1997
GEOLOGICAL SOCIETY OF MAINE
FIELD TRIP

Geologic Studies in the Sebago Lake Region, Maine

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Geological Society of Maine Field Trip
July 26 and 27, 1997

Introduction

The 1997 Geological Society of Maine summer field trip is headquartered at Sebago Lake State Park in Naples. We will visit sites around the north end of Sebago Lake on Saturday, and to the west and southwest of the Lake on Sunday. Even though we will be in a fairly small geographic area, we will see and discuss a wide range of geologic topics. A large variety of geologic studies are ongoing in the Sebago Lake area, and representatives of these various studies will be leading different field trip stops. We will hear about igneous and metamorphic bedrock geology, glacial geology, Holocene geology of northern Sebago Lake, modern lakeshore erosion problems, and hydrogeology. Much of the work we will hear about is still in progress, with many new ideas. The trip is designed to give us all a better idea of current problems, issues, and progress.

The list of leaders and their affiliations is given on the cover page. For each of the stop descriptions, the names of the leader or leaders for that stop are indicated in parentheses. The localities of stops to be led by John Creasy are shown on the maps and listed in the guidebook, but his text descriptions will be distributed separately on the field trip. Maps showing the field trip route and the locations of all the individual stops are given at the end of the book.

The work to be presented on the field trip has been supported by many funding sources including (but not limited to) the Maine Geological Survey, the US Geological Survey, and the Portland Water District. In particular, much of the bedrock and surficial mapping in this region has been supported by federal-state cooperative projects (COGEOMAP and STATEMAP) as part of the National Geologic Mapping Program.

DAY 1. SATURDAY, JULY 26

Meeting place: Day Use Area of Sebago Lake State Park, 9 am.

Stop 1. Sebago Lake Shoreline Change Studies, 1990-1997 (Johnston and Mixon)

Shoreline changes at Sebago Lake from 1990 to spring 1997 are discussed in this new report prepared for the Portland Water District (PWD). A previous study (Dickson and Johnston, 1994) reported on beach profiling at the north end of Sebago Lake from 1990 to 1993. The authors of that study documented transient seasonal beach changes and identified processes that caused those changes at 12 sites established at several beaches at the north end of Sebago Lake. Ten of those sites were south-facing and 2 were southwest-facing.

The present study follows 6 of those sites for 3 more years and reports on an additional 12 sites around the perimeter of the lake, with sites facing in all directions. In addition to beach profiling, a shoreline classification and mapping project was completed to determine the types and extents of different shoreline environments around the lake; and a monitoring program for eroding bluffs was initiated.

Background

Sebago Lake, Maine's second largest lake, is located approximately 20 miles (30 km) northwest of Portland. The lake covers a surface area of approximately 47.5 square miles (123 square kilometers) and is 316 feet deep (97 m). Sebago Lake is a multi-use lake. It is heavily used for recreational purposes including swimming, boating, fishing, and ice-fishing in the winter. It serves as a public water supply for approximately 160,000 people in the Portland area. The lake and associated wetlands provide habitat for a variety of wildlife. Its shoreline is heavily developed with year-round residences, vacation cottages, camps, and marinas. Water released through the Eel Weir Hydroelectric Project generates some of the power for operation of the S. D. Warren paper mill in Westbrook. Releases from the lake to the Presumpscot River supply minimum flows for water quality, and for power generation at 5 other hydropower sites operated by S. D. Warren and 2 additional sites operated by Central Maine Power (CMP).

Lake levels at Sebago Lake have been managed artificially since 1830 when the Basin Dam was first built by the Cumberland and Oxford Canal Company (Wheeler, 1994). The dam was originally constructed to provide for better navigation and to divert water to a newly constructed canal. The present full pool elevation is 266.65 feet above mean sea level. At the present time the water levels in the lake are governed by a water level management plan developed by S. D. Warren, the Federal Energy Regulatory Commission (FERC), the PWD, various state agencies and local citizen groups (FERC, 1997b). Shoreline erosion became a concern at Sebago Lake in the mid 1980's when the S. D. Warren Paper Company, the current owner of the dam, changed its water level management plan. Before 1986 there was no specific water level plan for the lake. In 1986, CMP implemented seasonal electric rates, with winter rates approximately 40 percent higher than summer rates. In 1987, S. D. Warren, began to hold more water in the lake during the fall and winter months in order to generate more of its own power and purchase less from CMP at the higher winter rates (FERC, 1997a). This raising of the water levels brought an increase in the number of complaints on their management of the water levels. At a number of places around the lake, erosion of the sand beaches was reported due to the higher water levels.

The Maine Department of Conservation, Bureau of Parks and Recreation (BPR), became involved in the water level when beach erosion exposed tree roots at Songo Beach in Sebago Lake State Park. The Maine Geological Survey (MGS) was asked by the BPR to look at the erosion problem. Those efforts resulted in the initial study by Dickson and Johnston cited earlier.

Due to continuing controversy and concerns about shoreline erosion, the MGS and PWD, with assistance from Friends of Sebago Lake, a local citizens group, initiated additional beach profiling sites covering most of the sand beaches around the lake, bringing the total to 50 sites. The present study is based on a subset of 18 of those sites, including some of the sites from the Dickson and Johnston study.

Since 1991, S. D. Warren has been managing lake levels in accordance with a plan developed by the Maine Department of Environmental Protection (DEP). In 1994, FERC issued an order (FERC, 1994) requiring S. D. Warren to file with the Commission a water level management plan that addressed the competing interests and issues surrounding lake water levels. Draft and Final Environmental Impact Studies were prepared by FERC (FERC, 1996 and 1997a). In April 1997 FERC issued an order amending S. D. Warren's license to operate the Eel Weir Dam to include a water level management plan which substantially reverses the late 1980's and early 1990's practice of maintaining high water levels in the fall.

This shoreline study, therefore, covers a transitional time period in the water level management on Sebago Lake. No similar studies are available to document beach conditions and dynamics prior to the high fall water levels of the late 1980's and early 1990's. Any future studies may document the impact of the new water level management curve on shorelines.

Results: Shoreline Classification

Results of the shoreline classification project are presented on a map at a scale of 1:24,000 which is available as a separate publication (Johnston and Dickson, in press). The shoreline classification project found the following types and amounts of surficial materials around the perimeter of the lake: glacial till (a mixture of sand, silt and clay), glacial outwash (sand and gravel), silt, clay, and wetland deposits (silt and decaying plant material). The types and lineal distances of the shoreline environments mapped are:

Marsh	6,622	meters
Sand beach	23,805	meters
Seawall behind beach	7,649	meters
Groins with sand in between	4,285	meters
Bluff behind sand beach	6,833	meters
Sand beach with boulders	3,491	meters
Glacial till (sand, silt and clay)	92,123	meters
Artificial fill	9,239	meters
Bedrock	6,326	meters
Total meters of shoreline	160,373	meters

Glacial till is the dominant shoreline environment mapped, followed by sand beaches. Shorelines modified by human action (including seawall behind beach, groins with sand in between, and artificial fill) total 21,173 meters, or approximately 12.5 percent of the Sebago shoreline.

A shoreline stability and classification study of the Songo River from the Songo Lock to Sebago Lake identified marsh, floodplain, upland, beach, and water as the modern geologic environments of the Songo River. A stability index (actively accreting, stable, moderately stable, moderately eroding or actively eroding) was assigned to each stretch of shoreline and human modifications (artificial fill, retaining wall, rip rap, and stabilization project) were mapped. Most of the river bank is presently classified as stable or moderately stable, with marsh and floodplain dominating the geologic environments. These results are available as a separately published map at a scale of 1:4,000 (Lewis and Johnston, in press).

Results: Bluff Erosion Study

The bluff erosion monitoring program was established in the summer of 1996, on six eroding bluffs (Smith, 1997). Data was collected through spring of 1997. Limited conclusions can be drawn from this study because of its short duration, but minor erosion was documented over this short time period.

