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HOLBROOK COVE SURVEY

A 1972 Student Summer Ocean Engineering Laboratory
Research Project

Massachusetts Institute of Technology

Cambridge, Massachusetts 02139

Report No. MITSG 72-19
Date: December 31, 1972

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Administrative Statement

A fundamental educational experience for undergraduate students of Ocean Engineering is the opportunity to design, construct and operate equipment in the marine environment in a coordinated attack upon some real-world problem. This is the primary objective of the Holbrook Cove Survey. The research objective is to gain a better understanding of the hydraulics and ecology of this small cove and to determine what effect the effluent that a mining operation discharges into this relatively confined estuary may have upon its ecological community. This is one of the projects of the 1972 Summer Ocean Engineering Laboratory.

A companion report, "The Search for DEFENCE and Other Projects of Students During the 1972 Summer Ocean Engineering Laboratory," (MITSG 72-20), describes the other Ocean Engineering projects undertaken by the students.

Funding for the 1972 Summer Ocean Engineering Laboratory was provided by:

The National Sea Grant Program, Grant No. 2-35150
The Henry L. and Grace Doherty Charitable Foundation, Inc.
The St. Anthony Foundation
The M.I.T. Undergraduate Research Opportunities Program
The M.I.T. Information Processing Board
The M.I.T. Freshman Advisory Council
The Maine Maritime Academy
The Massachusetts Institute of Technology

Alfred A. H. Keil
Director

December 1972

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The Maine Maritime Academy
The Massachusetts Institute of Technology

Equipment that was made available to the project at no cost included:

Equipment	Donor
Instruments for heavy metal analysis	Dr. Frank Aldrich and Mr. George Boylen, M.I.T. Environmental Medical Service
Polagraphic oxygen electrode	Dr. Frank Carey, Woods Hole Oceanographic Institution
Mechanical bathythermograph and Nansen bottle	Dr. Sloat Hodgson, Woods Hole Oceanographic Institution
Laboratory space and instrumentation for chlorophyll and heavy metal analysis	Professor Stephen Moore, M.I.T. Department of Civil Engineering
Research Vessel LOBSTER	Professor Damon E. Cummings, M.I.T. Department of Ocean Engineering
Various electronic components	SIGNETICS, Inc.

The individuals who donated their time to the projects without compensation include:

Individual	Organization
Professor A. D. Carmichael	M.I.T.
Professor Damon E. Cummings	M.I.T.
Professor Ira Dyer	M.I.T.
Mr. Herman Kunz	Searle Consultants
Professor Dean Mayhew	Maine Maritime Academy
CAPT Willard F. Searle, USN (Ret)	Searle Consultants

Miss Anita Harris permitted the use of her properties and facilities on Holbrook Island without which the Holbrook Cove Survey would have been impossible.

The list of faculty and staff at both the Maine Maritime Academy and the Massachusetts Institute of Technology who contributed to the success of the 1972 Summer Ocean Engineering Laboratory would be lengthy and nearly impossible to compile without inadvertent omissions, so to these individuals the participants express their sincere appreciation.

1972 Summer Ocean Engineering Laboratory

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1.0 INTRODUCTION

This report is the first of two volumes concerning the accomplishments of the 1972 M.I.T./Maine Maritime Academy Sea Grant Summer Ocean Engineering Laboratory. It describes the investigations students conducted in an oceanographic and biological survey of Holbrook Cove in July 1972. The second report deals with their successful search for the remains of a Revolutionary War privateer, the design and construction of equipment for use in future Summer Ocean Engineering Laboratories, and other activities.

The Summer Ocean Engineering Laboratory provides undergraduate ocean engineering students an opportunity to combine theory and practice when they design simple equipment and test and operate this equipment in the real environment for which the students must prepare themselves.

We selected two major projects in which all the students' equipment could be utilized in coordinated efforts; thus each student had an opportunity to contribute useful results to a real-world ocean engineering project. These two major projects are a comprehensive survey of Holbrook Cove and a systematic search for the remains of American Revolutionary War ship hulks.

For the students, the Summer Laboratory demonstrated that there is more to ocean engineering than just conceptual design and theoretical analysis. They dealt first-hand with Murphy's Law. They experienced the rigors of the marine environment, including the limitations of weather, the swift devastation of corrosion, and the exacting demands of hydrostatics.

Their benefits, judging from the students' post-Summer Lab interests and activities, include: a better perspective of their academic experiences; an enhanced appreciation for the relevance of the various elements that comprise an ocean engineering curriculum; an intensified curiosity directed toward unfamiliar facets of ocean engineering; and, in some cases, an inspiration for a special project or thesis.

In the report of the 1971 Summer Ocean Engineering Laboratory we stated:

The opinion of all who were involved with this project, students and faculty of both M.I.T. and Maine Maritime Academy, visiting faculty, and consultants, was that this program served an educational purpose that is essential early in the students' Ocean Engineering education. All hands were exposed to the myriad of problems encountered in attempting to apply theory and classroom experience to equipment and procedures that must work at sea without the enormous expense and pressure of full-scale industrial or government projects. The usual mistakes were made in an environment where they could be dealt with without cost or loss of essential data and the lessons were learned.

Our experience during this second Summer Ocean Engineering Laboratory reinforces our faith in the value of this educational experience.

2.0 SUMMARY

2.1 Objective

The objective of the Holbrook Cove Survey is to gain an understanding of its hydraulics and ecology in order to ascertain the effect which the effluent from the Callahan mine outfall has upon the Cove.

Holbrook Cove is located approximately one-half mile southwest of Castine, Maine, and appears on U.S. Coast & Geodetic Survey Chart number 311, as well as the Department of Interior/ Department of the Army topographical map of Castine, Maine.

2.2 Background

This project permitted the M.I.T. and Maine Maritime Academy students to design, construct and utilize individual equipment and employ them in the marine environment in a coordinated attack upon a real problem. It had come to the attention of those participating in the 1972 Summer Ocean Engineering Laboratory that heavy metal pollution is a problem in the coastal areas of Maine and that a relatively new mining operation had opened in Holbrook Cove. It is deemed possible that the effluent from the outfall of this mining operation has a profound effect upon the ecology. The following research projects were planned and coordinated to study this problem.

PROJECT	STUDENT PARTICIPANTS
Tidal Current Streamlines and Velocity	Cebelius, Kennedy and Lukens
Temperature and Salinity	Murphy
Chlorophyll 'A' Content	Chertow
Benthic Infauna Distribution	Dwyer, Lee, Seo
Tidal Height Fluctuations	Barnes
Detailed Bottom Topography	Cameron, Cianchette and Sautter
Bottom Soil Structure	Barriault
Water Oxygen Content	Murphy

2.3 Results

The results of the individual projects are as follows:

Project	Results
Tidal Currents	Streamlines at various tidal phases have been established. Current velocities have been calculated. Current velocities have been measured on a real-time basis at the northwestern and southern entrances to the Cove. Fluctuations indicate a seiche in the Cove has a profound effect upon the velocity at any given time.
Temperature and Salinity	These measurements were made. The results are contained in Tables 5.1, 5.2 and 5.3.
Chlorophyll 'A' content	These measurements were made. The results are contained in Figures 5.3, 5.4 and 5.5 and Tables 5.1, 5.2 and 5.3.
Benthic Infauna Distribution	Still being analyzed. Initial trends indicate that the biomass and numbers of individuals are at a minimum at the sampling station nearest the outfall. This may indicate that the effluent has an adverse effect on the biota.
Tidal Height Fluctuations	A tide gauge has been built and tested, but the scribe mechanism and the magnitude of frictional forces did not permit the gauge to give useful results.
Detailed Bottom Topography	A nomogram was prepared to permit the soundings to be related to the MLLW datum. In testing the nomogram against observed tidal heights at Castine, it was noted that the scope of tide appears to be about one foot greater than indicated in the tide tables. Time precluded the detailed sounding program execution.

