SEAHATS
LAND TRIALS

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PREFACE

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SEAHATS

LAND TRIALS

by

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I would like to thank Dr. David Wells for giving me the opportunity to come to Canada to work on the SEAHATS project. And I would like to thank Tim McCarthy, Harvey Nickerson, Hal Janes, and Pantelis Hourdakis for their pleasant cooperation.

This work was supported in part by a Strategic Grant entitled "Marine Geodesy" and a Strategic Equipment Grant entitled "Integrated Navigation Microprocessor Equipment" both awarded to Dr. Wells by the Natural Sciences and Engineering Research Council of Canada.

The possibility of working in Canada on this project was arranged through the International Association for the Exchange of Students for Technical Experience (IAESTE).

A van was borrowed for these tests from the UNB Department of Civil Engineering.

A Mini-Ranger III system was borrowed from the Bedford Institute of Oceanography. The assistance of Jack Davidson is appreciated.

This project forms the practical work required for the Engineering degree from the Technical University of Delft.

CHAPTER 1

OBJECTIVES

The SEAHATS system being developed at the University of New Brunswick (UNB) is the Surveying Engineering Apple-based Hydrographic data Acquisition, and Track control System.

My work was to put the parts of the SEAHATS system together, test the system, and look for possible improvements.

The SEAHATS system is an alternative to the present "HYNAV Navigator" [Anon, 1982] by Marinav. The system consists of a Mini-Ranger III positioning system [Motorola, 1980], which we borrowed from the Bedford Institute of Oceanography (BIO) in Dartmouth, N.S.; an Apple II computer, with software written by Tim McCarthy [McCarthy, 1983]; and a PS-01 Radio Positioning/Echosounder Computer Interface, between these devices, designed by Harvey Nickerson of the Centre for Advanced Microelectronics (CADMI) at UNB [Nickerson, 1983].

The PS-01 is designed in such a way that it will be possible to use other positioning instruments and other computers. The system performs horizontal positioning aboard a vessel and, in the future, depth determination will be possible by connecting a Skipper 802 echo sounder.

The SEAHATS system computes the position of a vessel, gives corrections on a display to the helmsman of the vessel every few seconds so that he can navigate along a pre-determined survey line, and logs positional information on a diskette. The survey line can be a straight line between two points (two waypoint mode) or a circular path (a whole circle or a part) around one point, for example, a shoal point in the water (one waypoint mode).

The display consists of:

- line number (of the survey line) [line #]
- point number (of the position of the vessel) [point #]
- northing [N] of the vessel
- easting [E] of the vessel
- along track distance [ATD]
- across track distance [XTD] (= amount of correction)
- distance to go [DTG]
- depth
- course (azimuth of the line you want to run)
- bearing (azimuth of the line you have actually run)
- five asterisks which show your five previous positions
- an arrow which shows if the helmsman has to correct to the left or right.

The logged data on the disk consist of:

- line number
- point number
- northing
- easting
- depth
- variance-covariance matrix of the position
- raw data observations.

A disadvantage of the HYNAV system is that there is a one-second lag between the position and depth samples. The SEAHATS system will, hopefully, solve this problem.

An advantage of the SEAHATS system is that it is cheap: the PS-01 and required Apple equipment costs around $5000 (Can) total. It will be used for educational purposes aboard the UNB vessel, the Mary-O, but it can also very well be used for bathymetric surveys near the coast.

After some problems we succeeded in making the system work and doing a land-based test using a van. Also we made the system work on the Mary-O. Further tests and further improvements in the software are planned.

CHAPTER 2

EQUIPMENT AND SOFTWARE

2.1 Software

The software was written by Tim McCarthy. The language is Pascal and it is written for an Apple computer. The test was done with an Apple II computer. For detailed information, see McCarthy [1983]. Small changes were made which I shall mention in this chapter and in Appendix A.

The software consists of two programs. The first program, PS01INIT, initializes the PS-01 interface by setting the date, time, sample interval (the time difference between two consecutive observations measured by the positioning instrument) and channel identification numbers (code numbers of the two reference stations of the Mini-Ranger). The second program, NAV, handles all data initialization, handles navigation routines for one and two waypoint modes, displays results, and logs the data. The present version of the NAV program (used for this report) has some differences from the version of the program documented in McCarthy [1983]. The least-squares adjustment was not changed. (The changes are described below.)

One of the changes that had to be made was to add a rejection of wrong range observations (due for example to reflections). Once the NAV program has accepted a bad reading, the calculated position is wrong. Since the last position is used as initial coordinates for the calculation of the next position, the rest of the calculated points will be far off the actual position. The rejection is done as follows (see Figure 2.1).

The ship moves from 1 to 2; a is the measured range at position 1; b is the measured range at position 2; c is the distance between point 1 and

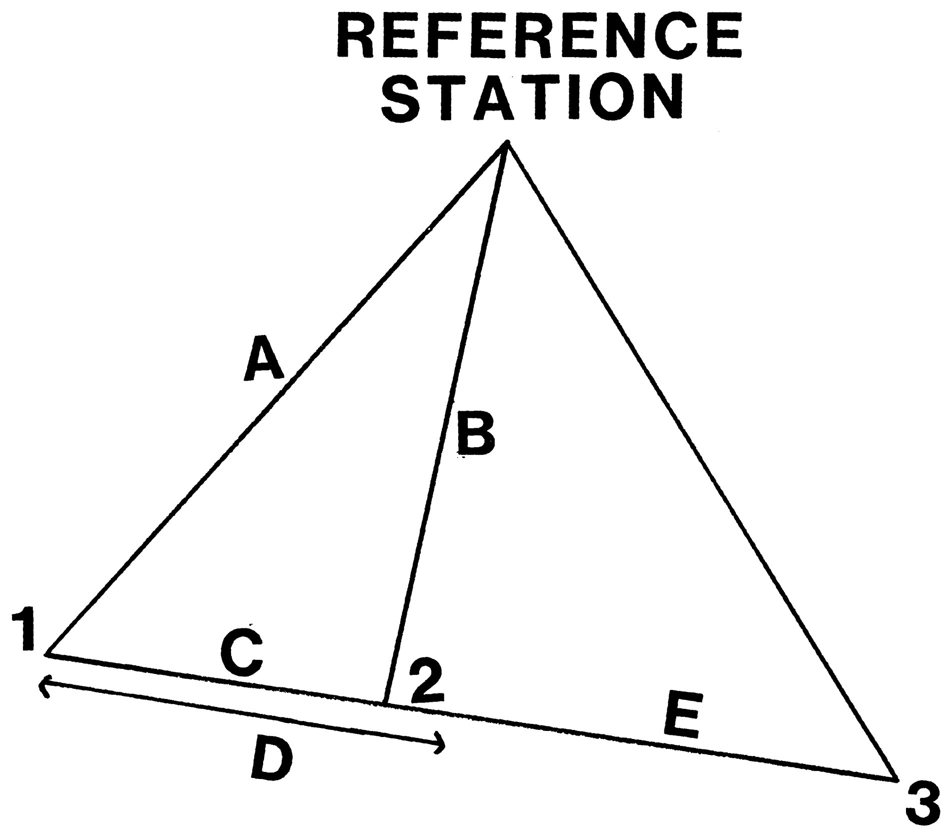

FIG 2.1

point 2; d is the distance calculated by multiplying the sample interval and the maximum speed of the vessel (which are both manually input by the operator during program initialization). Always d > c > a-b. If a-b > d, b is not accepted. The program will give the message

****SPURIOUS RANGE READING**REJECTED****.

As a further improvement (not yet implemented), it would also be possible to calculate the ship's speed between 1 and 2 from the coordinates of 1 and 2 and use this to calculate the approximate coordinates of 3. The rejection criteria will be smaller and the approximate coordinates of 3 can be used in the calculation of the position of 3 instead of using the position of point 2, so fewer iterations would be needed for the fix. This would not work when the ship is accelerating, so e (the distance between 2 and 3) is bigger than c. However, it would be a better method when the ship's speed is constant.

The PS-01 is connected with the Apple by a RS-232 Super Serial Card in the Apple. In the PS-01 User's Guide [Nickerson, 1983] the switch settings of this card are given. The PS-01 has a buffer, which contains up to 20 records with the range information from the Mini-Ranger. Every time the Apple program requests a record, the PS-01 sends one.