Results: Beach Erosion Study

Beaches were stable over the study period, showing seasonal sand oscillations as documented by Dickson and Johnston (1994), until the Songo, Frye Island, and Halls beaches and the Barton Residence at Harmons Beach experienced catastrophic changes in the fall of 1996. The Songo and Frye Island Beaches face south; Hall Beach faces southwest; and the Barton Residence faces east. These changes resulted from a rare combination of weather events and not from a lake-level management plan. On October 20-22, 1996 a major rain storm occurred in southern Maine, with rain in excess of 8 inches in the Sebago Lake basin over a period of about 12 hours (FEMA, 1996). This record-breaking storm resulted from a blocked "Northeaster" over the southern Maine region which was being fed tropical moisture from hurricane Lili, located 900 miles southeast of Portland. A strong high pressure system over Labrador kept the low pressure system from moving. As a result of this storm the Sebago Lake level rose 2 feet in just a few days. The overall rise in lake level during the following week was approximately 3.6 feet.

While lake levels were at or near this full pond level, a low pressure system tracking up the St. Lawrence River valley brought strong southerly winds to the lake on November 8th and 9th (NOAA, 1996). The combination of strong winds and high lake level allowed waves to reach and erode the upper beach areas, exposing tree roots and toppling trees along the shoreline at the Songo and Frye Island sites.

Halls Beach was affected more by the heavy rains than by the strong winds in November. Large gullies, approximately 4 feet deep, and as wide, developed across the beach in two locations, eroding the beach and forming deltas out into the lake.

The Barton Residence at Harmon's Beach is located near the north end of Harmon's beach. This site, although east-facing, suffered severe erosion, apparently a result of wave refraction.

The steepening of upper portions of profiles that occurred at the Songo Beach sites in the fall of 1996 continued into the spring of 1997, when further erosion occurred at those beaches. Exposure of tree roots at Songo and Frye Island beaches, and loss of the front line of trees along Songo beach, suggest that further changes in the profiles are likely before a new equilibrium profile is reached. Because the erosion occurred so high up on the beaches, it is not likely that sand will be returned to the eroded upper profile. Continued profiling at these sites will show the extent of change that eventually will result from the weather events of October and November 1996.

While not the result of any lake level management plan, these events sharply illustrate the role of high lake levels in shoreline erosion, by providing storm waves access to new ground. Although this event took place in the fall, comparable damage could occur at any time lake levels are high, and on any beach where the combination of wind direction, speed, and fetch allow development of storm waves.

Minor erosion events were also documented during the spring of 1994, and the late spring/early summer of 1995, at times of high water and winds.

Erosion was also documented during low lake levels. At low lake levels, however, erosion was not observed to result in permanent changes to the beach profiles, even when the volume of material removed from the beach profile was large. Significant erosion occurred in the fall of 1992 and late summer/fall of 1995, at low lake levels with high winds. Among the largest changes documented in the six years of beach profiling was an erosion event at the Songo site 3 between September 1 and October 3, 1995. The sand lost there was restored naturally over the following year. Low lake levels, therefore, do not appear to pose a risk of long-term change to beaches.

While the events of the fall of 1996 caused major erosion that is expected to be long- lasting, this type of change appears to occur relatively infrequently. Most of the beach changes documented were transient accumulations and losses of sand between different areas of the profile, as reported by Dickson and Johnston (1994), resulting in onshore and offshore beach profile shifts with rising and falling water levels; and ice-related accumulations of sand in the early spring, and their subsequent reworking.

Overall, the beach profile data present an emerging picture of beach dynamics in which long term stability is punctuated by sudden large, long-lasting and irreversible changes which result from storms during high water. This study included sites facing all compass directions. The south-facing beaches experienced the most change during the study period, but a longer period of data collection at the other beaches could alter this. The potential for a "Northeaster" during spring high lake levels is high. Such a storm could cause major and long-lasting changes at north to east-facing beaches.

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Stop 2. Songo River and Glacial Outwash Deltas, Sebago Lake State Park (Lewis)

Nowhere such a devious stream,
Save in fancy or in dream,
Winding slow through bush and brake,
Links together lake and lake.

Walled with woods or sandy shelf,
Ever doubling on itself
Flows the stream, so still and slow
That it hardly seems to flow.

~ Henry Wadsworth Longfellow

from Songo River, in Flight the Fourth, written on
September 18, 1875 after a visit to the Songo River.

Since human occupation, Sebago Lake and the Songo River have been utilized for travel. Next door to the state park, a site containing artifacts has been shown to be of Paleo-Indian age. In 1830, the Cumberland & Oxford Canal system was constructed roughly parallel to the Presumpscot River in order to economically allow lumber to be transported from inland forests to Portland on canal boats (and brought goods inland on the return trip) (Milliken, 1935; Anderson, 1982). The Songo River was an important link in the C & O canal route between Long Lake and the Bay of Naples to the north and Sebago ("large, open water" in Abenaki). As part of the C & O Canal system, a lock was built on the Songo River at its confluence with the Crooked River. This lock has been enlarged since its original construction and is still in use today under the authority of the Department of Conservation. In the late 1800's the Songo River was portrayed as a romantic escape in tourism/trade journals. Henry Wadsworth Longfellow himself visited the Songo and was inspired to write a poem describing the meandering river (Longfellow, 1975).

Sebago Lake was dammed in 1830 at Wescott Falls to improve navigation for the canal boats. This raised lake levels by four to five feet (Wells, 1869). The dam was raised again in 1876 by five feet after a water-rights conflict between the mills downstream on the Presumpscot River (Wheeler, 1994). The bedrock outlet of Sebago Lake is at Whites Bridge, on the eastern shore, and is shown on a 1949 Portland Water District survey map as having an elevation of 253 feet (77 m). Currently the average lake level is at about 265 feet (81 m), but can fluctuate 11 feet (3.4 m) during a year's time.

Geophysical data, 4 km of ground-penetrating radar (GPR) and 18 km of seismic reflection profiles, from Sebago Lake State Park and the Songo River delta have been used to construct the stratigraphy and a sequence of late- and post-glacial events which created the landforms seen in the area today. Subaerially, the Songo River has incised the larger glacial outwash delta upon which the park is situated. Offshore, the Songo River delta has partially buried, by progradation, the bottomset beds of the glacial outwash delta, resulting in an interfingering of facies. The elevation of the glacial delta indicates that it formed while the land surface was still isostatically depressed at deglaciation. Differential isostatic rebound resulting in tilting of the lake basin seems to be the most likely interpretation of the landform relationships and seismic and GPR facies as seen in the records collected at the state park. The glacial outwash delta surface appears to have been graded to the elevation of the bedrock outlet at Whites Bridge and limited at all stages of development and incision by the Songo River. The dip measured between these two locations is 1.1 m/km and is comparable with measurements of a post-glacial uplift gradient from mid-coast Maine of about 1.0 m/km (Barnhart et al.,1995).

Unlike Moosehead Lake, which experienced outlet switching during forebulge migration and tilting of its lake basin to the north (Balco, 1996), Sebago does not appear to have had an alternate surface outlet. Therefore, gradual flooding of the north end of the lake basin occurred while surface water continued to drain out its bedrock outlet at Whites Bridge.

A submerged shoreline, 11 m below present lake level (Johnston et al., 1994), is another feature related to lake-level change. A paleo-water balance calculation, in conjunction with other local paleoclimate data (e.g., Lake Auburn (Talbot, 1996)), supports a drier early-mid Holocene climate as the more likely cause of the formation of this shoreline rather than isostatic tilting.

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Stop 3. Sebago-Pacific Till Pit. (Hildreth)

Located about 1.6 km (1 mile) north of Songo Lock and the juncture of the Crooked and Songo Rivers, the pit is owned by Sebago-Pacific Trucking Co., Inc. It exposes 2-6 meters (6-20 feet) of massive glacial diamict (till) that is light olive gray, sandy, stony and moderately compact. The pit face is very steep on account of the compactness. The uppermost meter (3 feet) shows evidence of modern soil formation, but below that, the till is unweathered, except for some clasts of diabase-basalt dike material, which commonly have spalling spheroidal weathering rinds. Boulders (some as much as 3 meters (10 feet) in diameter) of the most common rock type in the region (Sebago granite) are common throughout the exposure. The abundance of boulders in this pit is greater than normal for till deposits in the region. The till here does not display any obvious fissility, and very faint stratification is present in only a few places.

