United States Department of Agriculture
Soil Conservation Service
160 East 7th Street
Chester, PA 19013-6092

Subject: Global Positioning Systems (GPS), LORAN-C, and Ground-Penetrating Radar (GPR) field studies and training

Date: September 9, 1991

To: Norman R. Kalloch, Jr.
State Soil Scientist
Soil Conservation Service
Orono, Maine

Purpose:
To provide technical assistance and field training on the set-up and use of Magellan's model 31001 (Nav 1000 Pro) GPS and Voyager's SportNav LORAN-C Navigator receivers.

Participants:
Jim Doolittle, Soil Specialist, SCS, Chester, PA
Larry Flewelling, Soil Party Leader, SCS, Dover-Foxcroft, ME
Wayne Hoar, Soil Scientist, SCS, Farmington, ME
Norman Kalloch, State Soil Scientist, SCS, Orono, ME
Jonathan "Buzz" Miller, Soil Survey Party Leader, SCS, Rangeley, ME
Raymond Voyer, GIS Specialist, SCS, Orono, ME

Activities:
I arrived in Bingham, Maine during the evening of 18 August 1991. Field studies were conducted with the GPS and LORAN-C units on the following 15 minute series topographic quadrangles: Bingham and The Forks, Maine (19 August); Bingham, Maine (20 August); Spencer and Chain of Lakes, Maine (August 21); Brassua, Maine (August 22).

The GPS/LORAN-C units were operated under a full range of weather conditions including Hurricane Bob on August 19.

Ground-penetrating radar field work was completed on August 22 and 23 near Brassua Lake and in Dover-Foxcroft (engineering; not reported in this paper), respectively.

Equipment:
The equipment used was the Magellan's model 31001 (Nav 1000 Pro) GPS unit and a Voyager's SportNav LORAN-C Navigator. Two Magellan Nav 1000 Pro units (serial numbers 31-002747 and 31-002748) and one Voyager Navigator (serial number 126122192) will remain in Maine until 1 December 1991. These units will be used principally to support the activities outlined in Norman Kalloch's work plan of 21 February 1991. However, their use by other staffs and for other applications is encouraged.

Discussion:

STATEMENT OF NEEDS

Maine's unorganized townships included about 10 million acres of woodlands. Soil mapping is currently being conducted in Somerset County Area and parts of Franklin and Oxford Counties (see attached mapped, unit 619) with field mapping planned for Northern Piscataquis and Northern Somerset Area (unit 620) and Western Aroostook County Area (unit 621). Soil mapping is being recorded on 1:62,500 scale base maps with a minimum delineation size of about 40 acres. Soil scientist must rely heavily on photo-interpretation skills and observations gathered from traverses across heavily wooded areas.

Many areas of the "Big Woods" are accessible only from logging roads maintained by the paper companies and from a few scattered state highways. New logging roads are constantly being built while others are being obliterated by large clear cut operations. It has been estimated that the paper companies construct about 300 miles of new roadways across the "Big Woods" each year. Unfortunately, as in the case of the soil survey of the Somerset County Area and parts of Franklin and Oxford Counties, base maps are quickly outdated by the ever changing road system into and across this large and remote area. Available United States Geological Survey (USGS) topographic maps (15 minute series only) are relatively old (1930-1950's) and do not adequately show the location of the roadways.

Mapping at a rate of about 1.5 square miles a day, soil scientists need to locate all existing roadways on their base maps. The location of these roadways is critical in order to (1) gain access into remote areas, (2) to plan and conduct traverses across selected landscapes, and (3) to improve the placement of soil map unit boundaries. The GPS/LORAN-C units can be used to chart the location of these roadways on USGS, 15 and 7.5 minute series topographic maps and, with suitable transfer techniques, onto existing base maps. Knowing the locations of these roads will provide recognizable features on maps, and will facilitate line placement (by providing landmarks) and mapping (by partitioning the woodlands into smaller parcels of land bounded by roadways).

