for boating: a popular river for general touring and whitewater practice. HIGHLY IMPORTANT for rare plants. MODERATELY IMPORTANT as a bass fishery; also IMPORTANT for water quality.

This segment of the West is a large, mild, clean, pretty river. It is separated from the road and and private for the first 10 miles, and then close to Rt. 30 for the last half. It has fine views of farmland and mountains. And the water, while never as intense as the segments near Jamaica, is fascinating. There are substantial rapids at high water and good whitewater practice areas at medium water. The overall gradient is not steep but the watershed is large, and there are a number of low ledges and rocky pitches with locally steepened gradients that make for interesting boating.

The run starts below Townshend dam. The first three miles, to the Rt. 30 bridge, are quickwater and have a number of short Class II rapids. This segment is not particularly rocky but there are some occasional places to practice eddy turns. It is nice touring water, and excellent practice for beginning whitewater boaters.

The next 3.5 miles, about to the south end of River Road in Newfane, are mostly quickwater. There are some beautiful bars in this stretch with handsome colonies of the sand cherry (*Prunus pumila*) a scarce plant in the state as a whole.

At this point (about one mile north of the mouth of the Rock River), the valley narrows, the floodplain vanishes and the channel becomes rocky. The next six miles have the most varied whitewater in this segment, and are the portion most used for whitewater practice.

The whitewater begins with a bouldery, 1/2 mile long rapid just above the Rock River confluence. The river is wide, and there are many different routes down it. The water is not very difficult, but because of all the big rocks it is great water for practice and teaching. The boulders are large and closely enough spaced that you can first paddle down a rapid and then work your way back to the top by ferrying and eddy-hopping. This is an ideal situation for practice because you can try running the rapid in many different ways.

Below the mouth of the Rock River there is a nice Class II+ hole and some good surfing waves on the left, then a Class II rapid in the channel, then quickwater to the site of the former West Dummerston Dam. The dam is gone but there are a few good waves at the dam site.

Below the dam site you see the big covered bridge 1 mile above West Dummerston. A series of ledges, highest on the left side of the river, begins just above the bridge. Boaters may sneak through these easily on the far right, or may select drops of varying difficulty by running further to the left. The routes and difficulty vary with the water level. At medium water there are many interesting Class II routes through the ledges, and some more difficult places with holes and rol-

lers that may interest competent closed-boat paddlers. There are also some excellent eddies and surfing waves below the ledges.

About 0.5 miles below the bridge there is a 3-4' ledge on the left, which at medium water is a Class III drop and has a serious hole below it. This can be passed safely by staying to the right. If you decide to run it it needs to be scouted, because at some levels it might trap you if you made a mistake.

At this point you are opposite Black Mountain. The gradient steepens slightly and large granite boulders begin to appear in the channel. The paddling is basically quickwater for about a mile until just below the steel bridge where there is a fine Class II rapid. Like the rapid above the Rock River there are many big rocks and good places to eddy, and you can stay in the rapid and work up and down.

Below this the river bends right and there is a large midchannel bar. On the outside of the left channel there is a Class II-III hole which has great surfing waves, and is sharp enough for closed-boats to do pop-ups and nose-stands in. This is followed by another excellent Class II rapid, again with lots of big rocks, just above the Dummerston Brattleboro line.

There is a convenient takeout here and boaters interested mostly in whitewater often end their runs here.

It is 3.5 miles from this takeout to the mouth of the river. The paddling is mostly quickwater, with one short Class II rapid which is nice but not as nice as the ones above. The last mile goes through the Retreat Meadows, a large marsh that is an important area for birds and wildlife.

* * *

As a whole this 18 mile section must be rated one of the finest river segments anywhere in the state. The water is clean and interesting and suitable both for touring and whitewater practice. The river valley is developed but the roads and buildings are for the most part set back from the river banks and so the river feels more private than it actually is. The run is long enough for a leisurely day trip and there are good camping places midway making it a possible over-night trip. Much or all of it can be paddled late in the spring, and often through the summer and fall if the year is wet. And there are many nice woods and rocks close to the river, and fine long views downstream and up into the surrounding hills.

* * *

Botanically this is one of the most interesting streams in the state. We have records of the riverweed *Podostemum*, the yellow rein orchid *Habenaria flava* (only current Vermont site), the sand cherry *Prunus pumila*, an odd aster (a variant of *Aster novi-belgii)*, the rush *Juncus marginatus*, the grass *Panicum rigidulum*, and the milkwort *Polygala sanguinea*. Also there is an unusual alien, *Thermopsis caroliniana*, a tall ornamental legume native to the southern mountains and very rarely reported wild in New England.

With the exception of the alien *Thermopsis*, these plants all have some preference for lime (which is interesting since the dominant rocks of the area are non-limy granites and schists), and are for the most part more widely distributed south of us. They make an interesting contrast to the rare plants of the upper West River, all of which are northern species. There are also several interesting species characteristic of alluvial woods near the mouth of the river, and several interesting historic records that have not been relocated. Taken altogether, the West is quite an important stream botanically, and could certainly stand further exploration.

The lower West also has a good fishery. This segment is too warm to be a good trout stream but supports an excellent bass population and is a very popular fishing stream.

Because the stream is shallow and warm in the summer, and because it receives nutrients from settlements and farms in the watershed we consider the rapids here important for water quality.

* * *

This segment is rated HIGHLY IMPORTANT for boating, fishing (because of the amount of use) and for rare plants. Also IMPORTANT for water quality.

10.24 WINHALL RIVER: Grahmville to West River

Length	ca. 6 miles
Towns	Winhall, Jamaica, Londonderry
Counties	Windham
Quadrangle	Londonderry 15'
Access	Rt. 30
Elevation	1360'-960'
Average Slope	ca. 60-70'/mile
Description	small to medium-sized upland stream; continuous class III rapids, with portions that are high Class III or Class IV at high water.
Surroundings	second-growth woods, bridges, buildings, some junk
Water Quality	good
Flow Regulation	none
Geology	Precambrian gneiss and schist
Hydrology	no gauge data: watershed 160 sq. km. at mouth
Biology	brook and brown trout; quality of fishery not known no botanical data
Known Use	moderate; known to many canoeists who visit the West River
Season	snowmelt and after rain
Suitable for	expert open boats, advanced & expert closed boats
Interruptions	low ledges behind the Winhall firehouse, and by the islands just below the second Rt. 11 bridge; dangerous Class IV chute and rapids 1 mile below the Rt. 100 bridge in Rawsonville
Importance	HIGHLY IMPORTANT for boating; one of the six rivers in Vt. with a continuous Class III run over 4 miles long.

The Winhall is a bouldery upland stream in a post-agricultural valley. It begins in the National Forest, then parallels Rt. 30 and then follows a dirt road to the join the West River at Winhall Station. It runs mostly next to the road or in second-growth woodlands. The upper segment -- above where it becomes runnable -- is one of the longest wild rivers in Vermont. The middle section, along Rt. 30, is unremarkable for scenery or wildness, but the last mile, where it leaves the paved road, is very pretty.

The middle Winhall is a steep stream with a gradient of 65'/mile. It is comparable in drainage area to the Saxtons but steeper; generally similar to the Ompompanoosuc West Branch; and less steep but with half again as much drainage area as the Wardsboro. It has tight bends, many boulders 3-4' high, a few large rocks, several low ledges, and one long dangerous set of ledges that are usually carried.

The Winhall is an exciting, technical stream, pushy and fast, with what we perceive as a streak of nastiness. Typically it is shallow, steep, and tight. It gives you very little time to see what's coming and very little space or water to do anything about whatever you see. Mostly you paddle in the middle of the stream, backpaddle on the corners, dodge rocks, and take the ledges anywhere you can.

With streams of this steepness the speed of the water increases faster than the depth, and the stream is already a technical Class III by the time it becomes runnable at all. At low water there are many rocks and tight congested chutes and corners where you need control but can't get your paddle in deep enough -- or keep it in long enough -- to get a solid stroke. As the water gets higher the rocks wash out and there are mostly a lot of waves, but at this level it is very fast, and there is some heavy water at the corners. At flood it becomes wild and dangerous, and should not be run at all, or only by experts and after careful scouting for obstructions.

The run begins from along Kendall Farm Road. The beginning is easy Class II. Half a mile below the Kendall Road bridge there are a pair of Class III drops, followed by some more Class II, and then a steep Class III chute with a small ledge and diagonal wave under the first Route 11 bridge. This is one of the two hardest places on the run and should be scouted.

Past this bridge is a very steep rocky pitch with a slope of ca. 100'/mile that feels a little like you are riding down a sawmill flume while someone tosses rocks at you. You then cross Rt. 11 a second time. Beyond this bridge there are some small islands with ledges next to them that can run high Class III. This is the other difficult spot and also needs scouting.

Below the islands you have more high speed water with sharp corners but no particularly nasty spots or ledges. You cross Route 11 a third time and then Route 100. One mile farther there is a small side road bridge. Take out here as there is a very dangerous set of Class IV ledges immediately below. At some levels these may be runnable, but boaters should note that they have sharp-edged, undercut rocks and it would be very easy for a boat to get pinned here.

You may carry around the ledges on the road to the left. Below them there is a very pretty 1.5 mile Class II run in the woods down to the confluence with the West River, or, if the pool behind the dam is high, with the Ball Mountain Reservoir. The slope here is about 40-50'/mile. The river is wider and more comfortable than above and there are a number of nice rocks for eddies.

* * *

We have little biological data on this segment. It is listed as a brook and brown trout stream. It has had some casual botanical survey but has not produced anything interesting.

* * *

The Winhall is rated HIGHLY IMPORTANT for boating as an excellent Class III run with a two mile lower section that is very pretty and wild.

10.25 WARDSBORO BROOK: Wardsboro to Jamaica[18]

Length	4 1/2 miles
Towns	Wardsboro, Jamaica
Counties	Windham
Quadrangle	Londonderry 15', Saxton's River 15'
Access	Rt. 100
Elevation	980'-560'
Average Slope	ca. 90'/mile
Description	small steep upland stream with large boulders and tight difficult rapids; Class III-IV, very dangerous at flood
Surroundings	second-growth hardwoods, road, houses, some hemlock; pretty ravine for last mile
Water Quality	good
Flow Regulation	none
Geology	Precambrian gneiss, Cambrian schist & gneiss
Hydrology	no gauge data: watershed at mouth 96 sq. km.
Biology	reported to have brook and brown trout; quality of fishery unknown; no botanical information
Known Use	much talked about but very few people have actually run it
Season	snowmelt and after rain
Suitable for	experts in closed boats
Interruptions	none

18. There are two Wardsboro Brooks in the West River watershed. This is the one that joins the West River in Jamaica.

Importance HIGHLY IMPORTANT: the most difficult regularly used stream in southern Vermont

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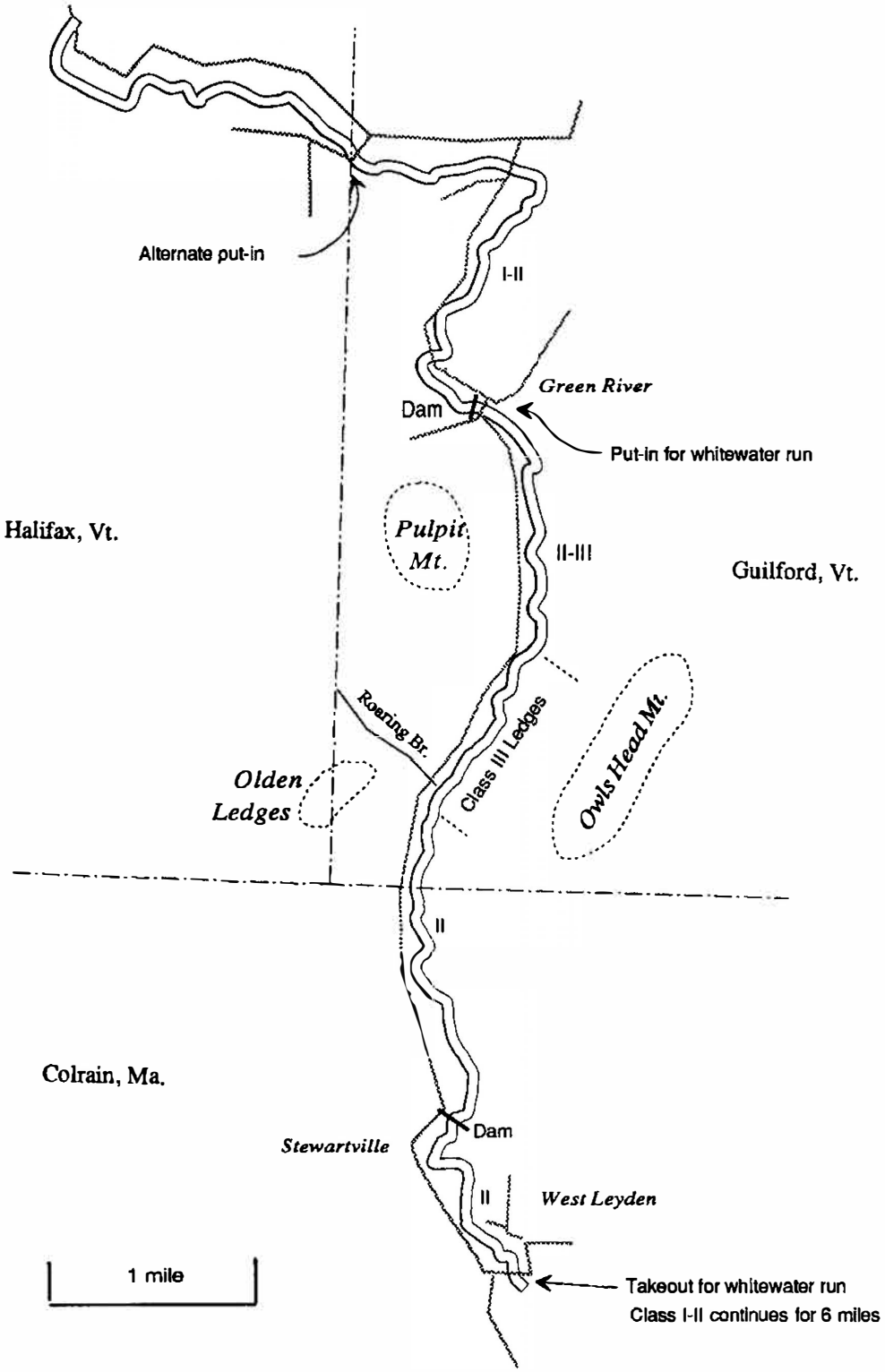
A small upland stream paralleling Vt. Rt. 100. The watershed is under 100 km. sq. but the slope is near 100' per mile. The stream is in a wooded valley and has steep banks and a boulder-filled channel. There are no major ledges, but almost no pools or eddies either. Because of the steepness when it is deep enough to run at all it is very fast. It has a number of large rocks in the channel, and these create some very narrow passages with no alternate routes. The narrow passages can easily get blocked by trees or brush and make dangerous obstacles. The turns are tight, and when the water is high there are very strong currents, big waves and substantial holes, especially in the last mile. At medium water is is Class II-III above, and probably Class IV below. At high water it is extremely difficult and dangerous, and probably would be rated Class IV above and perhaps Class V for the last mile.