Stop 4. Dragon Pits, North and South (Hildreth)

Dragon Pit North - This large pit (about 1.6 km (1 mile) north-northeast of Songo Lock) is part of an excavation complex associated with the Dragon Concrete Company. Excavation in the pit area has mostly been discontinued. The northeasternmost section includes an exposure of 1.5 to 3 meters (4-10 feet) of fine sand, silt and sand over 2.4 meters (8 feet) of pebbly sand and gravel extending down to the water table, below which appears to be several more feet of pebbly sand. From here southward, including a long trench south of the road, there appears to have been an esker, which has been minded out. Just 91 meters (300 feet) northwest of the road, and exposure of about a meter (several feet) of dune sand overlies 2.2 meters (7 feet) of laminated sand, silt, and pebbly sand. Here, a boulder dropstone (1 meter (3 feet) in diameter) is near the top of the laminated unit, which also contains small faults, sand-pebble dikes, convoluted bedding, and abundant Liesegand banding throughout (parallel rusty bands, several millimeters apart, formed by ground-water chemical precipitation).

Dragon Pit South - Located just south of the Dragon Pit North site. About 91 meters (300 feet) south of the road through the pit area, 1 meter (3 feet) of fine windblown sand overlies 1 meter (3 feet) of roughly laminated silt and clay, which in turn overlies 0.6 meters (2 feet) of sand, silt and clay beds, over more than 1 meter (3 feet) of well-laminated silt and clay. This exposure is on the west side of the trench from which an inferred esker has been excavated.

Optional Stop. P & K Borrow Pit. (Hildreth)

This pit is located in the north-central part of the quadrangle, immediately southwest of the junction of the Crooked River and Mill Brook. The pit has been visited by geologists many times over the past 20 years and the various deposits have been described over time (Thompson and Smith, 1977; and Thompson and others, 1995a, b). In 1995, one face of the pit contained 1-1.5 meters (3-4 feet) of silt-clay varves (totaling 16 in number, each being 5-7.5 cm [2-3 in.] thick) overlying 20 cm (8 in.)

rippled sand overlying 2.4 meters (8 feet) of varves (totaling 46 in number, each being 5-10 cm [2-4 in.] thick). The clay layer of each lamina is very thin (1-5mm thick) and the top is brown. Nematode worm tracks are present in some laminae. The varve deposits fill a depression on the surface of sand deposits that are exposed within 30 meters (100 feet) northwest of this exposure where there is a 12 meter (40 foot) sand bank. The varves are cut by younger sand deposits within 30 meters (100 feet) northeast where a 7.6 meter (25 foot) sand bank of dipping beds comprise a channel fill deposit. A few layers of the varves have convoluted bedding, but most are horizontal or dip parallel to the underlying drape surface. These deposits have been faulted and folded slightly through slumping and settling. Postdepositional Liesegang banding (rust-colored, rhythmic iron-oxide precipitate bands that are parallel to one another but not to bedding, straight or curved, and variable in orientation) is common throughout the deposits in this pit.

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Lunch and Stop 5. Quaker Hill (Creasy)

(Description to be distributed on field trip)

Stop 6. Edes Falls. (Creasy)

(Description to be distributed on field trip)

Stop 7. Edes Falls pit. (Hildreth)

Located on the border of the Naples and Casco quadrangles on the west side of the Crooked River, this pit is owned by P & K Sand and Gravel, Inc., of Naples. The pit is a long north-trending trench that is more than 0.5 km (0.3 miles) in length and 6-12 meters (20 to 40 feet) in depth. The north and south ends of the pit are not currently being mined, but the material exposed in the central part suggests that the mined-out sections probably constituted an esker (ice-channel filling) core of coarse-grained sand and gravel similar to that in the Dragon Pits. The material exposed in the banks of the pit is predominantly sand and silt plus minor sand and clay. The pit has been excavated in a relatively flat-topped terrace (elevation approximately 100 to 107 meters (330 - 350 feet) and is composed of glaciofluvial and glaciolacustrine deposits capped by a thin veneer of windblown sand. Thin-bedded silt and clay varves overlie the glaciofluvial deposits and occupy depressions in the terrace surface. The depressions are kettle holds underlain by faulted and folded glaciofluvial sand and gravel deposits. Bedrock is exposed in the floor of the pit.

Near the pit entrance, a 60-cm (24 inch) unit of silt-clay varves drapes gently over 2 meters (6 feet) of variable, faulted sand. Manganese and iron-oxide staining and cementation are found along and near the contact. Silt-clay rhythmites here have peculiar faint parallel, thin rusty lines 1 - 4 mm apart, which are called "liesegang banding." At the far western edge of the pit, 9 meters (15 feet) of fluvial pebbly-sand beds (and very minor pebble-cobble gravel and a few boulders) display large-scale cross stratification, including cut-and fill channels more than 6 meters (20 feet) across. At about the center of the pit, a 15 meter (50 foot) wide section contains the following units (from top to bottom): about 2 meters (6 feet) of concave, slumped, and folded thin-bedded silt, clay, and fine-grained sand rhythmites; about 3 meters (10 feet) of slumped and faulted sand; about 60 cm (24 inches) of undisturbed, horizontally bedded silt and clay; and 60-90 cm (24-36 inches) of thin-bedded sediments that have Type B climbing ripples, which indicate deposition by south-flowing currents. A probable boulder-pebble beach gravel (about 1 meter (3 feet) thick) caps the western wall of the pit at an elevation of about 107 meters (350 feet), which would indicate a glacial-lake shoreline at this level.

Stop 8. Madison Mountain; Stop 9, Rt. 302 roadcut; Stop 10, Rt. 302 roadcut, South Casco; and Stop 11, West of Songo Lock (Creasy)

(Descriptions to be distributed on field trip)

GSM Business Meeting and Cookout. 6:00 pm, Day Use Area, Sebago Lake State Park

DAY 2. SUNDAY, JULY 27

Meeting place: Sebago Elementary School, Jct. Rts 11 and 114, East Sebago, 9 am.

Stop 12. Stony Brook at East Sebago, Streamgaging station (Silverman)

The Stony Brook stream-gaging station was installed in October of 1995 in cooperation with the Portland Water District. This gage, along with a similar station on the Crooked River in Naples is used to gather streamflow data for an ongoing basin yield study in the Presumpscot River basin. The Stony Brook watershed covers an area of 1.50 square miles at the gage and is composed of three geohydrologic units, till, bedrock, and stratified drift. Stony Brook streamflow data were used to correlate discharge measurements at over 50 ungaged sites surrounding Sebago Lake. It has also been used in estimating groundwater discharge during low-flow conditions.

A pressure transducer, attached to a nitrogen bubbling system, reads the water level to the nearest hundredth of a foot every 15 minutes. This information is stored in the memory of a data collection platform and transmitted to a GOES satellite every four hours. The gage is powered by a 12 volt, 26 amp hour battery which is charged by a solar panel on the antenna mast.

A steel V-notch weir plate, attached to the upstream end of the roadway culvert, acts as the control for the gage pool where the water level is measured. The weir plate increases sensitivity of the control helping better define the stage-discharge relationship. Periodic streamflow discharge measurements, using current meter or volumetric methods, help ensure accuracy of the relationship. Flows measured at the Stony Brook gage range from .018 to 51.7 cubic feet per second.

Directions to Stop 13: From East Sebago, follow Long Hill Rd. to the northwest (past Fitch's General Store). At the stop sign, turn right onto Rt. 107. Take the first left onto Douglas Mtn. Road, following signs for the Jones Museum. At crest of road, turn left at road sign for "Douglas Mtn Rd., Stone Tower" (Fire Lane 52A). Drop passengers at the end of the road where the trail begins. Only 5 or 6 cars can park at the trailhead. Overflow parking is available part way down the hill, at the end of Fire Lane 52AA.

Stop 13. Douglas Mtn. (Berry) NO HAMMERS, PLEASE.