Though some may profess to have been, soil scientist are seldom "lost" while conducting field work. Though occasionally uncertain as to their exact location, soil scientists will closely approximate and plot their positions on base maps. However, the GPS/LORAN-C can be use to improve line placement in the unorganized townships of Maine.

LIMITATIONS OF TESTS

As this study constituted my first solo field experiments with both the Magellan and Voyager units, we were definitely in a learning phase. No significant problem were encountered with the instruction manuals or during the initial set-up of the units. Most will easily advance to data collection with both units.

Little time was available and no computer-assisted applications were conducted with the Magellan units. The need for post-processing of both GPS and LORAN-C information onto base maps was realized by participants. Manual entry of data points onto USGS topographic maps could be easily accomplished and may prove to be most satisfactory to soil scientists involved in soil mapping. However, if manual entry or use of USGS topographic maps is unsatisfactory to field soil scientists or more precise location of data points on the base maps (aerial photographs) is required, some post-processing of information will be necessary. Computer processing of position data would be difficult to accomplish (non-rectified 1975 base maps). The pilot project with William O'Keefe (Advance Concept Division, USDOT, in Cambridge, Massachusetts), has demonstrated the feasibility of using computer processing to more accurately plot position data on base maps and photographs.

CALIBRATION

GPS:

No significant location problems were experienced with the GPS units after the approximate position (within 1 degree) of the receiver was entered in the initial set-up procedure. MAST was set at 15 degrees and visibility was entered as being obscured. Using relatively old topographic maps (pre 1960), the 1927 North American datum was used.

Vegetation and topography interfered with the reception of signals from satellites close to the horizon. In addition, these features often interfered with the "line of sight" reception from satellites having higher declinations. However, signal reception from satellites was often improved by moving slightly (< 100 feet) along logging roads or to more open areas.

Availability of sufficient satellites was a major concern. On three of four days, sufficient satellites (three) were unavailable between the hours of 1000 to 1100 and 1600. No fixes could be obtained during these prime working hours.

Generally, time on station was less than 10 minutes, and often less than 3 minutes. Keeping the GPS unit with power-on while moving between waypoints will reduce the time spent on each station. Remaining on station for longer periods of time may improve the accuracy of data, but would reduce the utility of this equipment to field soil scientists. Averaging either 25 or 32 GPS fixes did not significantly change the recorded position data. Averaged versus non-averaged fixes varied by less than 0.01 sec. High PDOP (position dilution of precision) produce large errors. Values for PDOP in excess of 9 are unsatisfactory and value between 4 and 9 should be used with caution.

LORAN-C:

The approximate position (within 10 minutes) of the LORAN-C receiver was entered into the unit at the first site. For the initial set-up, the ATS was kept on. The Northeast chain of LORAN-C stations was selected. Based on signal strength and reception, ATS selected signals from stations located in Caribou, Maine, and Dana, New York.

However, it was noticed that positions were in error. The LORAN-C plotted our initial position too far to the west (85^{o} W. Long.). Charts revealed that Caribou, Maine, Dana, New York and Bingham, Maine (our position) were on approximately a straight line and poor geometry was suspected. The ATS was turned off and Nantucket was selected over Dana as a station. This procedure corrected the erroneous readings.

Once a position was determined with the LORAN-C, the indicated accuracy of the position ranged from within 112 to 119 feet. These readings appear to be programmed into the receiver and represent the best dreams of the manufacturers under ideal conditions. The indicated accuracy of positions on the receiver was found to err greatly from our plots of the data.

EFFECTS OF VEGETATION

The GPS and LORAN-C units are not well suited for use in densely wooded areas under leaf-on conditions. Vegetation (leaf-on) severely restricted the reception from satellites and increased the position dilution of precision (PDOP). In an experiment conducted with the Magellan unit in a clear-cut area and in an adjoining (less than 100 meters) densely wooded area, the PDOP increased from an acceptable 1.7 to an intolerable 13.7 level as the receiver selected satellites with an unobstructed line of sight but with poorer satellite geometry. Generally PDOP in access of 4 should be questioned and those in access of 9 should be considered too afoul for placement on base maps.