Jim Northup, an expert kayak paddler who gave us information about a number of Class IV streams, said that at high water this was one of the most threatening small streams he had ever been in. He recalled that he had paddled it with about five other kayak paddlers, all excellent boaters, and only two or three made it to the bottom. The rest spilled and chose not to continue once they got out. He said that the combination of great speed, small size, limited visibility around corners, and limited maneuverability because of the narrow channel made it both very difficult and very dangerous.

There are two points where the stream goes under Rt. 100. Above the first bridge it is fairly small, and mostly Class III at medium water. Below the first bridge it remains Class III at medium water but become Class IV at high water. Below the second bridge it gets steeper and then enters a narrow ravine. This is the most difficult part of the run. At high water it is prohibitively dangerous, even for an expert party.

* * *

Rated HIGHLY IMPORTANT for boating, as a uniquely difficult high gradient stream. Biological importance unknown.



Map 38: Green River, Vermont and Massachusetts

10.26 GREEN RIVER: *Green River, Vt. to West Leyden, Mass.*

Length	ca. 8 miles
Towns	Guilford, Leyden
Counties	Windham, Vt., Franklin, Mass.
Quadrangles	Brattleboro 15', Colrain (Mass.) 7.5'
Access	back road to Green River
Elevation	680-430
Average Slope	ca. 30'/mile
Description	small clean mountain stream; Class II with a few Class III spots at medium water, possibly largely Class III in flood
Surroundings	hemlock-hardwoods forest, ledges, occasional houses, one sawmill, no trash
Water Quality	good
Flow Regulation	dam at Green River but no regulation
Geology	Devonian limestone
Hydrology	no gauge data: watershed ca. 110 sq. km. at the VT-MASS border
Biology:	brook and brown trout present; looks to be a fine trout stream; no botanical information
Known Use	not much used by Vt. canoeists but popular with boaters from Mass.
Season	needs medium to high water and so runnable during snow- melt and for a few weeks after, and after heavy rains.
Suitable for	intermediate open boats at medium water, advanced open boats and kayaks at high water.
Interruptions	dam by sawmill in Stewartville, Mass., 2 miles above West Leyden.

Importance HIGHLY IMPORTANT for boating; extremely attractive run of moderate difficulty and length; very popular with boaters from the Connecticut Valley and receives much use; IMPORTANT as a trout stream.

The Green River is an an upland stream in a wooded valley, with maples and hemlocks, a few farms and houses, and a narrow dirt road on the west bank. The whole valley is post-agricultural and very much closed in by young woods. There are no paved roads, and even though it is moderately settled it feels quiet and private. The stream is narrow, and there are no views. When you are paddling you see mostly water and trees. The water is extremely clean, and the stream has lovely pools and small ledges, and looks like a perfect trout stream.

The Green River is an excellent example of what small amounts of local roughness can do for the quality of whitewater. This stream has a small watershed and a gradient of 30'/mile, and thus is comparable to streams like the East Branch of the Passumpsic which produce at most mild Class II water. But unlike them the Green River has a number of short steep passages and a few low ledges, and these give it local intense spots, which change the character of the run, and keep you on your toes the whole way.

The run is delightful. There are a lot of small rocks (typically 2-4' high), tight corners, and several steep places with 1-2' drops, narrow chutes, and some waves and holes. The river is small and keeps surprising you. One moment you are just cruising along enjoying the trees and steering around rocks. Then you go around a blind corner and there is a hole or an nice wave, and then another corner and a relaxed straight passage. At medium water it was all Class II, with a few spots on the upper end of Class II. At high water it will still be largely Class II, but have a number of individual spots that are Class III.

The run normally begins below the dam at Green River, though it is possible to start 2 miles higher if desired. The first two miles below the dam are easy Class II. Then there are 3 sets of Class III ledges, beginning 500 yards above the confluence with Roaring Brook, and ending under a small bridge where there is a diagonal wave and a hole to dodge.

Below this the run is basically Class II. There is a dam that must be portaged at Stewartville, Mass., and a low ledge 1/4 mile above the bridge at the takeout.

It is possible to continue the run another six miles to a water-supply dam near the Greenfield Town line. This part of the run is mostly Class I and mild Class II, and is continuously wooded with a number of beautiful pools.

This segment is a very popular run. There are many boaters in the Connecticut Valley, and this is the nearest good Class II water to many of them. It is used by many individual boaters, and also by a number of clubs and classes.

* * *

We have little biological information. The stream is reported to have brown and brook trout. It has a number of the characteristics of a good trout stream (fertile watershed, slope not to steep, ample shade, good pools) and might be a good fishery. Because of the limestone in the watershed and its position on the Massachusetts border it could easily be important botanically, but so far no field work has been done here.

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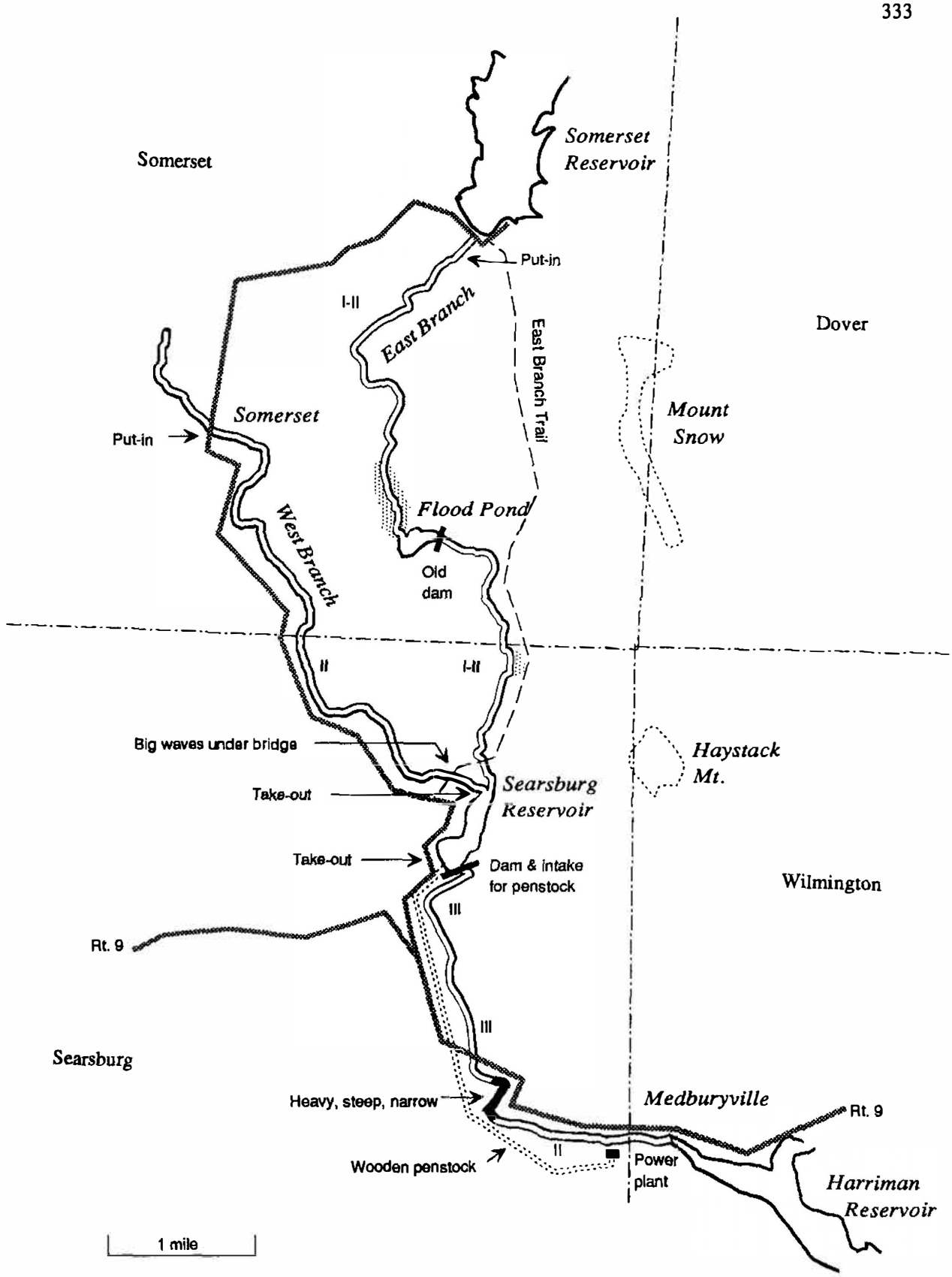
Rated HIGHLY IMPORTANT for boating, both because of its interest and beauty, and because of its popularity.



Map 39: Upper Deerfield River, Including East and West Branches

10.27 DEERFIELD RIVER, WEST BRANCH 1: *Somerset Road Bridge to the Confluence with the East Branch*[19]

Length	4 1/2 miles
Towns	Somerset, Searsburg
Counties	Windham
Quadrangles	Wilmington 15'
Access	from the dirt road to Somerset Reservoir
Elevation	1900'-1700'
Average Slope	40'/mile
Description	medium-sized upland stream, fairly remote & unsettled area, continuous Class II rapids, no ledges or dangerous spots
Surroundings	mountain hardwoods-spruce-fir forests; no buildings or clearings; fine wild country, beautiful scenery
Water Quality	none better
Flow Regulation	none
Geology	Precambrian gneiss & quartzite; small amounts of Precambrian marble have been reported from the watershed but have not been seen in the field
Hydrology	no gauge data; watershed at confluence with East Branch ca. 120 sq. km.
Biology	no rare plants; small populations of small trout
Known Use	a number of very faithful local users
Season	snowmelt and after heavy rains; snowmelt typically comes in early April and lasts about 2 weeks.
Suitable For	whitewater touring; intermediate open boats, beginning kayaks

19. The Deerfield has two West Branches (not to mention an East Branch which lies west of the North Branch.) This is the more northerly of the two.

Interruptions none

Importance HIGH IMPORTANCE for boating: very fine Class II run in undisturbed wild setting; also HIGH IMPORTANCE for biology because it is in a wild and largely undisturbed area

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This is a wild, clean run on a handsome stream back up in the mountains. The West Branch, or rather this West Branch, parallels the dirt road into Somerset north of Vermont Rt. 9. It is fine country: almost no houses, otter, bear, bobcat, and moose, spruce and fir, clean brown water, mountains all around. From the Somerset Road you have ten miles of woods on either side of you before you hit another road.

The West Branch has a substantial slope, comparable that to that of a number of Class III streams, but since the watershed is fairly small and there are no especially intense places it is essentially a Class II run.

The West Branch drains the mountain slopes west of Somerset Reservoir, and the whitewater season depends on snowmelt. It comes up in the first thaw days but only stays up as long as there is some snow on the mountains. The best runs are during sudden thaws when there is a foot or two of snow remaining and still lots of ice on the banks, but it is also runnable after some rainstorms. There is a gauge painted on a rock by the Forest Service footbridge one mile above the Searsburg Reservoir. Below two feet on the gauge it gets pretty thin, from two to three it is sweet, and over three it can be quite a ride. The waves under the footbridge are as high as any that will be encountered on this segment, and serve as a good indicator of water conditions.

The stream has a medium-size channel of even width and slope. It is bouldery rather than ledgy, and has no drops or narrow chutes. At all levels it is basically a safe river, with no places that need scouting.[20]

The run is spirited, continuous, and interesting, about three-fourths of it rocky Class II rapids and one fourth fastwater. There are no technical passages or difficult hydraulics but there are plenty of waves and some steep pitches and tight turns. At medium water good eddies and places to play. At high water and flood levels the rapids are very continuous, with fast current, big standing waves, and allegedly one hole with bears that swim around in it and tear up boats. The river remains Class II even at high water, but when the gauge is above three feet it is certainly as wet and strenuous a Class II as any you will ever see.