Project	Results
Bottom Soil Structure	A corer and release mechanism were designed and built. During the first *in situ* test the messenger line used for retrieval was severed and the unit could not be relocated for recovery.
Oxygen Content of Cove Water	An oxygen meter was designed and constructed for use with an oxygen probe borrowed from the Woods Hole Oceanographic Institution. Time precluded calibration. No measurements of oxygen content of Cove water were made.

2.4 Conclusions

It is apparent that the educational objectives of this project were met. All of the rigors of the marine environment were apparent from the restrictions of weather to the effects of corrosion. The constraints of time demonstrated that careful planning is necessary if this priceless commodity is to be conserved and that, if it is not conserved, the entire effort up to the deadline may end in frustration. The loss of the corer dramatically demonstrated the need for failure analysis and provision of safeguards to handle those failures which may occur if an entire project is not to be jeopardized by some malfunction. Finally, the students received practical training in boat handling, safety at sea, navigation and the discipline these activities imply.

The research objectives were partially met. The results of the investigations into the hydraulics of the Cove indicate that there may be a seiche that significantly affects the current velocity magnitudes. Sampling of data at thirty-minute intervals does not give a meaningful result in this instance since the sampling intervals must be less than half the period of the seiche to obtain a meaningful real-time result. The gross flow patterns in the Cove have been defined particularly in the vicinity of the three entrances. Finally, the results suggest that the variation of current velocity with respect to depth is significant and should be investigated.

The results of the temperature and salinity survey reveal no anomalies in the absence of flow from the mine outfall.

The chlorophyll 'A' measurements do not suggest any effect upon chlorophyll 'A' distributions in the vicinity of mine outfall. In the absence of a constant effluent flow, none would be expected.

The preliminary results in the study of the benthic infauna distribution suggest that there is a detectable adverse effect upon the ecology in the vicinity of the mine outfall.

2.5 Recommendations

The Holbrook Cove Survey is incomplete as of this writing. From the research point of view, there is still a great deal to be learned in this relatively small geographical area. A better and more complete survey could and should be conducted, taking advantage of the lessons and mistakes of the 1972 effort. Certainly, the equipment not used in the 1972 survey should be employed to complete those research objectives not carried out in this effort because of the limitations of time.

A determination of the period and magnitude of the seiche in Holbrook Cove and its effect upon the flow patterns is a very intriguing project and the most effective means appears to be through the use of current meters. A second study which suggests itself is the determination of the variation of current with respect to depth. Both of these projects would be enhanced by the design and construction of a device that will establish current direction for use with the current magnitudes as measured by the current meters.

If the Callahan mine outfall is discharging effluent, a repetition of the study of the chlorophyll 'A' distribution seems indicated. Perfection of a method to measure the concentration of heavy metal ions to correlate with the clorophyll 'A' patterns is highly desirable.

From the educational viewpoint, the efforts in surveying the Cove are ideal. The project is of necessity interdisciplinary and careful coordination is required if the results are to be meaningful. This coordination imposes the discipline of scheduling, which is one of the very real constraints not adequately imposed by any other form of educational experience. It is therefore recommended that the survey effort be considered for future Summer Ocean Engineering Laboratory projects.

3.0 DETERMINATION OF THE CURRENT PATTERNS IN HOLBROOK COVE

3.1 Objective

This project has as its objective the determination of the current velocities and streamlines in the Holbrook Cove estuary as a function of time and tide. Data were obtained by the use of drogue buoys (see Figure 3.1). By recording the geographical position of each buoy and the associated time, velocities and positions have been calculated.

Figure 3.1

Drogue Buoys

3.2 Procedure

Measurement of buoy positions and the related times were made at various locations in the Cove over the complete spectrum of tide states. Although it was originally planned to cover the entire area of the Cove, limitations of time forced the project to select those areas which appeared to be most crucial to the understanding of the Cove's current patterns, and concentrate the data-gathering efforts only in those areas.

Geographical measurements of buoy positions were made by establishing a baseline between two transits and recording both its length and line of bearing. Using the transits at the ends of the baseline, simultaneous measurements of the relative angle between the baseline and the line of sight from each transit to a buoy were made and recorded. The units of measure employed were:

Directions and angles--degrees and minutes
Baseline length--meters
Time--hours, minutes and seconds

3.3 Limitations of Accuracy

Factors affecting data accuracy were both natural and mechanical. The natural factor that was of concern was the effect of the wind upon the paths and velocities of the buoys. Wind velocities in excess of two knots were considered to measurably affect data accuracy, and wind velocities in excess of five knots were considered unacceptable. In reducing the data, all measurements taken in conditions involving wind velocities in excess of two knots were discarded. In reducing the data, it appears that there may be some measurable wind effect at velocities of one to two knots. This fact led the team to concentrate the data-gathering effort into the very early morning hours in which there is generally no measurable wind.

Mechanical factors affecting the accuracy of the data were the limitations equipment imposed upon the measurements of the baseline lengths, line-of-sight angles with respect to the baseline and the times of each measurement. The end positions of the baselines were established by locating them on a chart of the estuary with respect to landmarks depicted thereon. Lengths of the baselines were determined by first calculating the length by means of triangulation and then measuring the distance between the two end positions as located on the Coast and Geodetic Survey Charts. Table 3.1 contains a comparison of the length of the baselines as determined by triangulation and by measurement from the Coast and Geodetic Survey Charts.

It is estimated that the line-of-sight angles with respect to baseline were measured with limits of accuracy of about $\pm$one-half degree of arc. Time was measured to the nearest tenth of a minute (six seconds).

Table 3.1

COMPARISON OF LENGTH OF BASELINES AS DETERMINED BY TRIANGULATION AND MEASUREMENT (CGS CHARTS)

BASELINE	LENGTH MEASURED FROM CHART	LENGTH MEASURED BY TRIANGULATION
015/195	823	950
026/206	311	321
108/288	347	368
122/302	293	246
146/326	329	333
174/354	466	397

3.4 Data Reduction

The large volume of data collected made the use of a computer highly desirable. The quality of the data was carefully examined and several series of observations were disregarded because they appeared to have been severely affected by wind. The remainder of the data was then sorted first by utilizing a computer program to calculate buoy velocities and then discarding all inconsistent observations. For example, if a buoy's velocity changed drastically between observations and then appeared to return on succeeding observations to values consistent with earlier observations and the buoy's position was inconsistent with those established by preceding and succeeding observations, the data corresponding to the nonconforming observation was discarded. This procedure was adopted after it was noted that the paths of the buoys were linear or involved only slight degrees of curvature, except for a very few instances in which buoys came under the influence of a vortex. In those instances, only the most erratic cases were disregarded.

The data reduction required solutions of two equations of the form:

$P_n = f(x,y)$

$V_n = g(P_n, P_{(n-1)}, \Delta T)$

where

P_n and $P_{(n-1)}$ are buoy positions at times n and (n-1) respectively;

f and g are functions involving the parameters contained within the parentheses which follow them;

x and y are orthogonal coordinates in a two-dimensional grid system with the x coordinate measured parallel to the observation baseline;

ΔT is the time interval between the observations establishing the positions P_n and $P_{(n-1)}$.