This stop is to show the lithology and structural features of migmatites of the Rindgemere Formation. Reconnaissance mapping of this area has been done by Dick Gilman at 1:62,500 scale. He has published the Kezar Falls (Gilman, 1977) and Newfield (Gilman, 1991) 15' quadrangles, but the Sebago Lake 15' quadrangle, while incorporated in regional compilations, has not been published at large scale. More recent detailed work by Gilman along the crest of the Saddleback Hills was summarized by Gilman (1988). As part of the Maine Geological Survey's current bedrock compilation project for the Portland 1:100,000 sheet, Adam Schoonmaker focused on the nature of the "Vassalboro-Rindgemere" contact shown on the Bedrock Geologic Map of Maine and expanded the area of detailed mapping in the summer of 1996. His detailed map is in press.

We will look at four outcrop locations along the hiking trail, beginning at the base of the trail and working uphill to the south. Outcrop A is about 50 feet past the stone pillars where the trail runs on bedrock. Continue up the trail, taking the left fork (the "Ledges" trail) to a large, bare hillslope ledge; this is Outcrop B. Follow the trail up the hill across Outcrop B. Where the trail turns right at the top of the slope (with a view to the northeast) is Outcrop C. The summit is Outcrop D.

Outcrop A: Most of the outcrop consists of migmatitic gneiss. The darker, schistose layers contain quartz, muscovite, biotite, garnet, and sillimanite. The lighter layers are granitic to pegmatitic segregations mainly of quartz and feldspar. The thin, lighter layers are concordant and foliated parallel to the schistosity in the darker, more micaceous layers. The metamorphic foliation strikes northeast and dips steeply northwest. Some layers of quartz-feldspar-biotite +/- garnet granofels are also present. The granofels layers probably represent relict sedimentary beds, but their continuity is not well preserved here. Also, granite dikes cut cleanly across the metamorphic foliation with a more northerly strike.

Outcrop B: It may be difficult to see fine details because of the lichen on this large outcrop, but the general aspects of the structure and layering are well displayed. The foliation orientation is between N45E and N60E, similar to its orientation at Outcrop A, but on this large surface the warps and variations in orientation can be seen. Notice that the migmatitic segregations are deformed by these open warps together with the schistose and granofelsic layers indicating that the warping was synchronous with or after migmatization. In some places, the foliation appears to be truncated at a shallow angle against adjacent layers, but no throughgoing shear zones or consistent shear sense has been detected. These scant observations, together with the flattened shape of the migmatitic segregations, suggest that this deformation was mainly a flattening perpendicular to the foliation rather than a simple shear deformation. Some granofels layers show tight folds with steeply plunging hinge lines. It is difficult to follow layers for more than a few meters across the outcrop. A younger set of pegmatite and granite dikes with sharp contacts cut across the layering with more northerly orientations, such as N25E. Understanding the apparently complex deformation awaits detailed structural study of these rocks.

Outcrop C: An erratic boulder of white, fine-grained garnet-muscovite granite rests beside the trail. Layering in the metamorphic bedrock is better exposed here than at Outcrop B. Some of the schistose layers have conspicuous lumps of quartz+sillimanite The schistosity strikes N70E, more easterly than at Outcrop B. Minor folds of layering are more obvious here than they are below. A thin pegmatite dike (N15W, 48NE) leads up the trail.

Along the trail after Outcrop C, toward a big spruce tree, the foliation in the migmatite becomes very contorted. Just past the spruce tree, in a flat place, the trail crosses a large body of muscovite-garnet granite and pegmatite that continues to the summit.

Outcrop D (Summit): The bedrock around the base of the inscribed boulder is a premier exposure of the migmatite. Foliation is at N71E, 88SE. The thin granitic pods and stringers occupy a large volume of the schistose rock, while a granofels layer is not migmatized. This suggests that the felsic segregations represent trapped pockets of partial melt. The central part of the summit outcrop, to the east of the boulder, consists of muscovite-garnet granite and pegmatite. The contacts of this intrusive body cut sharply across the migmatite but with an irregular shape. The intrusion appears to trend roughly northwest , but not as a single parallel-sided dike. Ten feet northeast of the tower, near the tower steps, there is a discrete granite dike about 10 inches thick that cuts the migmatite at N54W, 63SW. From the features seen at all of these outcrops along the trail, it is clear that there are at least two ages of granite here; the older of which is deformed with the migmatite, and the younger of which is not. The absolute ages of the granites are not known, but the younger set is presumably related to granites of the Sebago pluton. This begs the question of whether the migmatites might also be related to the Sebago pluton or whether the migmatization might be older than the Sebago granites.

On a clear day, the summit tower affords excellent panoramic views to the northwest and north of some of New England's highest mountains in New Hampshire (Chocorua, Carrigan, Kearsarge, Washington), and in Maine (Old Speck, the Baldpates, Streaked Mountain). Geologically, most of these highest mountains are underlain by metamorphic rocks with significant amounts of quartzite, such as the Littleton and Rangeley Formations. By comparison, granites of the Sebago pluton are less resistant to weathering and have been eroded to form the broad lowland area to the north and east of Douglas Mountain, including most of the basin for Sebago Lake itself. The only significant relief within the area of the Sebago pluton is where younger, Mesozoic plutons intrude through it, such as at Pleasant Mountain in Bridgton or Rattlesnake Mtn in Casco. The view from the observation tower is a lesson in bedrock control of the landscape by the process of differential erosion.

At the northwest edge of the summit outcrop, there are glacial striations with an azimuth of 161 degrees.

Lunch and Stop 16. Steep Falls (Berry)

The metamorphic bedrock here consists of layered quartz-feldspar-biotite granofels with subordinate interlayers of diopside calc-silicate granofels and muscovite schist. Metamorphic layering dips gently to moderately toward the south. It is intruded by various small bodies of concordant to discordant muscovite-garnet-tourmaline pegmatite and granite. A prominent set of younger, presumably Mesozoic, mafic dikes with chilled margins is exposed at low water just south of the east end of the bridge. Several of these dikes strike about N45E, but one, along the east bank of the river, strikes N37W. The course of the river just at the bridge is parallel to this dike.

In the "early days" (Gilman, 1970, e.g.) the granofels here was originally mapped as Silurian-Devonian Berwick Formation. By the time of the Bedrock Geologic Map of Maine (1985) it was reassigned to the late Ordovician-Silurian Vassalboro Formation on the basis of correlation with similar and almost contiguous rocks in the Waterville-Vassalboro region. But since the type area of the Vassalboro Formation (in Vassalboro) has now been re-assigned to the Sangerville Formation (Osberg, 1988), the regional correlation and stratigraphic position of the rocks here at Steep Falls are no longer certain. This general rock type appears to be common in the Silurian sequence of south-central Maine, and similar-looking rocks can be found in the Hutchins Corner, Sangerville, and Madrid Formations.

Stop 17. Unnamed, well-bedded quartzite and schist unit. (Berry)

This is a "real life" stop, to look at natural outcrops in the woods. We are here today by special permission of the landowners. They ask only that there is NO SMOKING in the woods. This area was logged a few years ago, so please be careful of sticks, branches, and loose rocks underfoot. The trip leader will guide you to several outcrops *and boulders that display characteristic aspects of this stratigraphic unit. There is also plenty of rock that you may look at on your own, but please do not wander eastward down the hill into the deep woods.*

The rock here consists of rhythmically interbedded light gray quartzite and silvery muscovite-biotite schist. Bedding thickness is typically 1 to 3 inches, although occasional quartzite beds over a foot thick are present in the formation. The individual beds are laterally continuous and of nearly constant thickness. The quartzite beds are quite clean, certainly in comparison with the feldspathic beds we saw at stops 13 and 16, but they commonly contain small amounts of garnet, muscovite, or biotite. Scattered reddish-pink beds of garnet+quartz are also present. (Some might call them coticule, but I prefer garnet-quartz granofels for these particular beds.) Bedding contacts are sharp. Graded beds are common in this formation, although none have been observed at this locality. The schist contains quartz, muscovite, biotite, garnet, and sillimanite, and is poor in feldspar. This distinguishes it from the feldspathic schists we will see at stop 18. On Libby Mountain (just across the road to the southwest) and at several other places in the Limington quadrangle, fresh andalusite is also present in schist of this formation. Outcrops weather medium gray to dull reddish.

