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REMOTE SENSING OF HYDROLOGIC VARIABLES IN BOREAL AREAS

FINAL REPORT - PHASE 1

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REMOTE SENSING OF HYDROLOGIC VARIABLES IN BOREAL AREAS

1st ANNUAL REPORT

INTRODUCTION

The major effort by HYD-6 members has been to develop a network of flight lines to provide the maximum amount of information on the temporal and spatial variation in soil moisture for the BOREAS study areas.

Field visits to the southern study area (SSA) were conducted during May 1993 to obtain first hand information on the flight lines that had been previously selected for BOREAS snow studies. In September 1993 airborne gamma radiation surveys were conducted over the SSA, the northern study area (NSA), and for five flight lines along the transect between the two study areas. In situ measurements of soil moisture and water content of the Moss/Humus layer were obtained for calibration of selected gamma radiation flights lines in the SSA and for two of the transit lines. The flight lines for which soil moisture will be measured during the three IFCs during the summer of 1994 is a subset of the total flight lines that have been flown for the snow surveys.

During the WFC in February 1994, airborne gamma radiation surveys were flown over all of the flight lines. Members of HYD-4, under the direction of John Metcalfe, Atmospheric Environmental Service (AES), of Canada, collected in-situ measurements (soil moisture, water content of the Moss/Humus layer, and water equivalent of the snow cover).

COOPERATION

Continual contact has been made with Piers Sellers, Forest Hall and others of the BOREAS office at NASA Goddard, Space Flight Center, with Dennis Lettenmaier, Chairman of the BOREAS HYD group, and with members of HYD-4 (Barry Goodison and John Metcalfe of AES).

The following BOREAS workshops attended during the year provided excellent opportunities for coordination with other BOREAS scientists:

Winnipeg, Manitoba, Canada, May 26-28, 1993

Coolfont, West Virginia, USS, October 20-22, 1993

Plans have been made with the following members of BOREAS science groups to provide support for other BOREAS projects. These include:

HYD-1: R. H. Cuenca on surface measurements of soil moisture.

HYD-9: Nichos Kouwen for modelling of the Gull Basin in the SSA

AMF-11: Larry Mahrt for additional soil moisture flight lines and surveys to support the "Candle Lake Modelling Project"

The following scientists not directly participating in BOREAS provided assistance in soil sample analysis and information on the Boreal forest conditions.

Don Gray, Division of Hydrology, University of Saskatchewan , and

Henry Santeford, Michigan Technological University, Houghton, MI.

The offices of the National Operational Hydrologic Remote Sensing Center (NOHRSC), in Minneapolis, MN, were visited by the PI on July 21-22, 1993 to review the selected flight lines and to plan for the field trip in September 1993 and for the snow survey flights in February 1994.

AIRBORNE GAMMA RADIATION TECHNIQUES

The National Weather Service (NWS) airborne gamma radiation system consists of five downward, and two upward looking, sodium iodine (NaI) thallium (Tl) detectors, an associated pulse height analyzer, a mini-computer system, and temperature, pressure and radar altitude sensors as described by Carroll and Vadnais (1980). The spectral radiation data obtained by the system are used to compute the gamma fluxes for three radiation windows; the ^{40}K window (1.26 - 1.56 MeV), the ^{208}Tl window (2.41 - 2.81 MeV) and the gross count (GC) energy spectrum (0.41 - 3.0 MeV).

The concentration of radioisotopes in the ground is essentially constant with time [Zotimov, 1968]. Therefore, it is necessary to measure the ground soil moisture and establish background radiation by airborne surveys for the three radiation windows only once to calibrate a specific flight line. The airborne flight line measurement of soil moisture is considered to be a measurement of an area rather than a single line. The width of a flight line measurement has been accepted as 305 m; thus a measurement for a single BOREAS flight line of 6.2 km represents an areal measurement for an area of 1.9 km^2.

The NWS's soil moisture estimates for a flight line are the weighted average of estimates determined using data from the three spectral radiation windows. The weights are; (1) 0.346 for the ^{40}K window, (2) 0.518 for the ^{208}Tl window, and (3) 0.136 for the GC. These weights were derived from a 10-year historical data base of simultaneous ground measurements of soil moisture and airborne radiation data [Carroll and Allen, 1988]. The techniques used by the NWS system to measure soil moisture are discussed by Carroll and Allen [1988] and by Jones and Carroll [1983].

There are a number of possible sources of random and systematic errors in the airborne soil moisture measurements. One error results from random fluctuations in the radiation data as a result of the nature of the radioactive decay process [Knoll, 1979], resulting in "counting statistics errors." Two other sources of error are; (1) those associated with the ground measurements of soil moisture data used for calibration, and (2) those accounting for the airmass between the aircraft and the ground which absorbs a large portion of the emitted gamma radiation. A fourth source of error results from calculations to compensate for extraneous sources of radiation and scattering with the gamma spectrum, as discussed by Fritzsche [1979].

The counting statistics errors of the airborne soil moisture estimates can be reduced if the data acquisition time is increased. The acquisition time for a flight line is dependent on the speed of the aircraft and the length of the line. Since the air speed of the aircraft is nearly constant, the length of the line is a major factor in determining the acquisition time. Repeated flights over the same line is one way to increase the acquisition time and to improve the accuracy of the airborne estimates.