In order to define the positions of the buoys in terms of the coordinate system, x and y, using the baseline as the base of a triangle and the lines of sight from the ends of the baseline to the buoy as its other two legs, the computer was utilized. The known quantities are the length of the baseline and the two included angles between the lines of sight and the baseline. Establishing one end of the baseline as the origin of the coordinate system, the calculation of the orthogonal projection of the leg formed by the line of sight from that end of the baseline to the buoy defines the x coordinate. The calculation of the altitude of the vertex, formed by the intersection of the two lines of sight, with respect to the baseline defines the y coordinate. The computer was programmed to calculate the x and y coordinates using the law of sines. No attempt was made to utilize a single coordinate system for the entire estuary, but rather a different one was used for each baseline. If desired, a set of transformation equations could have been derived, but it would have unnecessarily complicated the problem. Streamlines were represented graphically on a chart of the Cove.
As a matter of expediency two Fortran IV programs were written. The first calculated the x and y coordinates and the velocities punching the calculated data onto cards which served as data

for the second program. The latter program plotted the streamlines on a mechanical plotter. These streamlines were then positioned on a chart of the Cove and a reproduction made from the result.

A listing of each of the two programs is found in Appendix A. A description of the first program is also included in the appendix, but, since the second program merely reads Cartesian coordinates and calls an IBM-supplied plotting subroutine, no description seems to be required.

3.5 Results

Figure 3.2 is a reproduction of the chart of Holbrook Cove showing its major physical features and the surrounding landmarks. The features which appear to have the greatest effect upon the flow patterns of the Cove are three entrances: the sandbar (northern entrance), the Nautilus Rock Channel (northwestern entrance) and the Goose Falls Channel (southern entrance) The sandbar is submerged from zero to eight feet, varying from three hours before high tide to three hours after high tide. Since the drogue buoys used in this project required at least five feet of water depth, little data was obtained in the vicinity of the sandbar. It should be noted that all times in the figures which follow are recorded in hours and minutes from the High or Low tide. The times of High and Low tide were calculated based upon the U.S. Department of Commerce Tide Tables using the correction factors for Castine, Maine (see Appendix B)

The data have been grouped into six time periods, each corresponding to approximately a two-hour phase in the Tidal Cycle. The names and approximate time limits of each phase are contained in Table 3.2.

Figures 3.3 and 3.4 contain the streamlines and flow velocities. Tables 3.3 through 3.8 list the dates of the observations, initial and final observation times (recorded with respec to the hours and minutes before or after the high/low tide) and the baseline from which the observations were made. The baselines are identified in Figure 3.2.

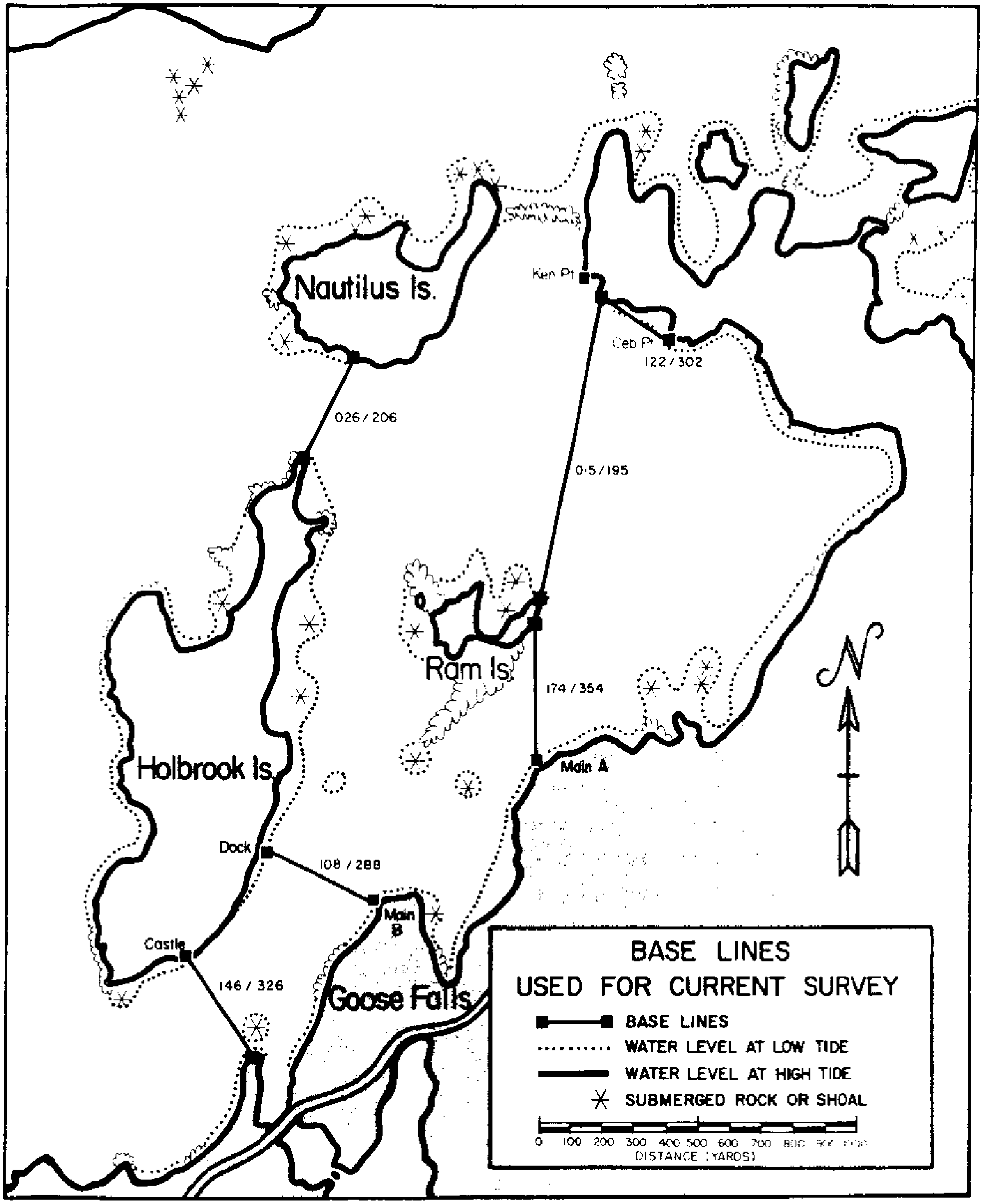


Figure 3.2

Holbrook Cove

Table 3.2

NAME AND APPROXIMATE TIME BOUNDARIES OF TIDAL PHASES

NAME	BEGINNING	END
Pre-High Phase	3 hours before high tide	1 hour before high tide
High Phase	1 hour before high tide	1 hour after high tide
Post-High Phase	1 hour after high tide	3 hours after high tide
Pre-Low Phase	3 hours before low tide	1 hour before low tide
Low Phase	1 hour before low tide	1 hour after low tide
Post-Low Phase	1 hour after low tide	3 hours after low tide

3.6 Conclusions

The streamline and velocity charts for the pre-high phase (Figures 3.3 and 3.4) reveal that buoy direction reversals begin with those buoys located closest to the southern entrance. The tidal flows appear to initiate approximately 45 minutes earlier at the southern end than at the northern end of the Cove. There appears to be a tidal phase gradient in the area of the Cove bounded by the southern entrance and by Ram Island. The streamline chart (Figure 3.3) for the pre-low phase indicates slack water about one hour before the predicted low tide at Castine, Maine. The velocity chart (Figure 3.4) for the low phase indicates rather high velocities at the times of predicted slack water at Castine, Maine. It is noted that buoy velocities appear to decrease as they approach Ram Island.

The basin north of Ram Island can be pictured as a large tank with four inlets/outlets (one of which is open for about three hours before and after high tide). The currents through the northwestern and southern entrances to the Cove in post-low and pre-high phases are in opposition in the shallow channel west of Ram Island. The current from the southern entrance is predominant and forces water back toward the northwestern entrance.