Minor folds are easily discerned because of the abundance of closely-spaced, sharp bedding contacts. The most common set of folds has a tight, almost chevron-style, hinge zone. The axial plane fabric is a crenulation cleavage, indicating that it is a second-stage cleavage, and the original schistosity must have formed prior to the dominant fold set. Axial surfaces here strike northerly and dip at shallow to moderate angles toward the west. Hinge lines have various orientations but plunge generally toward the west or southwest approximately down dip of the axial surfaces, to give a "reclined" fold geometry. Graded beds on Libby Mtn. indicate that some of these folds face north. Folds with more upright axial surfaces and more northerly trending hinge lines are also present in this region, and may represent separate fold sets.

This formation of thinly bedded quartzite and schist is currently unnamed. It has been included with the Rindgemere Formation in most previous mapping, but Gilman (1970) reported and described this particular rock type as a potentially mappable unit. Current mapping (in progress) demonstrates that it is laterally continuous, and can be traced for many miles from the Saddleback Hills (Schoonmaker, *in press*), through the Limington quadrangle (Berry, *in prep.*), and across much of the Waterboro quadrangle to the south (Guzofski, 1996; and *in press*). Gilman (1986, 1991) reviews the regional relationships of similar rocks in the Newfield 15' quadrangle. One of the hypotheses under consideration is that this unit may correlate with the Perry Mountain Formation of western and south-central Maine.

Stop 18. Rt. 117, south of Limington village (Berry)

This uninspiring road cut shows rocks of the Rindgemere Formation. Outcrops weather to various shades of brown to rusty-brown. Bedding is difficult to discern on casual inspection because lithologic contrasts between adjacent beds are not dramatic. Yet, various rock types are present, including silvery-gray mica schist, medium gray feldspathic schist, and quartz-feldspar-mica gneiss with wispy streaks of sillimanite. In contrast with the previous stop, the rocks are more feldspathic. Neither clean quartzites nor highly aluminous, fissile schists are common here. Bedding thicknesses are variable from outcrop to outcrop.

Bedding here is oriented N49W, 52NE, but minor folds are common. Bedding in the small outcrop in the yard across the road is oriented N15E, 45NW. Minor folds in the road cut have axial planes that dip at shallow angles toward the southwest, with hinge lines plunging gently to the southeast. The shallow to moderate dips and variable fold orientations seen here and at Stop 17 represent the structural style of a broad region from here westward to New Hampshire. To the east, in the Standish and North Windham quadrangles, however, foliation and layering strike consistently to the northeast and dip moderately to steeply to the southeast (see Hussey, 1996a; 1996b; and Stop 19 of this field trip).

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Stop 19. Dry Channel of the Saco River at Route 35, Standish. (Marvinney)

During periods of low water flow, rocks mapped as the Hutchins Corner Formation are spectacularly exposed along the "Dry Channel" portion of the Saco River where water has been diverted to the west side of the island at Bonny Eagle for power generation. Defined by Osberg (1988), the Hutchins Corner Formation is significant metasedimentary unit in southwestern Maine. The unit consists of predominantly medium-grained quartz-plagioclase-biotite granofels arranged in beds of generally medium thickness (5-10 cm) although thinner packets and beds up to several meters thick occur. Weathered granofels is usually light tan in color while fresh has a distinct salt-and-pepper character. Large outcrops often expose beds which grade from medium-grained granofels upward into thin quartzose biotite schist; bases of these beds are sharp and distinct. Small calc-silicate-rich lenses and thin beds occur infrequently in the granofels. Perhaps 10% of the unit consists of generally massive, rusty-weathering quartzose biotite schist arranged in sequences to a meter in thickness.

From the large ledges just south of this point to the dam north of the Rte. 35 bridge over the Saco River at Bonny Eagle there is about 1/2 mile of nearly continuous exposure of the Hutchins Corner Formation. This stop well illustrates the bedding style of the Hutchins Corner which varies from thinly bedded granofels to some rather thick beds. These thicknesses are grouped in packets. Some graded beds are apparent. Numerous basaltic and pegmatitic dikes intrude the formation here. A dike directly below the base of the dam north of Rte. 35 is largely composed of ultramafic nodules ranging to 15 cm in diameter. This is the only dike known to contain these nodules in the entire area mapped by Marvinney

(1995) and Hussey (1996). Folding is subtle and best exposed north of Rte. 35. Folds are tight to isoclinal and plunge to the northeast.

We will focus our review on the exposures south of the Rte. 35 bridge. In this section are numerous examples of the bedding style and sedimentary structures within the Hutchins Corner Formation. The abundance of mafic dikes here allow us to examine the contact relationships of these dikes. As part of our ongoing investigations of arsenic in ground water of the region, we have been using geophysical techniques to map the dikes both within the "dry channel" and beneath the glacial cover of the island. We originally thought that the mafic dikes might be a source of ground-water arsenic, but recent geochemical data suggest that the calc-silicate portions of the unit may contribute more arsenic than the dikes.