The coordinates of the vessel are calculated by a least-squares adjustment [McCarthy, 1983, page 8]. Since we use only two remote stations, the number of observations is always two, so there is no redundancy. The convergence criteria for the iteration is 0.5 metres. The program needs normally two or three iterations to reach that. The number of iterations is now fixed at three to save time.

During the test using the van the system calculated positions a little less often than every four seconds. The reading of the record from the PS-01 takes a half second, refreshing the screen display takes 1.5 to 2 seconds, and the fix computation takes 1.5 to 2 seconds. The 40 character monitor display mode is used, instead of the 80 character mode optionally available, because it is faster to refresh, and most of the text can be seen on the 40 character screen. To see the rest of the text, the operator must hold down the 'CTRL' key and press 'A'. To go back to the left half of the page, press 'CTRL A' again.

For suggested further improvements to the program, see Chapter 6. For some remarks on using the program, see the User's Guide (Appendix A to this report).

2.2 The PS-01 Radio Positioning/Echo Sounder Computer Interface

The PS-01 intelligent interface was designed and built by CADMI MICROELECTRONICS/MICROELECTRONIQUE INC [Nickerson, 1983]. For the present, it acts as a data collection buffer between an Apple microcomputer and a Mini-Ranger III positioning instrument. The position data coming from the Mini-Ranger is collected and temporarily stored in a local buffer of the PS-01 along with time and date information. The position data come from two channels on the Mini-Ranger III. The data is then formatted and transmitted to the Apple microcomputer via an RS-232 interface card; the Apple issues commands to the PS-01 on the RS-232 and can control the collection and transmission of data. Ultimately the data is stored on floppy diskette on the Apple computer. The communication protocol has been designed to be unspecific for the Apple; it can work well with almost any computer with an RS-232 interface. Also the microcomputer can be replaced by a CRT or ASCII terminal for a printout. With a few slight changes the PS-01 can be connected with other radio positioning instruments (for example, LORAN-C).

In the future the PS-01 will be interfaced to a Skipper 802 echo sounder which provides depth data, as well as to other positioning systems.

The front panel contains only a power indicator lamp, the rear panel a power switch, fuse holder, AC power cord, two RS-232 connectors and three cables to connect to the Mini-Ranger III.

Data records are transmitted from the local buffer in the PS-01 to the computer in the following format:

#nn yy-mm-dd hh:mm:ss A=xx AS=xx AR=xxxxxx B=xx BS=xx BR=xxxxxx DP=xxxxx CR LF

where nn is the number of data records left in the buffer

yy-mm-dd is the date the sample is taken

hh:mm:ss is the time the sample is taken

A/B are the transducer channel codes (01-04)

AS/BS are the signal strengths from channels A and B (the Mini-Ranger III used for this test had no signal strength option installed)

AR/BR are the observed ranges in metres

DP is the depth value from the echo sounder (presently set to zero).

The record length, without CR (carriage return) and LF (line feed), is 72. Each record sent from the PS-01 to the Apple is displayed on the Apple monitor.

For complete information on the PS-01, see Nickerson [1983]. Note that the Mini-Ranger III Manual in Appendix F of this PS-01 manual refers to an older type of Mini-Ranger than the one we used (which is described in [Motorola, 1983]). For important user details, see the User's Guide (Appendix A to this report).

2.3 The Mini-Ranger III Positioning System

The Mini-Ranger III provides accurate determination of the position of any mobile unit such as a hydrographic vessel (like the Mary-O); dredge; aircraft; or land vehicle (as used in these tests). It is a range/range system, operating on the principle of pulse radar. The Mini-Ranger III measures the range or distance from a receiver-transmitter (R/T) station located on the mobile unit to a minimum of two fixed reference stations (remote stations/transponders) located on points with known coordinates. We use two reference stations.

The elapsed time between the interrogation transmitted by the master receiver/transmitter (R/T) station, and the reply received from each reference station is the basis for determining the ranges, which are displayed on the range console. The range console is used on board the vessel and is connected with the R/T station. The ranges are displayed in metres. The range information together with the known coordinates of each reference station can be trilaterated to obtain the position of the mobile unit. There must be line-of-sight between the R/T and the reference stations, because the system operates at microwave frequencies (around 5500 MHz). The minimum measuring range is 100 m, the maximum range is 37 km using standard equipment, and up to 185 km with optional high-powered equipment.

The measuring accuracy is 2 metres. This is the standard deviation of a set of observations. A single observation can be 3 sigma (6 metres) in error.

To minimize the position error the sites for the reference stations should be selected so that the angle of intersection between the lines from the R/T to the two reference stations is between 30^{o} and 150^{o}; 90^{o} gives the best accuracy, because then the position error is the smallest.

The antenna of the R/T and reference stations must be kept 60 cm from and above large metal surfaces or masts larger than 15 cm in diameter.

The range console does not operate below $0^{o}C$. The minimum temperature for the reference stations and the receiver-transmitter is $-50^{o}C$.

During the test using the van the R/T station was mounted on top of the van, and on the Mary-O it was mounted above the mast. The reference stations were mounted on tripods. Each has a certain code (unique delay between two returned pulses). These are denoted 1, 2, 3, or 4. The REF STATION SELECT switches on the range console must agree with the codes of the reference stations being used.

The position error of the Mini-Ranger III depends on three factors:

(1) System errors caused by equipment tolerances, jitter and weather. These have been minimized by the design of the system.

(2) Slant-range error: the Mini-Ranger III measures the slant range instead of the horizontal distance, which is what we want to know. An accepted practice is to work no closer than ten times the height difference of the two antennas of the R/T and one reference station. Under these conditions the resultant range error will be no greater than 0.5 percent longer than the actual range. The height differences in the test area (for the van and the Mary-O) are too small to bring this error into consideration. However, it would be possible to modify the NAV program to automatically correct for slant range (requiring the operator to input heights of reference station and vessel antennas during initialization), using

$$r_h = r_o \; [\, 1 - (dh \,/\, r_o)^2 \,]^{1/2}$$

where r_o is the observed slant range, dh is the height difference between reference station and vessel, and r_h is the corrected horizontal range.

(3) Geometry changes: a measured range has a certain accuracy, which affects the accuracy of the calculated position, depending on the angle of intersection of the lines from the R/T to each of the reference stations. A certain intersection angle gives a certain position error (see Figure 2.2). Intersections of 90^o give the smallest error. Figure 2.2 is based on a measuring accuracy of the Mini-Ranger III of 2 metres. If the measuring accuracy is 3 metres, all position errors are 3/2 times bigger.

The electrical power demand of the Mini-Ranger III is as follows:

	Range Console and R/T	Reference Station
Voltage	24 Vdc	24 Vdc
Current on standby (no interrogation)	2.5 A	0.5 A
Current at maximum interrogation rate	3.0 A	1.0 A

