THE GEOGRAPHY OF WISCONSIN'S TROUT STREAMS

C. W. Threinen and Ronald Poff

Trout of the brook, brown and rainbow species are a highly valued and relatively scarce fish resource largely restricted to cold-water streams. The location of those cold-water streams capable of supporting trout, therefore, becomes a matter of interest for management of the fish and habitat protection purposes, because of the tenuous character of these limited habitat conditions. In order to show locations, all known trout streams are noted on a hydrographic map of the state. The circumstances leading to their origin are then interpreted.

Certain environmental requirements which become limited to trout formed the basis for this interpretation. Cool water in summer is the primary requirement. Trout of all three species (brook, brown, and rainbow) have thermal tolerances which can be exceeded by summer temperatures. This temperature is generally recognized to be 77.5° F. for brook trout under prolonged exposure (Brett, 1956) and somewhat higher for the other species (Needham, 1938). Brett (1956) noted the optimum temperature for growth and feeding for brook trout was 19° C (66.2° F).

Since brook and brown trout spawn during fall and rainbow trout spawn during fall or spring, water conditions have to be suitable for spawning and development of eggs and young. Trout usually spawn in October and November at which time the females seek out water of suitable temperatures and conditions, dig redds in gravel riffles and, following fertilization, bury their eggs. As a reflection of these conditions, concentrations of spawning trout (especially brook trout) occur near springs. The eggs are dependent upon steady percolation of water through the gravel for aeration, and development of the egg proceeds most rapidly and successfully with steady and moderate water temperatures. Mortalities of eggs are known to be high where the water temperatures are low (near freezing).1 Ground water springs are, therefore, essential to produce these conditions.

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1 Unpublished research of the Wisconsin Conservation Department.
Another possible limiting factor cited by other workers in the mountain states is the formation of anchor ice (Maciolek and Needham, 1952). Under very cold conditions in the northern part of the state, anchor ice can form over the rocks and riffles and result in the movement or displacement of the stony bottom materials and destruction of redds and food resources. Obviously warm waters would not allow the formation of anchor ice. A usual characteristic of good trout waters is that they are seldom covered by ice because of the warmer temperatures of the ground water springs feeding trout streams with temperatures between 48° and
50° F. These are streams fed by significant amounts of ground water. Benson (1953) called streams free of ice on cold days "good" trout streams and those ice covered "poor".

CLIMATE CONDITIONS AND THE HYDROLOGICAL CYCLE

Rain falling on the ground either soaks in to become part of the ground water, becomes absorbed by the surface soils or runs off on the surface. If it percolates into the ground to become part of the ground water, it will flow downhill later to reach surface drainage. The capability for percolation into the ground and movement underground will obviously be best when soils are light and where sufficient hydraulic gradient prevails, and it will be poorest with heavy soils and poor gradient. With trout streams heavily dependent upon cool water, the ground water flow, circumstances providing slope and surface infiltration will be the conditions most productive of trout streams. All streams are dependent upon ground water for their base flow but to have importance for trout during critical periods, a high portion of the base flow must be recently expressed ground water which has not yet warmed or cooled to surrounding temperatures.

Water absorbed by surface soils is of no immediate value to trout streams. It either evaporates or is transpired by plants. The heavy soils will hold more water and infiltrate less than light soils and therefore make a lesser contribution to ground water and make more available to evaporation and transpiration. Similarly surface runoff is of limited value to trout streams because it closely reflects surrounding temperatures, and it lacks permanence because of the intermittency of rainfall.

Wisconsin has a northern climate typical of the continental land mass. It is characterized by hot summers (July average, 66°–72° F) and cold winters (January average, 10°–22 F). Daytime summer temperatures are hot enough to warm surface waters above the maximum tolerated by trout. Winter temperatures are sufficiently cold to freeze surface waters and to cause moisture storage in the form of snow from December through March. Although there are intermittent thaws which make contributions to the surface water, this weather cycle causes some of the lowest runoff of the year to occur in the winter. Streams or portions of streams without strong ground water sources, therefore, tend to fluctuate in both volume and temperatures more than those with and, therefore, provide a less stable habitat for fish. Another low period in stream discharge usually occurs in the summer when vegetation is actively transpiring water and evaporation rates are high. Drescher (1956) described rapid rises in ground water levels
in the spring, and discharge exceeding recharge during the growing season.