The last mile has some of the most continuous rapids and steepest pitches, with only a few places to stop. Paddlers in open boats will want to do their bailing before this part, and not think that be-

20. The road on the other hand is not safe. In early spring it also has holes and waves and recirculating parts. A stick or pole sticking out of the middle of the road is a local sign meaning a hole over 2' deep. Cars that pull off onto to what looks to be solid ground at the edge of the road sometimes sink altogether. Sometimes they come up again when the road freezes in the fall, but at least one Mercury that was lost in an extremely muddy spring has never been found.

cause the run is nearly over they can make do with a water-laden boat for a few minutes more. Be careful under the cable bridge, and if you have water in the boat keep close to the right hand shore and try to sneak through among the rocks rather than getting out in the waves.

You can take out on the right just below the confluence with the East Branch, or paddle another half mile to the stillwater above Searsburg Dam and take out there. Be careful above the dam. The dam supplies water to a penstock, and the intake is near the right hand shore, just above the dam. There can be a dangerous whirlpool when the penstock is use.[21]

The West Branch is less important for biology than for boating. No rare plants are known, despite many trips in the area. Brook trout are present, but the watershed is infertile and gets fairly warm in the summer. Local fisherman much prefer to fish the East Branch where water from Somerset Reservoir keeps the temperatures lower and summer water levels more constant. But it is still a wild and undisturbed stream in a remote area, and these are rare enough in Vermont that every one is important.

* * *

Rated HIGHLY IMPORTANT for boating: a very fine medium to high Class II run in itself, with a wonderful undisturbed mountain setting. General biological importance HIGH because it is a wild stream in a remote area.

21. Chris Tolle, and the late Ray Gaudette, who introduced me to this river and liked to sit in eddies and pass an un-AMC-approved bottle and tell stories about rivers and airplanes said that they once made, 'not exactly on purpose' the two mile run down the inside of the penstock to the surge tank above the Medburyville power station. According to them the run down the penstock is Class IV, and 'A flashlight would have helped.' They said that while they were paddling around inside the surge tank they considered trying the last drop from the surge tank through the turbines and out the tailrace, but that it looked hard and they were going to be late getting home already.

10.28 DEERFIELD RIVER, WEST BRANCH 2: Searsburg Reservoir to Harriman Reservoir[22]

Length	4 miles
Towns	Searsburg, Wilmington
Counties	Bennington, Windham
Quadrangle	Wilmington 15'
Access	from the road to Somerset Reservoir
Elevation	1700'-1500'
Average Slope	50'/mile
Description	bouldery mountain stream with steep gradient, tight bends, and some big rocks. Steep, fast, and mean, Class III at high water
Surroundings	mountain woods, highway and penstock right-of-ways; Water Quality excellent
Flow Regulation	substantial amounts of flow shunted around this segment by a penstock when the power plant at Medburyville is operating
Geology	Precambrian schist & gneiss
Hydrology	no gauge data: watershed at Harriman dam ca. 230 sq. km.
Biology	no botanical information; brook trout present, fishing poor because of low summer flows
Known Use	rarely used by local boaters
Season	spring high water and after rains
Suitable For	experienced open boats and kayaks
Interruptions	none

22. This is the continuation of the previous West Branch, and is not the number two West Branch down by Readsboro.

Importance would be important for boating if it ever had much water in it; potentially the best Class III water in this part of the state but usually to low because of the divereted flow

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This segment of the Deerfield, from Searsburg Reservoir to Harriman Reservoir, is rougher and less used than the preceding ones. The drainage area is over twice that of either the East Branch or upper West Branch, but much of that flow is either intercepted by Somerset Reservoir or diverted around this segment by the penstock. It is usually a feast or famine situation -- near flood or not enough water to run.

This segment parallels first the Somerset Road, and then Vermont Rt. 9. It has a few houses on it and is less wild than the upper part. It has some fine views, and is quite pretty.

It is also quite mean -- a solid Class III boulder-bashing mountain stream, comparable in watershed to the upper Lamoille but measurably steeper. It has big rocks, steep pitches and tight corners, and is very pushy and tricky. In watershed and slope it is roughly equivalent to the Winhall, Saxtons, or upper Lamoille. The difficulty is fairly uniform, with the exception of a Class III constriction and drop about a mile below the Route 9 bridge. It is a good kayak run and quite capable of sinking (and smashing) an open canoe. You should look it over carefully from the road or from the old railroad grade on the east bank -- once you get on it there won't be much time for looking around, and there are very few places to stop.

You can put in immediately below the dam at the Searsburg Reservoir. Normal take-outs are at the Medburyville Bridge or Harriman Reservoir. Watch the S-turn under the Rt. 9 bridge, the constricted part about a half mile further on, and the cross-rips from water released by the powerplant at Medburyville.

Because of its unreliable water levels and occasional un-nicenesses to boats it is not one of our best-loved runs. But none the less it can be some exciting paddling, and skilled boaters who have caught it at the right level and survived talk about it for years afterwards.

* * *

Biologically undistinguished, at least given present knowledge: a warm stream that dries up in the summer when the flow is diverted in the penstock, and an infertile watershed -- hence poor fishing. No plant records of interest.

* * *

Rated IMPORTANT for boating. It is an intense and interesting run and would rate as highly important if it were not for the diversion of water and the consequent difficulty of catching it at runnable levels.

10.29 DEERFIELD RIVER, EAST BRANCH: Somerset Reservoir to confluence with West Branch

Length	5-6 miles
Towns	Somerset, Searsburg
Counties	Bennington
Access	carry down from the outlet of Somerset Reservoir
Quadrangle	Wilmington 15'
Elevation	2020'-1760'
Average Slope	40'/mile
Description	outlet stream of Somerset Reservoir; small, remote, wild, with continuous Class II water
Surroundings	spruce-fir-hardwoods forests; some beaver ponds; large marshy pond (Flood Pond); no buildings or roads
Water Quality	good
Flow Regulation	by Somerset Dam
Geology	Precambrian schist; maps show Precambrian marble near the confluence with the West Branch, but this has not been located in the field
Hydrology	no gauge data; watershed at confluence with West Branch ca. 85 sq. km.; flows may be somewhat lower than would be expected for this watershed because Somerset Reservoir (which stores water for power generation at the Medburyville and Whitingham power stations) has a very large capacity and doesn't let out much water in the spring.
Biology	good brook trout fishery; interesting river-edge plant community; good populations of narrow-leaved gentian at Flood Pond; very wild area, used by otter, bobcat and bear
Known Use	many fishermen, few local boaters; not generally known

Season	snowmelt, during water releases, fall drawdown
Suitable for	intermediate open boats, novice kayaks
Interruptions	breached dam at Flood Pond, 3 miles below reservoir; occasionally run but usually carried.
Importance	HIGHLY IMPORTANT for boating and biology; nice stream occasionally runnable in summer; remarkable setting; good fishing, interesting biology

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This stream parallels the West Branch, and in an ana-cartological way lies between the West Branch and the North Branch. It is accessible at top or bottom by road, but otherwise wild and accessible only by foot. It lies in beautiful mountain country, beaver and spruce and otters, very quiet and private. We believe it to be wildest and most remote whitewater stream in Vermont.

The East Branch is only a few miles from upper West Branch, and similar in slope but with a somewhat smaller watershed. The flows are regulated by Somerset Dam which holds back much water in the spring, and so it probably never becomes as intense as it might be if unregulated. Thus it is never a heavy whitewater run. At average levels it has a nice fast current and lots of rock dodging but not big holes or waves. In flood it might be something else.

According to local boaters the best time to catch it at runnable levels is when the power company is drawing Somerset Reservoir down in the fall. There are no gauges by which to judge this. Somerset Dam has several outlet tubes, and the local word is that when one and a half tubes are open it makes a good open boat run.

Flood Pond, halfway down, was used to provide water for log drives in the days before the construction of the Reservoir. The old dam at the south end of the pond is partially breached. It supposedly can be run but there may be hazards, and the turn in the chute below it is nasty. I have never known anyone to run it. SCOUT IT CAREFULLY IF YOU INTEND TO TRY.

This is one of the few whitewater streams in the state easily accessible at both ends but remote in the middle. It is not a difficult stream, but sometimes has nice sporty water, and its length and remoteness give it great charm. They also make it potentially hazardous since when you are at Flood Pond you are 3 miles from the nearest road access. Boaters who use it should be aware that this run presents some of the difficulties of a wilderness trip, and make sure the party is strong enough to be self-supporting in the event of an accident.

* * *

The biology of the stream owes much to Somerset Dam. The minimum flows are higher here than in the West Branch, and summer temperatures stay lower because the reservoir is quite deep, and

feeds the river with bottom rather than surface water. The stream is a natural brook trout fishery, and local fishermen say it is the best fishing stream in this part of the Green Mountain Plateau.

Because the stream is remote it is a good area for wildlife. The late Bill Poole, a man of legendary abilities as a woodsman and tracker, spent 60 years exploring the East Branch country. He maintained that East Branch was the best area for wildlife in the southern Green Mountains. He was personally familiar with about eight different bears that lived in the surrounding mountains and fed along the stream. The East Branch always has several deer yards near the stream, produces sign of bobcat and otter throughout the winter, and is an exceptionally good place to look for signs of other wildlife.

Part of the attractiveness of the area for wildlife may be related to an unusual plant formation that occurs there. The frequent and regular variation of the water level below Somerset Dam has created a narrow belt of sedge marsh along both sides of the East Branch. These marshes are typically 10-40' wide. In vertical range they begin at the average low water level and grade into shrubs and other normal shore vegetation at about the average high water level. Hence they are structurally a form of tidal marsh. The dominant plants are sedges (*Carex torta, Scirpus cyperinus,* etc.) but a number of grasses and tall herbs (including, curiously enough, skunk cabbage) occur.

These marshes are used by a number of animals, particularly moose, bear (mostly in the spring), and deer. They are probably equivalent to beaver ponds as sources of food and cover but may be additionally important in that they extend along the river for several miles, and so are available to animals from a fairly large area.

The marshes are also interesting in themselves; while they do not include any uncommon plants or even any uncommon grouping of plants, they are an unusual, and hence instructive example of how fluctuating water levels can extend the normal shoreline communities. So far as I know they have no parallel on any Vermont stream.

Excellent populations of the narrow-leaved gentian (*Gentiana linearis)* occur on the shores of Flood Pond, in the middle of this segment. This is a plant that is frequent in the southern Green Mountains but scarce in this state as a whole. The population here is a nice one (several hundred plants or more), and hence of statewide significance.

* * *

The East Branch is rated HIGHLY IMPORTANT for boating, for wildlife, for fishing, and for an unusual plant formation. The whole valley is beautiful, rare, wild place and a treasure for anyone who loves the woods.

THE WILDNESS OF THIS AREA IS ONE OF ITS MOST IMPORTANT VALUES. WE RECOMMEND THAT THE STATE BE AWARE THAT IT IS A ROADLESS AREA AND ONE THAT WOULD BE BADLY DEGRADED BY DEVELOPMENT OR INCREASED ACCESS. It is one of the finest back-country rivers in the state, and should be regarded as a unique (and easily damaged) asset.

10.30 DEERFIELD RIVER, NORTH BRANCH: *West Dover to Harriman Reservoir*

Length	ca. 7 miles
Towns	Dover, Wilmington
Counties	Windham
Quadrangle	Wilmington 15'
Access	Rt. 100
Elevation	1660'-1500'
Average Slope	20-30' per mile
Description	small to medium sized upland stream; Class I-II
Surroundings	meadows, condominiums, bars, ski shops, village of Wilmington, some trash, etc.
Water Quality	good above Wilmington, receives wastes in town
Flow Regulation	none
Geology	Precambrian gneiss; Cambrian gneiss & schist
Hydrology	no gauge data: watershed at Wilmington ca. 95 sq. km.
Biology	brown & brook trout present; quality of fishery unknown; no botanical information
Known Use	very little; not in guides
Season	snowmelt, spring, and after rain
Suitable for	open boats
Interruptions	none
Importance	IMPORTANT for boating, mostly as a tour rather than as a whitewater run.

This is a small stream that is mostly quickwater rather than whitewater. It has a more consistent flow than the other branches and so is useful later in the season. It runs south through the Dover-Wilmington Valley, and so is in the midst of much traffic and development. Despite this many parts of the stream are still rural, and there are some nice views of the surrounding hills.

Most of the stream parallels Route 100 and can be scouted from the road. We have not run the stream, but at medium water it appears to have mostly Class I rapids with some scattered Class II on the bends. This is consistent with the watershed and slope. The AMC Guide reports a short Class II rapid about a mile above Wilmington. There is a chute through the center of Wilmington which may be Class III at high water, and another Class III drop about 1/2 mile west of Wilmington.

* * *

Rated IMPORTANT for general touring, and probably not used as a whitewater run.