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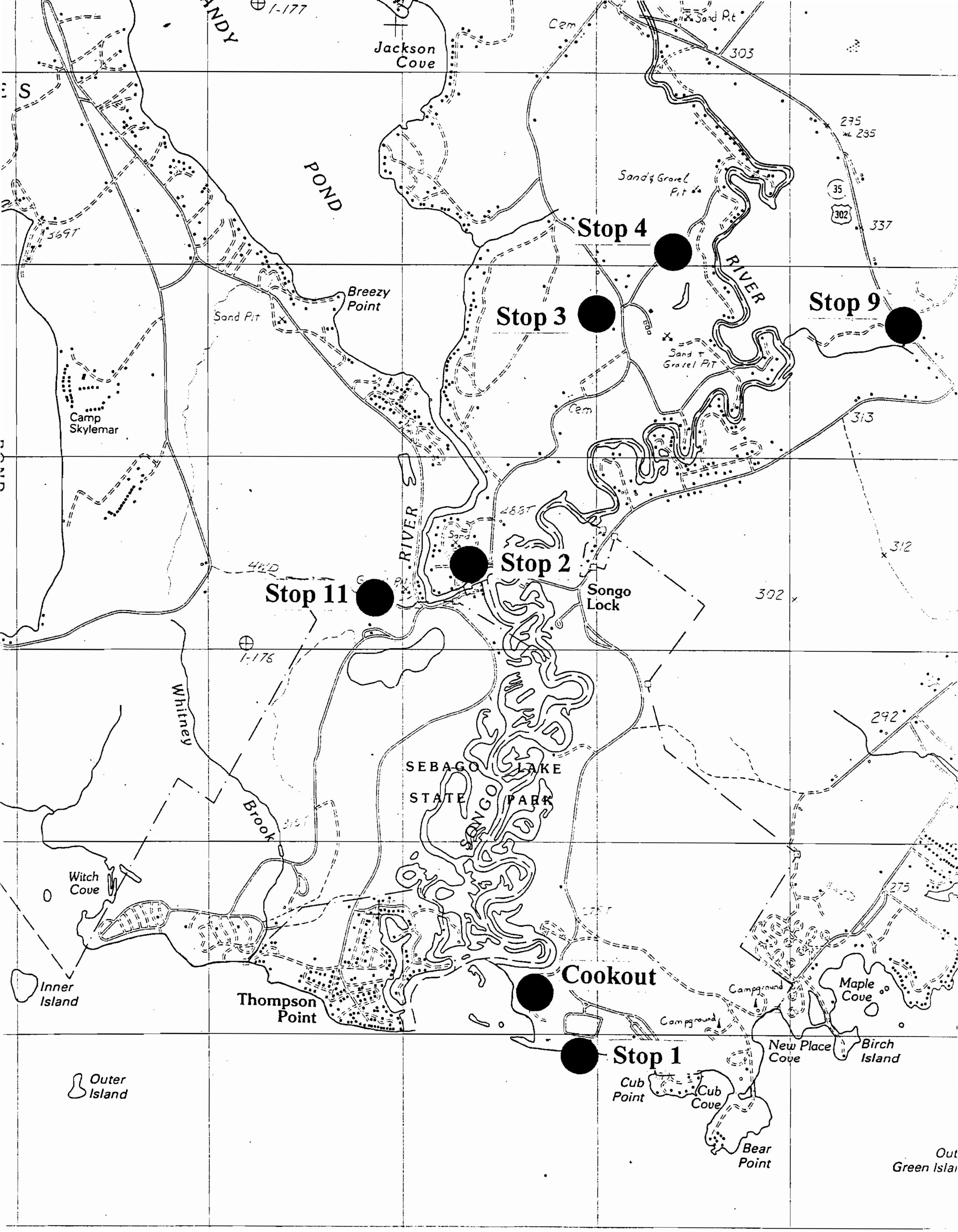
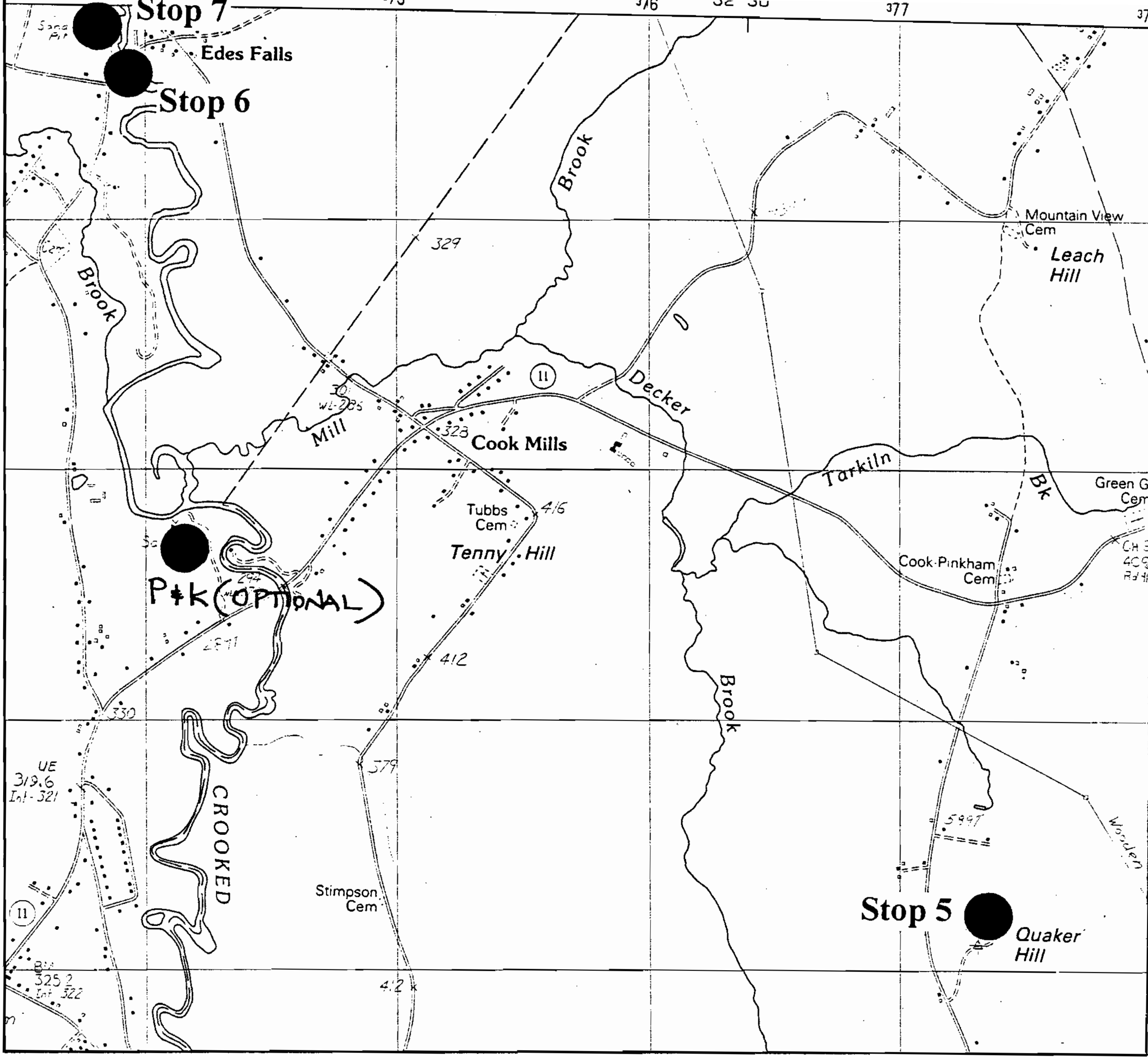


Jackson Cove
POND
Cem
303
275
Sand & Gravel Pit
Stop 4
RIVER
Stop 9
Stop 3
Breezy Point
Sand Pit
Sand & Gravel Pit
Camp Skylemar
Cem
313
RIVER
Stop 2
Stop 11
Songo Lock
302
312
Whitney
Brook
SEBAGO LAKE STATE PARK
SONGO
292
275
Witch Cove
Inner Island
Thompson Point
Cookout
Campground
Maple Cove
Campground
Stop 1
New Place Cove
Birch Island
Cub Point
Cub Cove
Outer Island
Bear Point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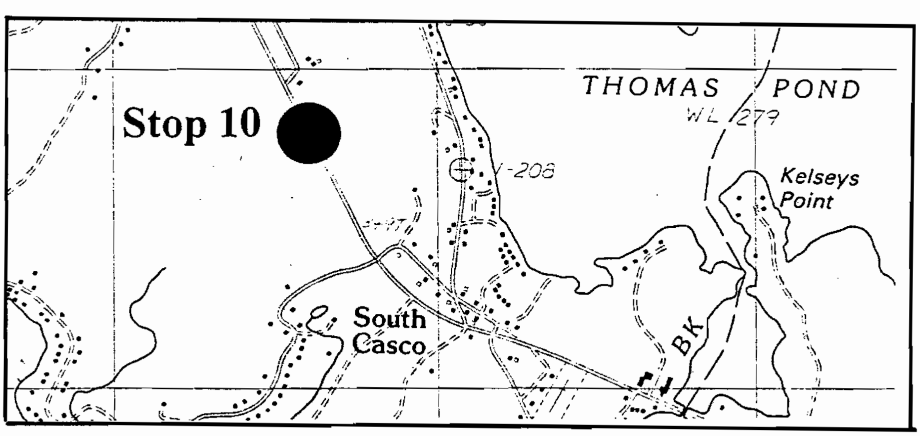
Edes Falls
Stop 6
Brook
Brook
Mill
Cook Mills
Decker
Tarkiln
Bk
Tubbs Cem
Tenny Hill
P&K (OPTIONAL)
Mountain View Cem
Leach Hill
Green G Cem
Cook-Pinkham Cem
Brook
CROOKED
Stimpson Cem
Stop 5
Quaker Hill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Kelseys Point
South Casco
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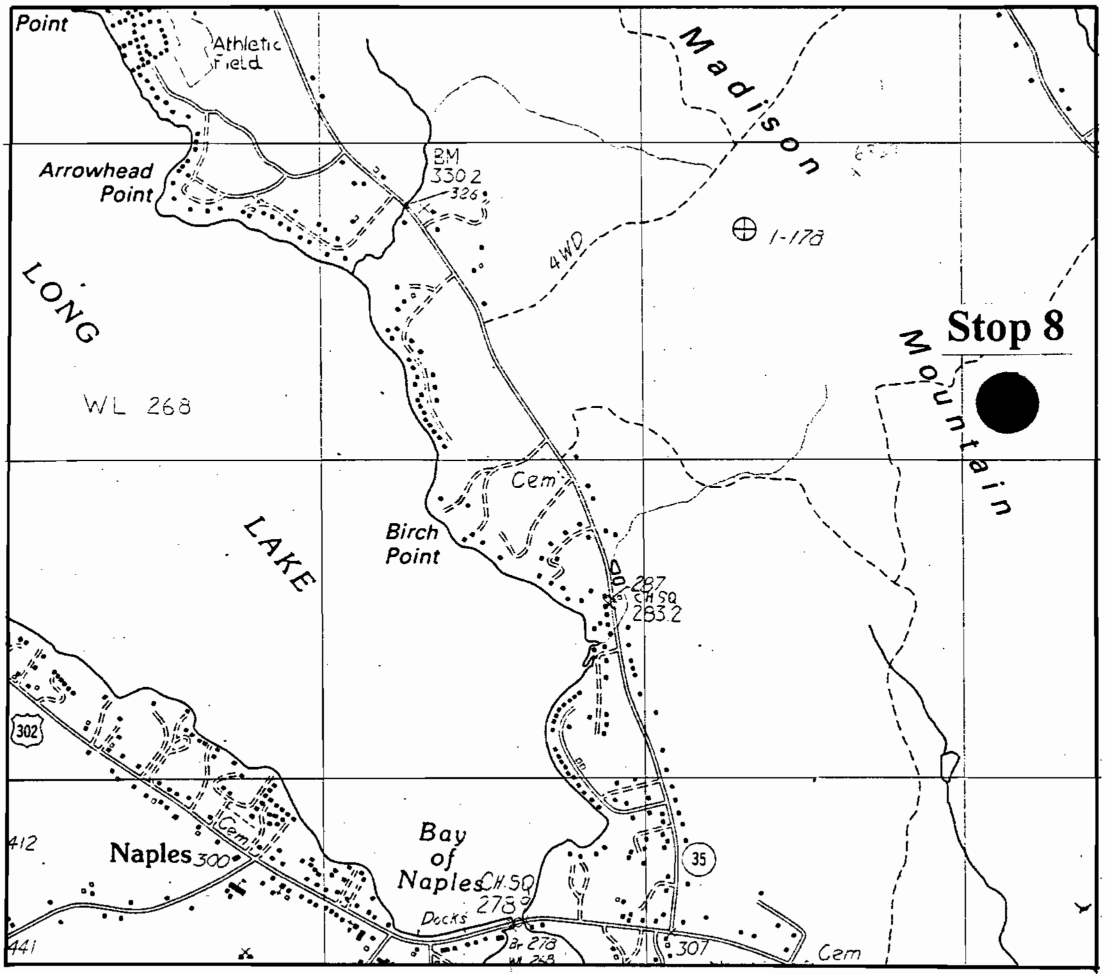