As the current in the southern entrance begins to shift from flood to ebb, water continues to fill the basin. By the time the current at the northern entrance (the sandbar) begins

Table 3.3

TIDE PHASE: PRE-HIGH

DATE	BUOY	TIME START	TIME END	OBSERVATION BASELINE
7/25	F3R	-3:00	-2:29	026/206
7/25	F4R	-2:10	-1:07	026/206
7/25	F3O	-3:56	+0:36	026/206
7/19	K3B	-5:05	-3:36	108/288
7/19	K2RB	-5:00	-3:04	108/288
7/19	K3RB	-2:41	-1:48	108/288
7/19	K3R	-2:43	-1:55	108/288
7/19	K3W	-2:42	-1:48	108/288
7/19	K3WG	-2:39	-1:50	108/288
7/25	E3W	-1:53	+0:08	146/326
7/26	C2R	-2:22	-1:54	108/288
7/26	C3W	-3:03	-2:25	108/288
7/26	C2B	-4:10	-2:55	108/288
7/26	C3B	-2:30	-2:20	108/288
7/26	D2O	-2:08	-1:21	174/354
7/26	D2R	-3:19	-2:58	174/354
7/25	E3Y	-2:40	-2:12	146/326
7/25	E4Y	-1:54	-0:50	146/326
7/25	E3RB	-2:35	-2:09	146/326
7/25	E2W	-2:41	-2:14	146/326
7/25	F3B	-3:35	-3:00	026/206