10.31 DEERFIELD RIVER, WEST BRANCH # 2: Heartwellville to Readsboro

Length	ca. 5 miles
Towns	Readsboro
Counties	Bennington
Quadrangle	Wilmington 15'
Access	Rt. 100
Elevation	1760'-1240'
Average Slope	100'/mile
Description	steep narrow bouldery upland stream; Class III-IV in flood
Surroundings	second-growth woods, few houses
Water Quality	good
Flow Regulation	none
Geology	Cambrian schist & gneiss
Hydrology	no gauge data: watershed at Readsboro ca. 130 sq. km.
Biology	brown and brook trout reported; quality of fishery unknown; no rare plants known
Known Use	some local use; not in guide books
Season	snowmelt and after storms
Suitable for	kayaks and closed boats
Interruptions	fall , steep cascades and 50 yard tunnel at Readsboro Falls; cascades and very tight channel at Readsboro
Importance	possibly IMPORTANT as the most difficult stream in this part of the state, but not currently used

Our information on this stream comes from Mike Steele. He says it is a possible kayak stream which is narrow and can have very heavy water. There are some dangerous places (Readsboro Falls, near one of the bridges, near the bottom of the run, etc.) and it is hard to find eddies to get out. All in all an interesting stream but definitely pushy and quite hazardous.

Hydrologically this is as steep as Wardsboro Brook and has 1/3 more volume. Hence we have to regard it as a Class IV stream and very likely to be dangerous at high water. IT SHOULD ONLY BE TRIED BY EXPERT BOATERS AFTER CAREFUL SCOUTING. WE DO NOT KNOW WHETHER IT CAN BE RUN AT HIGH WATER.

Rated as IMPORTANT provisionally, pending more detailed information.

CHAPTER 11. APPENDIX

11.1 Brief Notes on Poorly Known Streams

These are a few streams about which we have only limited information.

The Jail Branch of the Stevens River, a tributary of the Winooski south- east of Montpelier, was mentioned by Louise McCarren. She said it was a steep rocky stream but did not seem to her of particularly high value. It is a streep stream with a a gradient of 80-100'/mile and a watershed of ca. 100 sq. km., making it potentially a powerful and dangersous small stream, something like Wardsboro Brook. A field check at highwater found intense Class III whitewater, but a comparatively short possible run and a number of places where obstructions might occur.

Mendon Brook, which parallels Rt. 4 east of Rutland, is another steep rocky stream. Tom Hartman said he got in it in a kayak but got out again after a mile and that it was too fast and rocky for him. The gradient is nearly 200'/mile and the watershed quite small. Several streams of about this size and steepness occur along the western scarp of the southern Green Mountains, and none of them have proven to be useful whitewater runs.

The East Branch of the North River in Jacksonville is a small stream that is used by Massachusetts boaters. They run about 1-2 miles of the stream in Vermont and continue into into Maschusetts. It is small and rocky and has some difficult Class III water in the Halifax Gorge. There also may be a drop or waterfall in this segment.

The Rock River below Williamsville, which we suggested as a potential whitewater run in the text, turns out to be regularly used by boaters and classes from the New England Outdoors Center in Miller's Falls, Mass. They say it is an excellent small Class III river, and that runs of differing intensity are available on the different branches. The lower gorge is dangerous at high levels.

The Browns River has limited amounts of whitewater below Westford, but it is not clear whether it is really runnable. Starting at the covered bridge in Westford there mixed Class II-III rapids for almost 2 miles, mixed with a number of obstacles. We went down it, half paddling and half walking, and noted an old mill dam, several Class III drops, and two waterfalls which might be runnable. We have not found anyone who has paddled this stretch.

11.2 Isolated Rapids and Individual Pitches of High Difficulty

The following is a partial list of what we call isolated rapids. These are short rapids less than 2 miles long, which are markedly more difficult than the rest of the stream on which they occur.

Isolated rapids may be important biologically or recreationally, and are also noteworthy because they may be hazardous to boaters that are not equipped for whitewater.

While the primary focus of this study was longer rapids we have done our best to compile information on as many isolated rapids as we could. This information is of varying quality. A number of sites have not been field-checked at all, and many others have not been seen at high water, or have been seen but not run.

The recreational significance of isolated rapids is that they can sometimes be used for practice and play. They are especially valuable when the occur in larger rivers and in areas where there is not otherwise much whitewater, because they allow boaters to practice near home, and to boat at seasons when there is no continuous whitewater available.

We use the following symbols in the following list.

- NF not field checked
- D possibly dangerous to touring boaters
- S runs in wet periods in the summer or fall
- P good for whitewater practice and play
- O important for oxygenation at low flows
- B botanical site

Where we know that a site has particular recreational or biological importance we have indicated this in parenthesis. Because may of these sites have not been examined, the fact that we have not recognized the importance does not mean that we have concluded that no importance exists.

River	Location	Description (m=mile)	Notes
Battenkill	1/2m N of Arlington (IMPORTANT FOR WHITEWATER PRACTICE)	1/4m of Class II	D,S,P
Poultney	near Middletown Springs gorge,	NF	
	Poultney-Carver Falls 2 Class III	O	
	below Carver Falls (water levels depend on hydro plant)	gorge, Class II-III	
Lemon Fair	1/2m below Shoreham C.	gorge, ? Class III-IV	NF
	4m below Shoreham C.	ledge & 1/4m rapids	NF
Otter	S. Wallingford	1/2m Class III-IV	D, O
	Wallingford	1/2m Class II	

	River Street, Rutland 1/2m Class II	NF	
	1st dam at Middlebury Class II (threatened by a hydro project)	? S, P	
	2nd Middlebury dam	short rapids	D
	below Beldens Dam Class III gorge (IMPORTANT *small gorge, makes an exciting run)*	1/4 mile Class II, D, S, O	
	1/4 mile below Beldens 1/4 mile Class III gorge (IMPORTANT summer rapid for practice)		D, S, P, O
	Huntington Falls Dam	1/4 mile Class III	O
	Weybridge Dam	"	" NF
Mill	Clarendon Gorge (so far as we known this has never been run, and may not be runnable)	gorge, ? Class V	? kayaks
New Haven	New Haven Mills	? Class II-III	D, O
	below Rt. 7 bridge	falls & ledge	D, O
Lewis Creek	1 mile below lower covered bridge	4' ledge	NF
	above N. Ferrisburg bridge	falls	D,O
	below N. Ferrisburg bridge	ledge	D, NF
	1/4 below Rt. 7	ledge	D, NF
Dog River	1 1/4m below Northfield 6' drop	NF	
	3 1/2m "	"	8' drop NF
Winooski	GMP plant, Marshfield	II-III	
	Marshfield Dam	1/2m II	NF
	below Twinfield HS	"some II"	
	Plainfield Dam	1/2m III	
	Winooski Hydro dam East Montpelier	Class II-III	
	1/4m W of Middlesex Dam (IMPORTANT FOR SUMMER WHITEWATER PRACTICE)	constriction & Class II to Class III ledge	D,S,P
	below Mad River (IMPORTANT FOR SUMMER WHITEWATER PRACTICE)	1/4m Class II-III ledge & rapids	D, S, P, R
	below Bolton Falls Dam	ledge & Class II-III	D, S, P

		rapids	
	(IMPORTANT FOR SUMMER WHITEWATER PRACTICE)		
Browns	north of Westford	ledges, falls, ca. D, O 1-2m Class II-III	
Lamoille	Dogs Head Falls (1m above Johnson)	NOT RUNNABLE	D, O
	Sloping Falls (3/3m above Johnson)	UNDERCUT, VERY DANGEROUS	D, O
	3/4 below Rt. 15 bridge in Johnson	constriction and Class II-III drop	D, O, S, P
	(IMPORTANT FOR SUMMER WHITEWATER PRACTICE)		
	Ithiel Falls 1 mile below Rt. 15 bridge in Johnson	100 yds Class II	O
	below West Milton Dam	50 yards Class II-III D, O	
	Missisquoi	above Big Falls (N. Troy)	? 1/2 mile P, O
	below Rt. 105 bridge in Richford	Class III ledges	D, O, S, P
	(IMPORTANT FOR SUMMER WHITEATER PRACTICE)		
	Samsonville	Class II-III ledge	NF
	Sheldon Springs	gorge, 1/2m III-V	O, B
	below Enosberg dam (possible summer practice place)	3/4m II-III	D, O,
	just above E. Highgate	ledges	D, O
	below bridge in East Highgate (possible summer practice place)	2 sets Class II-III ledges	D, O
	ledge above Highgate Dam	?	D, O
	below Swanton Dam (possible whitewater pracice place)	Class II-III ledges	
Black	Coventry	2 waterfalls	D, O
Barton	N of Barton (8' drop at second RR bridge below rapid)	Class III-IV rapids	O
	between 2nd & 3rd Rt. 5 bridges N of Barton	Class II-III drops	O

Connecticut	Beecher Falls	short Class II	NF
	Rt. 114 Bridge, Caanan short Class III drop NF		
	S. Lunenburg	Class II rapid	NF
	Hartland Rapids	Class III-V drops	D, O, S, P, B
	(Also called Sumners Falls. At high water a dangerous rapid that must be carefully scouted. Several deaths have occurred, but mostly to unprepared flatwater boaters who didn't know the rapids were there. At low or medium water a challenging run and an excellent place for practice and play. Controlled by releases from Wilder Dam; these vary considerably, but there is normally enough water released for the rapids to be used through the summer; high importance as a summer and fall practice spot and used by kayackers from all over. Also a famous botanical site -- see the Vt. Gorge and Waterfall Report for details.) Appendix 2, cont.		
Wells River	Groton	1/2m Class II	NF
	below Ryegate	1 1/2m Class II + 4' ledge	NF
	below Boltonsville	small gorge + 4' falls	NF
	last 2 1/2 miles	many scattered ledges	NF
3rd Branch of White	East Granville	1/4m Class II	NF
	near Riford Brook	Class III drop	NF
	Rt. 12 bridge, Randolph low dam + II-III ledges NF		
Ottauquechee	Quechee Gorge	1 mile Class III-V	O, B
	(At medium water the gorge has been run, carrying around the big drop under the bridge. Very dangerous at high water.)		
Black River	Cavendish Gorge	1/2m gorge	O, B
	(We don't think anyone has ever run this; a beautiful gorge, very steep and tight, per haps within the limits of expert kayakers, perhaps impossible.		
Williams River	3 miles below Chester	Class IV-V drop	D

11.3 Species-Abundance Data From the Botanical Survey

The list has been slightly edited for taxonomic uniformity by treating *Oenothera biennis, Agrostis stolonifera,* and *Festuca rubra* as collective species, and refering all likely unknowns to them.

* alien species
Sites number of sites
% Presence (number of sites/total number of sites) x 100

	Sites	% Presence		Sites	% Presence
Carex torta	26	76.4	Fraxinus americana	9	26.4
Eupatorium maculatum	25	73.5	Matteuccia struthiopteris	9	26.4
Salix rigida	23	67.6	Oenothera biennis	9	26.4
Ulmus americana	22	64.7	Parthenocissus quinquefolia	9	26.4
Onoclea sensibilis	21	61.7			
Solidago graminifolia	21	61.7	Populus tremuloides	9	26.4
Phalaris arundinacea	20	58.8	Salix sericea	9	26.4
Agrostis stolonifera	19	55.8	Vicia cracca*	9	26.4
Tussilago farfara*	18	52.9	Agropyron repens*	8	23.5
Aster umbellatus	17	50.0	Cornus stolonifera	8	23.5
Equisetum arvense	17	50.0	Mentha arvensis	8	23.5
Panicum clandestinum	17	50.0	Panicum lanuginosum	8	23.5
Spiraea latifolia	16	47.0	Populus deltoides	8	23.5
Vitis riparia	16	47.0	Rubus odoratus	8	23.5
Eupatorium perfoliatum	15	44.1	Solidago juncea	8	23.5
Hypericum perforatum	15	44.1	Apocynum cannabinum	7	20.5
Phleum pratense*	15	44.1	Bromus ciliatus	7	20.5
Solidago gigantea	15	44.1	Carex sp. (ovales)	7	20.5
Thalictrum polygamum	15	44.1	Eleocharis tenuis	7	20.5
Alnus rugosa	14	41.1	Galium asprellum	7	20.5
Apios americana	13	38.2	Lysimachia terrestris	7	20.5
Aster lateriflorus	13	38.2	Myosotis scorpioides	7	20.5
Oxalis europaea	13	38.2	Pinus strobus	7	20.5
Aster puniceus	12	35.2	Plantago major*	7	20.5
Calamagrostis canadensis	12	35.2	Rhus radicans	7	20.5
Chrysanthemum leucanthemum*	12	35.2	Tilia americana	7	20.5
Tsuga canadensis	12	35.2	Agrostis scabra	6	17.6
Clematis virginiana	11	32.3	Anthoxanthum odoratum*	6	17.6
Poa compressa*	11	32.3	Carex lurida	6	17.6
Rubus idaeus	11	32.3	Dactylis glomerata*	6	17.6
Saponaria officinalis*	11	32.3	Festuca rubra	6	17.6
Solidago canadensis	11	32.3	Fragaria virginiana	6	17.6
Sphenopholis intermedia	11	32.3	Iris versicolor	6	17.6