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Athletic Field
Arrowhead Point
Madison
Mountain
4WD
Stop 8
LONG
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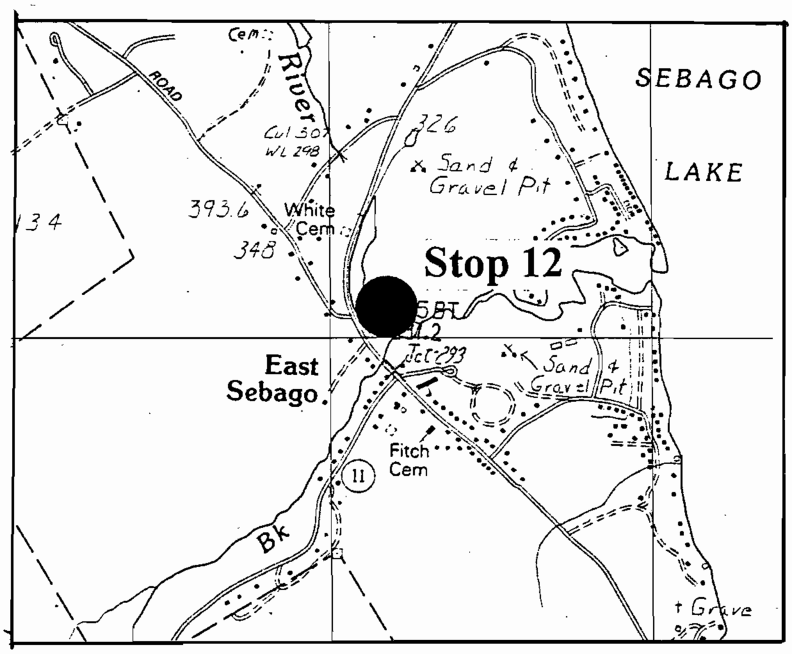
307
Cem