The gamma radiation measured in the ^{208}Tl radiation window is less subject to extraneous sources of radiation and scattering within the gamma spectrum than the measurement in the ^{40}K radiation window [Carroll and Allen, 1988]. Both of these windows are much less subject to these sources of error than the GC window. The total count in the GC window, however, is typically an order of magnitude greater than the counts experienced in the ^{40}K and the ^{208}Tl windows, and therefore much less subject to "counting statistic errors."

NETWORK OF BOREAS FLIGHT LINES

Snow Survey Flight Lines

A set of 31 snow surveys flight lines for BOREAS were originally established during 1992-1993 by members of HYD-4 in cooperation with members of HYD-6. The original 31 lines were flown by the NWS airborne gamma radiation planes for HYD-4 during the winter of 1993 over the Prince Alberta area (13 flights lines), over the research area near Thompson (13 flights lines) and five lines along roads between the two areas.

Soil Moisture Flight Lines

Originally it was felt that the flight lines established for the HYD-4 snow survey project would serve the needs for soil moisture information for most of the primary research sites. The flight lines established over the Thompson research area will provide soil moisture information for research sites in the NSA. However, prior to, and during the Winnipeg workshop, it became clear that most of the tower sites for the SSA were to be in the White Gull Creek watershed area rather than in the Prince Albert national forest where most of the original BOREAS snow survey flight lines were established. it was determined that additional flight lines should be established covering the White Gull Creek area and for representing different vegetative cover (type and age of trees mainly) of the forest cover at the tower research sites. To investigate the White Gull Creek area and to obtain first hand information as to the possible locations for additional flight lines, the field visit during the latter part of May, prior to Winnipeg workshop was in the Prince Albert area (SSA).

Maps for the BOREAS Study Areas

Inventory maintenance maps for the Prince Albert national forest and similar maps containing detailed forest information for all of the research areas were furnished by the BOREAS staff. Large scale maps, 1 to 50,000, for most of the study areas, were furnished during the Winnipeg meeting. These maps showing the forest information for the SSA and the 1 to 125,000 scale TM photo of August 6, 1990, furnished by the BOREAS staff, were used to select flights lines in the Gull Creek area representing the various forest types of the tower sites. Three additional flight lines in the SSA were selected to represent forest cover of Black Spruce (BS-SSA), the Young Jack Pine (YJP-SSA) and the Old Jack Pine (OJP-SSA).

All of the proposed flights lines, for both soil moisture and snow water equivalent measurements were reviewed on July 21-22, 1993 during a visit with the NOHRSC pilots who fly the airborne gamma radiation planes. Some of the flights lines selected in the Gull Creek area are much shorter than the originally selected BOREAS flight lines. To provide the required radiation information for these shorter flight lines the lines will be flown two to four times during each airborne survey day.

During February 1994 airborne snow surveys were conducted by members of the NOHRSC staff and ground surveys by members of HYD-4. As a result of these surveys some modifications were made in the proposed flight lines and a few new lines were selected and flown.

Maps showing the BOREAS flight lines (identified as BPxxx) and some standard Canadian flight lines (CRxxx) in the study areas are shown on Figure 1 for the SSA, Figure 2 (lines between the SSA and NSA areas), and Figure 3 for the NSA. The 13

original lines in the SSA are labeled BP100 to BP112. The new flight lines in the White Gull Creek basin and other areas in the SSA are BP113 to BP122. Additional straight flights lines were selected for the NSA by the aircraft crews during the February snow surveys and will be flown in addition to the original 13 flight lines.

Snow Surveys

All of the flight lines shown in Figures 1, 2 and 3, were flown during the WFC in February 1994.

Soil Moisture Surveys

The following flight lines will be flown for measuring soil moisture during the 1994 summer field campaigns IFCs. Other flight lines may be established in response to specific needs of other BOREAS science groups; it is planned that some lines will be established and flown in support of the Candle Lake Modelling Project.

AREA	**FLIGHT LINES**
SSA	BP102, BP103, BP105. BP 109,
	BP111 to BP 122 (16 flight lines), and
	CR955 to CR960 (6 flight lines)
NSA	BP201 to BP213 (13 flight lines)
Transect	BP301 to BP305 (5 flight lines)

Total of 40 flight lines.

RESULTS OF INITIAL GROUND SURVEYS

Soil Moisture sampling data

During the period 7th to 13th of September 1993, HYD-6 and HYD-4 crews conducted ground surveys while members of the NOHRSC flew airborne surveys. Airborne surveys were made for all of the flight lines in the SSA area, and for flights lines BP301, BP302, BP303 and BP304 of the BOREAS transect (a total of 94 line surveys were performed). Ground calibration data were collected for 15 of the established flight lines in the SSA. Calibration data for the remainder of the flight lines will be collected during the 1994 IFCs. Examples of the information collected for in-situ ground measurement sites are shown in Attachment 1 for flight line BP114. Attachment 2 is a graph of the variation of the measurements of the soil moisture (SM) of the mineral soil and the depth of the Moss/Humus layer along the BP114 flight line.

Ground sampling of the soil moisture of the top 20 cm of the mineral soil (percentage by weight using the gravimetric method, oven drying) normally provides all of the ground data required to calibrate the airborne gamma radiation flight line. Along some BOREAS flight lines, the water content (WC) in the moss and the humus layer of decaying organic material situated above the mineral soil was found to be very significant and an important factor in the attenuation of the radioactive emissions from the mineral soil. In order to properly account for the WC of the Moss/Humus layer, a new technique was developed during the September field surveys to measure the WC of the Moss/Humus layer. The ESC snow tube (30 square cm) was used to obtain cores of the Moss/Humus layer. The gravimetric technique was used to calculate the WC of the layer. Attachment 3 is a summary of the soil moisture and Moss/Humus

measurements made during the field survey in September 1993.