POSITION ERROR DUE TO GEOMETRIE

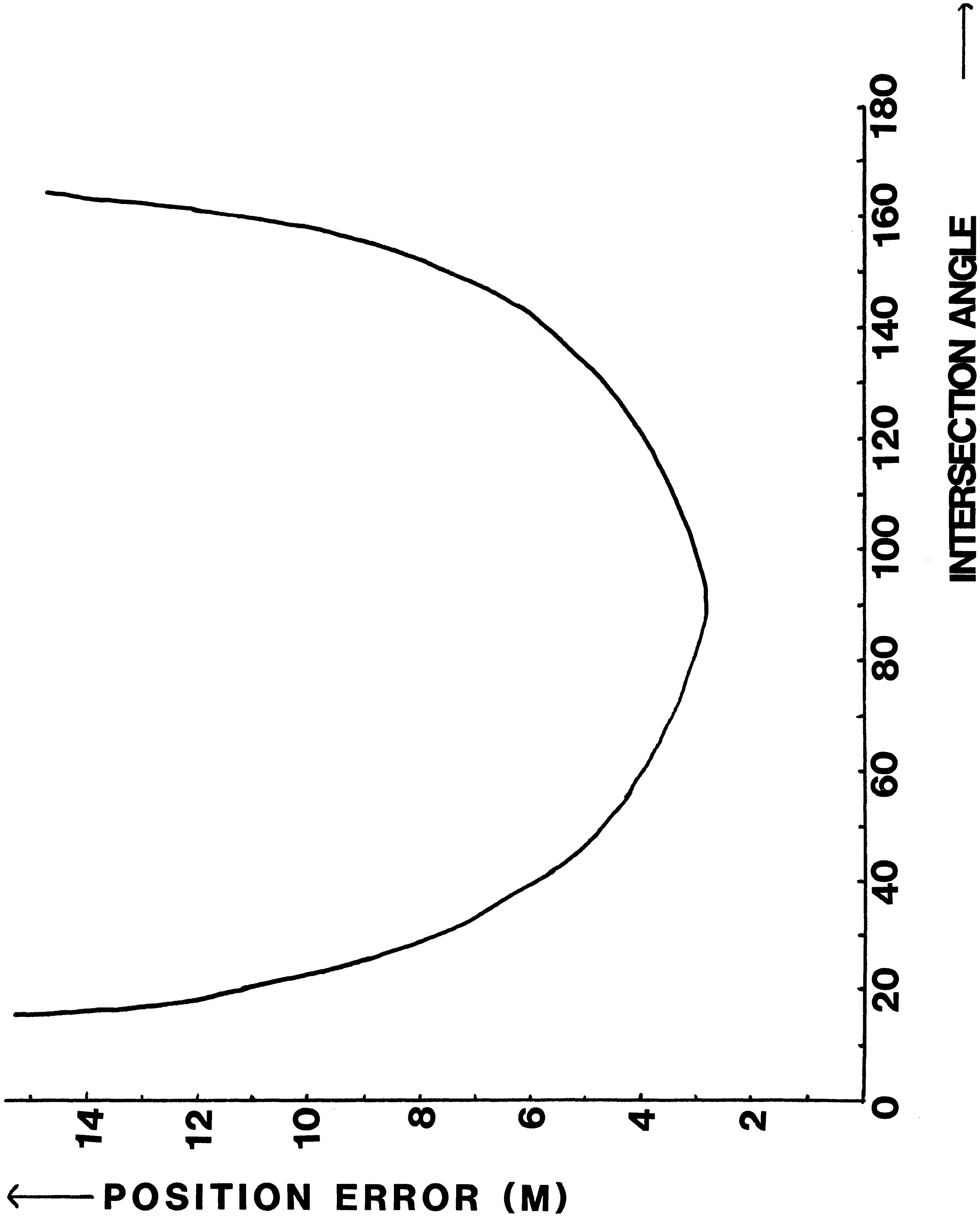

FIG 2.2

CHAPTER 3

DESIGN OF STATIC LAND TEST

For the land test we used a van from the UNB Department of Civil Engineering. The van is equipped with a power supply providing 120 volt power for the PS-01, Apple computer, disks, and monitor. The receiver-transmitter was mounted on an ski rack on top of the van. The rest of the equipment was mounted on shelves in the van.

The test was done on Wednesday, 31 January 1984. The test area is east of the Princess Margaret Bridge in Fredericton (see Figure 3.1). The test area, control points and geometry are described in this chapter.

Control points on the south side of the St. John River were used to check the accuracy of the SEAHATS system. Coordinates for the monuments were taken from microfiche of the Land Registration and Information Service (LRIS) in the Maritime Provinces of Canada. These microfiche contain all the survey data about every control point in New Brunswick updated to January 1983.

The Universal Transverse Mercator (UTM) coordinates, referred to the ATS77 adjustment performed by LRIS, of the control used for this test are shown in Table 3.1 (in metres).

Two new stations were established on the north side of the St. John River, for the Mini-Ranger III reference stations. These stations were called "BRIDGE" and "318NEW" (see Figure 3.1), and the surveys and computations used to establish their coordinates are contained in Appendix B of this report.

Point 242 on the Princess Margaret Bridge would also be a good reference station point, because it is high above the river. But it is

TEST AREA

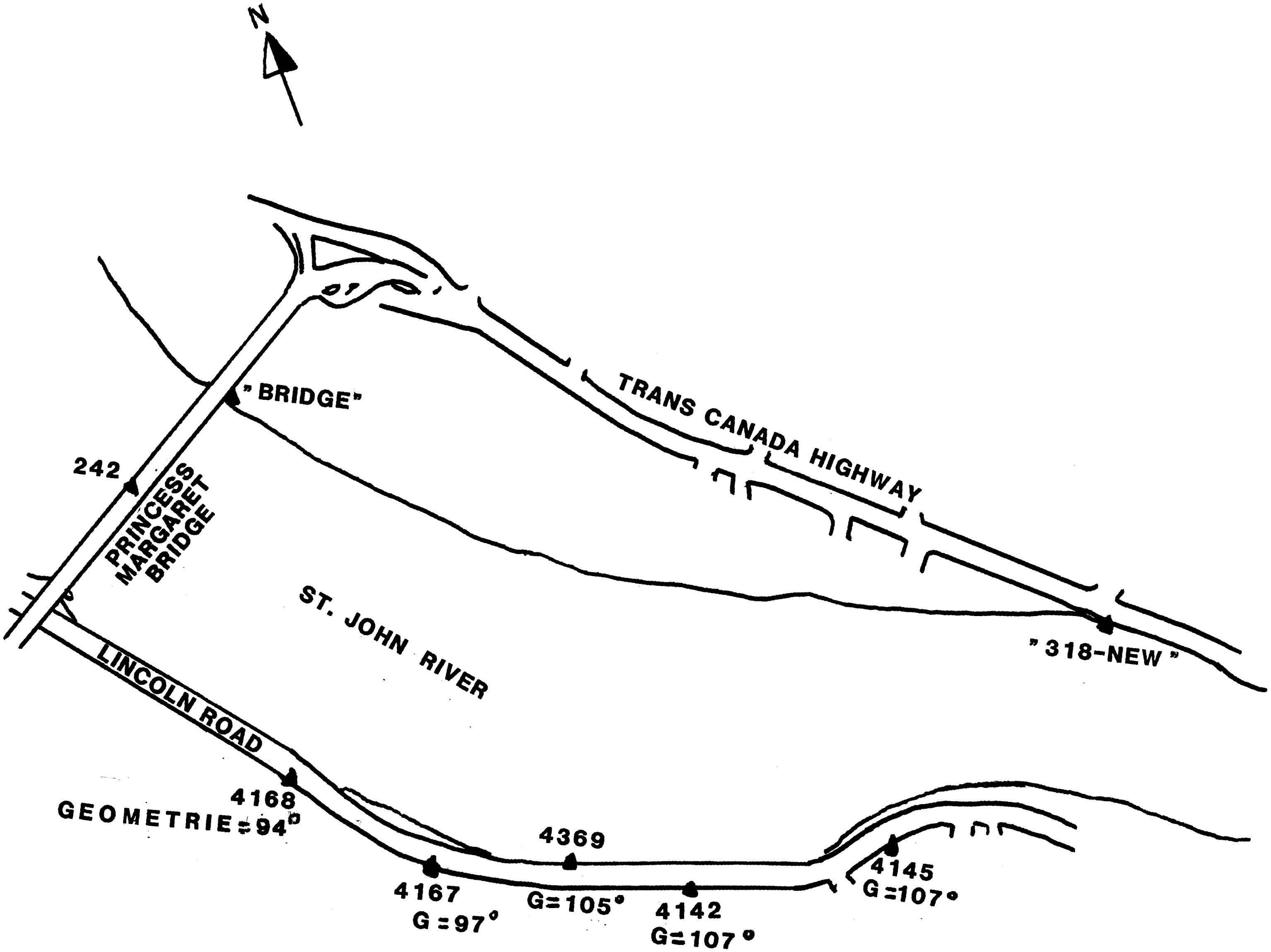

FIG 3.1

between a lot of steel, so instead we established the new point "BRIDGE" under the Princess Margaret Bridge. Point 318 was a well-situated point, but the monument had been destroyed. We established the new point "318NEW" in the neighbourhood of 318. Point 319 between the bridge and 318 cannot be seen from the other side of the river.

TABLE 3.1 CONTROL STATION COORDINATES (SOUTH BANK)

Point number	Easting	Northing
4168	290307.050	737053.563
4167	290460.921	736758.568
4369	290814.231	736524.942
4142	291069.007	736373.952
4145	291622.501	736212.933

TABLE 3.2 REFERENCE STATION COORDINATES (NORTH BANK)

Point number	Easting	Northing
"BRIDGE"	290532.551	738015.403 (Mini-ranger III code 2)
"318NEW"	292412.007	736410.876 (Mini-ranger III code 3)
318	292410.111	736421.289 (destroyed)
242	290240.200	737907.134 (high on bridge)

Before the test the Mini-Ranger III range console was calibrated at point 4142 by adjusting the REF STATION CAL screws. The calibration should be done in similar environment to that in which the instrument will be operating, with the ranges approximately equal to the range of operation.