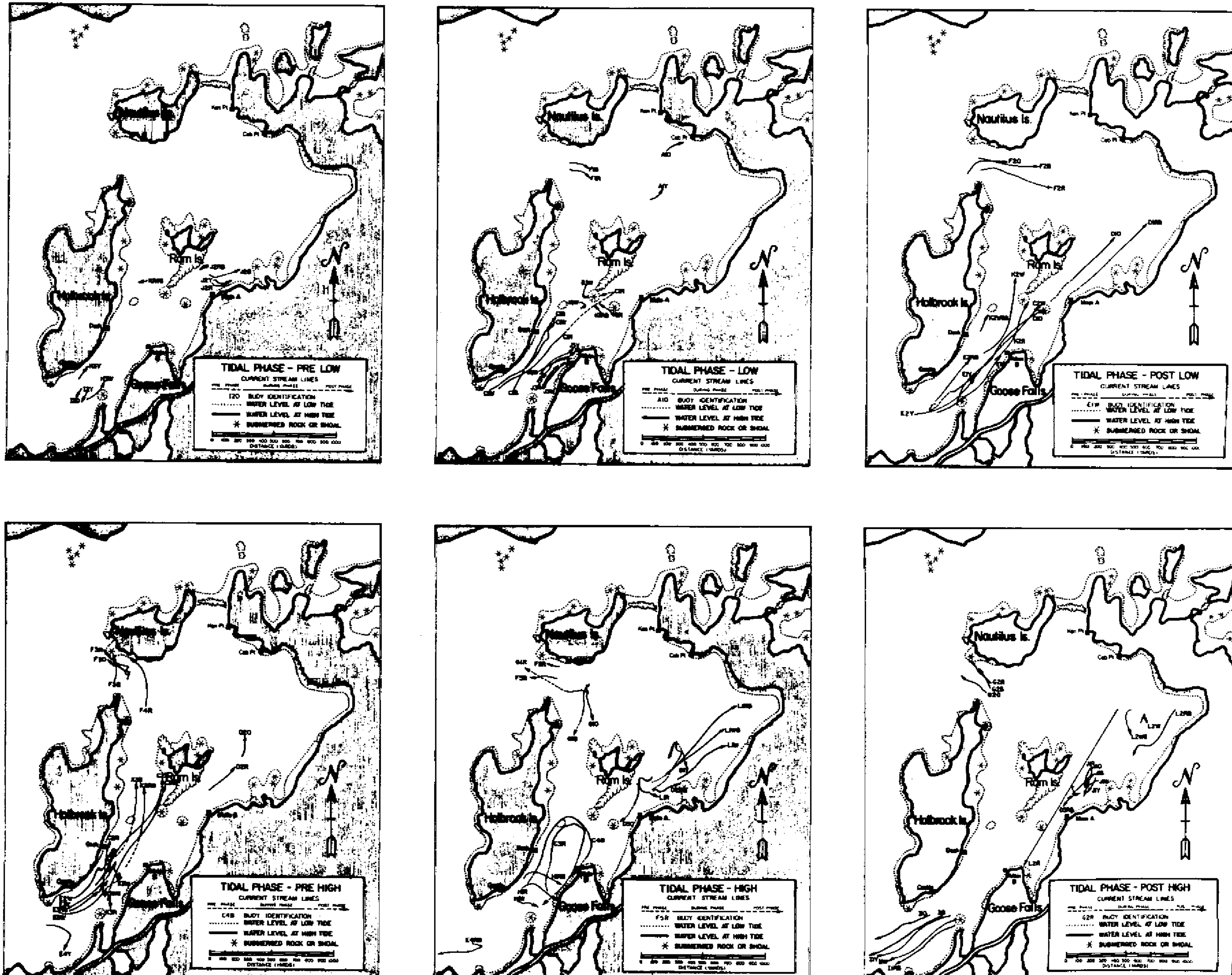


Figure 3.3 Pre-High, High and Post-High Streamlines and Current Velocities

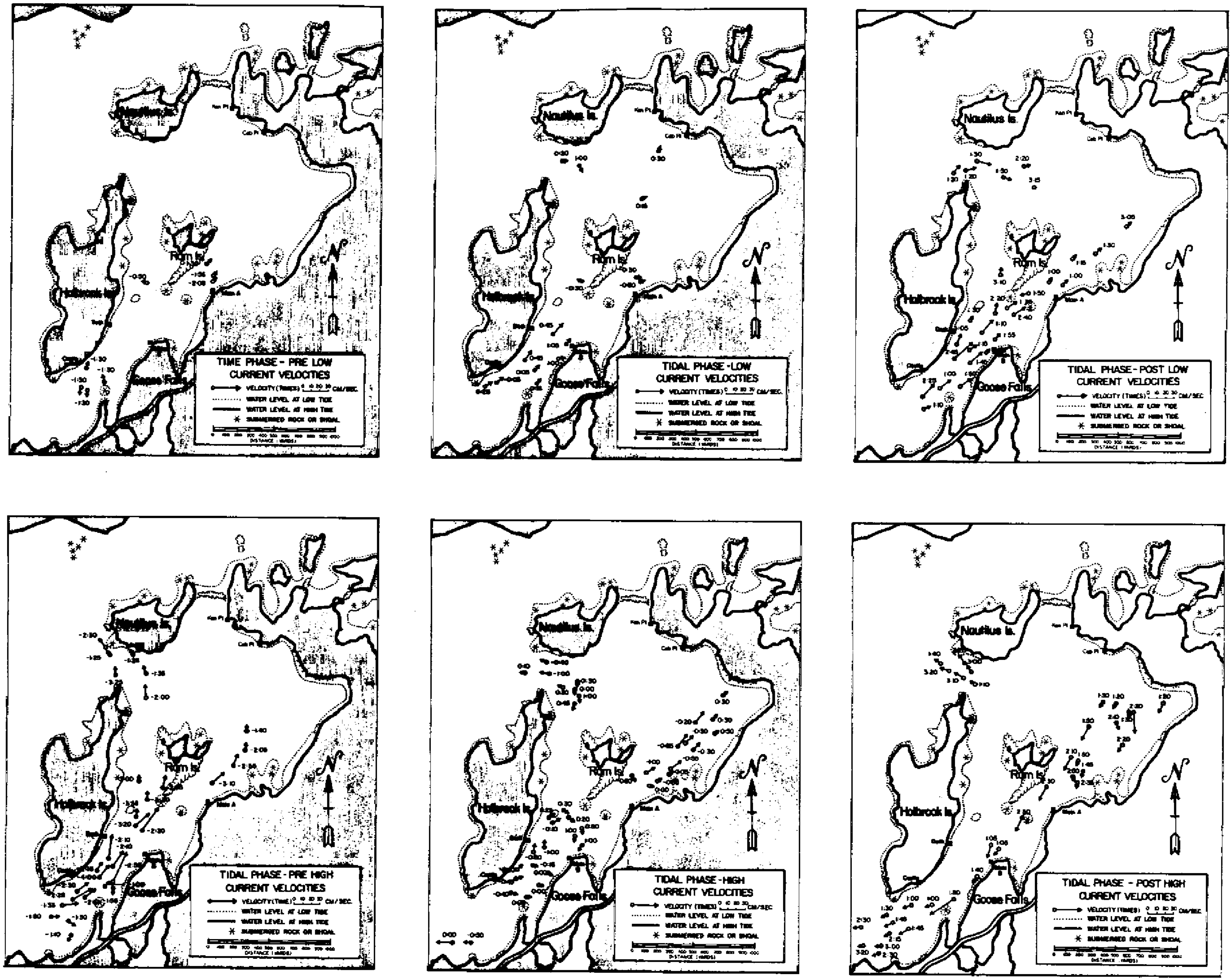


Figure 3.4 Pre-Low, Low and Post-Low Streamlines and Current Velocities

Table 3.4

TIDE PHASE: HIGH

DATE	BUOY	TIME START	TIME END	OBSERVATION BASELINE
7/26	D1Y	-2:06	+2:03	174/354
7/26	D3O	-0:59	+1:57	174/354
7/26	D2RB	-1:00	+0:41	174/354
7/26	C3R	-1:31	+1:40	108/288
7/26	C4B	-1:56	+1:50	108/288
7/24	G1O	-0:04	+1:45	015/195
7/24	G1R	-0:06	+1:42	015/195
7/25	F5B	-1:03	+0:35	026/206
7/25	F5R	-0:59	+0:37	026/206
7/24	G1B	-0:04	+1:38	015/195
7/24	H1W	-0:42	+0:22	146/326
7/24	H1RB	-0:45	+0:25	146/326
7/11	L1R	-1:03	+0:25	122/302
7/11	L1W	-1:04	+0:27	122/302
7/11	L1WG	-1:06	+0:30	122/302
7/11	L1RB	-1:05	+0:31	122/302

to ebb, the basin has begun to empty. The current through the northern entrance (the sandbar) begins to flow into the basin and the currents through the outlets formed by the northwestern entrance and the channels east and west of Ram Island flow out of the basin. When the water level falls below the sandbar in the northern entrance, blocking flow, the currents through the remaining three outlets continue to flow out of the basin until the next current reversal at low tide.

3.7 Recommendations

The use of buoys and transits is subject to many limitations. First and foremost is the restriction on their use to periods of

Table 3.5

TIDE PHASE: POST HIGH

DATE	BUOY	TIME START	TIME END	OBSERVATION BASELINE
7/23	I1RB	+0:51	+2:32	015/195
7/23	I1W	+0:52	+2:32	015/195
7/23	I1B	+1:00	+2:34	015/195
7/23	I1O	+0:57	+2:31	015/195
7/24	G2O	+2:54	+3:22	015/195
7/24	G2R	+2:53	+3:21	015/195
7/24	G2B	+2:56	+3:20	015/195
7/24	H2RB	+1:17	+3:12	146/326
7/24	H2Y	+1:16	+3:13	146/326
7/24	H2W	+1:20	+3:09	146/326
7/8	M1RB	+2:07	+2:42	122/302
7/8	M2RB	+3:12	+3:44	122/302
7/11	L2R	+1:26	+3:17	174/354
7/11	L2WG	+1:20	+2:20	174/354
7/11	L2W	+1:21	+2:21	174/354
7/22	J1W	+1:45	+2:51	108/288
7/11	L2RB	+1:20	+2:20	174/354
7/22	J2R	+1:43	+2:49	108/288
7/22	J1B	+1:44	+2:50	108/288
7/22	J1Y	+1:44	+2:36	108/288
7/22	J1O	+1:57	+5:26	108/288
7/26	D3RB	+1:08	+1:55	174/354
7/23	I1Y	+0:53	+3:20	015/195

Table 3.6

TIDE PHASE: PRE-LOW

DATE	BUOY	TIME START	TIME END	OBSERVATION BASELINE
7/22	J2Y	-2:27	-0:15	108/288
7/22	J2R	-2:30	-0:52	108/288
7/22	J2B	-2:32	-0:27	108/288
7/22	J2RB	-2:33	-0:42	108/288
7/24	H3Y	-2:09	-1:25	146/326
7/24	H3W	-2:14	-1:26	146/326
7/23	I2Y	-1:43	-1:23	015/195
7/23	I2O	-1:41	-1:22	015/195
7/19	K1WG	-1:19	-0:31	108/288

little or no wind. This severely limits the time available for gathering data. In addition, the buoys proved to be difficult to place in position, transport and store.

The transits require rather large crews since two transits are required per baseline and two or three men are needed at each station to communicate, man the transit, and record data.

The communications and recording duties can often be combined but, since at one of the transit stations a person must coordinate the sighting by the two stations, it is difficult to operate with less than four persons manning the two transits, while five persons appear to be optimum. There is also the added problem that, since buoys often run aground and in order to understand the currents, buoys must be frequently repositioned, an additional person is required to man a boat. Fatigue will also begin to take its toll, if a station is to be run over four or five hours and a replacement crew will be required. In short, buoy and transit stations require too many people to be an optimum solution.

Table 3.7

TIDE PHASE: LOW TIDE

DATE	BUOY	TIME START	TIME END	OBSERVATIC BASELINE
7/27	A1O	-3:03	+1:30	026/306
7/27	A1Y	+0:09	+1:29	026/306
7/26	C1B	-0:18	0:00	108/288
7/27	B3W	+0:33	+1:21	108/288
7/22	J3RB	+0:03	+1:08	108/288
7/22	J2O	+0:05	+1:07	108/288
7/22	J3R	-0:01	+0:47	108/288
7/22	J3B	+0:02	+1:08	108/288
7/22	J3Y	0:00	+1:15	108/288
7/22	J3W	-0:02	+0:38	108/288
7/19	K1W	-1:16	-0:02	108/288
7/19	K1RB	-1:17	+0:04	108/288
7/19	K1R	-1:18	+0:03	108/288
7/25	F1R	+0:14	+0:59	026/206
7/25	F1B	+0:12	+1:02	026/206
7/26	C1R	-0:22	+1:52	108/288
7/26	C1W	+0:06	+1:37	108/288

Before buoys are employed in future projects, they should be redesigned to permit operation under unfavorable wind condi- tions. The visible part of the buoy should be made more easily identifiable and less dependent on lighting conditions, so in- creased distance and bad weather will not hamper tracking. The operational maximum was six buoys with a sighting period of approximately six minutes. The optimum was four buoys with a three-minute tracking period. Acoustical tracking by means of sonar might be an alternative.

The use of stationary current meters would eliminate many of the problems of buoy tracking, but would raise new ones. As

Table 3.8

TIDE PHASE: POST-LOW

DATE	BUOY	TIME START	TIME END	OBSERVATION BASELINE
7/26	D1RB	+0:14	+3:05	174/354
7/26	D1O	+0:15	+3:00	174/354
7/26	K2W	+1:13	+3:12	108/288
7/26	K2R	+1:15	+3:15	108/288
7/26	K2WGS	+2:01	+2:28	108/288
7/25	F2O	+1:09	+1:55	026/206
7/25	F2R	+1:18	+3:14	026/206
7/25	F2B	+1:16	+2:19	026/206
7/25	E1W	+1:10	+2:43	146/326
7/25	E2RB	+2:22	+2:47	146/326
7/25	E2Y	+2:02	+2:45	146/326
7/26	C1O	-0:19	+2:43	108/288
7/26	C2W	+1:53	+2:44	108/288
7/25	E1Y	+1:13	+1:44	146/326

it stands now, most current meters provide a current magnitude, but a current direction would also have to be obtained. Another limitation of current meters is the fact that they are difficult to moor and reposition.