The initial sampling of the Moss/Humus layer was accomplished by the HYD-6 ground crew (Eugene Peck, Hydex, Bob Maxson, NWS, and a part time field aide, Kevin Robinson, of the Canadian Forest Service contracted for by Hydex) near the Black Spruce study tower (SSA-OBS) north of Candle Lake. An average of 2.3 cm (average of 4 measurements) of water was measured in 15 cm of the Moss/Humus layer. Additional samples were obtained along flight line BP114 using a simple grab method. The HYD-4 ground crew (John Metcalfe, etc.) found along flight line BP302 near Flim Flon, Manitoba, a thick layer (75 cm) of Moss/Humus that contained over 32 cm of water. Details pertaining to the measurements are shown in Attachment 3.

Field measurements of the WC of the Moss/Humus layer will be made during the collection of calibration data for each BOREAS flight line. Those data will provide the information needed to account for the WC of the Moss/Humus layer separately from the SM of the mineral layer. During periods of no snow cover when the SM of the mineral soil is known, a direct measurement of the WC of the Moss/Humus layer, which is an important component of the biomass, will be obtained. Knowledge of the WC of the Moss/Humus layer will improve measurements of the WE of the snow cover.

DOCUMENTATION AND DATA FOR BORIS

Ground Data Files

From discussions with members of the BOREAS information system (BORIS) all ground data (and location of sampling points) will be submitted in one file. This file will include all of the information shown in Attachment 1 plus the following when available:

1. Location of sampling points in longitude and latitude (map data)
2. Five measurements of the depth of the Moss/Humus layer (at the site and at five meters from the site along and across the flight line).
3. Water content of the Moss/Humus layer at the sampling site.
4. Five measurements of the depth of the snow cover.
5. The water equivalent of the snow sample at the measurement site.

Data for the ground samples collected during September have been prepared. The ground measurements collected during the WFC in February 1994 will be added by HYD-6 when received from HYD-4 to the file of ground data so that a user will have all measurements of SM in one file (those made with and without snow cover).

Airborne Files

Two files will be submitted to BORIS. One will contain information on the location of the airborne gamma radiation flight lines and a separate file of the airborne estimates of soil moisture.

Each flight line, those for snow surveys as well as for SM, is divided into sections (Peck, et al. 1990) so that additional information on the spatial variability of the WE of the snow cover, of the SM of the mineral soil, and of the WC and depth of the Moss/Humus layer may be determined from the gamma radiation values. The number

of sections a flight line is divided into is determined by the variability of the variable (tree cover, etc.) along the flight line and the number and distribution of the ground samples available for calibration. Four of the flight lines surveyed during September 1993 have been divided into sections.

The file on the location of the flight lines will contain the longitude and latitude of the end points, the location of the turning points, and section break points. The airborne measurements of the computed SM of the mineral soil and the WC of the Moss/Humus layer for the entire flight line and for each section of each flight line will be computed and prepared for BORIS by HYD-6. Values of the WE of the snow cover will be prepared for BORIS by HYD-4. The BORIS file for the airborne measurements will be similar to that submitted to FIS in the FIFE project.

FUTURE ACTIVITIES

Planned Participation in 1994 IFCs

Airborne gamma radiation surveys and ground measurements for calibration of all flight lines have been scheduled for IFC 1, IFC 2, and IFC 3. During the IFCs other measurements of soil moisture will be available from the work of other BOREAS groups and from BOREAS core measurements. Scheduling of ground surveys for calibration of flight lines will be coordination with BOREAS operations each day so that a maximum amount of ground data will be available for calibration of each flight line.

Processing of Calibration Data

After the final calibration data set has been established for a flight line, all previous radiation data have to be processed to determined the radiation window values for each section of a flight line. Airborne estimates (SM and WC), for each day

radiation survey data are available, can then be made for each section of the flight line. For those flight lines for which the calibration data are collected late in IFC 3, no estimates of the SM, WC or WE for sections of flight lines can be obtained until the processing of the data is completed. Estimates of the variables (SM, WC and WE) for the entire flight line can be computed in real time during an IFC when the calibration data are installed in the computer of the aerocommander.

DISCUSSION AND CONCLUSIONS

The Airborne Gamma Radiation System, normally used by the NWS in the United States and in Canada to measure soil moisture (SM) and the water equivalent (WE) of the snow cover along flight lines that average 16 km in length, are being used to measure soil moisture over the BOREAS study areas. A set of 40 flight lines have been established over the southern study area (SSA) , the northern study area (NSA) and along a transect between the two BOREAS study areas.

Airborne gamma radiation surveys were conducted in September 1993 and in February 1994. Ground data were collected and calibrations established for some of the flight lines. The remainder of the flight lines will be calibrated during the IFCs in the summer of 1994.

Normally only soil moisture (SM) measurements of the mineral soil collected at the same time the airborne gamma radiation survey is made are required to calibrate a flight line for measuring SM and WE. Ground surveys of the BOREAS flight lines, especially in areas of Black Spruce in the SSA, showed that the depth of the moss and humus layer was substantial. Procedures were established to measure the average depth of the Moss/Humus layer and to measure the WC of the layer.