Verbena hastata	11	32.3	Juncus articulatus	6	17.6
Athyrium filix-femina	10	29.4	Juncus dudleyi	6	17.6
Betula alleghaniensis	10	29.4	Juncus tenuis	6	17.6
Elymus riparius	10	29.4	Leersia oryzoides	6	17.6
Glyceria striata	10	29.4	Melilotus alba*	6	17.6
Mimulus ringens	10	29.4	Osmunda claytoniana	6	17.6
Populus balsamifera	10	29.4	Polygonum cuspidatum*	6	17.6
Prunella vulgaris*	10	29.4	Polygonum sagittatum	6	17.6
Ranunculus acris*	10	29.4	Solanum dulcamara*	6	17.6
Taraxacum officinale*	10	29.4	Ambrosia artemisiifolia	5	14.7
Acer negundo	9	26.4	Carex vulpinoidea	5	14.7
Acer rubrum	9	26.4	Erigeron annuus	5	14.7
Acer saccharum	9	26.4	Hypericum mutilum	5	14.7
Betula papyrifera	9	26.4	Lotus corniculatus*	5	14.7
Festuca pratensis*	9	26.4	Lycopus americana	5	14.7
Lysimachia ciliata	5	14.7	Thalictrum polygonum	3	8.8
Lysimachia nummularia*	5	14.7	Trifolium repens*	3	8.8
Platanus occidentalis	5	14.7	Xanthium strumarium	3	8.8
Scirpus atrocinctus	5	14.7	Zizea aurea	3	8.8
Acer spicatum	4	11.7	Acer saccharinum	2	5.8
Achillea millefolium*	4	11.7	Anemone virginiana	2	5.8
Agrostis perennans	4	11.7	Aquilegia canadensis	2	5.8
Apocynum sibiricum	4	11.7	Arctium lappa*	2	5.8
Asclepias syriaca	4	11.7	Aster divaricatus	2	5.8
Campanula aparinoides	4	11.7	Aster macrophyllus	2	5.8
Carex flava	4	11.7	Aster simplex	2	5.8
Carex hystericina	4	11.7	Barbaria vulgaris*	2	5.8
Cerastium vulgatum*	4	11.7	Carex granularis	2	5.8
Convolvulus sepium*	4	11.7	Centaurea maculosa*	2	5.8
Daucus carota*	4	11.7	Cicuta maculata	2	5.8
Galeopsis tetrahit*	4	11.7	Cirsium arvense*	2	5.8
Galium mollugo*	4	11.7	Cornus alternifolia	2	5.8
Juncus brevicaudatus	4	11.7	Cyperus strigosus	2	5.8
Lobelia inflata	4	11.7	Danthonia compressa	2	5.8
Lycopus uniflorus	4	11.7	Desmodium canadense	2	5.8
Mentha piperita*	4	11.7	Diervilla lonicera	2	5.8
Poa pratensis	4	11.7	Echinocystis lobata	2	5.8
Prunus serotina	4	11.7	Elymus virginicus	2	5.8
Prunus virginiana	4	11.7	Equisetum hyemale	2	5.8
Quercus rubra	4	11.7	Erigeron canadensis	2	5.8
Rhus typhina	4	11.7	Eupatorium rugosum	2	5.8
Rubus allegheniensis	4	11.7	Festuca arundinacea*	2	5.8
Scirpus atrovirens	4	11.7	Galium tinctorium	2	5.8
Silene cucubalis*	4	11.7	Habenaria fimbriata	2	5.8
Thelypteris palustris	4	11.7	Hamamelis virginiana	2	5.8

Tovara virginica	4	11.7	Helianthus decapetalus	2	5.8
Trifolium pratense*	4	11.7	Helianthus tuberosus*	2	5.8
Veratrum viride	4	11.7	Hieracium aurentiacum*	2	5.8
Agrimonia striata	3	8.8	Hieracium piloselloides*	2	5.8
Amelanchier sp.	3	8.8	Hieracium scabrum	2	5.8
Aster cordifolius	3	8.8	Hydrocotyle americana	2	5.8
Betula populifolia	3	8.8	Hypericum virginicum	2	5.8
Bidens sp.	3	8.8	Juglans cinerea	2	5.8
Brachyeletrum erectum	3	8.8	Juncus nodosus	2	5.8
Bromus inermis*	3	8.8	Lactuca biennis	2	5.8
Chelone glabra	3	8.8	Lonicera morrowi*	2	5.8
Danthonia spicata	3	8.8	Lychnis alba*	2	5.8
Eleocharis obtusa	3	8.8	Lythrum salicaria*	2	5.8
Epilobium glandulosum	3	8.8	Muhlenbergia frondosa	2	5.8
Galium triflorum	3	8.8	Osmunda regalis	2	5.8
Houstonia caerulea	3	8.8	Ostrya virginiana	2	5.8
Impatiens capensis	3	8.8	Plantago lanceolata*	2	5.8
Juncus effusus	3	8.8	Plantago rugelii	2	5.8
Leontodon autumnalis*	3	8.8	Poa palustris	2	5.8
Potentilla norvegica	3	8.8	Potamogeton nodosus	2	5.8
Potentilla simplex	3	8.8	Rosa blanda	2	5.8
Rhynchospora capitellata	3	8.8	Rumex obtusifolius*	2	5.8
Rubus occidentalis	3	8.8	Sagittaria latifolia	2	5.8
Rudbeckia serotina*	3	8.8	Scirpus cyperinus	2	5.8
Salix bebbiana	3	8.8	Scirpus microcarpus	2	5.8
Scirpus validus	3	8.8	Smilacina racemosa	2	5.8
Scutellaria lateriflora	3	8.8	Spiraea tomentosa	2	5.8
Solidago bicolor	3	8.8	Tanacetum vulgare*	2	5.8
Solidago nemoralis	3	8.8	Trifolium agrarium*	2	5.8
Solidago rugosa	3	8.8	Acer pensylvanicum	1	2.9
Actaea rubra	1	2.9	Equisetum variegatum	1	2.9
Aegopodium podagraria*	1	2.9	Erigeron pulchellus	1	2.9
Agrostis sp.*	1	2.9	Erigeron strigosus	1	2.9
Alnus serrulata	1	2.9	Fagus grandifolia	1	2.9
Alnus viride	1	2.9	Fraxinus nigra	1	2.9
Alopecurus aequalis	1	2.9	Galium palustre	1	2.9
Ambrosia artemesiifolia	1	2.9	Gentiana clausa	1	2.9
Amphicarpa bracteata	1	2.9	Geum canadense	1	2.9
Anaphalis margaritacea	1	2.9	Glyceria grandis	1	2.9
Apocynum androsaemifolium	1	2.9	Gylceria striata	1	2.9
Apocynum sp.	1	2.9	Habenaria flava	1	2.9
Arisaema triphyllum	1	2.9	Hemerocallis fulva*	1	2.9
Asclepias incarnata	1	2.9	Heracleum maximum	1	2.9
Aster foliaceus	1	2.9	Hieracium sp.	1	2.9
Aster novae-belgii	1	2.9	Hypericum boreale	1	2.9

Aster novi-belgii	1	2.9	Hypericum majus	1	2.9
Aster tradescanti	1	2.9	Hystrix patula	1	2.9
Barbarea vulgaris*	1	2.9	Ilex verticillata	1	2.9
Berberis vulgaris*	1	2.9	Impatiens pallida	1	2.9
Berteroa incana*	1	2.9	Juncus canadensis	1	2.9
Betula lenta	1	2.9	Juncus marginatus	1	2.9
Boehmeria cylindrica	1	2.9	Lactuca canadensis	1	2.9
Bromus latiglumis	1	2.9	Laportea canadensis	1	2.9
Bromus purgans	1	2.9	Leersia virginica	1	2.9
Campanula rapunculoides*	1	2.9	Lilium canadense	1	2.9
Campanula rotundifolia	1	2.9	Lolium perenne*	1	2.9
Capsella bursa-pastoris*	1	2.9	Lonicera x bella*	1	2.9
Carex annectens	1	2.9	Luzula multiflora	1	2.9
Carex aurea	1	2.9	Lycopus americanus	1	2.9
Carex crinita	1	2.9	Lysimachia quadrifolia	1	2.9
Carex eburnea	1	2.9	Malus sylvestris*	1	2.9
Carex echinata	1	2.9	Malva alcea*	1	2.9
Carex lenticularis	1	2.9	Medicago lupulina*	1	2.9
Carex pallescens	1	2.9	Mirabilis nyctaginea*	1	2.9
Carex retrorsa	1	2.9	Nasturtium officinale*	1	2.9
Carex so. (ovales)	1	2.9	Oenothera perennis	1	2.9
Carex stipata	1	2.9	Osmunda cinnamonea	1	2.9
Carex trichocarpa	1	2.9	Parthenocissus inserta	1	2.9
Centaurea jacea*	1	2.9	Pastinaca sativa*	1	2.9
Chelidonium majus*	1	2.9	Penthorum sedoides	1	2.9
Chenopodium album*	1	2.9	Phlox paniculata*	1	2.9
Cichorium intybus*	1	2.9	Pilea pumila	1	2.9
Cinna latifolia	1	2.9	Podestemon ceratophyllum	1	2.9
Cornus rugosa	1	2.9	Polgonum persicaria*	1	2.9
Crataegus sp.	1	2.9	Polygonella articulata	1	2.9
Cryptotaenia canadensis	1	2.9	Polygonum caespitosum*	1	2.9
Cynanchium nigrum*	1	2.9	Polygonum longisetum*	1	2.9
Cyperus esculentus*	1	2.9	Potamogeton perfoliatus	1	2.9
Cystopteris fragilis	1	2.9	Quercus macrocarpa	1	2.9
Dennstaedtia punctilobula	1	2.9	Ranunculus repens*	1	2.9
Deschampsia cespitosa	1	2.9	Ranunculus reptans*	1	2.9
Desmodium glutinosum	1	2.9	Rhinanthus crista-galli*	1	2.9
Dryopteris marginalis	1	2.9	Rhododendron prionophyllum	1	2.9
Dulichium arundinaceum	1	2.9	Robinia pseudo-acacia*	1	2.9
Echinochloa crus-galli	1	2.9	Rorippa sylvestris*	1	2.9
Eleocharis acicularis	1	2.9	Rosa multiflora*	1	2.9
Elodea canadensis	1	2.9	Rosa sp.	1	2.9
Epipactis helleborine*	1	2.9	Rubus pubescens	1	2.9
Equisetum fluviatile	1	2.9	Rumex acetosella*	1	2.9
Equisetum scorpioides	1	2.9	Rumex crispus*	1	2.9

Salix alba	1	2.9	Spiranthes cernua	1	2.9
Salix discolor	1	2.9	Stellaria graminea*	1	2.9
Salix lurida	1	2.9	Thuja occidentalis	1	2.9
Salix nigra	1	2.9	Trifolium arvense*	1	2.9
Salix pellita	1	2.9	Trifolium hybridum*	1	2.9
Salix purpurea*	1	2.9	Ulmus americanus	1	2.9
Sanguisorba canadensis	1	2.9	Urtica sp.	1	2.9
Satureja vulgaris*	1	2.9	Utricularia minor	1	2.9
Scirpus expansus	1	2.9	Uvularia sessilifolia	1	2.9
Scirpus pendulus	1	2.9	Vaccinium caespitosum	1	2.9
Sisyrinchium montanum	1	2.9	Vaccinium cespitosum	1	2.9
Smilacina stellata	1	2.9	Verbascum thapsus*	1	2.9
Smilax herbacea	1	2.9	Veronica chamaedrys*	1	2.9
Solidago flexicaulis	1	2.9	Viburnum trilobum	1	2.9
Sonchus arvensis*	1	2.9	Viola cuculata	1	2.9
Sorbus americana	1	2.9	Viola pallens	1	2.9

11.4 Plant Species Lists From Survey Sites

This is a compilation of survey data gathered from 34 sites on 17 rivers in the summer of 1984. Field surveys and raw data entry were done by Peter Zika, tabulation and data analysis by Jerry Jenkins. The sites were chosen randomly. With one or two exceptions they are all on the banks of segments used as recreational whitewater. The sites are not of uniform size, and no attempt was made to choose sites that seemed representative of the segment as a whole. An effort was made made to restrict each survey to the portion of the banks below the annual high-water mark, but in some cases the banks slope gradually and an upper boundary for the area surveyed could not be chosen accurately.

Site 1: Black River, Cavendish; altitude ca. 650', bedrock quartz-mica schist. Wooded banks, cobble shoreline; Class III whitewater.

Agrostis perennans
Agrostis sp. (stolonifera?)
Apios americana
Aster umbellatus
Betula alleghaniensis
Calamagrostis canadensis
Carex lurida
Carex torta
Crataegus sp.
Eupatorium maculatum
Eupatorium perfoliatum
Helianthus decapetalus
Hypericum mutilum
Hypericum perforatum
Juncus effusus
Juncus sp. (articulatus?)
Solidago juncea
Spiraea latifolia
Tilia americana
Tovara virginica
Tsuga canadensis
Ulmus americana
Verbena hastata
Lysimachia terrestris
Matteuccia struthiopteris
Mimulus ringens
Onoclea sensibilis
Panicum clandestinum
Phalaris arundinacea
Pinus strobus
Polygonum cuspidatum*
Polygonum sagittatum
Quercus rubra
Rosa sp.
Salix sericea
Scirpus atrocinctus
Scirpus expansus R
Solidago canadensis
Solidago graminifolia

Site 2: Black River, Cavendish, altitude ca. 600', bedrock as at Site 1, rocky shore with hemlock and yellow birch woods, Class II water.

Acer pensylvanicum
Acer rubrum
Apios americana
Apocynum cannabinum
Aster lateriflorus
Aster umbellatus
Betula alleghaniensis
Carex torta
Clematis virginiana
Desmodium canadense
Eupatorium maculatum
Hamamelis virginiana
Houstonia caerulea
Iris versicolor
Lycopus uniflorus
Mimulus ringens
Onoclea sensibilis
Osmunda claytoniana
Osmunda regalis
Panicum clandestinum
Parthenocissus quiquefolia
Phalaris arundinacea
Polygonum cuspidatum*
Prunus serotina
Rhus radicans
Rosa sp.
Salix rigida
Solidago gigantea
Solidago graminifolia
Spiraea latifolia
Spiraea tomentosa
Thelypteris palustris
Tilia americana
Tsuga canadensis
Vitis riparia

Site 3: Browns River, Fairfax; altitude ca. 300'; bedrock schistose gray-wacke; site at edge of field, with sandy bank and gravel and cobble shores; Class I water.