An optimum approach might be the use of a combination of buoys and current meters. The buoys, of course, utilize a Lagrangian type of coordinate system, while the current meters use a Eulerian type of system, but with the information from both, an exceptional picture of the hydrodynamics of the Cove could be obtained.

4.0 DETERMINATION OF CURRENT VELOCITIES VERSUS REAL TIME IN THE SOUTHERN AND NORTHWESTERN ENTRANCES OF HOLBROOK COVE

4.1 Objective

The objective of this project is to measure current velocities in the center of the channel at the southern and northwestern entrances of Holbrook Cove over a complete tidal cycle.

4.2 Procedure

The current meters were moored in approximately the center of the southern and northwestern channels at a depth of approximately 10 feet at low tide. A clock-timing device was used to record the current meter pulses on magnetic tape for a period of four minutes at half-hour intervals, on the hour and half-hour. The magnetic recorders were later retrieved. An operator rewound the tape, placed the tape recorder in the "play" mode and counted the number of pulses over a 10-second interval. Current velocities were then determined using the pulses per second to enter the calibration curves.

4.3 Results

Figures 4.1 and 4.2 are plots of current velocities at 30-minute intervals. The tidal phase noted at the bottom of the figures relate the time to the tidal phase at Castine. Figures 4.3 and 4.4 compare buoy velocities calculated from observations taken in the vicinity of the current meter positions with the results of the current meters. It should be noted that the buoy observations were not made on the same day that the current meters were implanted and that the buoy positions are in the same general area, but not identical to the positions of the current meter. It should also be noted that the current meters were placed a fixed distance from the bottom of the Cove and their depths therefore vary with the height of the tides. It is estimated that the depth of the current meters varied from approximately 10 feet to approximately 20 feet over the complete tidal cycle.

4.4 Conclusions

In comparing the results of the current meters and the buoys, it appears that there may be a periodic velocity fluctuation that significantly affects the magnitudes of the currents