Rainfall averages about 30 inches a year in Wisconsin divided as follows: 17.2 per cent falls in the winter months of December, January, February, and March; 22.5 per cent falls during the nongrowing season of April, October and November; and 60.3 per

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**MAJOR SOIL REGIONS**

Adapted from maps of the Wisconsin Geological and Natural History Survey and the Department of Geography, University of Wisconsin.

1. REDDISH CLAY LOAMS
   Level or gently rolling.

2. GRAYISH LOAMS
   and SANDY LOAMS
   Gently rolling or hummocky, often stony.

3. SANDS
   Level or gently rolling.

4. GRAYISH-YELLOW SILT LOAMS
   Level or gently rolling, often well.

5. SANDY LOAMS
   Gently rolling, hilly or steep.

6. GRAYISH-BROWN UNGlaciated SILT LOAMS
   Hilly or steep.

7. GRAYISH-BROWN GLACIATED SILT LOAMS
   Nearly level or rolling.

8. PINK LOAMS
   Nearly level or rolling.

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**Figure 2.** Trout stream complexes superimposed on a soils and topographic map of Wisconsin.
cent falls during the growing season (USDA, 1941). The humid climate of Wisconsin has ground water within 100 feet of the surface except beneath high, steep-sided hills (Drescher, 1956).

Wojta's (1949) summary reported 6 per cent runoff on the surface, 15 per cent went to subsurface runoff, 70 per cent went to evaporation and transpiration and 9 per cent went to ground water. It must be recognized, however, that great variation can occur. Ground water levels closely correspond to precipitation, so changes in spring flow can be expected to result from changes in precipitation (Drescher, 1956). The term "spring" as used in this report is defined as surface expression of ground water.

DISTRIBUTION AND CHARACTER OF TROUT STREAMS

Designation of streams as "trout streams" is the product of many years of surveys and creel observations gathered by the field personnel of the Wisconsin Conservation Department. This designation means that a stream has shown consistent ability to support trout without excessive natural mortalities. It is recognized that stream habitat conditions change and could affect this designation. This is particularly true where impoundments have been constructed. Such structures frequently change a cold-water environment to a warm-water environment.

Although there are individual and partial losses of trout water which have been reported, these have not been great enough to alter seriously the general geography of Wisconsin's trout streams. In our opinion, most of the alterations have occurred within the present complexes of trout streams. Perhaps the greatest change has occurred in the cranberry and duck marsh areas of central Wisconsin in the bed of glacial Lake Wisconsin.

We have several complexes of trout streams plus some scattered streams. The largest and most important complex occupies an arc beginning in Adams and Marquette Counties and extending north and northeast into Florence and Marinette Counties. Within this belt are some of the best-known trout streams in the state and almost without exception there is substantial natural reproduction of trout in them. The complex second in size and trout concentration lies in the northern tier of counties most of whose drainage flows into Lake Superior. This includes some of the more spectacular streams with high gradients such as the Brule. The third major complex occupies the unglaciated southwestern part of the state. There are minor complexes centered in Lincoln County and portions of adjoining counties, and in Rusk, Barron, Dunn, Pierce, and St. Croix Counties.
Regions conspicuously lacking trout streams or lightly represented are the lake regions of the north, the heavy soil regions of Marathon, Taylor, Clark and Wood Counties, much of the bed of old glacial Lake Wisconsin, and most of southeastern Wisconsin. Further inspection of the hydrography will show that the trout streams are not unique to particular drainages, but that they do have regional distribution. The largest complex has streams flowing into both the Lake Michigan drainage and the Wisconsin River.