The ESC snow tube (30 square cm) was used to obtain cores of the Moss/Humus layer and the gravimetric method was used to determine the water content (WC) of the layer. The WC of the Moss/Humus layer is known to vary greatly. The WC of the Moss/Humus layer plays a highly significant role in attenuating the natural gamma radiation emitted from the mineral soil. The WC of the Moss/Humus layer, along with the SM of the mineral soil, is now used in the calibration of flight lines. For future soil moisture measurements a knowledge of the SM of the mineral soil will permit the measurement of the WC of the Moss/Humus layer. When WE measurements of the snow cover are computed using the calibration data and the airborne gamma radiation a knowledge of the WC of the Moss/Humus layer is required along with a knowledge of the SM of the mineral soil.

The BOREAS data set will provide information on adapting existing procedures for measurement of the WC of the Moss/Humus layer and improving measurements of the WE of the snow cover by accounting for the attenuation of the gamma radiation emitted from the mineral soil by the WC of the Moss/Humus layer.

ACKNOWLEDGMENTS

Thanks to Forest G. Hall, Piers J. Sellers, and others of the BOREAS staff at NASA for their support, to Barry Goodison and John Metcalfe of AES, Canada for their support and cooperation, to Don Gray for his advice and for providing use of a laboratory for analyses of soil moisture samples, and to Henry Santeford for information on the boreal forest system. Special thanks for the outstanding field work by Bob Maxson and to him and Rob Postun of the NWS NOHRSC, in Minneapolis, in the planning and establishing the airborne flight lines.

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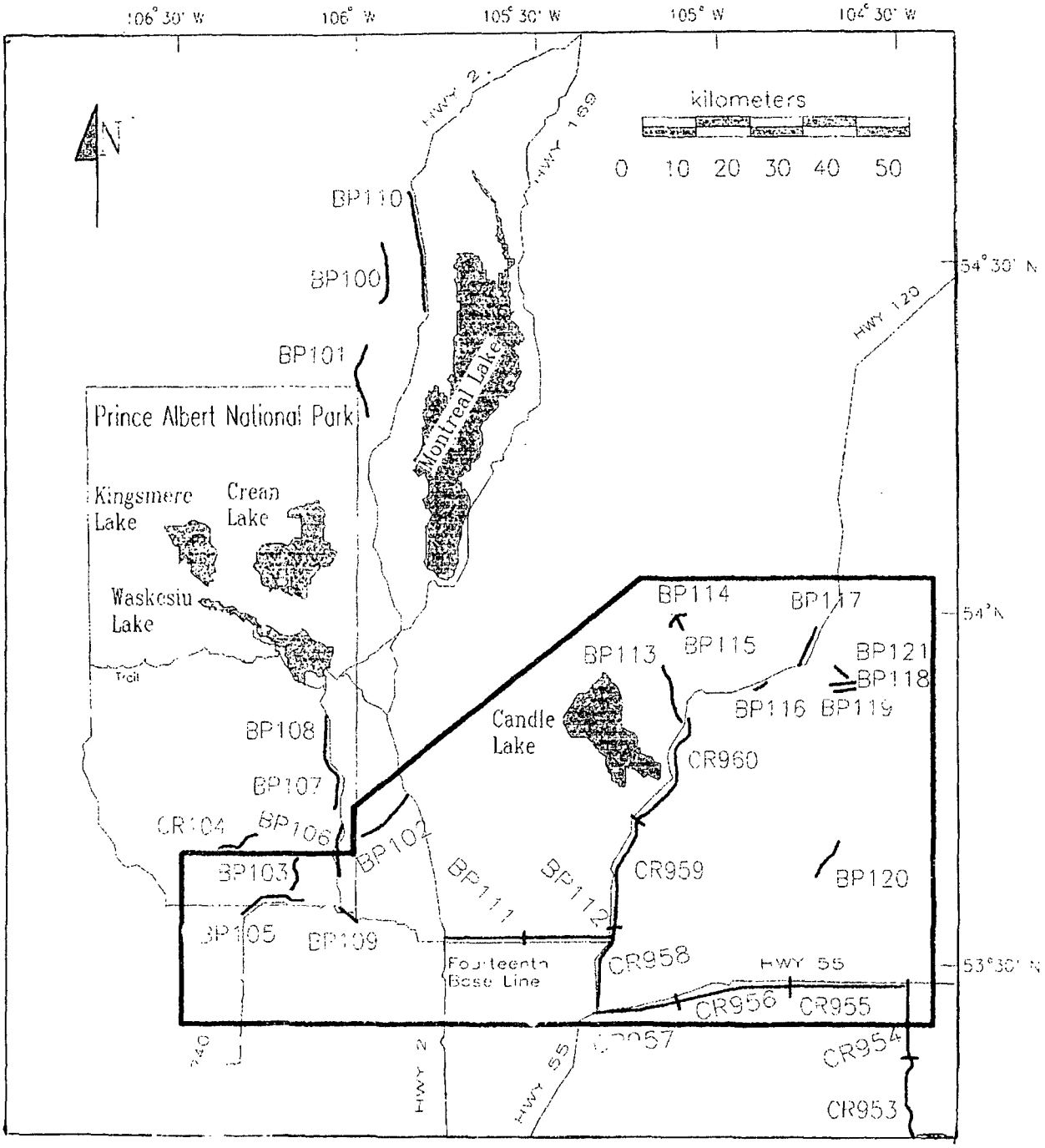