The van was driven along the Lincoln Road from point 4168 to 4145 and then in reverse direction. The length one way is around 1650 metres.

Two other LRIS points would have provided longer survey lines. But point 4185 was not found (back in a field), and point 4146 could not be used because the reference stations are not visible from this point.

This test was a static test. The van stopped at the control points to check the accuracy of the coordinates determined by the SEAHATS system, against the known LRIS values. The control points were marked by poles.

A dynamic test will hopefully be done later. In this case the van would drive along the road without stopping, and the time when it passes a monument is recorded for later comparison with the SEAHATS data at that instant (requiring interpolation of the recorded SEAHATS data).

In order to check that the SEAHATS system can track rapidly changing Mini-Ranger III ranges, the speed of the van was around 50 km/h. This is much faster than the speed of the Mary-O, which is normally around 15 to 20 km/h. No problems were encountered.

CHAPTER 4

LAND TEST RESULTS

The two way test run in the van took about ten minutes to complete. The SEAHATS sampling interval was set at four seconds (the assumed time required for the NAV program to complete the processing of one set of observations). The data recorded by SEAHATS on the Apple disc is shown in Table 4.1.

The forward run contained the first 57 fixes in Table 4.1. The NAV program detected the end of the first line at fix 57 and stopped computing fixes, as it is designed to do. The van was turned around and the second (reverse) line began at fix 58 about 70 seconds later.

Where there is a + sign beside the time in Table 4.1, SEAHATS did not record a position fix, but according to the sample interval of 4 seconds, there should have been one. This happened 32 times. Possible reasons for this are

- there was an obstruction between the van and a reference station;
- there was a spurious range reading;
- the program skipped one record (since reading calculating and displaying one record may take more than four seconds).

The recording of data onto the Apple disk stopped at fix 98. The reason is not clear. The realtime monitor display continued to the end of the reverse line. At that point (control point 4168) the 'Distance to go' value shown on the screen was 2 metres, which indicates that the position fixing continued without problems.

In this single static test, the van was stopped near each control point, and between four and ten four-second samples taken. The average

TABLE 4.1 SEAHATS OBSERVATIONS AND RESULTS

Fix	Control point	Time	Northing	Easting	Range to "BRIDGE"	Range to "318NEW"
1	4168	13:00:19	737054	290309	987	2199
2	4168	23	7052	0308	989	2199
3	4168	27	7050	0310	990	2197
4	4168	31	7054	0310	986	2198
5	4168	35	7052	0313	988	2195
6	4168	39	7054	0310	986	2198
7	4168	43	7051	0308	990	2199
8	4168	47	7056	0310	985	2199
9	4168	51	7055	0309	986	2199
10	4168	59+	7052	0312	988	2196
11		01:03	7035	0319	1003	2184
12		07	7012	0328	1024	2169
13		11	6982	0342	1050	2147
14		19+	6907	0371	1120	2100
15		23	6865	0389	1159	2073
16		27	6826	0412	1195	2043
17	4167	35+	6753	0453	1265	1989
18	4167	39	6752	0459	1265	1983
19	4167	43	6757	0459	1260	1983
20	4167	51+	6750	0460	1267	1981
21		59+	6748	0467	1269	1974
22		02:03	6741	0483	1275	1957
23		07	6721	0505	1294	1932
24		15+	6666	0576	1350	1854
25		19	6631	0613	1386	1812
26		27+	6565	0700	1460	1719
27		31	6541	0747	1489	1670
28	4369	39+	6514	0806	1526	1609
29	4369	42	6513	0807	1527	1608
30	4369	51+	6511	0806	1529	1609
31	4369	55	6511	0811	1529	1604
32		59	6503	0828	1540	1587
33		03:03	6485	0863	1565	1551
34		11+	6447	0943	1621	1469
35		15	6423	0985	1655	1427
36		23+	6385	1053	1711	1359
37	4142	27	6376	1068	1724	1344
38	4142	31	6377	1073	1725	1339
39	4142	39+	6376	1073	1726	1339
40	4142	13:03:43	736376	291073	1726	1339

Fix	Control Point	Time	Northing	Easting	Range to "BRIDGE"	Range to "318NEW"
41	4142	13:03:51+	736376	291073	1726	1339
42	4142	55	6376	1070	1725	1342
43		59	6375	1076	1728	1336
44		04:07+	6348	1131	1771	1283
45		11	6321	1171	1810	1244
46		15	6299	1217	1847	1200
47		23+	6246	1324	1938	1100
48		27	6228	1379	1977	1049
49		35+	6219	1492	2036	940
50		39	6227	1549	2057	882
51	4145	47+	6220	1621	2099	814
52	4145	51	6219	1622	2100	813
53	4145	59+	6221	1623	2099	812
54	4145	05:03	6219	1621	2100	814
55	4145	07	6220	1623	2100	812
56	4145	11	6219	1622	2100	813
57		15	6221	1636	2106	799
58	4145	06:23	6226	1622	2095	811
59	4145	27	6224	1620	2095	814
60	4145	31	6224	1620	2095	814
61	4145	35	6224	1621	2095	813
62	4145	39	6227	1623	2094	810
63	4145	43	6228	1622	2093	811
64	4145	51+	6225	1620	2094	814
65		55	6226	1604	2085	829
66		59	6227	1582	2073	850
67		07:03	6226	1542	2054	889
68		11+	6222	1461	2019	970
69		15	6216	1408	2000	1023
70		19	6233	1358	1964	1069
71		27+	6276	1263	1886	1157
72		31	6301	1213	1844	1204
73		39+	6352	1123	1765	1290
74		43	6373	1084	1732	1329
75	4142	51+	6382	1065	1718	1347
76	4142	55	6380	1068	1720	1344
77	4142	59	6382	1073	1720	1339
78	4142	08:07+	6381	1070	1720	1342
79	4142	15+	6382	1072	1720	1340
80	4142	13:08:19	736379	291065	1720	1347

Fix	Control Point	Time	Northing	Easting	Range to "BRIDGE"	Range to "318NEW"
81		13:08:23	736393	291048	1702	1364
82		27	6405	1018	1681	1394
83		35+	6446	0943	1622	1469
84		39	6464	0904	1595	1509
85		47+	6500	0834	1545	1580
86		51	6511	0813	1530	1602
87	4369	55	6518	0811	1522	1605
88	4369	09:03+	6516	0807	1524	1608
89	4369	07	6516	0807	1524	1608
90	4369	11	6517	0810	1523	1606
91		15	6519	0802	1520	1614
92		23+	6546	0748	1485	1669
93		27	6567	0710	1459	1709
94		31	6589	0672	1433	1749
95		39+	6648	0595	1368	1832
96		43	6679	0558	1336	1873
97		51+	6741	0487	1275	1953
98		13:09:59+	736753	290453	1265	1989

ranges and positions for each of these stops are shown in Table 4.2. The measuring accuracy of the Mini-Ranger III is 2 m, but a single observation can be 6 m in error. Therefore the difference between the highest and lowest four second observation could be as much as 12 m. The difference between the highest and lowest range reading in each set was not that high for this test, but the test involved limited numbers of observations.

The NAV program is written in the Apple PASCAL language, which is capable only of single precision (6 to 7 decimal digit) arithmetic. Whether this results in a significant error was tested in the following way. Ranges to the transponders were calculated using the average coordinates at each stop. These calculated ranges were compared with each of the averaged ranges. The maximum difference between the calculated and averaged observed ranges is 0.6 m.

Simulations to evaluate the error resulting from the least squares calculation of the coordinates in the program resulted in errors of as much as 1 m, but most times it was lower (the convergence criteria is 0.5 m). This is a much smaller effect than position errors resulting from Mini-Ranger III ranging errors. For example, when the system is run dynamically, only single observations are taken, which may have errors of four to six metres. Depending on the angle of intersection between the range lines, this may result in position errors of six to nine metres.

The NAV program displays coordinates rounded off to integer values (whole metres). Position errors could be made smaller by retaining decimals in the coordinates. However, because the ranges are measured in whole metres, the results would not be improved significantly.