Acer negundo
Acer rubrum
Acer saccharinum
Agropyron repens*
Agrostis sp.
Alnus rugosa
Alnus serrulata
Ambrosia artemesiifolia
Apios americana
Apocynum cannabinum
Asclepias syriaca
Betula papyrifera
Betula populifolia
Bidens sp.
Bromus inermis*
Calamagrostis canadensis
Carex torta
Carex trichocarpa R
Carex vulpinoidea
Clematis virginiana
Convolvulus sepium*
Cornus stolonifera
Cyperus esculentus*
Eleocharis tenuis
Impatiens sp.
Lysimachia nummularia*
Mentha arvensis
Muhlenbergia frondosa
Onoclea sensibilis
Panicum clandestinum
Parthenocissus quiquefolia
Phalaris arundinacea
Phleum pratense*
Pinus strobus
Polgonum persicaria*
Potentilla norvegica
Rudbeckia serotina*
Salix nigra
Salix rigida
Solidago gigantea
Stellaria graminea*
Thelypteris palustris
Ulmus americana
Verbena hastata
Xanthium strumarium
Galium asprellum
Galium sp.
Helianthus decapetalus

Elymus riparius
Equisetum arvense
Eupatorium maculatum

Site 4: Huntington River; altitude ca. 600'; bedrock quartzite schist; rocky shore with steep cobble banks, scattered rocks in channel; Class I- II water.

Acer rubrum
Achillea millefolium*
Agrimonia striata
Agrostis scabra
Agrostis stolonifera
Alnus rugosa
Ambrosia artemisiifolia
Anemone virginiana
Anthoxanthum odoratum*
Apocynum sibiricum
Aster lateriflorus
Aster puniceus
Aster umbellatus
Athyrium filix-femina
Betula alleghaniensis
Betula papyrifera
Betula populifolia
Bromus ciliatus
Campanula aparinoides U
Carex torta
Carex vulpinoidea
Clematis virginiana
Cornus stolonifera
Cryptotaenia canadensis
Cyperus strigosus
Dactylis glomerata*
Daucus carota*
Eleocharis tenuis
Elymus riparius
Equisetum arvense
Eupatorium maculatum
Eupatorium perfoliatum
Festuca arundinacea*
Festuca pratensis*
Galeopsis tetrahit*
Galium sp.
Galium tinctorium
Gentiana clausa
Hieracium piloselloides*
Hydrocotyle americana
Hypericum perforatum
Juncus articulatus
Lycopus uniflorus
Lysimachia ciliata
Melilotus alba*
Myosotis scorpioides
Oenothera perennis
Onoclea sensibilis
Oxalis europaea
Panicum clandestinum
Phalaris arundinacea
Phleum pratense*
Pinus strobus
Poa compressa*
Poa palustris
Populus tremuloides
Potentilla simplex
Prunella vulgaris*
Prunus virginiana
Ranunculus acris*
Rhus typhina
Rubus allegheniensis
Rubus idaeus
Rubus odoratus
Rudbeckia serotina*
Salix alba
Salix rigida
Salix sericea
Solanum dulcamara*
Solidago gigantea
Solidago graminifolia
Solidago juncea
Sphenopholis intermedia
Spiraea latifolia
Spiraea tomentosa
Thalictrum polygonum
Thelypteris palustris
Tilia americana
Trifolium arvense*
Trifolium hybridum*
Tussilago farfara*
Ulmus americana
Verbena hastata
Vicia cracca*

Juncus dudleyi
Lycopus americana
Lycopus americana
Vitis riparia

Site 5: Huntington River, Richmond; altitude ca. 600', bedrock quartze schist; river wooded on north with pasture on south bank; bottom of cobbles, no boulders present. Water ? Class I.

Agrostis stolonifera
Alnus rugosa
Anthoxanthum odoratum*
Aster lateriflorus
Barbaria vulgaris*
Carex annectens U
Carex flava
Carex hystericina
Carex lurida
Carex sp. (crawfordii?)
Carex torta
Cerastium vulgatum*
Chrysanthemum leucanthemum*
Dactylis glomerata*
Eleocharis acicularis
Eleocharis obtusa
Eleocharis tenuis
Epilobium glandulosum
Equisetum arvense
Erigeron annuus
Erigeron canadensis
Eupatorium maculatum
Eupatorium perfoliatum
Festuca ovina*
Galium sp.
Glyceria grandis
Glyceria striata
Hypericum majus
Hypericum mutilum
Juncus articulatus
Juncus marginatus R
Juncus tenuis
Lobelia inflata
Lycopus americana
Lysimachia nummularia*
Medicago lupulina*
Melilotus alba*
Mentha arvensis
Mentha piperita*
Mimulus ringens
Oenothera parviflora
Panicum clandestinum
Panicum lanuginosum
Phleum pratense*
Plantago lanceolata*
Plantago major*
Plantago rugelii
Polygonum sp.
Populus deltoides
Populus tremuloides
Prunella vulgaris*
Ranunculus acris*
Salix rigida
Scirpus atrocinctus
Scirpus atrovirens
Scirpus cyperinus
Silene cucubalis*
Solidago canadensis
Solidago graminifolia
Spiraea latifolia
Trifolium repens*
Tussilago farfara*
Ulmus americana

Site 6: Lamoille River, Hardwick; altitude ca. 1100'; bedrock limestone and schist; hayfield on banks, gravely shores; water Class II

Agrostis scabra
Agrostis sp.
Alnus rugosa
Festuca sp.
Glyceria striata
Juncus articulatus

Anthoxanthum odoratum*
Aster puniceus
Barbaria vulgaris*
Bromus purgans
Carex aurea
Carex flava
Carex hystericina
Carex lurida
Carex pallescens
latifolia
Equisetum variegatum
Eupatorium maculatum
Festuca ovina*
Festuca pratensis*
Juncus dudleyi
Myosotis scorpioides
Pastinaca sativa*
Phleum pratense*
Rhinanthus crista-galli*
Salix rigida
Scirpus rubrotinctus
Sisyrinchium montanum
Sphenopholis intermedia Carex stipata Spiraea

Thalictrum polygonum
Tussilago farfara*

Site 7: Lamoille River, Hardwick; altitude ca. 1000'; bedrock as at Site 6; channel with 1-5' rocks; young deciduous forest on banks; water Class III.

Acer saccharum
Acer spicatum
Aster lateriflorus
Aster puniceus
Aster umbellatus
Betula alleghaniensis
Carex torta
Dactylis glomerata*
Equisetum arvense
Equisetum scorpioides
Matteuccia struthiopteris
Populus balsamifera
Prunus virginiana
Ranunculus acris*
Ranunculus repens*
Rubus allegheniensis
Sphenopholis intermedia
Taraxacum officinale*
Thalictrum polygamum
Thuja occidentalis
Tsuga canadensis
Tussilago farfara*
Ulmus americana
Viburnum trilobum

Site 8: Lamoille River, Hardwick; alt. ca. 1000'; bedrock as at Site 6; banks with hayfields and deciduous forest; channel with silt and gravel bars; water ? Class I.

Agropyron repens*
Agrostis sp. (gigantea?)
Alnus rugosa
Arctium lappa*
Bromus inermis*
Carex flava
Carex lurida
Carex torta
Chrysanthemum leucanthemum*
Cornus stolonifera
Dactylis glomerata*
Equisetum arvense
Eupatorium maculatum
Eupatorium perfoliatum
Festuca arundinacea*
Leersia virginica
Leontodon autumnalis*
Lolium perenne*
Lycopus americanus
Melilotus alba*
Mimulus ringens
Myosotis scorpioides
Phalaris arundinacea
Phleum pratense*
Plantago major*
Poa pratensis
Populus balsamifera
Populus deltoides
Salix lurida
Salix rigida

Festuca ovina*
Festuca pratensis*
Festuca sp. (ovina?)*
Galium mollugo*
Galium palustre
Glyceria striata
Habenaria psychodes
Hypericum mutilum
Hypericum perforatum
Juncus sp. (brevicaudatus?)
Zizea aurea
Salix sericea
Saponaria officinalis*
Silene cucubalis*
Solidago graminifolia
Sphenopholis intermedia
Taraxacum officinale*
Thalictrum polygonum
Trifolium pratense*
Tussilago farfara* Juncus dudleyi Tussilago farfara*
Vicia cracca*

Sites 9-11: Lamoille River, in Village of Hardwick; altitude ca. 800; bedrock limestone and schist; river channalized, very rocky, with only small amounts of shore; water Class III.

Site 9:

Carex torta
Matteuccia struthiopteris
Myosotis scorpioides
Nasturtium officinale*
Populus balsamifera
Solidago graminifolia
Spiraea latifolia

Site 10:

Acer negundo
Ambrosia artemisiifolia
Clematis virginiana
Festuca pratensis*
Populus balsamifera
Salix discolor
Salix rigida

Site 11:

Achillea millefolium*
Agropyron repens*
Alnus rugosa
Apocynum cannabinum
Asclepias syriaca
Aster simplex
Aster umbellatus
Barbarea vulgaris*
Berteroa incana*
Bromus ciliatus
Calamagrostis canadensis
Chrysanthemum leucanthemum*
Equisetum arvense
Eupatorium maculatum
Festuca ovina*
Galium mollugo*
Hypericum perforatum
Poa pratensis
Rosa blanda
Rubus idaeus
Salix bebbiana
Saponaria officinalis*
Silene cucubalis*
Solanum dulcamara*
Solidago canadensis
Solidago gigantea
Taraxacum officinale*
Thalictrum polygamum
Tussilago farfara*
Ulmus americana
Vicia cracca*

Lonicera morrowi*
Mentha arvensis
Oenothera parviflora
Parthenocissus quinquefolia
Phalaris arundinacea
Phleum pratense*
Poa compressa*

Site 12: Lamoille River, Fairfax; alt. ca. 300'; bedrock schistose greywacke; deciduousforest on banks, slity shores, scattered 4-8' rocks in channel. Water Class I.

Acer rubrum
Acer saccharinum
Apios americana
Betula alleghaniensis
Betula papyrifera
Bidens. sp.
Calamagrostis canadensis
Cirsium arvense*
Convolvulus sepium*
Cornus rugosa
Cornus stolonifera
Equisetum arvense
Eupatorium maculatum
Laportea canadensis
Lysimachia ciliata
Matteuccia struthiopteris
Onoclea sensibilis
Oxalis europaea
Panicum clandestinum
Phalaris arundinacea
Rhus radicans
Rhus typhina
Salix rigida
Solidago gigantea
Thalictrum polygamum
Tilia americana
Tsuga canadensis
Ulmus americana
Urtica sp.
Xanthium strumarium

Site 13: Lamoille River, Georgia; alt. ca. 300'; bedrock quartzite; shores of cobbles and scattered rocks, riverbed rocky. Water Class II.

Acer rubrum
Acer saccharum
Agrostis sp. (stolonifera?)
Alnus rugosa
Amelanchier sp. (laevis?)
Anthoxanthum odoratum*
Apios americana
Aster lateriflorus
Aster umbellatus
Athyrium filix-femina
Betula papyrifera
Bidens sp.
Bromus ciliatus
Calamagrostis canadensis
Campanula aparinoides U
Carex crinita
Carex lurida
Carex sp. (lanuginosa?)
Carex sp. (ovales)
Carex torta
Carex vulpinoidea
Centaurea jacea*
Cerastium vulgatum*
Chelone glabra
Cicuta maculata
Cyperus strigosus
Festuca pratensis*
Galium asprellum
Galium sp.
Galium triflorum
Glyceria striata
Hypericum perforatum
Juncus articulatus
Juncus dudleyi
Juncus nodosus
Juncus sp.
Leersia oryzoides
Lilium canadense
Lysimachia ciliata
Lysimachia nummularia*
Mentha arvensis
Mentha piperita*
Myosotis scorpioides
Onoclea sensibilis
Oxalis europaea
Panicum clandestinum
Phleum pratense*
Plantago major*
Poa compressa*
Polygonum sagittatum
Populus tremuloides
Potamogeton nodosus

Daucus carota*
Diervilla lonicera
Eleocharis sp. (obtusa?)
Eleocharis tenuis
Elodea canadensis
Epilobium sp. (glandulosum?)
Equisetum arvense
Equisetum fluviatile
Equisetum hyemale
Eupatorium maculatum
Eupatorium perfoliatum
Scirpus atrovirens
Scirpus validus
Scutellaria lateriflora
Solidago canadensis
Solidago gigantea
Solidago graminifolia
Sphenopholis intermedia
Tilia americana
Trifolium repens*
Potamogeton perfoliatus
Prunella vulgaris*
Quercus rubra
Ranunculus acris*
Ranunculus reptans* Elymus riparius Rhus radicans
Rorippa sylvestris*
Rubus odoratus
Sagittaria latifolia
Salix rigida
Salix sp. (alba?)*
Scirpus atrocinctus
Tussilago farfara*
Ulmus americana
Veratrum viride
Verbena hastata
Vicia cracca*
Viola sp.
Vitis riparia
Xanthium strumarium

Sites 14-16: Lewis Creek, Charlotte; alt ca. 300'; bedrock shales and phyllites with some limestone; water Class II.