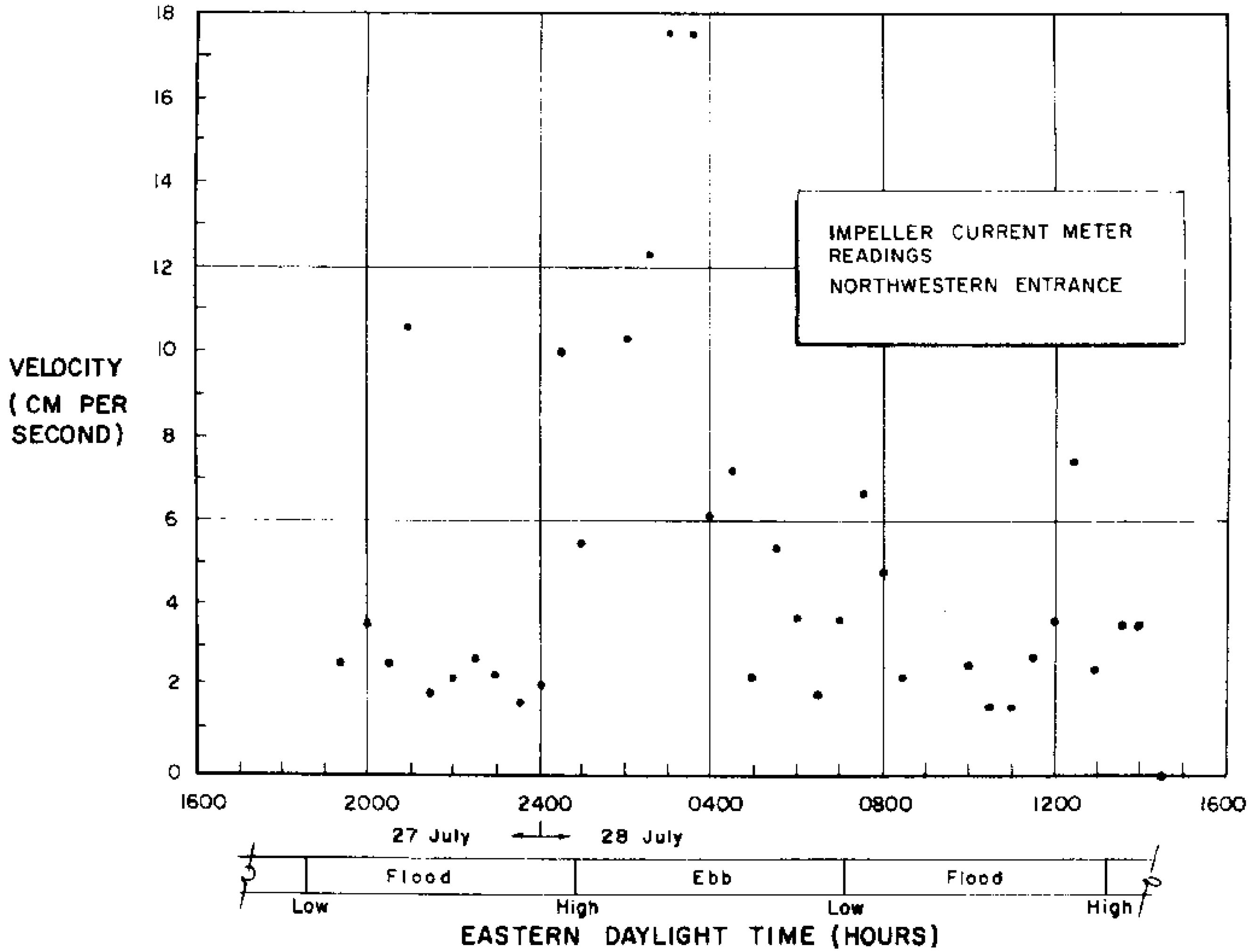


Figure 4.1

Impeller Current Meter Results in
Northwest Entry to Holbrook Cove

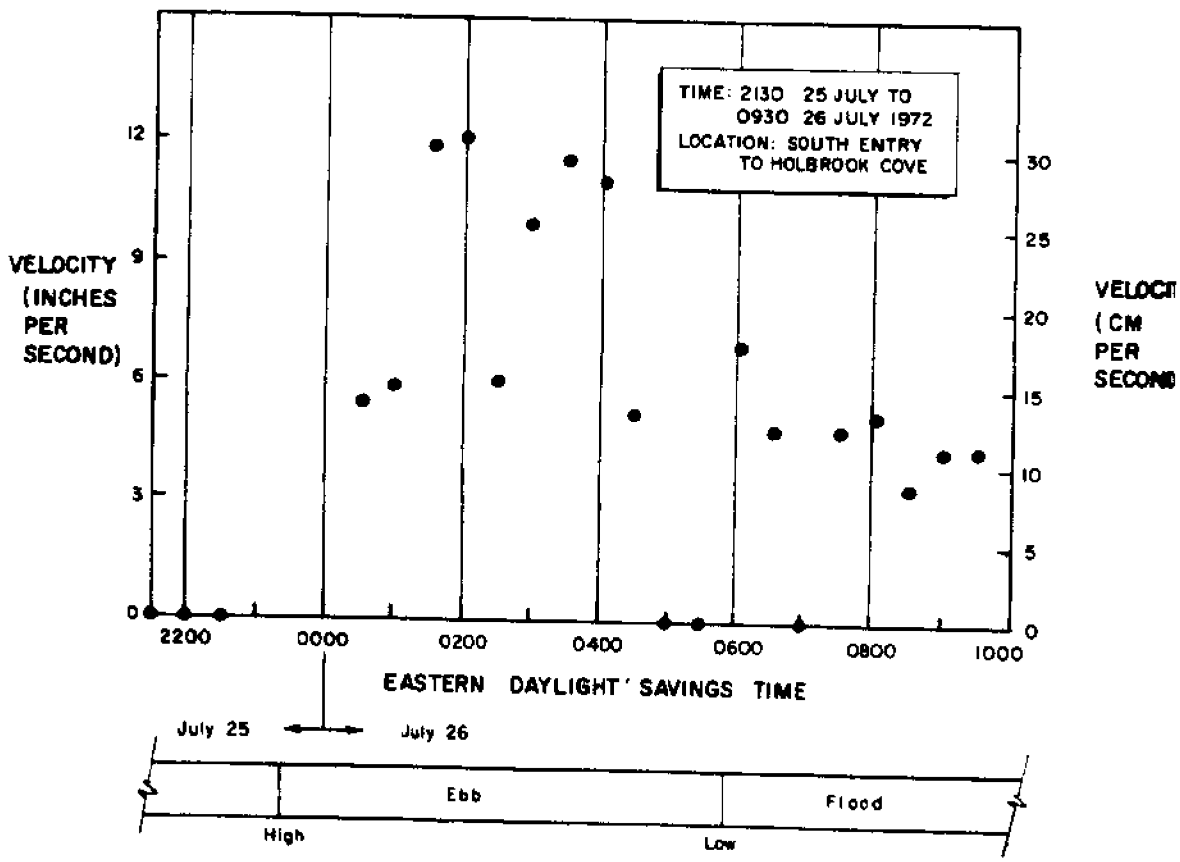


Figure 4.2

Karman Vortex Trail Current Meter Results
in South Entry to Holbrook Cove

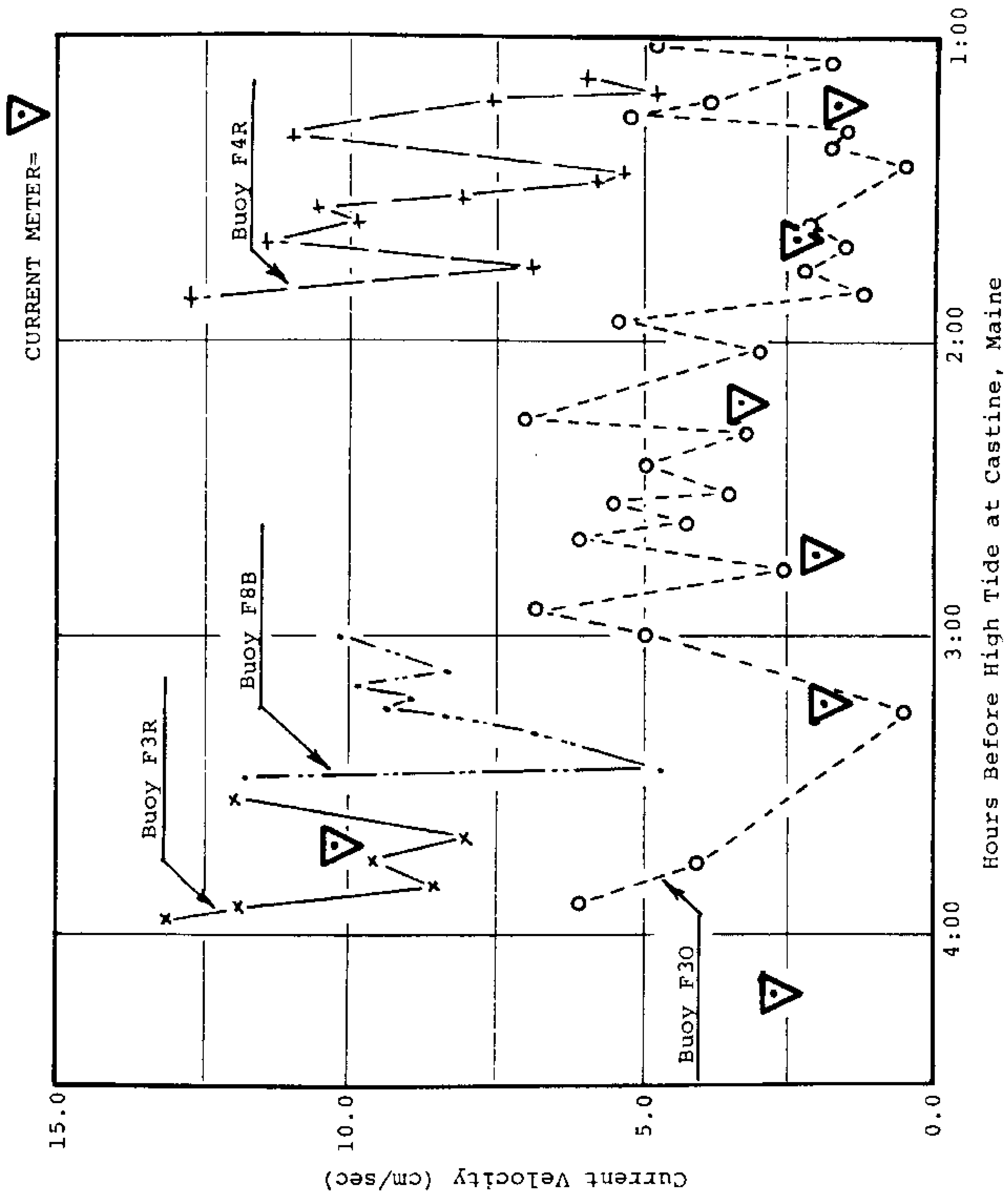


Figure 4.3

Comparison of Buoy Velocities and Current Meter Results
Northwestern Entrance to Holbrook Cove