In the same experiment, the performance of LORAN-C receiver was also impaired by the dense forest canopy. The LORAN-C receiver continued to search for and average signals after about 10 minutes beneath the dense canopy. After 10 minutes signal quality was significantly less under the canopy than in the open area and the displayed position was considered exceptionally poor (>10000 ft).

Plots

Figure 2 is a plot of access roads using both GPS and LORAN-C data. A known benchmark (1282) along Highway 16 was used to test the accuracy of the two units. The averaged GPS position data plotted within about 300 feet and the LORAN-C data within 500 feet of this benchmark.

In Figure 2, the numbered crosses represent the locations of identical waypoints along the access roads as determined by GPS and LORAN-C. The dashed line represents the approximate location of the road as defined by GPS; the solid line by LORAN-C. GPS waypoints 2 and 3 had PDOP values of 11.3 and 8. Waypoint 2 is estimated to be about 3500 feet away from the correct road position. No GPS data were collected after waypoint 5 because of the unavailability of satellites.

The LORAN-C provided a better relative plot of the approximate location and orientations of the roads. In Figure 2, if the location data for each waypoint were corrected by the offset of the LORAN-C's position from the benchmark (waypoint 1), the plot of the access roads would be improved.

Figure 5 is a plot of uncorrected GPS and LORAN-C position data from seven identical waypoints along an access road. Waypoints were located at road intersections or bridges. The area was forested and relief was moderate. Table 1 lists the offset distance of the plots from the location of the waypoints on this 15 minute topographic map. Generally, the uncorrected GPS location were closer to the map locations than the LORAN-C. However, by using the waypoint correction factor for waypoint 1 on the other six waypoints a corrected values was obtained. The "corrected" values were closer (Table 1) to the map locations than either the uncorrected GPS or LORAN-C data. This technique though rather primitive may satisfy the needs of the soil scientist mapping in the unorganized townships.

TABLE 1

Difference of GPS and LORAN-C plots from Map Locations
(all measurements are in feet)

Waypoint	GPS	LORAN-C	Corrected LORAN-C
1	1700	2380	0
2	1850	2640	130
3	1060	1450	530
4	1190	2430	400
5	530	2110	1000
6	1060	1850	660
7	1850	2690	660
Averaged	1320	2220	560 (excluding wp 1)

Conclusions:
1. The soil survey staff in Maine should prepare a report discussing the adequacy of both GPS and LORAN-C for plotting roadways and use by soil scientist. The report should contain the impressions and recommendations of users. In addition the report should discuss the adequacy of manual plotting of positions on topographic maps, transfer of location data to base maps, and the need for post-processing of both GPS and LORAN-C information.

2. Buzz Miller has worked with the Magellan's model 31001 (Nav 1000 Pro) GPS and the Voyager's SportNav LORAN-C Navigator and is considered qualified in their operations.

3. Based on this study continued contact with USDOT (Advance Concept Division) personnel concerning post-processing and information displays is encouraged.

I enjoyed this opportunity to work in the "Big Wood" and look forward to your report.

With kind regards,

Jim Doolittle
Soil Specialist

cc:
J. Culver, Nat. Leader, SSQA, NSSC, SCS, Lincoln, NE
E. Knox, Nat. Leader, SSIV, NSSC, SCS, Lincoln, NE
R. Liston, Nat. Leader GIS & Remote Sensing Dev. GIS Division, NHQ, SCS, Washington, D.C.
W. O'Keefe, Advance Concepts Division, DTS-35, USDOT, Transportation System Center, Cambridge, Massachusetts 02142
C. Olson, Field Investigation Staff Leader, SSIV, NSSC, SCS, Lincoln, NE
W. Roth, Soil Scientist, Soil Survey Div. NHQ, SCS, Washington, D.C.