So the uncertainty in the results is almost totally due to the Mini-Ranger III observation errors. A good calibration before operating is

TABLE 4.2 AVERAGED POSITIONS FROM SEAHATS DATA

Point	Number of Obsvns	Fix Numbers	Average Calculated Easting	Average Calculated Northing	Average Ranges "BRIDGE"	Average Ranges "318NEW"	Highest - Lowest Range
In forward direction:							
4168	10	1-10	290309.9	737053.	987.5	2197.8	5 m
4167	4	17-20	290457.75	736753.	1264.25	1984.	8 m
4369	4	28-31	290807.5	736512.25	1527.75	1607.5	5 m
4142	6	37-42	291071.67	736376.17	1725.33	1340.33	5 m
4145	6	51-56	291622.	736219.83	2099.67	813.	2 m
In reverse direction:							
4145	7	58-64	291621.14	736225.43	2094.43	812.43	4 m
4142	6	75-80	291068.83	736381.	1719.67	1343.17	8 m
4369	4	87-90	290808.75	736516.75	1523.25	1606.25	3 m

TABLE 4.3 COORDINATES OF OFFSETS FROM CONTROL POINTS

Point	Easting	Northing
4168	290312.136	737056.727
4167	290464.621	736762.268
4369	290812.214	736520.628
4142	291071.351	736378.323
4145	291623.238	736223.004

TABLE 4.4 DISCREPANCIES BETWEEN AVERAGED SEAHATS POSITIONS AND OFFSETS CONTROL POINT POSITIONS

Point	Easting	Northing
In forward direction:		
4168	2	4
4167	6	9
4369	5	8
4142	0	2
4145	1	3
In reverse direction:		
4145	2	-2
4142	3	-3
4369	3	3

very important.

The problem of detecting and throwing out unacceptable ranges is handled by program NAV by establishing a window (based on sample interval and maximum velocity) around the previous range. The next range must fall within that window or it will be rejected. Otherwise when a bad reading occurs (say due to reflections), the resulting coordinates, which will be used as initial coordinates in the next fix calculation, will be wrong, and the next fix may be far off the real position.

The window used now is quite small: a sample interval of 4 seconds with a maximum speed of the vessel of 20 km/h gives a window of 22 m.

This window could be made even smaller (see Section 2.1). In Figure 2.1, c is always smaller than a-b, so c can be a certain percentage of a-b. Two kinds of calculations could be used to reject more ranges. One is the method described in Section 2.1. Another way that could be used when the ship's speed is almost constant (as on a survey line) is the following: the program calculates the vessel's speed from the two previous positions. From this it calculates the window (which will be smaller). Also the initial coordinates of the next point could be predicted, instead of using the coordinates of the previous point. The resulting position fix may converge in fewer (maybe even one) iterations.

More tests have to be done. From this single test without even a complete disk output it is difficult to draw conclusions. Dynamic testing is especially important.

Another problem is to know more precisely the coordinates of the reference points offset on the road from the LRIS control points monuments, and just where the van will be stopping (for static tests) or where it will be during dynamic testing. Even more challenging is to know precisely reference positions for dynamic testing aboard the Mary-O.

For this test, offset points from each LRIS monument were measured to the edge of the road, perpendicular to the road. The coordinates of these points are in Table 4.3. These offset points are on the side of the road on which the van stopped during the forward run (except for point 4369).

Table 4.4 compares the reference coordinates in Table 4.3, with the average SEAHATS coordinates in Table 4.2. The differences are only a few metres. In future tests the van should be stopped as closely as possible to the offset reference points. Even more precision could be achieved by removing the R/T unit from the van at each point and mounting it over the LRIS monument itself.

CHAPTER 5

SEA TEST DESIGN

A test of the SEAHATS equipment was done aboard the Mary-O in St. Andrews, New Brunswick on 4 February 1984. The goal of this test was not to evaluate the accuracy, as for the land tests, but to judge the general operation of SEAHATS on a moving vessel.

Convenient LRIS control points were not available, so the remote stations were put on points, the coordinates of which were scaled from a hydrographic chart.

The R/T station was mounted on the mast of the Mary-O, and the rest of the SEAHATS equipment was mounted inside on a shelf. We succeeded in making it work. The power supply of the boat (120V) was good.

We ran along a survey line, but the disk output was lost. This is probably because we used the wrong commands at the end of the line--not 'CTRL Q' and 'Q'(uit)--due to inexperience (see Appendix 'A').

Except during the period November to May, when the St. John River is frozen, SEAHATS can be tested on the Mary-O in the same test area as this land test, east of the Princess Margaret Bridge. The same reference points can be used, namely "BRIDGE" and "318NEW". The test area could likely extend 1500 metres downriver (east) of the Princess Margaret Bridge.

In case of visibility problems with point "BRIDGE", point 242 could be used. This point is high on the bridge so it can be seen from far off. It may be better to survey a point on the east side of the bridge (242 is on the west side). The Mini-Ranger III transponder would have to be installed higher than the 90 cm high steel fence on the bridge. There will be a large slant-range error near the bridge, so program NAV should be modified first to correct for this.

The Mini-Ranger III manual [Motorola, 1980] gives the rule for the selection of the shore sites, in order to obtain a satisfactory position error (namely a maximum position standard deviation of 7.7 m). According to this rule, the intersection angle between the two ranges should be between 30^{o} and 150^{o}. See Figure 5.1. Only a very small part in the test area does not satisfy this rule. In the middle of the river, the intersection angle is around 125^{o} over the whole length. The best geometry is along the southern shore of the river.

A one-waypoint test has to be done. This is difficult to do on land. On a boat it is a problem to know precisely the coordinates of the centre point of the circle. There are no control points in the water. As the centre point, perhaps point 4369 could be used. Only a part of a circle could be run. Perhaps a tracking EDM instrument could be mounted over the centre point (4369) to provide reference ranges to the boat. If this is not possible, control positions for the boat would have to be determined from theodolite intersections, which will involve problems in synchronizing the timing of the observations.