FIGURE 1 Flight Lines for Southern Study Area

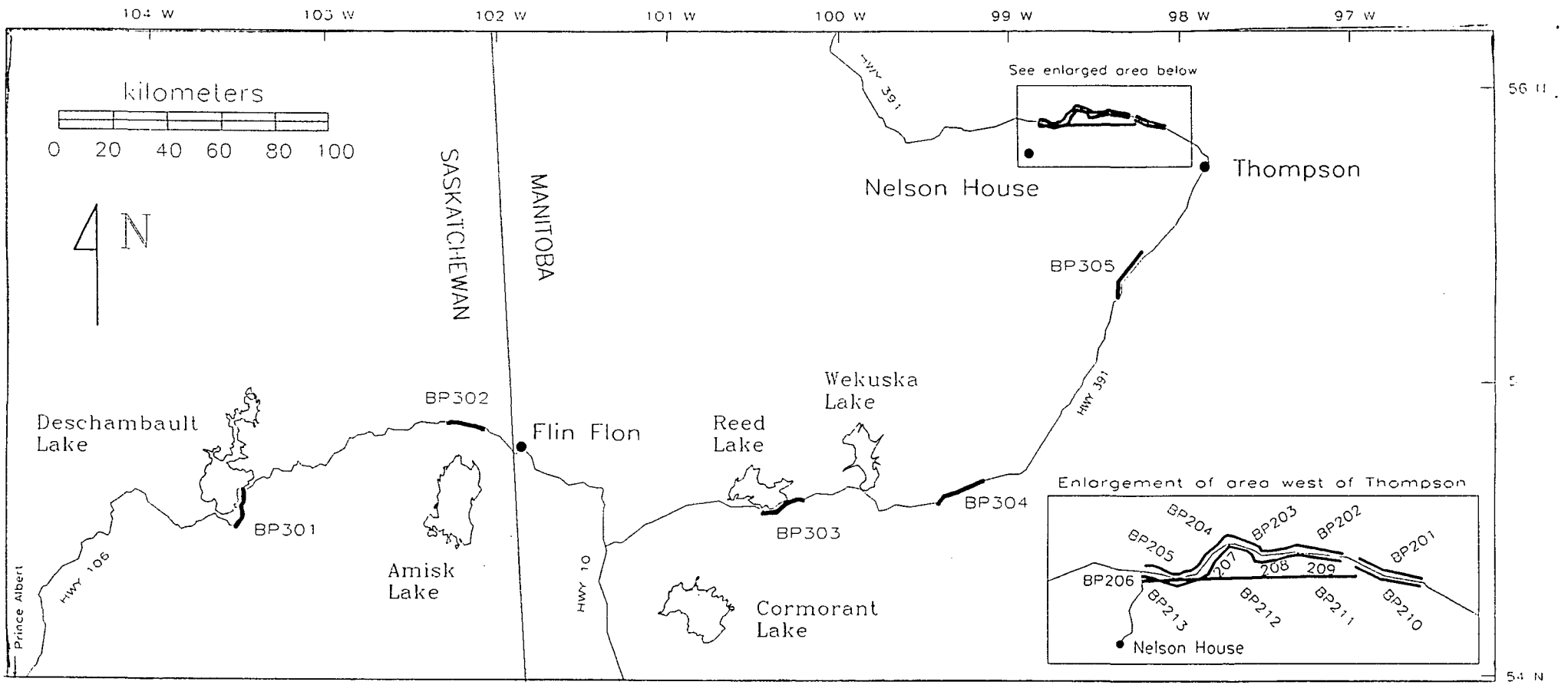


FIGURE 2 Flight Lines Along