Site 14: deciduous forest on shores, rocks to 3' in channel

Acer saccharum
Actaea rubra
Apios americana
Aster cordifolius
Aster macrophyllus
Boehmeria cylindrica
Calamagrostis canadensis
Carex granularis
Carex retrorsa
Carex sp.
Carex sp. (ovales)
Carex torta
Carex vulpinoidea
Cicuta maculata
Cornus stolonifera
Eleocharis tenuis
Equisetum arvense
Eupatorium maculatum
Eupatorium perfoliatum
Fraxinus nigra
Galium asprellum
Glyceria striata
Heracleum maximum
Juglans cinerea
Leersia oryzoides
Matteuccia struthiopteris
Mimulus ringens
Myosotis scorpioides
Onoclea sensibilis
Phalaris arundinacea
Phleum pratense*
Poa palustris
Polygonum sagittatum
Sagittaria latifolia
Salix rigida
Scirpus atrocinctus
Scirpus validus
Scutellaria lateriflora
Solidago gigantea
Tilia americana
Ulmus americana
Veratrum viride
Vitis riparia

Site 15: hemlock-hardwoods forest, abrupt banks, cobble shores, rock to 2' in channel

Agrostis perennans
Anemone virginiana
Apios americana
Berberis vulgaris*
Betula alleghaniensis
Bromus latiglumis
Carex amphibola
Carex echinata
Carex sprenglii
Carex torta
Desmodium glutinosum
Elymus virginicus
Equisetum arvense
Equisetum hyemale
Fagus grandifolia
Fraxinus americana
Hamamelis virginiana
Leersia oryzoides
Phalaris arundinacea
Onoclea sensibilis
Ostrya virginiana
Oxalis europaea
Pilea pumila
Polygonum sp.
Quercus macrocarpa
Rhus radicans
Smilacina racemosa
Solanum dulcamara*
Solidago flexicaulis
Solidago gigantea
Sphenopholis intermedia
Thalictrum polygamum
Tilia americana
Tsuga canadensis
Tussilago farfara*
Vitis riparia

Site 16: Hemlock, black birch, elm forest, steep banks, 2-3' rocks in channel

Achillea millefolium*
Agrostis sp.
Amphicarpa bracteata
Apios americana
Apios americana
Asclepias incarnata
Aster divaricatus
Aster lateriflorus
Athyrium filix-femina
Betula lenta
Calamagrostis canadensis
Carex eburnea
Carex granularis
Carex hystericina
Carex sp.
Carex sp. (ovales)
Carex torta
Carex vulpinoidea
Cystopteris fragilis
Eleocharis tenuis
Elymus virginicus
Epipactis helleborine*
Erigeron annuus
Erigeron pulchellus
Eupatorium perfoliatum
Juncus dudleyi
Juncus effusus
Juncus nodosus
Leersia oryzoides
Lysimachia ciliata
Lysimachia terrestris
Lythrum salicaria*
Mimulus ringens
Onoclea sensibilis
Panicum clandestinum
Penthorum sedoides U
Phalaris arundinacea
Potamogeton nodosus
Rhus radicans
Salix rigida
Satureja vulgaris*
Scirpus atrocinctus
Scirpus pendulus U
Scirpus validus
Solidago gigantea
Solidago graminifolia
Sphenopholis intermedia
Sphenopholis intermedia
Thalictrum polygamum
Tsuga canadensis

Festuca pratensis*
Galium triflorum
Hypericum virginicum
Iris versicolor
Ulmus americana
Verbena hastata
Vicia cracca*
Vitis riparia

Site 17: Mad River, Moretown; alt. ca. 500'; bedrock schist with amphibolite and phyllite; mixed deciduous-coniferous forest; shores of sloping ledges below a rock-walled gorge.

Acer rubrum
Acer saccharum
Agrostis sp.
Alnus rugosa
Amelanchier sp.
Apios americana
Aquilegia canadensis
Aster tradescanti
Betula alleghaniensis
Betula papyrifera
Campanula rotundifolia
Carex flava
Danthonia spicata
Dryopteris marginalis
Eleocharis obtusa
Elymus riparius
Eupatorium maculatum
Eupatorium perfoliatum
Fragaria virginiana
Fraxinus americana
Houstonia caerulea
Juncus articulatus
Juncus brevicaudatus
Juncus effusus
Lotus corniculatus*
Lycopus americana
Lysimachia nummularia*
Mentha arvensis
Osmunda claytoniana
Panicum clandestinum
U Panicum lanuginosum
Phalaris arundinacea
Poa compressa*
Polygonum sagittatum
Polygonum sp.
Prunella vulgaris*
Ranunculus acris*
Rhynchospora capitellata
Rubus sp.
Solidago canadensis
Solidago graminifolia
Solidago nemoralis
Spiraea latifolia
Spiranthes cernua
Trifolium pratense*
Tsuga canadensis

Ulmus americana
Vaccinium caespitosum U
Verbena hastata
Viola sp.

Site 18: Moose River, Saint Johnsbury; alt. ca. 700'; bedfrock phyllite and schist; channelized north bank, young aspen woods on south bank, gravel bar in channel, rocks under 1'. Water ? Class I.

Acer negundo
Alnus rugosa
Apocynum cannabinum
Aster novae-belgii
Aster umbellatus
Calamagrostis canadensis
Carex torta
Clematis virginiana
Equisetum arvense
Hypericum perforatum
Iris versicolor
Onoclea sensibilis
Phalaris arundinacea
Poa sp. (palustris?)
Populus tremuloides
Prunus serotina
Salix sp. (rigida?)
Thalictrum polygamum

Eupatorium maculatum
Galium asprellum
Galium tinctorium
Tussilago farfara*
Ulmus americana
Viola sp.

Site 19: New Haven River, Lincoln; alt. ca. 1100'; bedrocke schist and greywacke; shores with mixed deciduous-coniferous forest, large ledges and boulders in channel, cobble shores

Acer spicatum
Agrostis scabra
Alnus rugosa
Aster puniceus
Aster umbellatus
Athyrium filix-femina
Betula alleghaniensis
Betula populifolia
Brachyeletrum erectum
Carex sp. (ovales)
Carex torta
Clematis virginiana
Danthonia compressa
Dennstaedtia punctilobula
Eupatorium maculatum
Eupatorium perfoliatum
Fragaria virginiana
Fraxinus americana
Geum sp.
Gylceria striata
Hieracium aurentiacum*
Hypericum perforatum
Juncus brevicaudatus
Viola sp.
Juncus tenuis
Onoclea sensibilis
Osmunda claytoniana
Oxalis europaea
Panicum lanuginosum
Parthenocissus quinquefolia
Poa sp. (palustris?)
Populus balsamifera
Potentilla simplex
Prunella vulgaris*
Prunus virginiana
Ranunculus acris*
Rubus idaeus
Salix bebbiana
Salix rigida
Solidago gigantea
Solidago graminifolia
Solidago rugosa
Spiraea latifolia
Taraxacum officinale*
Thalictrum polygamum
Tussilago farfara*
Ulmus americana

Site 20: New Haven River, Lincoln; alt. ca. 1000'; bedrock schist & greywacke; young deciduous forest, rocky shore, boulders to 2' in channel. Water Class II.

Acer negundo
Acer saccharum
Acer spicatum
Agropyron repens*
Agrostis stolonifera
Ambrosia artemisiifolia
Aster macrophyllus
Aster puniceus
Brachyeletrum erectum
Capsella bursa-pastoris*
Carex torta
Chelidonium majus*
Impatiens pallida
Juncus tenuis
Lychnis alba*
Matteuccia struthiopteris
Oenothera sp. (biennis?)
Oxalis europaea
Phleum pratense*
Poa compressa*
Populus deltoides
Potentilla norvegica
Prunus serotina
Ranunculus acris*

Chenopodium album*
Chrysanthemum leucanthemum*
Cichorium intybus*
Cirsium arvense*
Cornus alternifolia
Equisetum arvense
Erigeron annuus
Erigeron canadensis
Fragaria virginiana
Fraxinus americana
Galeopsis tetrahit*
Glyceria striata
Hieracium aurentiacum*
Impatiens capensis
Ulmus americana
Vitis riparia
Rubus idaeus
Rubus occidentalis
Rubus odoratus
Rumex crispus*
Salix sericea
Scirpus sp.
Solidago canadensis
Solidago graminifolia
Solidago juncea
Sphenopholis intermedia
Spiraea latifolia
Taraxacum officinale*
Thalictrum polygamum
Tussilago farfara*

Site 21: New Haven River, West Lincoln; alt. ca. 800'; bedrock quartzite; banks with second-growth deciduous forest; channel with boulders 2-4', some to 15'. Water Class III-IV

Acer negundo
Agrimonia striata
Agropyron repens*
Agrostis scabra
Agrostis stolonifera
Amelanchier sp.
Anthoxanthum odoratum*
Aster lateriflorus
Aster puniceus
Aster umbellatus
Athyrium filix-femina
Betula alleghaniensis
Betula papyrifera
Bromus ciliatus
Campanula aparinoides U
Carex torta
Cerastium vulgatum*
Chrysanthemum leucanthemum*
Cinna latifolia
Clematis virginiana
Danthonia compressa
Danthonia spicata
Daucus carota*
Elymus riparius
Populus deltoides
Populus tremuloides
Potentilla simplex
Prunella vulgaris*
Ranunculus acris*
Equisetum arvense
Erigeron annuus
Eupatorium maculatum
Eupatorium perfoliatum
Fraxinus americana
Hypericum mutilum
Hypericum perforatum
Impatiens sp.
Leersia oryzoides
Lotus corniculatus*
Melilotus alba*
Mimulus ringens
Oenothera sp.
Onoclea sensibilis
Osmunda claytoniana
Oxalis europaea
Phalaris arundinacea
Phleum pratense*
Pinus strobus
Plantago rugelii
Poa compressa*
Poa pratensis
Polygonum cuspidatum*
Populus balsamifera
Solidago graminifolia
Solidago juncea
Spiraea latifolia
Thalictrum polygamum
Trifolium agrarium*

Rhus typhina
Rubus idaeus
Salix rigida
Salix sericea
Saponaria officinalis*
Smilacina racemosa
Solidago canadensis
Solidago gigantea
Zizea aurea
Trifolium pratense*
Trifolium repens*
Tsuga canadensis
Tsuga canadensis
Tussilago farfara*
Ulmus americana
Vicia cracca*
Vitis riparia

Site 22: New Haven River, Bristol; alt. ca. 500'; bedrock quartzite; banks with young birches & road fill; channel with cobbles & scattered boulders 4-8'. Water Class III.

Acer negundo
Acer saccharum
Acer spicatum
Aegopodium podagraria*
Agrimonia striata
Agrostis sp.
Agrostis stolonifera
Ambrosia artemisiifolia
Apocynum sibiricum
Aster lateriflorus
Aster umbellatus
Betula papyrifera
Bromus ciliatus
Carex torta
Centaurea maculosa*
Chrysanthemum leucanthemum*
Elymus riparius
Eupatorium maculatum
Eupatorium perfoliatum
Festuca pratensis*
Fragaria virginiana
Fraxinus americana
Galeopsis tetrahit*
Galium sp.
Glyceria striata
Hypericum perforatum
Impatiens capensis
Lycopus americana
Mimulus ringens
Onoclea sensibilis
Oxalis europaea
Panicum clandestinum
Panicum lanuginosum
Parthenocissus quinquefolia
Phalaris arundinacea
Plantago major*
Poa compressa*
Polygonum sp.
Populus deltoides
Prunus serotina
Rubus idaeus
Rubus occidentalis
Rubus odoratus
Rumex obtusifolius*
Salix rigida
Salix sp. (sericea?)
Saponaria officinalis*
Scutellaria lateriflora
Solanum dulcamara*
Solidago canadensis
Solidago graminifolia
Spiraea latifolia
Taraxacum officinale*
Thalictrum polygamum
Thelypteris palustris
Tussilago farfara*
Ulmus americana
Verbena hastata
Vicia cracca*
Vitis riparia
Vitis riparia
Acer negundo

Site 23: New Haven River, Bristol; altitude ca. 400'; bedrock quartzite; old mill site sith stone walls and young deciduous trees; stream with 3-6' boulders. Water Class III-IV.

Agropyron repens*
Agrostis stolonifera
Ambrosia artemisiifolia
Asclepias syriaca
Aster cordifolius
Aster umbellatus
Athyrium filix-femina
Bromus ciliatus
Carex torta
Centaurea maculosa*
Chrysanthemum leucanthemum*
Convolvulus sepium*
Echinocystis lobata
gigantea
Eupatorium maculatum
Eupatorium perfoliatum
Eupatorium rugosum
Festuca pratensis*
Hypericum perforatum
Lonicera morrowi*
Mentha arvensis
Muhlenbergia frondosa
Onoclea sensibilis
Panicum clandestinum
Parthenocissus quinquefolia
Phalaris arundinacea
Phleum pratense*
Platanus occidentalis
Poa compressa*
Poa pratensis
Populus deltoides
Rhus typhina
Rubus odoratus
Salix rigida
Salix sp.
Saponaria officinalis*
Solidago canadensis Elymus riparius Solidago

Solidago graminifolia
Solidago juncea
Sphenopholis intermedia
Tanacetum vulgare*
Taraxacum officinale*
Trifolium pratense*
Tussilago farfara*
Ulmus americana
Vicia cracca*
Vitis riparia

Site 24: East Branch of Passumpsic, Lyndon; alt. ca. 700'; bedrock limestone & phyllite schist; hayfields and scattered deciduous trees; grevel and sand bottom. Water Class I.