GROUND-PENETRATING RADAR

Two, long transect were conducted with the SIR System-8 near Brassua Lake on 22 August 1991. These transects were located in areas of soil map unit 76C (Telos-Chesuncook-Elliotsville) and 89C (Elliotsville-Monson). The taxonomic classifications of these soils are listed in Table 2.

TABLE 2

TAXONOMIC CLASSIFICATION OF SOILS

Chesuncook	coarse-loamy, mixed, frigid Typic Haplorthods
Elliottsville	coarse-loamy, mixed, frigid Typic Haplorthods
Monson	coarse-loamy, mixed, frigid Typic Haplorthods
Telos	coarse-loamy, mixed, frigid Aquic Haplorthods

The transects were conducted along logging access roads. The transects were about 3500 (M.U. 76C) and 2800 (M.U. 89C) feet long with observation points spaced at 100 foot intervals. Depth to bedrock along each transect was interpreted from the radar profiles (Table 3). In addition, at each observation point, drainage classes were inferred from landscape positions and vegetation by the soil survey party leader. The two transects were sub-divided into 1000 foot lengths and the drainage class/depth to bedrock at each observation point along each transect was reported separately (see tables 4 and 5).

TABLE 3

Percent Composition based on Depth to Bedrock

		DEPTH TO BEDROCK (in cm)			
Transect	Observ.	0 to 50	50 to 100	100 to 150	>150
76C	35	6%	8%	23%	63%
89C	28	4%	21%	23%	52%

TABLE 4

Percent Composition Based on Depth to Bedrock and Drainage Classes for Map Unit 76C

Transect 1

DRAINAGE	DEPTH TO BEDROCK (in cm) 0 to 50	50 to 100	100 to 150	>150
Well	--	--	--	--
Mod-well			30%	70%
Somewhat poor	--	--	--	--

Transect 2

DRAINAGE	DEPTH TO BEDROCK (in cm) 0 to 50	50 to 100	100 to 150	>150
Well	20%	10%	30%	--%
Mod-well	--	10%	--	--
Somewhat poor	20%	--	10%	20%

Transect 3

DRAINAGE	DEPTH TO BEDROCK (in cm) 0 to 50	50 to 100	100 to 150	>150
Well	--	--	--	30%
Mod-well	--	--	--	--
Somewhat poor	--	--	--	70%

Transect 4

DRAINAGE	DEPTH TO BEDROCK (in cm) 0 to 50	50 to 100	100 to 150	>150
Well	--	--	--	--
Mod-well	--	20%	--	--
Somewhat poor	--	--	20%	60%

TABLE 5

Percent Composition Based on
Depth to Bedrock and Drainage Classes
for
Map Unit 89C

Transect 1

DRAINAGE	DEPTH TO BEDROCK (in cm) 0 to 50	50 to 100	100 to 150	>150
Well	--	20%	20%	10%
Mod-well			10%	10%
Somewhat poor	--	--	10%	20%