SEATEST DESIGN

TEST AREA

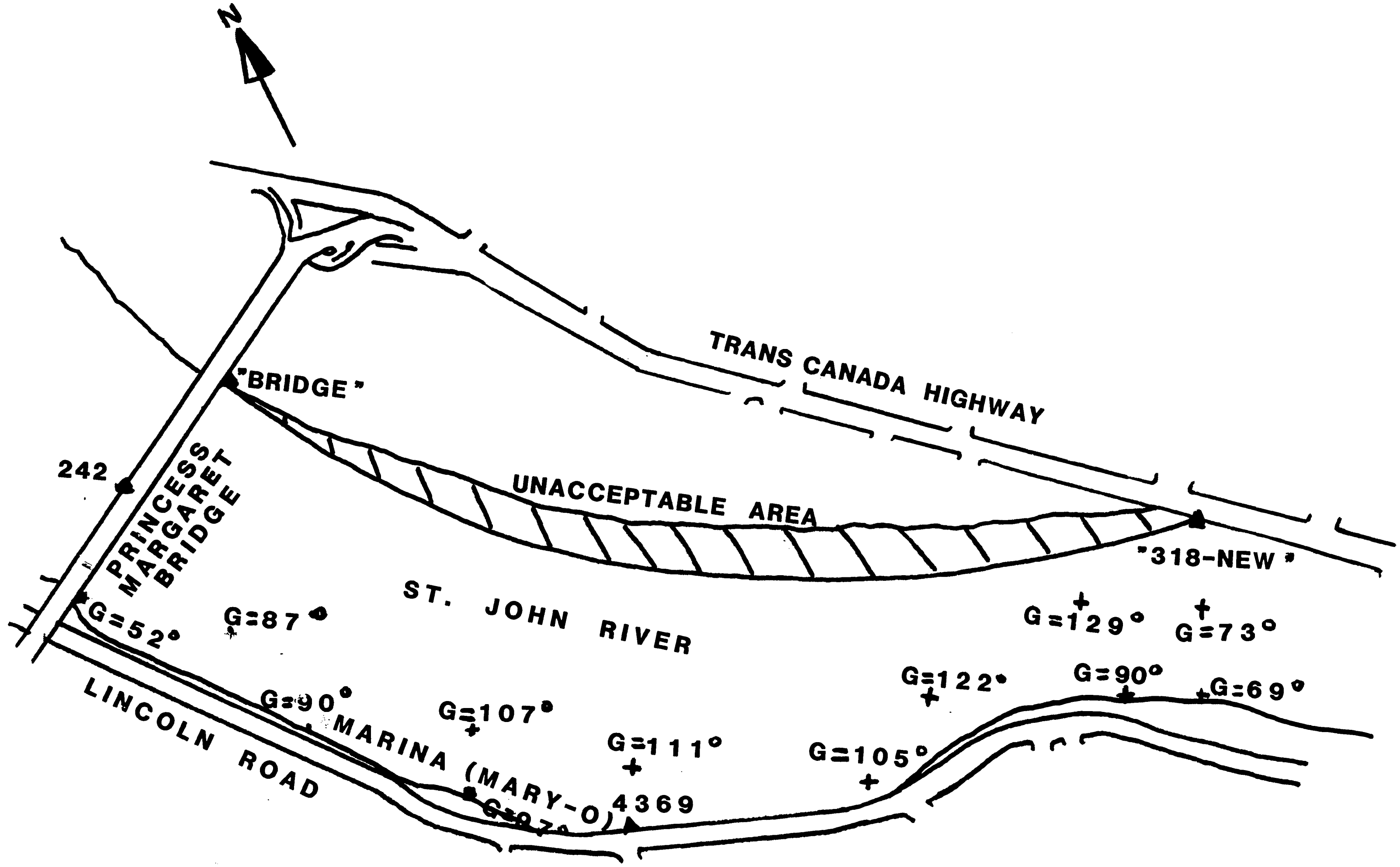

FIG 5.1

CHAPTER 6

CONCLUSIONS

After some problems the system was put to work and tested. Hopefully these problems are solved now and will not occur in the future. Some improvements in the software can be made. The system needs more testing with the Mini-Ranger III. Software should be written for the Hewlett-Packard computer of the Department of Surveying Engineering to simulate the Mini-Ranger III and PS-01, in order to speed up software development and testing.

Improvements which should be made in the software:

(1) The display should not scroll. Display of the records from the PS-01 and the spurious range readings should be omitted (except for a debugging mode). Only values of northing, easting, line-running values, and the arrows and asterisks should be displayed. Changes to any of these whenever a record from the PS-01 is taken would be easily seen. This display fits almost perfectly onto the 40 character screen. The only thing that does not fit is the rightmost column (/). This could easily be changed.

(2) It would be better if the XTD value (across track distance = amount of correction) were shown near the newest asterisks or the arrow, so the helmsman will see at a glance in what direction and how much he has to correct. Now he has to look for the XTD value between all the other values. This is especially important when there is a screen output every few seconds.

(3) When the van was run in reverse direction during the test (in the two waypoint mode, with the mobile unit at the end of line, enter in the

program that you want to do the same line in reverse direction) the OUT OF RANGE arrows were pointing in the wrong direction, namely <<<<<<<< instead of >>>>>>>>. This must be corrected.

(4) The input coordinates (of the shore stations), and all other input data should also be logged on the output diskette.

(5) The values entered for shore station coordinates, waypoints and data options should be entered into a file, so that they need not be re-entered every time.

(6) There are some spelling mistakes in the program:

in procedure number 26 LINEWIDTH:DISTANC - DISTANCE appears on screen
in procedure number 28 INITIALOLDRANGE VARIAABLE - VARIABLE just comment
in procedure number 29 APPROXCOORDS MAXIMIN - MAXIMUM appears on screen
in procedure number 33 INITDATA WAYPIONT - WAYPOINT
in procedure number 31 LISTDATAOPTIONS DISABELED - DISABLED
in procedure number 34 LISTOPTIONS WAYPIONT - WAYPOINT
in procedure number 35 CHECKRANG3 MAXIMIN - MAXIMUM
in procedure number 37 RECIEVE RECIEVE - RECEIVE several places in program.

(7) The program should calculate the initial coordinates of the vessel from the ranges measured by the Mini-Ranger III. At present the user has to enter them manually. This is difficult, because at sea it is not always easy to know the present coordinates of the vessel, particularly if the vessel is moving during or after the coordinates are entered. At present the vessel must be stationary at known coordinates while the program is started and initial data are entered. The program should calculate the coordinates automatically immediately before or after the start of the survey. Note that at present when the vessel is far from the survey line or circular path (more than 200 m), the initial position has to

be entered as a waypoint, and the two-waypoint mode can be used to navigate to waypoint 1 (for this part disk output is not necessary).

(8) The program is not very forgiving when you input a number in the wrong way. For example, when you input 260939,2 instead of 260939.2, the program will give the message

'INPUT INVALID DIGIT'

and there will be an arrow ---> at the beginning of the next line. However there is no way of correcting it. Whatever the next input is, there will be another arrow at the beginning of the next line. The only way out of this trap is to restart the input from the beginning.

(9) Now the fastest display update rate is around every four seconds. It is desireable to have the display updated as fast as possible. Hopefully the delay could be reduced to 2 seconds by changing the screen update method to modifying only the characters being updated in the screen memory map, rather than writing out a whole new screen each time.

There are no problems in using the PS-01 interface.

REFERENCES

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Motorola (1980). "User's manual, operation and installation instructions, Mini-Ranger III positioning system." Document 68-P03802R. 76 pages.

Nickerson, H.J. (1983). "Operation and technical manual for the PS-01 Radio Positioning/Echosounder Computer Interface." Final report for CADMI project 8302, Fredericton. 210 pages.

APPENDIX A

USER'S GUIDE

A.1 Connections

The system consists of an Apple computer, the PS-01 interface and a Mini-Ranger III positioning instrument.

The Apple computer is connected to two disk drives, which get their power from the computer and are used to read and write to the diskette containing the program, and the diskette containing the output files. The Apple is also connected to a monitor, which needs 120 VaC power. The Apple is connected to the PS-01 via a cable, a so-called RS-232-C, 25 pin D connector. The Apple and PS-01 need both 120 Volts AC, and their power cables have three wire plugs.

The PS-01 is connected with the Mini-Ranger III via three cables, so-called Amphenol Military connectors, which have to be inserted in the appropriate mating jacks on the rear of the Mini-Ranger III. Two cables are for channel A and B (CHA/CHB on the PS-01, CHANA-BCD J5 and CHAN B-BCD J4 on the Mini-Ranger III). However interchanging these cables gives no resulting errors in data collection. The third cable is for external control (EXT on the PS-01, EXT CONTROL J2 on the MR-III).

The connection between the PS-01 and the Skipper 802 echo sounder will be defined at a later date.

On the rear panel of the PS-01 are two RS-232 connectors A and B. The system will only work when the RS-232-C cable is connected to connector B.

The Mini-Ranger III consists of a range console, an R/T station, and two reference stations. The range console is connected with the R/T via a cable which also supplies power to the R/T. The range console receives its power from two 12 volt batteries. Take the three prong plug of the power cable and put alligator clamps on the two smaller cables inside the thick cable. The white cable is positive, the black cable is negative. Also each reference station gets its power from two 12 volt batteries. There are four connecting cables. The red cable is positive, the black is negative and the two green cables are the jumpers between the batteries. The Mini-Ranger III needs 20 minutes warm up before calibrating and operating.

The PS-01 manual [Nickerson, 1983, Chapter 3, page 1] says that for the PS-01 to function properly the front panel DISPLAY RATE control of the Mini-Ranger III must be fully counter-clockwise in the 'EXTERNAL' (EXT) position and that the channel code switches also must be in the 'EXTERNAL' position to allow remote selection. The PS-01 has been slightly changed so that the system will also work when the channel code switches are in the 'INTERNAL' (INT) position. However, in this case the range measurements will not be synchronized in time with the time tag assigned to them by the PS-01 clock.

A.2 Switch Settings

Before the PS-01 is connected to a power source, the serial interface should be configured using the dip switches internal to the chassis. To change the switch settings, lift the top cover after removing the four retaining screws. The switches are labelled 1 through 8 and must be set as follows:

<u>Baud Switches PS-01</u>

1	OFF)	
2	OFF)	baud rate = 1.2 k
3	OFF)	
4	ON)	
5	ON	1 stop bit
6	ON	7 data bits
7	OFF	even parity
8	OFF	enable parity

The baud rate must be 1200 because the NAV program now uses an assembler routine which requires this. For proper communication between the PS-01 and the Apple, the baud rate on the interface card inside the Apple computer must also be 1200. When they are both for example 9600, the PS01INIT file will work, but not the MINI file.