The gradient characteristics of trout streams vary greatly. They include everything from white water to spring ponds, and from ditches and tiny feeders to rivers. Some examples of the extremes follow: The Little Brule in Florence County has much white water; the Nine Mile in Langlade County is a slow, meandered stream flowing through a swamp; Trout Springs is a spring pond in Vilas County; Ten Mile Creek is a ditch through a former marsh in Portage County; the Wolf River in Langlade County is a substantial river at least 50 feet in width. In many cases only a part of the stream will be trout water, with summer water too warm both above and below, an example of which is Rocky Run Creek, Columbia County. Most have this in common: They are generally the headwaters of river systems, and the big river trout stream is the exception rather than the rule.

**RELATIONSHIP TO TOPOGRAPHY**

The major complexes of trout streams have been superimposed on a combination soils and relief map adapted from Whiteson, (1927) and Martin (1932) (Fig. 2). In the absence of an elaborate topographic map with contours, the topography of the state is evident in the hydrographic map (Fig. 1) by noting the drainage divides. State elevations begin at 1,650 feet in the northern highlands and drop to 595 feet in the Mississippi, 581 feet in Lake Michigan and 602 feet in Lake Superior. Wisconsin is fundamentally a sculptured plain which slopes gradually from the northern highlands to the south, east, and west and more abruptly to the north. Major water courses originate in the highlands and flow in these directions. The hills of the terminal moraines generally are some of the highest features on the landscape, and they often form the drainage divides. In the southwest, erosion has cut through the level plain of the upland with elevations of 1000-1200 feet to form deep valleys or coulees leading to the major water courses with elevations approximately 600-700 feet.

Almost all the trout stream complexes are associated with some hilly topography but not all hilly topography has trout streams.
FIGURE 8. Trout stream complexes superimposed on a glacial deposit map of Wisconsin.

The largest complex has as its center the terminal moraines of the Green Bay lobe of the last Wisconsin glacial period and streams flow in both directions. Although many of the trout streams are associated with hilly moraine areas, this feature is not always productive of trout streams as will be noted by the scarcity of trout
streams in the extensive Kettle Moraine hills. Surface topography is important in this regard: The ground water moves from recharge areas, which are usually divides and hills, toward discharge points of lower elevation, and springs occur where the ground water table coincides with the surface. Thus, the hills provide hydraulic gradient toward points of discharge. Also, where the stream cutting exposes an aquifer endowed with water, or the ground water itself, a spring can originate. Surface cutting and erosion has not been great on the younger surface of the glaciated regions, but it has been extremely important in the unglaciated portion of southwestern Wisconsin. Sharply cut and deeply eroded valleys which have carved the plateau are characteristic of this region.

Another factor can be the stream gradient. A sluggish stream does not have the water exchange of a stream with large gradient, and thus is less likely to retain the cool summer and warm winter temperatures required of a trout stream. As noted, however, some trout streams are sluggish. The typical drainage system in the unglaciated portions of Wisconsin has small feeder streams of high gradient and a sluggish main stream of lower gradient.

Aside from the unglaciated region, we note that the hilly topography of the Lake Superior drainage and the Barron Hills has a high incidence of trout streams, but the hilly western portion of Marathon County, eastern Clark County and southern Taylor County has relatively few trout streams. It is a well-known fact that streams in this region have seasonal flows comprised mainly of surface runoff. There are relatively few springs feeding these streams and they may become intermittent. Although having sufficient gradient, ground water storage is limited because of the thin ground water reservoir.

Evidently sharp topography is not always necessary for the presence of trout streams. There is a group of them that flows through part of the extremely flat bed of old glacial Lake Wisconsin and in the sand and gravel deposits in the central sand plain in Adams and western Portage Counties. One group consists of the drainage ditches that drained the old Buena Vista Marsh, a very flat piece of landscape. These streams owe their existence to exceptionally favorable ground water conditions. On the other hand the bed of old glacial Lake Oshkosh has not a single trout stream in it. This area is generally the lower part of the major drainages and is impregnated with numerous shallow lakes and marshes. Few springs occur in this region.
GLACIAL GEOLOGY

The glaciers had a profound influence on all the Wisconsin landscape except parts of the driftless area. For an evaluation of the contribution of glacial geology, the trout stream complexes have been superimposed on the glacial map of Thwaites (1956) (Fig. 3).