Transect Between Study Areas

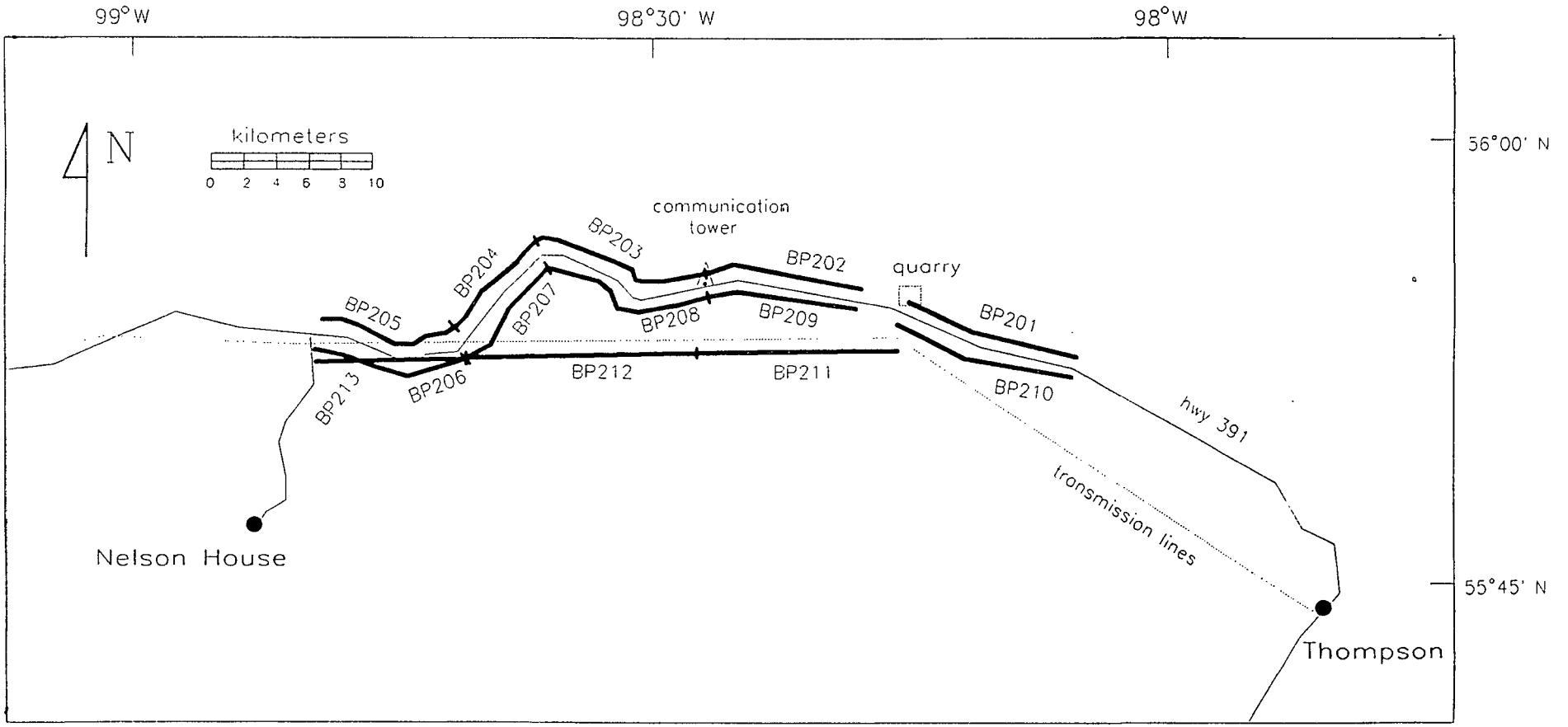
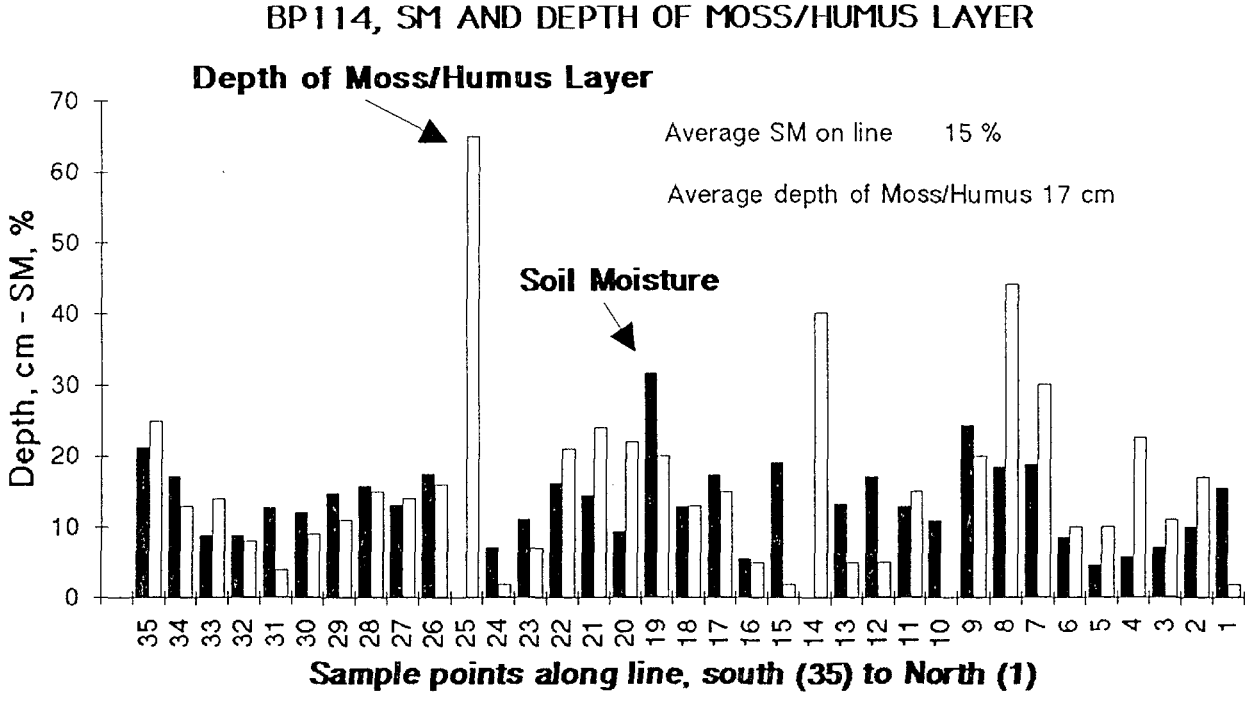