Agrostis stolonifera
Alnus rugosa
Asclepias syriaca
Aster puniceus
Aster umbellatus
Bromus inermis*
Campanula rapunculoides*
Carex hystericina
Carex sp. (ovales)
Carex torta
Clematis virginiana
Cornus stolonifera
Eupatorium maculatum
Eupatorium perfoliatum
Hypericum perforatum
Hypericum virginicum
Juncus articulatus
Thalictrum polygamum
Ulmus americana
Juncus dudleyi
Lycopus uniflorus
Lysimachia terrestris
Matteuccia struthiopteris
Melilotus alba*
Mentha arvensis
Mentha piperita*
Phalaris arundinacea
Populus balsamifera
Rubus idaeus
Salix rigida
Saponaria officinalis*
Scirpus atrovirens
Solidago graminifolia
Solidago juncea
Spiraea latifolia
Taraxacum officinale*

Vitis riparia

Sites 25-26: Saxtons River, Rockingham; alt. ca. 500'; bedrock limestone & schist. Water Class III.

Site 25: Deciduous forest with sycamore; silt and cobble shore, rocks to 2'.

Agropyron repens*
Agrostis perennans
Agrostis sp. (stolonifera?)
Apocynum cannabinum
Aster cordifolius
Carex torta
Chrysanthemum leucanthemum*
Dactylis glomerata*
Elymus riparius
Eupatorium maculatum
Eupatorium perfoliatum
Fraxinus americana
rigida
Hystrix patula
Lysimachia nummularia*
Matteuccia struthiopteris
Oenothera biennis
Vitis riparia

Ostrya virginiana
Oxalis europaea
Panicum clandestinum
Parthenocissus inserta
Phleum pratense*
Platanus occidentalis
Polgonum cuspidatum*
Polygonum caespitosum*
longisetum
Prunella vulgaris*
Rubus idaeus
Rudbeckia serotina* Helianthus tuberosus* Salix

Saponaria officinalis*
Solidago graminifolia
Tovara virginica
Ulmus americana

Site 26: Old mill site; vertically bedded schist; young deciduous forest Cobbles to 1'.

Acer rubrum
Acer saccharum
Apios americana
Apocynum cannabinum
Aster umbellatus
Athyrium filix-femina
Betula papyrifera
Carex torta
Cerastium vulgatum*
Chrysanthemum leucanthemum*
Cornus stolonifera
Daucus carota*
Desmodium canadense
Equisetum arvense
Erigeron strigosus
Eupatorium maculatum
Festuca pratensis*
Galium sp.
Geum canadense
Hieracium piloselloides*
Hypericum perforatum
Juncus spp.

Platanus occidentalis
Poa compressa*
Polygonum cuspidatum*
Populus deltoides
Prunella vulgaris*
Quercus rubra
Ranunculus acris*
Rhynchospora capitellata
Robinia pseudo-acacia*
Rosa multiflora*
Rubus odoratus
Salix purpurea*
Salix rigida
Saponaria officinalis*
Scirpus atrovirens
Scirpus cyperinus
Solanum dulcamara*
Solidago bicolor
Solidago gigantea
Solidago juncea
Solidago nemoralis
Spiraea latifolia

Lactuca canadensis
Lobelia inflata
Lysimachia ciliata
Mimulus ringens
Mirabilis nyctaginea*
Onoclea sensibilis
Osmunda claytoniana
Panicum clandestinum
Parthenocissus quinquefolia
Phalaris arundinacea
Pinus strobus
Plantago major*
Tanacetum vulgare*
Taraxacum officinale*
Thalictrum polygamum
Tovara virginica
Tsuga canadensis
Tussilago farfara*
Ulmus americana
Verbena hastata
Viola sp.
Vitis riparia

Site 27: Wardsboro Brook, Jamaica; altitude ca. 600'; bedrock gneiss & schist; mixed hemlock-hardwoods forest; flat shores with sand, gravel and boulders 1-3'. Water Class IV.

Achillea millefolium*
Agrostis sp.
Alnus rugosa
Aster lateriflorus
Betula papyrifera
Carex sp. (ovales)
Carex torta
Chrysanthemum leucanthemum*
Echinochloa crus-galli
Equisetum arvense
Fragaria virginiana
Galium mollugo*
Hieracium scabrum
Hieracium sp.
Hypericum mutilum
Hypericum sp.
Juncus brevicaudatus
Juncus tenuis
Lobelia inflata
Solidago nemoralis
Lysimachia terrestris
Oenothera sp.
Oxalis europaea
Panicum lanuginosum Aster puniceus Pinus strobus
Plantago major*
Platanus occidentalis
Poa compressa*
Polygonella articulata
Populus balsamifera
Populus deltoides
Populus tremuloides
Potentilla norvegica
Quercus rubra
Rubus idaeus
Salix rigida
Salix sericea
Saponaria officinalis*
Solidago bicolor
Solidago graminifolia

Site 28: West River, Jamaica; sample from an extended survey along 1 1/2 miles of shore; altitude 800-500'; bedrock gneiss & schist with small amounts of lime locally; mixed deciduous & confireous forest; shores with boulders or cobbles; boulders to 6' in channel. water Class III-IV.

Alnus viride
Apios americanus
Apocynum androsaemifolium
Aquilegia canadensis
Aster puniceus
Aster simplex
U Panicum clandestinum
Phalaris arundinacea
Populus tremuloides
Prunus virginiana
Ranunculus acris
Rhododendron prionophyllum

Athyrium felix-femina
Brachyeletrum erectum
Calamagrostis canadensis
Carex torta
Clematis virginiana
Diervilla lonicera
Equisetum arvense
Eupatorium maculatum
Fragaria virginiana
Galium sp.
Habenaria sp.
Habenaria sp.
Houstonia coerulea
Hydrocotyle americana
Hypericum perforatum
Ilex verticillata
Iris versicolor
Malus sylvestris
Onoclea sensibilis
Osmunda cinnamonea
Osmunda claytoniana
Osmunda regalis
Oxalis europaea
Rhus toxicodendron
Rosa blanda U
Rubus allegheniensis
Rubus odoratus
Rubus pubescens
Salix sericea
Sanguisorba canadensis
Smilacina stellata U
Smilax herbacea
Spiraea latifolia
*Taraxacum officinale**
Thalictrum polygamum
Ulmus americanus
Uvularia sessilifolia
Vaccinium cespitosum
Veratrum viride
Viola cuculata
Viola pallens
Vitis riparia
Zizia aurea

Site 29: West River, Brookline & Newfane; altitude ca. 350'; bedrock biotite gneiss & amphibolite, perhaps locally limy; cobble shore with deciduous woods, scattered rocks to 1'. Water Class I.

Apios americanus
Apocynum sibiricum
Aster novi-belgii
Carex lurida
Cynanchium nigrum*
Eupatorium maculatum
Habenaria flava
Juncus canadensis
Juncus tenuis
Onoclea sensibilis
Panicum lanuginosum
Platanus occidentalis
Poa sp.
Podestemon ceratophyllum R
Rhynchospora capitellata
Salix rigida
R Solidago graminifolia
Sphenopholis intermedia

Site 30: Connecticut River, Lemington; alt. ca. 1000'; bedrock schist & phyllite, perhaps with occasional lime; mixed coniferous-deciduous woods, cobble shores, boulders to 2' in channel. Water Class I.

Acer rubrum
Agrostis perennans
Alopecurus aequalis
Aster foliaceus
Aster lateriflorus
Aster umbellatus
Juncus tenuis
Luzula multiflora
R Lysimachia terrestris
R Oenothera biennis*
Onoclea sensibilis
Panicum clandestinum

Calamagrostis canadensis
Carex from Ovales
Carex lenticularis
Carex torta
Cirsium sp.
Deschampsia cespitosa
Dulichium arundinaceum
Eleocharis tenuis
Euptorium maculatum
Galium asprellum
Galium triflorum
Glyceria striata
Habenaria fimbriata
Hypericum boreale
Iris versicolor
Juncus sp.
Panicum lanuginosum
Phalaris arundinacea
U Phleum pratense
Polygonum sagittatum
Populus balsamifera
Prunella vulgaris
Salix pellita R
Salix rigida
Scirpus microcarpus
Scirpus sp.
Solidago graminifolia
Thalictrum polygamum
Tussilago farfara
Veratrum viride
Vicia cracca*

Site 31: number not used

Site 32: Wild Branch, North Wolcott; alt. 900'; bedrock quartzite-granulite; young deciduous forest, cobble shores, rocks to 3'. Water Class II.

Acer rubrum
Acer saccharum
Agrostis stolonifera
Alnus rugosa
Anthoxanthum odoratum*
Aster lateriflorus
Aster puniceus
Calamagrostis canadensis
Carex torta
Dactylis glomerata*
Epilobium glandulosum
Eupatorium maculatum
Eupatorium perfoliatum
Eupatorium rugosum
Festuca rubra
Galium asprellum
Galium mollugo*
Hypericum sp.
Juncus brevicaudatus
Leontodon autumnalis*
Lotus corniculatus*
Lychnis alba*
Lysimachia terrestris
Mentha arvensis
Mentha piperita*
Myosotis scorpioides
Oenothera sp.
Oxalis europaea
Phleum pratense*
Plantago lanceolata*
Polygonum sagittatum
Polygonum sp.
Populus balsamifera
Populus tremuloides
Prunella vulgaris*
Rumex acetosella*
Rumex obtusifolius*
Salix sp. (nigra?)
Saponaria officinalis*
Solidago canadensis
Solidago gigantea
Solidago graminifolia
Solidago rugosa
Ulmus americana
Verbascum thapsus*
Verbena hastata
Veronica chamaedrys*

Site 33: Williams River, Rockingham; alt. ca. 500'; bedrock schist & quartzite; hayfields and deciduous forest, some road {fill, 2-3' rocks in channel. Water Class I.

Acer negundo
Agrimonia sp.
Agropyron repens*
Agrostis scabra
Agrostis stolonifera
Alnus rugosa
Apocynum cannabinum
Aster lateriflorus
Aster umbellatus
Athyrium filix-femina
Campanula aparinoides
Chelone glabra
Chrysanthemum leucanthemum*
Clematis virginiana
Cornus stolonifera
Elymus riparius
Equisetum arvense
Fraxinus americana
Galium sp.
Hypericum perforatum
Verbena hastata
Leersia oryzoides
Lonicera x bella*
Lotus corniculatus*
Lysimachia quadrifolia
Mimulus ringens
Oenothera sp. (biennis?)
Onoclea sensibilis
Oxalis europaea
Panicum clandestinum
Panicum lanuginosum
U Phalaris arundinacea
Poa compressa*
Polygonum cuspidatum*
Rhus radicans
Rubus idaeus
Salix bebbiana
Salix rigida
Salix sericea
Saponaria officinalis*
Solidago juncea Iris versicolor Spiraea latifolia

Site 34: Winhall River, Winhall; alt. ca. 1100'; bedrock gneiss & schist; maple, pine & aspen woods; cobble shores with 1' rocks; 4-6' rocks in channel. Water Class III.

Acer saccharum
Agrostis scabra
Agrostis sp.
Anaphalis margaritacea
Apocynum sibiricum
Aster divaricatus
Aster lateriflorus
Aster puniceus
Aster umbellatus
Bromus ciliatus
Calamagrostis canadensis
Carex torta
Chelone glabra
Chrysanthemum leucanthemum*
Clematis virginiana
Convolvulus sepium*
Danthonia spicata
Elymus riparius
Eupatorium maculatum
Galeopsis tetrahit*
Lotus corniculatus*
Lycopus uniflorus
Lysimachia terrestris
Malva alcea*
Melilotus alba*
Onoclea sensibilis
Panicum clandestinum
Parthenocissus quinquefolia
Phleum pratense*
Pinus strobus
Plantago major*
Populus tremuloides
Rubus allegheniensis
Rubus idaeus
Rubus occidentalis
Salix rigida
Silene cucubalis*
Solanum dulcamara*
Solidago bicolor
Solidago canadensis

Galium asprellum
Galium sp.
Glyceria striata
Hieracium scabrum
Hypericum perforatum
Lactuca biennis
Leontodon autumnalis*
Lobelia inflata
Solidago graminifolia
Spiraea latifolia
Thalictrum polygamum
Trifolium agrarium*
Tsuga canadensis
Tussilago farfara*
Verbena hastata

Site 35: Winooski River, Berlin & Middlesex; alt. ca. 400'; bedrock quartzite granulite;mixed hemlock-deciduous woods on one bank, meadows on the other; narrow muddy shores; few rocks to 3'. Water Class I or less.

Acer negundo
Apocynum sp.
Arctium lappa*
Arisaema triphyllum
Aster puniceus
Aster umbellatus
Athyrium filix-femina
Betula alleghaniensis
Cornus alternifolia
Echinocystis lobata
Erigeron annuus
Fraxinus americana
Glyceria striata
Helianthus tuberosus*
Hemerocallis fulva*
Ulmus americana
Impatiens capensis
Juglans cinerea
Lactuca biennis
Lythrum salicaria*
Matteuccia struthiopteris
Onoclea sensibilis
Parthenocissus quinquefolia
Phlox paniculata*
Rubus odoratus
Solidago gigantea
Solidago rugosa
Sonchus arvensis*
Sorbus americana
Tovara virginica
Tsuga canadensis