Basically the repeated glaciers filled the valleys with sediments, leveling the landscape, giving much of Wisconsin a gently rolling character alternately consisting of low hills and lowlands of the ground moraine with its poor drainage, produced outwash plains of sandy soils, some pitted, some not and gave rise to steep hilly topography in the terminal moraines. Pitted outwash plains of the glaciers gave rise to most of the lake regions (Thwaites, 1959). Unpitted outwash consists of the well-drained sandy till which has such excellent water-bearing and transmission qualities. Such streams as the Chippewa, Black, Wisconsin, and Mississippi Rivers were major drainages to the south, which carried the load of melt water.

The gently rolling hills and lowland of southeastern Wisconsin, with drainage to the south, has few trout streams except on its western edges. The western-most streams have cut through the higher elevation of the plateau of the driftless area and terminal moraine to join the lower main stream. The streams of southeastern Wisconsin aside from these are geologically young with less elevation and have not eroded down into deep valleys as compared with those of southwestern Wisconsin. Almost nowhere is bedrock exposed by their erosive action and the clay till of southeastern Wisconsin has poor waterbearing characteristics. Almost all the streams in southeastern Wisconsin have low gradients (except when they originate in the hills of a moraine) and low runoff (Table 1). Here and there among the gravel hills of the Kettle Moraine, there are large deposits of sand and gravel furnishing a good ground water reservoir. The local steep gradient of the ground water table produces springs of sufficient magnitude to permit the existence of a trout stream. Trout streams are, however, conspicuously absent all along the shore of Lake Michigan where there is usually quite a fall. Almost all the smaller streams up and down the Michigan shore are intermittent also because of the poor water-bearing qualities of the soil, although subterranean drainage is naturally toward the lake as is the surface drainage. Artesian conditions prevail along much of the shore because of impermeable rock and soil conditions along the shore.
<table>
<thead>
<tr>
<th>STREAM</th>
<th>YEARS OF RECORD</th>
<th>RANGE IN RUNOFF (IN.)</th>
<th>MEDIAN RUNOFF (IN.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trout Streams</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wolf River (Keshena)</td>
<td>40</td>
<td>9.00-17.14</td>
<td>12.76-12.80</td>
</tr>
<tr>
<td>Embarrass River (Embrarrass)</td>
<td>31</td>
<td>5.11-16.46</td>
<td>10.03</td>
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<tr>
<td>Brule River (Brule)</td>
<td>7</td>
<td>15.97-23.00</td>
<td>18.04</td>
</tr>
<tr>
<td>Pike River (Amberg)</td>
<td>35</td>
<td>7.59-19.25</td>
<td>12.36</td>
</tr>
<tr>
<td>Prairie River (Merrill)</td>
<td>27</td>
<td>8.90-22.89</td>
<td>15.74</td>
</tr>
<tr>
<td><strong>Nontrout Streams</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>West Branch Fond du Lac River</td>
<td>10</td>
<td>1.74-8.43</td>
<td>3.53-3.54</td>
</tr>
<tr>
<td>Cedar Creek (Cedarburg)</td>
<td>19</td>
<td>2.12-13.08</td>
<td>6.55</td>
</tr>
<tr>
<td>Duncan Creek (Bloomer)</td>
<td>6</td>
<td>5.07-10.91</td>
<td>8.12-8.18</td>
</tr>
<tr>
<td>Crawfish River (Milford)</td>
<td>18</td>
<td>2.10-11.62</td>
<td>6.02-6.24</td>
</tr>
<tr>
<td>Turtle Creek (Clinton)</td>
<td>10</td>
<td>6.44-8.49</td>
<td>7.14-7.52</td>
</tr>
</tbody>
</table>

*Source: USGS water supply papers 1307 and 1308.
*Only streams not having any trout streams as tributaries were utilized.