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Cul 307
WL 298
Sand & Gravel Pit
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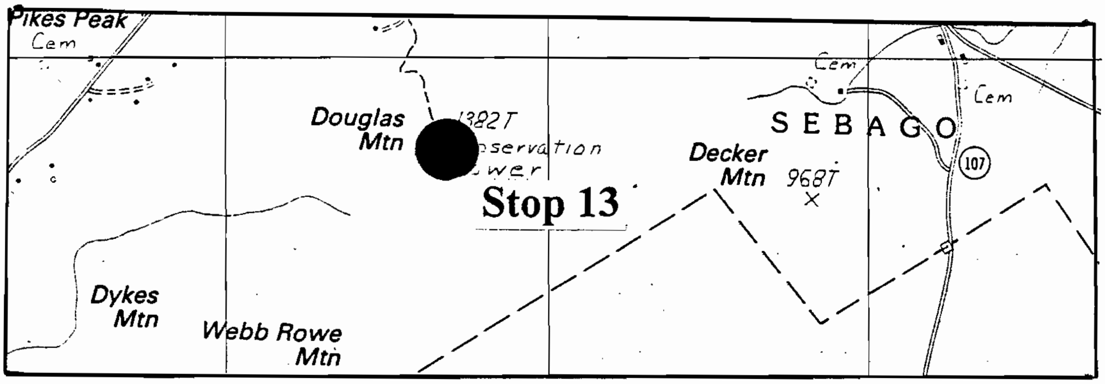
Sand & Gravel Pit
Fitch Cem
11
Bk
Grave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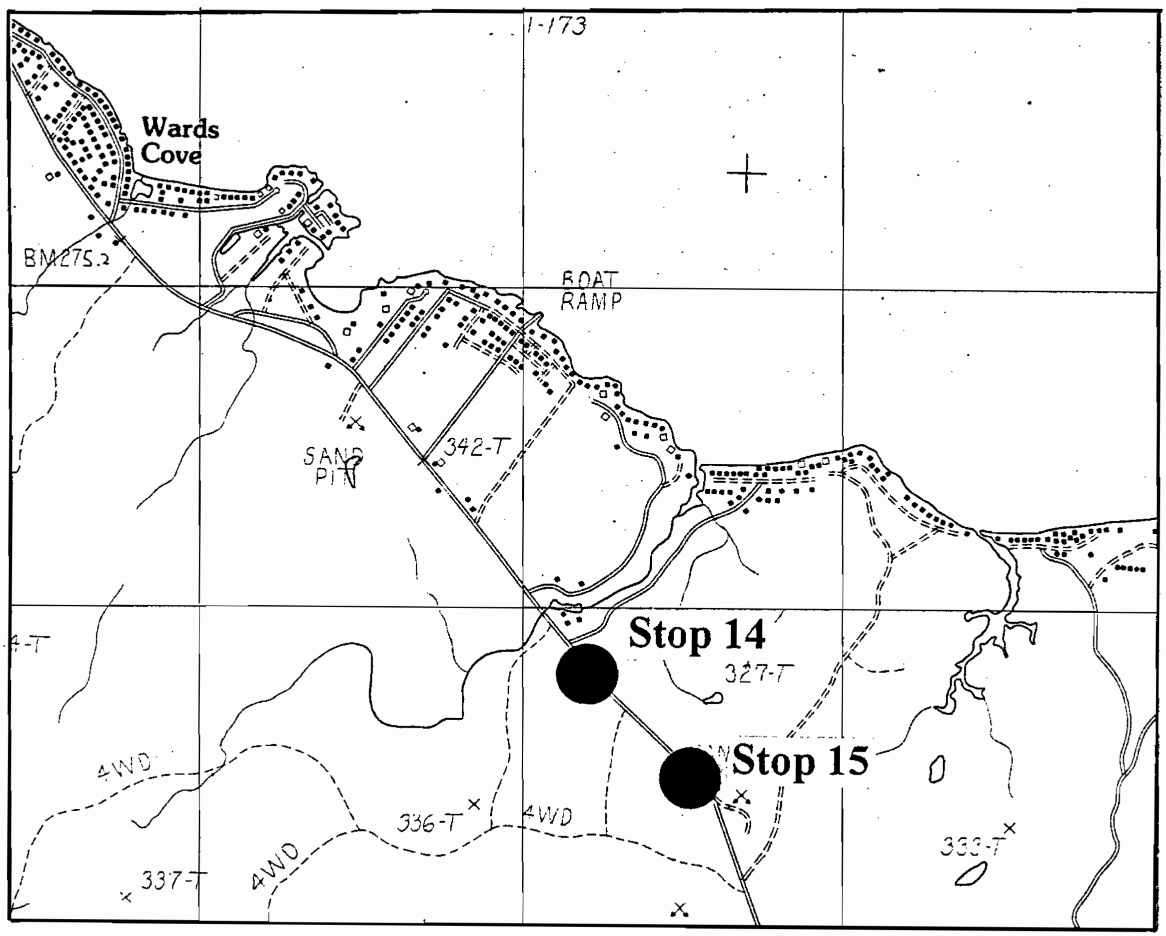
Mtn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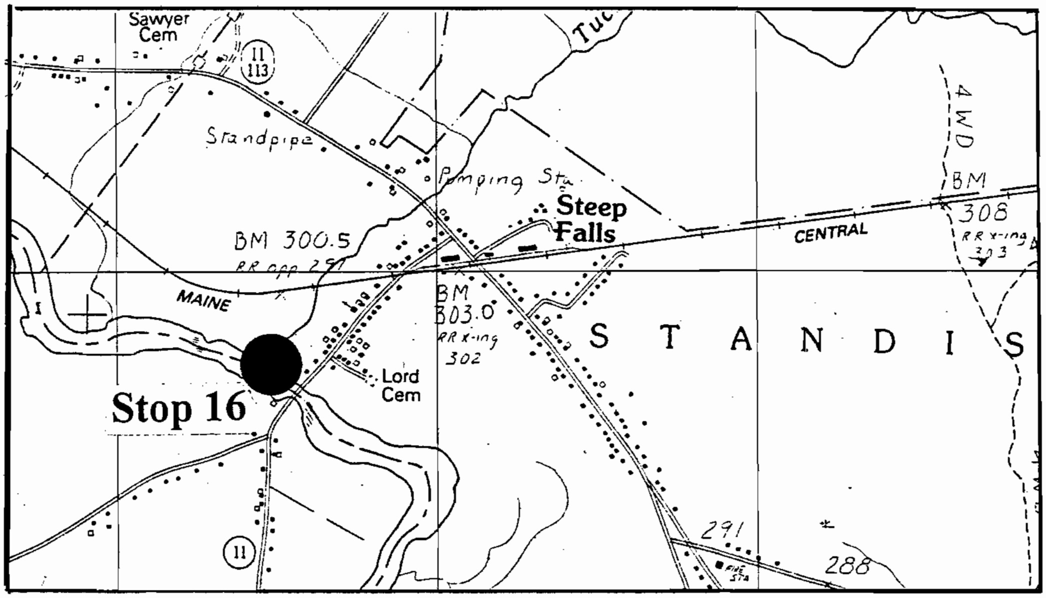
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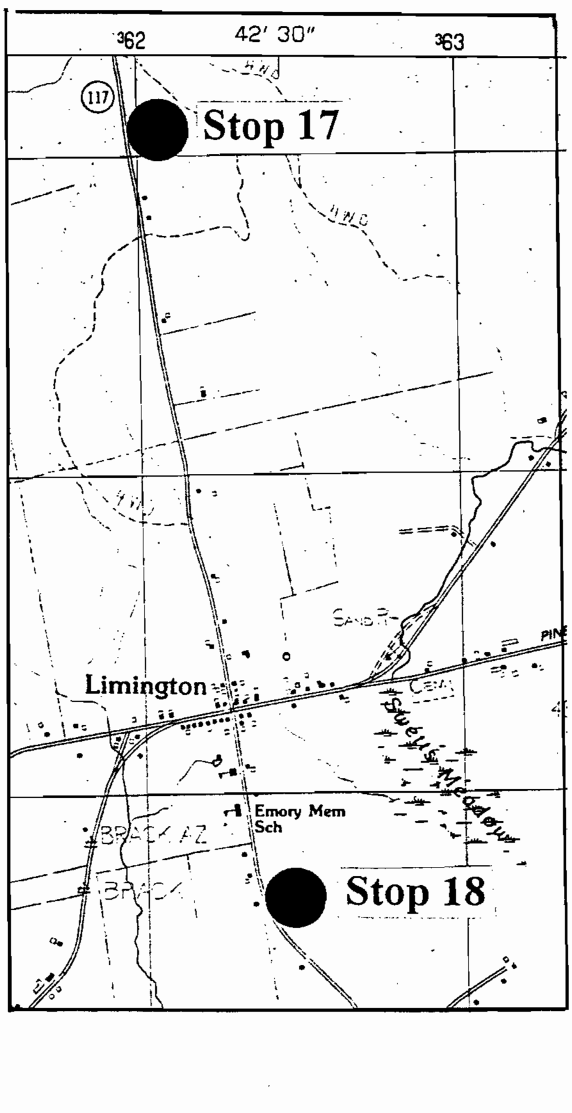
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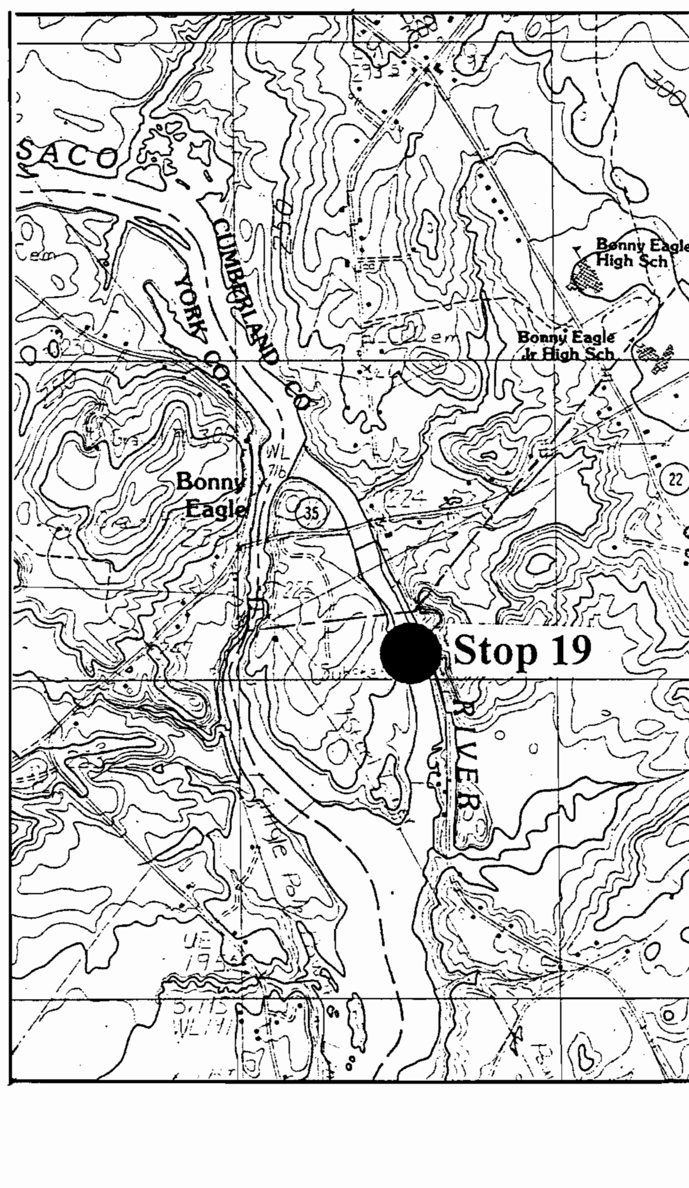
42′ 30″
363
Stop 17
Limington
Emory Mem Sch
Stop 18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YORK CO
Bonny Eagle High Sch
Bonny Eagle Jr High Sch
Bonny Eagle
Stop 19
RIVER