FIGURE 3 Flight Lines for Northern Study Area

ATTACHMENT 1 Ground Data for Flight Line BP114

BOREAS SM SAMPLES BP114													
FL LINE	DATE	TIME	TOTAL	DRY	WATER	SOIL	% SOIL	SLOPE	ASPECT	SOIL TYPE	VEGETATION	MOSS/	REMARKS
SAMPLE	DDDYY	24 HR	WGT	WGT			MOIST			DEPTH SAMPLE		HUMUS	
BP114.67	25293	1710	105.15	84.69	15.76	74.19	21.2	0	0	Gray Clay 22 cm	BS no undercover	25	green Moss
BP114.44	25293	1726	95.50	78.98	11.82	68.48	17.3	0.25	E	fine Sand 22 cm	Mixed OBS YJP A	13	green Moss
BP114.43	25293	1714	89.71	78.97	06.04	68.47	8.8	0.25	ESE	fine Sand 18 cm	Mixed OJP BS A	14	mixed veg/Humus
BP114.15	25293	1716	90.33	79.55	06.08	69.05	8.8	1	SE	Sand 15 cm	OTA hvy undercover	8	leaves/Humus
BP114.14	25293	1711	86.48	73.74	08.04	63.24	12.7	3	SSE	Sand 18 cm	OBS OTA hvy undercover	4	litter
BP114.13	25293	1704	87.21	74.75	07.76	64.25	12.1	2	SE	fine Sand15 cm	OBS OTA	9	green Moss/leaves
BP114.66	25293	1639	62.85	52.01	06.14	41.51	14.8	2	E	sandy rocks 11 cm	OJP 20% undercover small trees 4-5 m	11	Humus
BP114.42	25293	1639	124.37	104.74	14.93	94.24	15.8	0.25	E	fine Sand 21 cm	BS	15	green Moss
BP114.41	25293	1632	131.23	113.10	13.43	102.60	13.1	0.25	NE	fine Sand 22 cm	Mixed BS others along game hwy	14	green Moss/humus
BP114.40	25293	1620	128.50	106.90	16.90	96.40	17.5	0.5	E	fine Sand 21 cm	BS stand on old cleared road - big game hwy	16	Grass/Humus
BP114.12	25293	1639	NO SAMPLE					0	0		OBS very thick	65	green and white Moss/Humus
BP114.11	25293	1630	105.13	94.48	05.95	83.98	7.1	1	NE	course Sand 19 cm	YJP YTP old logging site	2	white Moss
BP114.10	25293	1623	77.72	66.76	06.26	56.26	11.1	0	0	Sand 14 cm	OJP YBS mod undercover	7	green and white Moss
BP114.09	25293	1615	73.84	60.98	08.16	50.48	16.2	0	0	Sand 11 cm	YBS OBS hvy underbrush	21	green Moss/Humus
BP114.64	25293	1551	115.92	98.47	12.75	87.97	14.5	1	SE	gray sandy Clay 23 cm	OJP no undercover	24	green moss/humus
BP114.63	25293	1540	105.45	92.97	07.78	82.47	9.4	0	0	gray sandy Clay 21 cm	OJP no undercover	22	green moss/humus
BP114.39	25293	1556	123.76	92.99	26.07	82.49	31.6	0.25	E	fine Sand wet 22 cm	small stand A surrounded by BS in drianage area	20	thin Grass/Humus
BP114.38	25293	1544	107.02	91.84	10.48	81.34	12.9	0.25	ESE	fine med Sand 21.5 cm	open stand BS	13	mixed veg white Moss
BP114.37	25293	1538	110.96	92.07	14.19	81.57	17.4	0.25	SE	fine Sand 22 cm	BS	15	Humus
BP114.08	25293	1556	53.69	46.96	02.03	36.46	5.6	2	SE	Clay 11 cm	OBS OTA hvy underbrush	5	green Moss Leaves
BP114.07	25293	1547	97.31	79.48	13.13	68.98	19.0	2	E	Sand and Clay 19 cm	OTA YTA YBS hvy undercover	2	leaves
BP114.06	25293	1541	NO SAMPLE					2	NE		OBS TA	40	green Moss/Humus at least 40 cm
BP114.62	25293	1503	49.39	40.70	03.99	30.20	13.2	0	0	gray snady Clay 15 cm	JP Poplar fallon trees	5	Humus
BP114.61	25293	1457	101.09	83.86	12.53	73.36	17.1	1.5	NE	gray sandy Clay 19 cm	JP Poplar small trees 2.5 m fallon trees	5	Moss/Humus
BP114.36	25293	1520	100.66	86.19	09.77	75.69	12.9	0.25	SSE	fine Sand 21 cm	transition zone BS to A	15	mixed veg/Humus
BP114.35	25293	1809	107.66	93.82	09.14	83.32	11.0	0.5	S	fine Sand 20 cm	BS	0	bare ground
BP114.34	25293	1502	101.35	79.77	16.88	69.27	24.4	0.25	E	wet Sand 18 cm	BS on rabbit hwy	20	Moss/Humus
BP114.05	25293	1502	125.76	103.84	17.22	93.34	18.4	0	0	Sand 19cm	OBS very thick	44	wet green Moss/Humus
BP114.04	25293	1452	144.36	119.20	20.46	108.70	18.8	0	0	Sand 21 cm	OBS very thick mod undercover	30	8 cm green moss 22 cm Humus
north end of line at boardwalk to BS Tower						AVG	15					17	
BP114.33	25293	1440	82.15	72.16	05.29	61.66	8.6	3	S	fine lt. Sand 19 cm	mixed stand Pine Spruce Aspen	10	Mixed veg/Humus
BP114.32	25293	1433	81.00	73.38	02.92	62.88	4.6	2.5	S	fine lt. Sand 19 cm	mixed stand Pine Spruce Aspen	10	mixed shrubs/Humus
BP114.31	25293	1424	85.27	76.68	03.89	66.18	5.9	2.5	S	fine lt. Sand 18 cm	mixed stand Pine Spruce Aspen	22.5	mixed shrubs/Humus
BP114.03	25293	1437	103.12	92.58	05.84	82.08	7.1	0	0	Sand 19 cm	OJP OBS mod undercover	11	wet greem Moss
BP114.02	25293	1430	73.15	63.18	05.27	52.68	10.0	1	NE	Sand and Clay 14 cm	OJP OTA OBS mod undercover	17	wet green Moss
BP114.01	25293	1423	94.07	78.73	10.64	68.23	15.6	0	0	Sand and Clay 17 cm	YBS TA hvy undercover	2	leaves