The flat bed of old glacial Lake Oshkosh in the Green Bay lobe has no trout streams in it. It is significant that much of this basin is covered with reddish clay loam, a soil not well adapted to water infiltration or lateral movement. Marshes and shallow lakes are characteristic of this region and in many places artesian water conditions prevail.

Moraines appear to have a high incidence of trout streams, especially the moraine that marks the edge of the Green Bay lobe of the glacier. A high incidence also occurs in the moraine of glacial Lake Duluth. This is, however, not always the picture. Trout streams are relatively scarce in most of the Kettle Moraine and scarce in the moraine stretching across Taylor County. As a whole trout streams are notably scarce in the unsorted glacial till but well represented in the alluvium, with some exceptions. These exceptions are the important lake districts such as the highlands of Vilas and Oneida Counties; the northwest lake district of Polk, Burnett, Washburn, Sawyer and southern Bayfield and Douglas Counties; and the small, concentrated lake district occupying northern Chippewa County and southern Rusk County. The lakes act as impoundments and cause the water to become too warm for trout in the summer time. Only a few short streams occur in this region. Elsewhere lakes are not so concentrated that they influence the location of trout streams.

The coarse, well-sorted sandy alluvium such as found in central and northwestern Wisconsin makes an excellent infiltration bed for
the recharge of ground water, the source of springs. Comparatively less water will be held by the sands in these surface layers and remain available for evapotranspiration. The unsorted till, on the other hand, contains the poorly sorted soil mixtures and pockets strong on the silts and clays which inhibit free percolation and lateral movement of ground water and yet hold a great deal of it.
The fractions of the soil particles of various sizes are reproduced from Weidman and Schultz (1915) to illustrate this point (Table 2).

SOIL TYPES

The location of trout streams in relation to soil types is presented by imposing the trout stream complexes upon a soils map of the state. The conventional soils map of Whitson (1927) was adapted for this purpose (Fig. 2).

This map is indicative of the infiltration capabilities of the various soils. There is a good correlation between trout stream location and certain soil types, with some exceptions which of course are what would be expected from our review of the glacial geology. In most areas, the trout streams do not occur in the clay and glaciated clay loams and silt loams which include the red clay region of glacial Lake Oshkosh, the grayish-brown glaciated silt loams of the southeast, and the grayish-yellow silt loams of the north central region. Some local exceptions occur. Many of the streams flowing into Lake Superior pass through the red clay belt along the shore. Most, however, originate in the lighter sandy soils to the south.

Streams in the southwest originate from lands covered with soils originating from sandstones and dolomites. In recognition of the greater presence of springs in the southwest than the southeast, it must be concluded that unglaciated silt loam is capable of contributing to ground water through percolation and porous rock formations capable of taking it up. Thus, other conditions being favorable, it will give rise to springs and trout streams. Evidently, the gradient or topography and bedrock formations determine whether or not a soil region gives rise to springs. In the southwest there is a soil mantle of variable thickness which in many places is eroded right down to or into the bedrock. Erosion of the surface soils and rock has nowhere proceeded to this extent in the southeast.

BEDROCK GEOLOGY

The circumstances which produce springs most commonly are: (1) a ground water table which reaches the surface or, in other words is exposed by the surface elevations, and (2) less permeable stratum that restricts the downward movement of water and allows it to move laterally to discharge as a spring. We have seen how this would readily occur in the southwestern part of the state with its eroded stream courses which cut deeply into the soil and rock mantle (Fig. 7). The question is, how does the bedrock geology affect spring development elsewhere? The trout stream com-
plexes have been superimposed on the geologic map of the state (Bean, 1947) for an illustration (Fig. 4).

The greatest concentration of trout streams is located over the impervious Canadian Shield or near its edge with some notable gaps. One of these gaps occurs in the silt loams of north central Wisconsin—a heavy soil region where poor percolation, poor lateral subsurface movement and little storage would be expected. Of special interest is the fact that the line of streams coinciding with the Green Bay lateral moraine also lies right on the edge of the Canadian Shield. The topography overlying the Shield has its highest point in the northeastern highlands of Vilas County and slopes off toward the various water courses. It is the edge of this slope with a high gradient where subsurface water movement is readily intersected by the surface drainage. A cross-sectional diagram of this scheme adapted from Weidman and Schultz (1915) appears in Fig. 5.