Transect 2

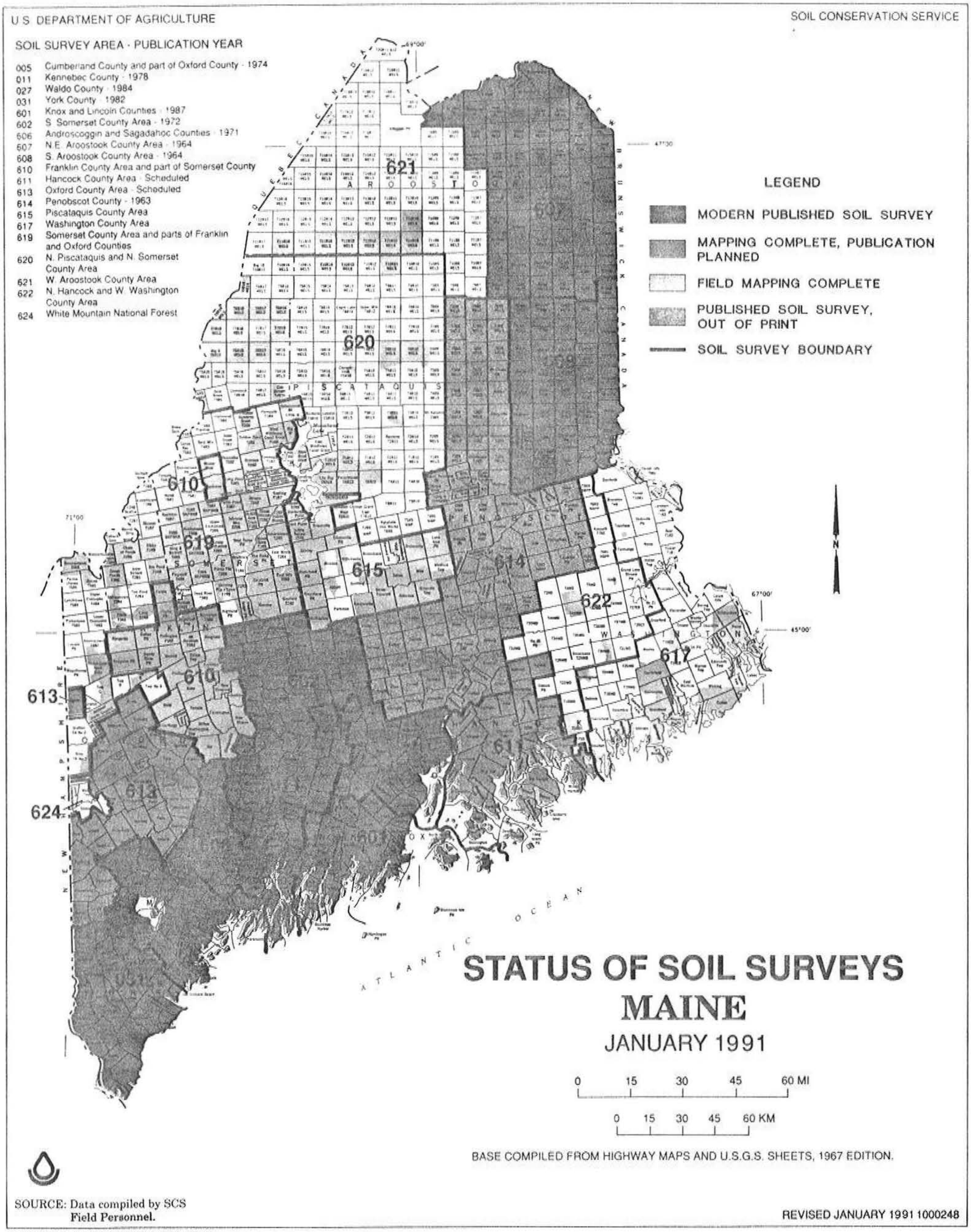
DRAINAGE	DEPTH TO BEDROCK (in cm) 0 to 50	50 to 100	100 to 150	>150
Well	--	20%	30%	20%
Mod-well	--	--	--	--
Somewhat poor	--	10%	--	20%

Transect 3

DRAINAGE	DEPTH TO BEDROCK (in cm) 0 to 50	50 to 100	100 to 150	>150
Well	12%	12%	--	76%
Mod-well	--	--	--	--
Somewhat poor	--	--	--	--

The data reported in Tables 3, 4 and 5 are too limited for an acceptable determination of the taxonomic composition of these map units.

Recommendation:
It is recommended that the soil survey party locate additional sites during field mapping for GPR surveys. GPR field studies should be scheduled for next fiscal year.