ATTACHMENT 2 Variation of Soil Moisture and Moss/Humus Depths Along Flight Line BP1114



ATTACHMENT 3 Summary of Moss/Humus Field Measurements, September, 1993

YR 1993 OBSERVERS__KM, RM, EP__Page__1___of__1__HYDEX 11/11/93

DAY 252 1/ **BOREAS - SOUTHERN RESEARCH AREA**

OBTAINED 20 METERS SSW FROM HOUSE AT BLACK SPRUCE TOWER SITE

SAMPLE	C DEPTH CM	D TOTAL WGT 2/	E DRY WGT 3/	F WATER D-E-4.7	G SOIL E - 10.5	H % SM	AVG. SM
MINERAL SOIL MEASUREMENTS							
SOIL 2	18	115.27	93.70	16.87	83.20	20.28	
SOIL 3	15	121.90	100.04	17.16	89.54	19.16	21
SOIL 4	20	124.50	99.99	19.81	89.49	22.14	
SOIL 5	16	99.07	78.52	15.85	68.02	23.30	

MOSS AND HUMUS MEASUREMENTS (USING ESC SNOW TUBE, 30 cm2)

					M/H		MOSS/HUMUS gr/cm2		WATER cm
MOSS 2	20	55.27	18.00	32.57	7.50		0.3		1.1
MOSS 3	15	51.00	19.79	26.51	9.29		0.3		0.9
MOSS 4	15	113.97	44.54	60.03	23.54		0.6	TOTAL	2.0
MOSS 4.1 4/		67.66	24.96	38.00	14.46	HUMUS ONLY	0.5	1.3	1.8
MOSS 4.2 5/		46.31	19.55	17.36	9.05	MOSS ONLY	0.3	0.6	
MOSS 5	15	128.64	49.89	74.05	28.89		1.0	TOTAL	2.5
MOSS 5.1 4/		79.24	33.95	40.59	23.45	HUMUS ONLY	0.8	1.4	2.4
MOSS 5.2 5/		49.20	15.84	28.66	5.34	MOSS ONLY	0.2	1.0	

AVERAGE VALUES FOR MOSS/HUMUS LAYER DEPTH OF 15 cm

	TOTAL MASS (VEG) gm/cm2	TOTAL WATER cm
IF MOSS ONLY	0.3	0.9
HUMUS ONLY	0.6	1.4
MOSS + HUMUS	0.9	2.3

ALONG ROAD NORTH OF AND WEST OF BLACK SPRUCE TOWER (FLIGHT LINE 114)

MEASUREMENT OF SM OF MINERAL SOIL

114-63	15	105.45	92.97	7.78	82.47	9.43

GRAB SAMPLES OF GREEN MOSS LAYER (by hand, no tube)

SAMPLE	DEPTH CM	TOTAL WGT 2/	DRY WGT 3/	WATER D-E-4.7	M/H E - 10.5		MOSS gr/cm2		WATER cm
114-63.1	15	50.12	19.87	25.55	9.37		0.3		0.9
114-63.2	15	73.51	35.91	32.90	25.41		0.8		1.1
114.65.1	7.5	38.49	23.25	10.54	12.75		0.4		0.4
114.65.2	11.5	62.52	44.25	13.57	33.75		1.1		0.5
						AVG	0.7	AVG	0.7

FLIGHT LINE BP302 (SAMPLE BY JOHN METCALFE, AES)								WATER cm
BP302.01	75				982			32.7+

1/ Georgian day 2/ with lid 3/ without lid 4/ humus part only 5/ moss part only

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13. ABSTRACT *(Maximum 200 words)*

The major effort by HYD-6 members has been to develop a network of flight lines to provide the maximum amount of information on the temporal and spatial variation in soil moisture for the BOREAS study areas.

Field visits to the southern study area (SSA) were conducted during May 1993, to obtain first hand information on the flight lines that had been previously selected for BOREAS snow studies. In September 1993, airborne gamma radiation studies surveys were conducted over the SSA, the northern study area (NSA), and for five flight lines along the transect between the two study areas. In situ measurements of soil moisture and water content of the Moss/Humus layer were obtained for calibration of selected gamma radiation flight lines in the SSA and for two of the transit lines. The flight lines for which soil moisture will be measured during the three IFCs during the summer of 1994 is a subset of the total flight lines that have been flown for the snow surveys.

During the WFC in February 1994, airborne gamma radiation surveys were flown over all of the flight lines. Members of HYD-4, under the direction of John Metcalfe, Atmospheric Environmental Service (AES), of Canada, collected in-situ measurements (soil moisture, water content of the Moss/Humus layer, and water equivalent of the snow cover).

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