The ground water level of the sandy soils of this region is maintained by the impervious rock substrate. The existence of this slope and movement of ground water can be illustrated by the Wolf River. Most of its feeders known to be trout water are on the west side. This does not, however, explain the southern extension of this group of streams, which occur in Waushara, Marquette and Adams Counties, all underlain by Upper Cambrian sandstone. In this general area there is still a hydraulic gradient arising from the moraine hills and adequately recharged through the sandy soils. It is perhaps significant that the Pre-Cambrian granite comes to the surface in some localities in Marquette County and may contribute to this slope.

Many streams flowing over trap rock or the Lake Superior sandstones have rich spring sources from overlying alluvium. A high

![Figure 5. Geology, soils and trout stream distribution across an east-west section of Wisconsin at the latitude of Wausau. Adapted from Wiedman and Schultz (1915) and Whitson (1926).](image-url)
ground water level is maintained by the impervious cemented sandstone of the trap rock, and the high elevation of this region gives the ground water ample hydraulic gradient to flow downhill through the sandy till to emerge as springs. Most of the springs supplying the Brule and other south shore streams have their origin above the lacustrine clay belt that marks the bottom of glacial Lake Duluth and their infiltration bed is the Brule sand barrens. Bean (1944) diagrammed this picture in detail.

![Figure 6](image1.png)

**Figure 6.** An east-west geologic section from Madison to Milwaukee with areas of trout stream occurrence noted. Recoped from Thomas (1952) who adapted work of Wiedman and Schultz (1918).

![Figure 7](image2.png)

**Figure 7.** A north-south geological cross-section of the terrain that creates spring sources and trout streams in southwestern Wisconsin (Wiedman and Schultz, 1915).

The southeastern part of the state does not have many large springs nor much gradient to its streams. The deep layer of poorly sorted drift over porous bedrock in many places is not conducive to development of numerous and consistent spring sources. The clay loams have poor recharge properties and, should water reach the rock aquifers, it would flow toward areas of discharge (streams, lakes, wells, etc.) to the east or south. Rock aquifers include the porous St. Peter sandstone, Cambrian sandstone, the
less porous Prairie du Chien dolomite, and the Galena dolomite. Cities digging wells in this region usually seek either the St. Peter sandstone or the Cambrian sandstone. Even the Niagara limestone which underlies all the lake shore counties is reasonably permeable due to the numerous fractures and joints. A simplified diagram of the system has been reproduced from the report of Thomas (1952) (Fig. 6).

There is much to be gained by observing the runoff of important streams which lie within these regions. It is low for the streams in the southeast and much higher for the streams which originate on the Canadian Shield and streams that originate in the Southwest. This is further evidence that precipitation enters the ground to be expressed at distant points and does not become an immediate part of surface discharge; is retained by the clayey soils to enter the evapotranspiration cycle; or is impounded in marshes or lakes. The streams with good spring sources on the other hand have a high base flow with little fluctuation which is well distributed through the year (Table 1).

**DISCUSSION**

Wisconsin has abundant rainfall amounting to 27–34 inches per year—enough to make contributions to the ground water, surface runoff, evaporation and vegetation growth. The fraction that enters the ground and becomes expressed as springs and seeps in what interests us the most because of the trout's dependence on the cool ground water. This amounts to 5.0 inches per year for southern Wisconsin according to Wojta's (1949) review and much higher in sandy regions, reaching 80–90 per cent (Drescher, 1955). Most of this recharge takes place during the periods when vegetation is not actively transpiring water, and it is very much greater in porous materials than in semi- or nonporous materials. With sufficient water for recharge, we can assume the potential for trout stream development always exists provided other physical conditions occur. An additional requirement is springs of sufficient number and size to sustain desired water temperatures. The size of streams inhabited by trout is suggestive of temperature requirements. Large streams do not make good trout water except seasonally. They have too much of their water volume derived from distant sources, which would have been subject to the tempering influence of weather conditions and excessively warmed or cooled, to have other than very local or seasonal value to trout. It will, therefore, be only the small- and medium-sized waters which can be sufficiently cooled or warmed by ground water springs—the head-
# Table 2. Mechanical Analysis of Typical Soils of Wisconsin*