In order to set the switches on the RS-232 interface card in the right way, remove the cover of the Apple (power OFF). On the interface card you will see two rows of switches. The switches have to be set as follows ('0' corresponds to off and '1' to on).

<u>Baud Switches Apple</u>

<u>Row 1</u>

1	0)	
2	1)	
3	1)	baud rate 1200
4	1)	
5	1	
6	1	
7	1	

<u>Row 2</u>

1	1	one stop bit
2	0	seven data bits
3	0	even parity
4	0	even parity
5	0	do not generate line feeds
6	1	do forward interrupt
7	0	off for communications mode

Note that McCarthy [1983] states that SWITCH ROW 2 NR 6 is OFF ('0'). Actually it must be ON ('1').

Whenever there are doubts about the communication between the PS-01 and the Apple, check it in the following way:

Type twice 'CTRL RESET':

] appears on the screen

Type IN #2

Hold down the CTRL key and press the A key at the same time

Then APPLE SSC: appears

Type T T

Give any of the following commands: TM CM, ST, SD, SI, SA, SB, BY, EX, RQ, ZR, ID, IN

If there is a response, like '00=NO ERROR', or similar, the PS-01 has received commands given by the computer and the communication is alright.

If there is no response, something is wrong. Check, for example, that the baud-rate switch settings in both the PS-01 and the Apple are right.

A.3 Software

For the input of the program, see McCarthy [1983, Chapter 3, page 16]. Here are some remarks:

For the PS01INIT program the code filename is PS01INIT; for the NAV program the filename is MINI. They are both on one diskette, which has to be inserted in drive #4. The output diskette for the logged data must be inserted in drive #5. During the input, the program reads ranges twice, so the vessel must be at a spot where the Mini-Ranger III is able to measure ranges. The first range is read after the input of the shore station's coordinates, the second time after the input of the approximate coordinates.

Menus are used during manual data input. The sample interval should be chosen to be no less than 4 or 5 seconds, since this is the time needed for the program to read the record, do the calculations and update the display. After the input of the sample interval SI, the VIDEO RCVD indicator on the Mini-Ranger III will light every time a sample is taken.

In the data options menu, the program now also asks for the maximum speed of the vessel. If only one survey line is used, 0 can be entered for the SET LINE SPACING. When you enable disk output (answer 1 for ENABLE/DISABLE DISK OUTPUT), the program asks for the file name. Input

#5: FILENAME

(FILENAME can be any name, but different names have to be used for different files). The lamp on disk drive #5 will now come on. Every 20 records the accumulated data is logged from memory to diskette. The remaining records at the end of a line are logged when 'CTRL Q' is pressed. Each time data are logged, the disk lamp comes on. If you want an output of all calculated positions, answer 0 for INTERSTA LOGGING DISTANCE.

Immediately after the last question of the main menu is answered the Apple will take samples and the program starts running. So if you have entered the coordinates, etc., but you want to wait before starting the survey, just do not answer the last question. In the two-waypoint mode the last question is the waypoint number at the end of the line, and in the one-waypoint mode the centre point number of the circular path.

It is important when execution is stopped at the end of the line and you want to have disk output, never type 'CTRL RESET' (you lose your disk output), and never remove the diskette (no end of file is written, so it is not possible to read to diskette later). You must first type 'CTRL Q' (hold down the 'CTRL' key and type 'Q'). At this point the buffer will be written to diskette. Then type 'Q' (quit). Also if you want to stop execution in the middle of a line, type 'CTRL Q'.

APPENDIX B

OBSERVATIONS AND CALCULATIONS IN SURVEYING POINTS "BRIDGE" AND "318NEW"

For the angle measurements, a Wild T2 theodolite was used. For distance measurements, an AGA was used. The measurements were made 5 November 1983. The new points were observed from points 4168 and 4142.

B.1 Observed Distances

From		To BRIDGE	To 318NEW
4168		987.779	2200.893
		.782	.896
		.779	.890
	Mean	987.780	2200.893
4142		1726.964	1343.471
		.964	.472
		.965	.472
	Mean	1726.964	1343.472

B.2 Observed Horizontal Angles

From	To	I	II	Average (I,II)	Reduced angles
4168	BRIDGE	354-11-55.6	174-12-12.2	354-12-03.9	000-00-00.0
	318NEW	87-59-20.1	267-59-35.3	87-59-27.7	93-47-23.6
	4167	133-27-58.2	313-28-11.7	133-28-05.0	139-16-00.9
	BRIDGE	354-11-53.3	174-12-15.2	354-12-04.3	
		Mean for BRIDGE		354-12-04.1	
4142	BRIDGE	000-47-47	180-47-37	000-47-42	000-00-00.0
	318NEW	107-19-03	287-18-45	107-18-54	106-31-12.2
	4145	125-06-30.5	305-06-18.5	125-06-24.5	124-18-42.7
	BRIDGE	000-47-46	180-47-37	000-47-41.5	
		Mean for BRIDGE		000-47-41.8	

B.3 Observed Vertical Angles

From	To	I	II	Average (I,II)
4168	BRIDGE	90-23-50	269-35-17	90-24-16.5
	318NEW	90-01-13	269-58-15	90-01-29
4142	BRIDGE	90-09-47	269-49-43	90-10-02
	318NEW	89-56-25	270-02-58	89-56-43.5

B.4 Reduction of Distances

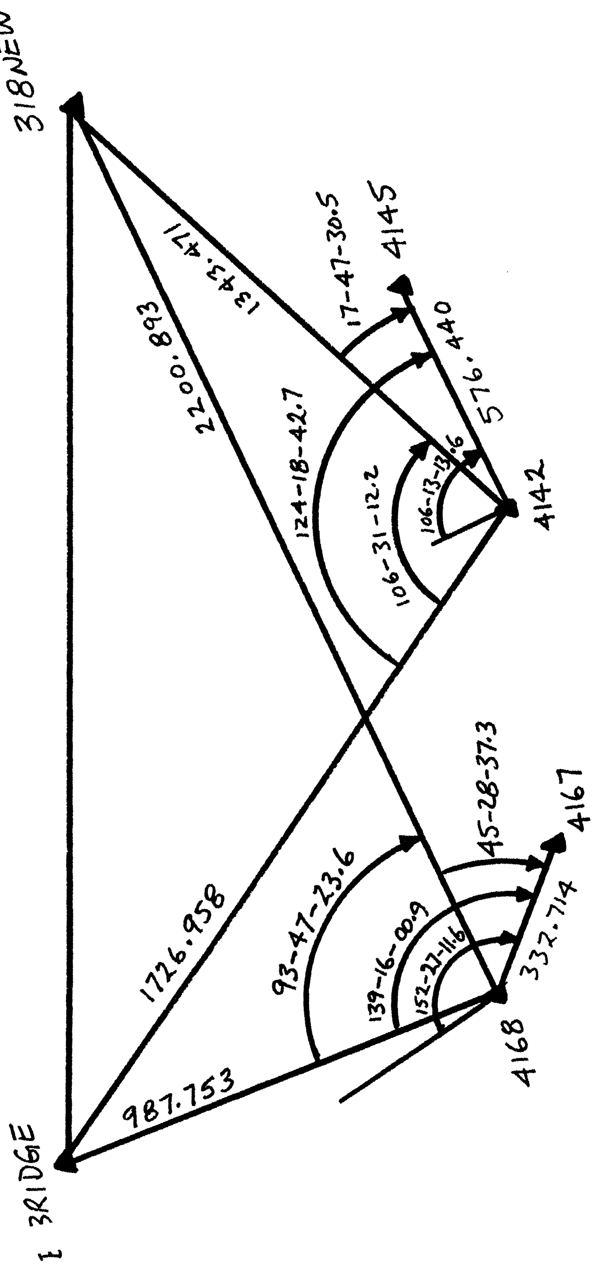
From	To	Measured	EDM Height	Target Height	Zenith angle	dh	Horizontal Distance
4168	BRIDGE	987.780	1.415	1.185	90-24-16.5	-7.31	987.753
	318NEW	2200.893	1.415	1.185	90-01-29	-1.02	2200.893
4142	BRIDGE	1726.964	1.360	1.185	90-10-02	-4.66	1726.958
	318NEW	1343.472	1.360	1.185	89-56-43	+1.58	1343.471