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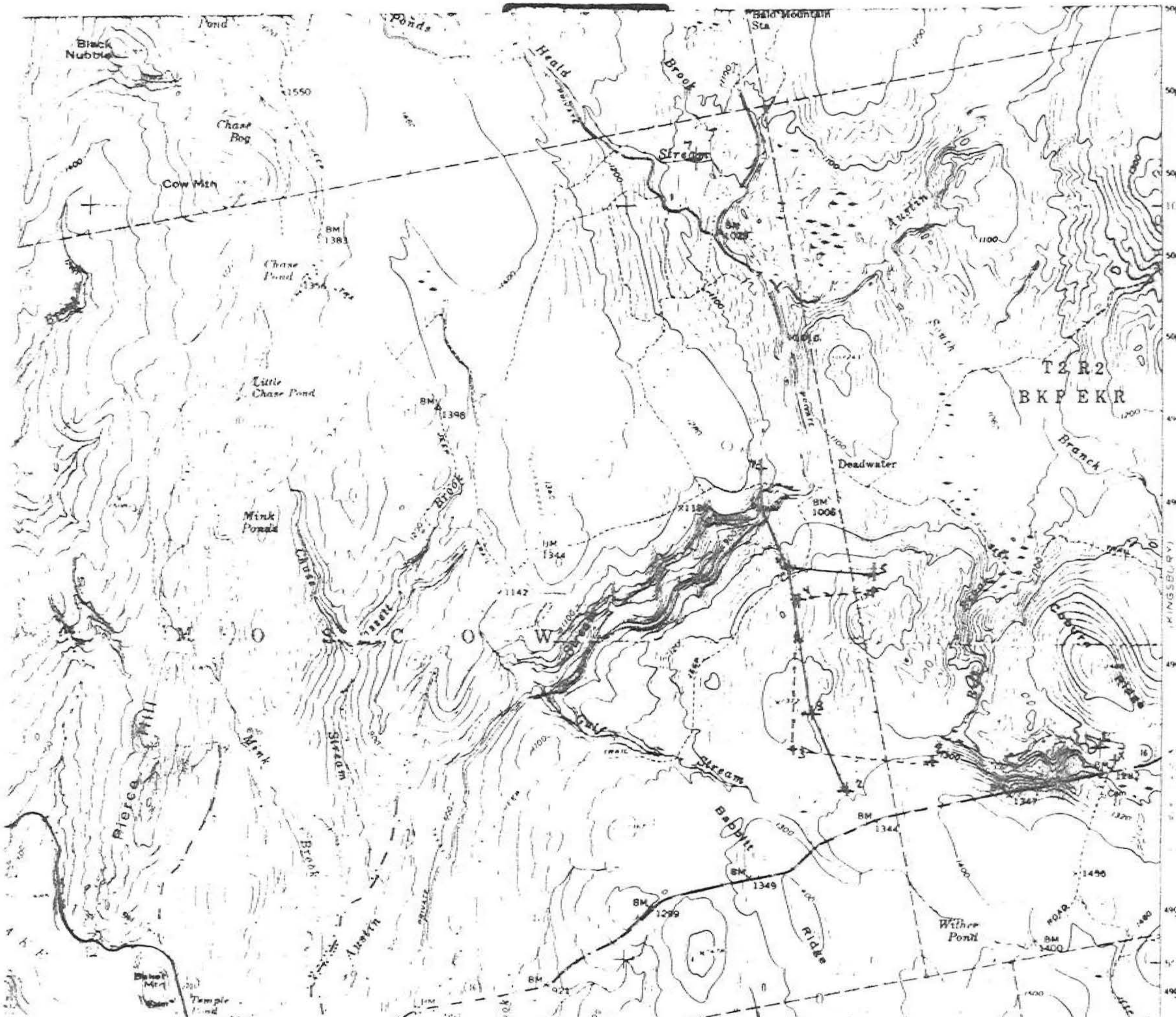

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