<table>
<thead>
<tr>
<th></th>
<th>Per Cent of Soil Fraction</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Fine Gravel 2 to 1 mm.</td>
</tr>
<tr>
<td>Plainfield sand</td>
<td>Outwash</td>
</tr>
<tr>
<td>Plainfield sandy</td>
<td>Outwash</td>
</tr>
<tr>
<td>Boone fine sandy loam</td>
<td>Outwash</td>
</tr>
<tr>
<td>Chelsea (Coloma) loam</td>
<td>Outwash</td>
</tr>
<tr>
<td>Colby silt loam</td>
<td>Ground moraine</td>
</tr>
<tr>
<td>Knox silt loam</td>
<td>Unglaciated—loess.</td>
</tr>
<tr>
<td>Miami fine sandy loam</td>
<td>Ground moraine</td>
</tr>
<tr>
<td>Miami clay loam</td>
<td>Ground moraine</td>
</tr>
<tr>
<td>Superior clay</td>
<td>Lake bed</td>
</tr>
</tbody>
</table>

*Reproduced in part from Weidman and Schultz (1915).
waters for most streams. Usually the trout water will extend down about a mile below the significant spring sources.

The circumstances which have produced significant springs are multiple. First and most important, it takes a good porous soil to make contributions to the ground water through infiltration. This requirement has been well met by the glacial alluvium with its sandy soils. Trout streams are abundantly represented in this surface type or in conjunction with it. The second requirement is ground water with sufficient hydraulic gradient to cause the ground water to reach the surface such that interception by drain- age is possible. The slopes of the Canadian Shield, moraine hills and coulees provide this requirement.

Thirdly, there must be free lateral underground movement of the ground water so that it can reach the surface drainage systems which have cut down into the surface deposits. Free movement is permitted in the sorted alluvium with its predominantly sands and gravels in the overlay, but it is not permitted in the unsorted till or original lake clays with their higher fraction of clays or frequent pockets of clay and silt. Free movement of water is permitted in some of the sandstones which are exposed in the central and the western parts of the state.

It is perhaps fortunate that sandy soils and hilly regions are most productive of trout streams. Intensive agriculture will not be so demanding of these waters for irrigation nor will there be complete tillage of the soil with attendant erosion. The one crop that thrives on the sandy silt loams of outwash flats is potatoes. Since this crop gives the best yields when irrigated, competition for surface water from spring sources in such areas can be expected. The sandy soils and hillsides are more intensively dedicated to forest enterprises, a land use that indirectly contributes to rainfall infiltration, delayed runoff and ultimate expression as ground water springs.

The geography besides heavy soil types which is unproductive of trout streams contains many lakes. Also, it is a well-known fact that an impoundment will mark the lower limits of trout water. Impounded waters whether in lakes of glacial or man-made origin usually have surface outflow and become warmed beyond the tolerances of trout. These circumstances suggest that if protection of trout streams is to be achieved, impounding of trout waters should be avoided. The trend toward construction of small impoundments for farm ponds, private fish hatcheries and other recreational and business enterprises is regarded as a serious threat to the future of trout streams.
SUMMARY

Trout streams in Wisconsin have been located on a hydrographic map of the state. In this manner the geography leading to the existence of the streams can be seen. Since the trout require cold waters in summer and warm waters in winter, they are dependent upon ground water for these conditions. Trout streams occur abundantly in regions with good slope that provide a hydraulic gradient for ground water, in regions that have permeable sandy soils which permit ready infiltration and lateral movement of ground water. Trout streams are lacking in regions of little slope and clay soil types, and in regions containing abundant lakes. Impoundment of trout streams is regarded as the greatest threat to the maintenance of trout waters.

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