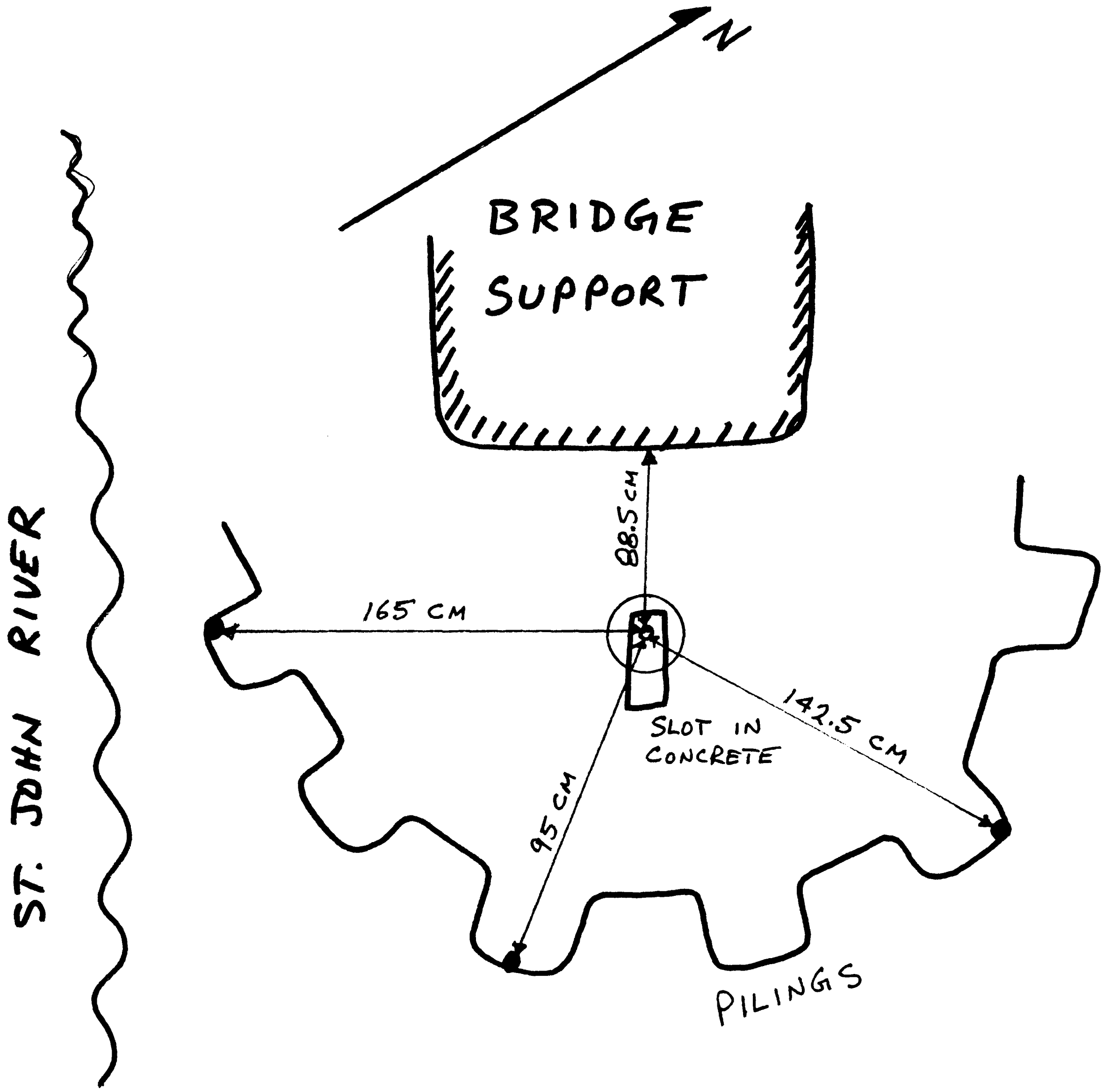
B.5 Known Coordinates

Point	Easting	Northing
4168	290307.050	737053.563
4167	290460.921	736758.568
4142	291069.007	736373.952
4145	291622.501	736212.933

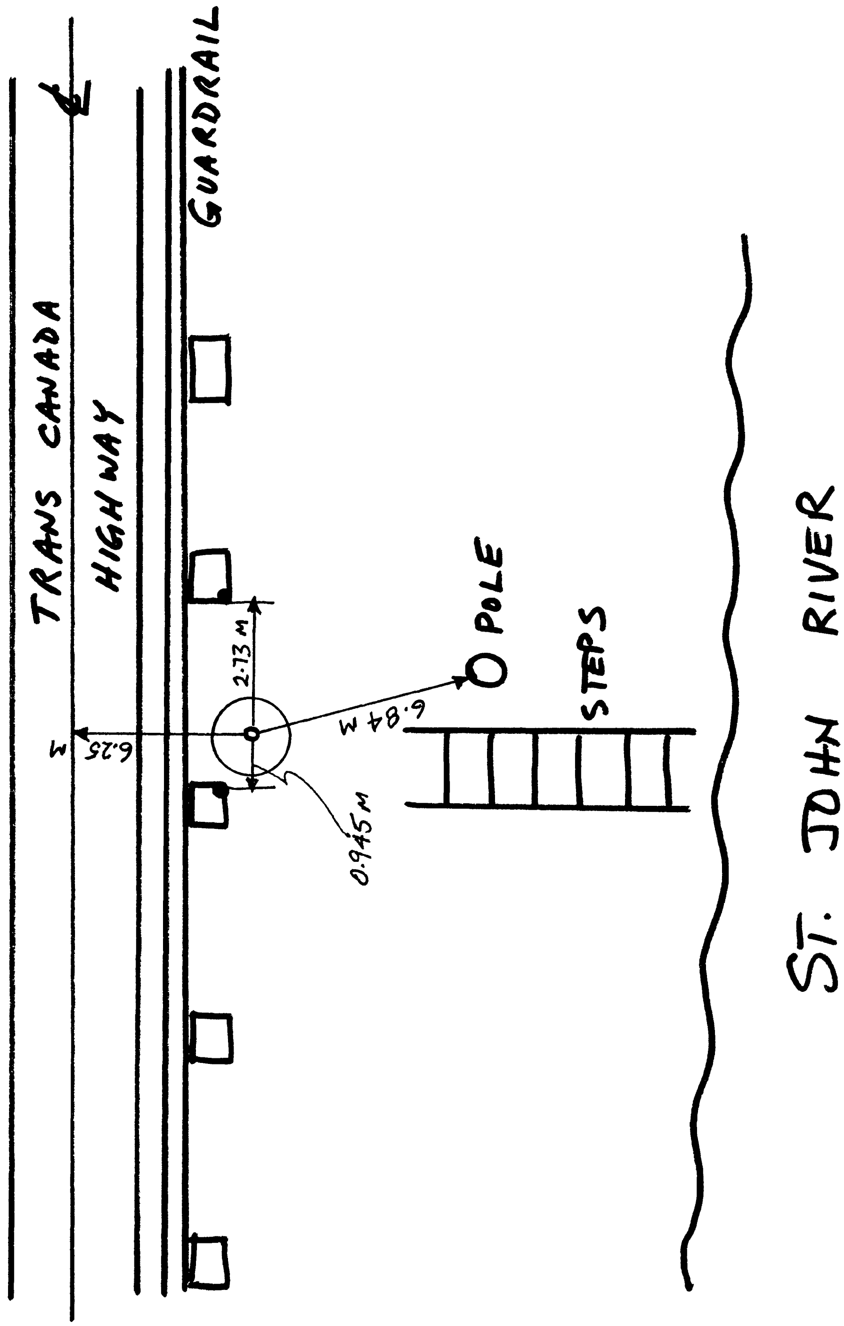
B.6 Calculated Coordinates

BRIDGE	290532.551	738015.403
318NEW	292412.007	736410.876


318NEW
4145
17-47-30.5
1343.471
2200.893
576.440
124-18-42.7
106-31-12.2
106-13-13.6
4142
1726.958
93-47-23.6
45-28-37.3
4167
139-16-00.9
152-27-11.6
332.714
4168
987.753
3RIDGE



SKETCH OF
STATION
"BRIDGE"



SKETCH OF
STATION
"318 NEW"