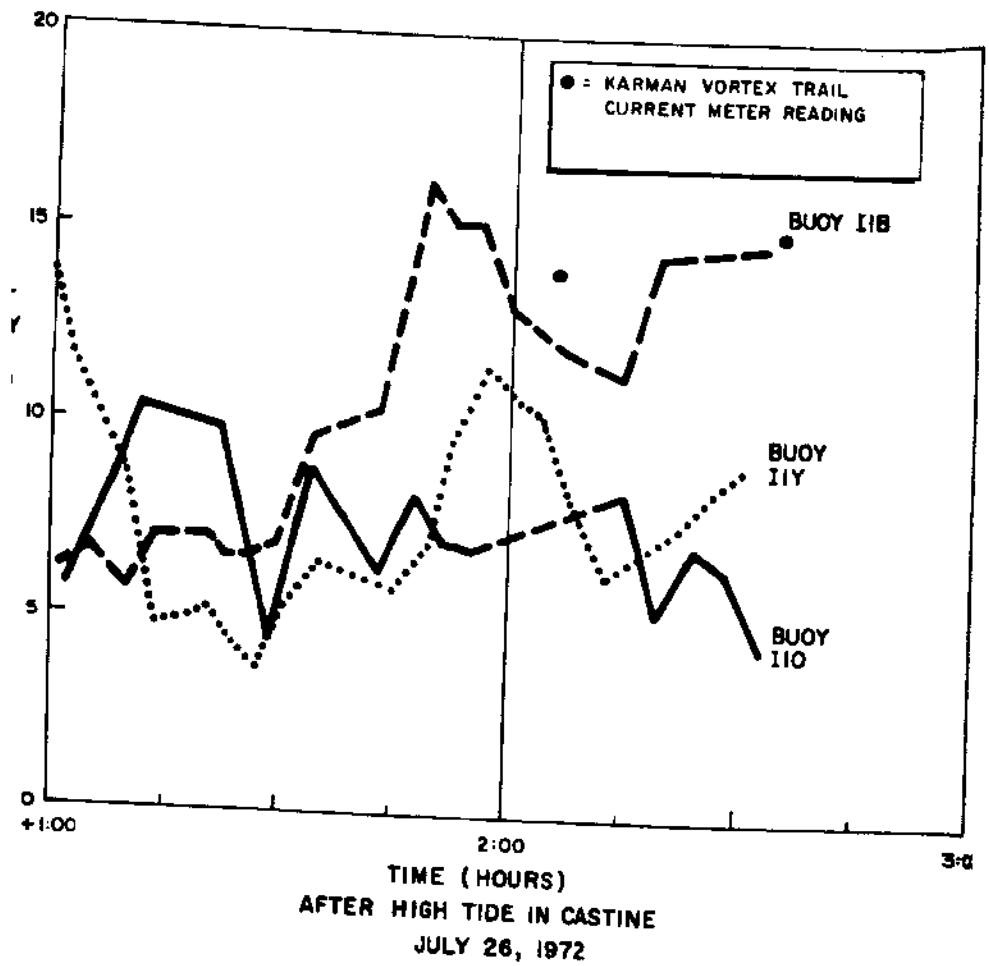


Figure 4.4

Comparison of Current Meter and Body Velocity Results in South Entry to Holbrook Cove in the Cove. The results suggest that the period of this oscillation is about 8 to 12 minutes and the velocity variations may be as much as plus or minus 30 percent around some mean value.

Based upon the results of both the current meters and the buoy velocities, it is concluded that the tidal currents in Holbrook Cove are significantly affected by a seiche. In planning the project, this result was not anticipated and the time intervals selected for recording currents was arbitrarily set at 30 minutes. In addition, it appears that there is a significant reduction in the current velocities recorded by the current meter when the depths are greatest, i.e., near high tide.

4.5 Recommendations

While it appears that the current meter and recording system functioned properly, the reduction of data by counting the number of "beeps" over a time interval as a means of establishing velocity is far too time-consuming. It is therefore recommended that a means of recording velocity that will permit a more automated reduction of data be devised.

It is also recommended that any future projects consider the possibilities of a seiche and velocity measurements be made continuously over longer time spans or, if intermittent current velocity measurements are made, the interval between measurements be shortened to a period that is less than half the period of the estimated seiche.

Finally, it is recommended that a vertical array of current meters be deployed to establish the velocity profile as a function of depth.

5.0 TEMPERATURE, SALINITY AND CHLOROPHYLL

5.1 Temperature and Salinity Patterns

5.1.1 Objective

The purpose in studying temperature and salinity in Holbrook Cove is to obtain baseline data usable in density analysis. This data will be useful in establishing the prevailing conditions in Holbrook Cove, and how these conditions may affect biology and water movement. The design of inexpensive water sampling bottles and their construction was required to achieve the primary objective (see Figure 5.1).

5.1.2 Background

Salinity and temperature analysis is a standard practice in physical oceanography. Salinity gives a good idea of the horizontal and vertical extent of dilution in the Holbrook micro-estuary. Presumably, fresh water from both the Bagaduce and Penobscot Rivers dilute sea water in the area of the Cove. Rain water also has a day-to-day effect, although sampling was not extensive enough to draw any conclusions about this effect.

Temperature is of equal value to the oceanographer. Within any geographical basin, one generally finds more than one water type. Temperature tends to be the prime indication of a transition from one water type to another; and the word thermocline denotes just such a boundary. Temperature is seasonal, and has a controlling effect on the biological community.

Finally, temperature and salinity, coupled with the depth at which the sample was taken, can be combined to calculate the density of the water sample. Density, also a characteristic of the particular water, determines the physics of that water body to some extent. Statically, more dense water will lie at the bottom of basins. Dynamically, the forces on waters of different density are the cause of water movement.

5.1.3 Results

The results of this investigation are tabulated in Table 5.1, 5.2 and 5.3. The column headed "Chlorophyll 'A'" is discussed in Section 5.2.

Figure 5.1

Sampling Bottles

TABLE 5.1

TEMPERATURE, SALINITY, DENSITY AND CHLOROPHYLL 'A'

AT DEPTH = 0 METERS

STATION	TEMPERATURE (DEGREES CENTIGRADE)	SALINITY	SIGMA 'T'	CHLOROPHYLL 'A' (MICROGRAMS PER LITER)
1A	17.5	26.18	19.22	2.071
1B	17.5	25.44	18.12	1.526
1C	17.5	25.30	18.02	1.417
2A	17.0	25.66	18.40	1.417
2B	15.0	25.22	18.49	1.417
2C	17.0	24.34	17.78	1.744
3A	17.0	25.30	18.13	1.417
3B	17.0	25.30	18.13	1.090
3C	18.0	25.02	17.96	0.931
4A	17.5	24.65	17.79	1.417
4B	17.5	24.88	17.70	1.990
4C	18.0	25.44	18.01	1.417
5A	17.0	25.37	18.56	1.199
5B	14.0	26.20	19.44	0.981
5C	17.2	27.10	19.45	1.417
6A	17.0	25.66	18.40	1.308
6B	13.0	21.05	16.20	1.744
6C	14.0	26.92	19.99	2.130
7A	17.0	26.13	18.80	0.931
7B	17.5	25.93	18.50	0.872
7C	17.0	25.33	18.15	0.981
8A	17.5	[illegible]	18.61	0.436
8B	18.0	26.40	18.74	0.931
8C				

TABLE 5.2

TEMPERATURE, SALINITY, DENSITY AND CHLOROPHYLL 'A'

AT DEPTH = 3 METERS

STATION	TEMPERATURE (DEGREES CENTIGRADE)	SALINITY	SIGMA 'T'	CHLOROPHYLL 'A' (MICROGRAMS PER LITER)
1A	15.0	28.72	20.62	1.526
1B	16.0	26.20	19.03	1.308
1C	14.0	26.29	19.51	1.635
2A	17.0	25.82	18.52	1.744
2B	11.5	26.11	19.82	1.962
2C	15.0	26.38	19.38	2.289
3A	12.0	27.46	20.78	1.635
3B	10.0	27.28	20.97	1.526
3C	10.0	29.07	22.36	1.199
4A	10.5	27.39	20.97	1.744
4B	10.0	27.08	21.03	1.853
4C	10.5	26.18	20.03	1.199
5A	12.5	28.51	21.50	2.071
5B	9.5	28.18	21.74	1.962
5C	11.0	28.87	22.04	2.398
6A	11.0	28.29	21.59	1.744
6B	9.5	29.00	21.79	2.507
6C	10.0	28.91	22.23	2.071
7A	12.0	27.10	20.50	1.635
7B	12.0	29.03	21.98	1.962
7C	12.0	28.54	21.54	1.744
8A	12.0	26.96	20.39	1.199
8B	11.5	28.42	21.61	1.526
8C				

TABLE 5.3

TEMPERATURE, SALINITY, DENSITY AND CHLOROPHYLL 'A'

AT DEPTH = 6 METERS

STATION	TEMPERATURE (DEGREES CENTIGRADE)	SALINITY	SIGMA 'T'	CHLOROPHYLL 'A' (MICROGRAMS PER LITER)
1A	8.5	29.54	22.92	0.763
1B	9.5	29.34	22.64	0.763
1C	10.0	28.56	21.96	2.616
2A	11.0	29.90	22.84	1.199
2B	9.0	29.72	23.02	0.545
2C	11.0	29.32	22.39	0.218
3A	9.0	29.90	23.16	0.981
3B	8.5	29.90	23.23	0.654
3C				
4A	8.5	29.61	23.00	0.436
4B	8.5	29.61	22.78	0.327
4C	9.5	29.63	22.87	0.763
5A	8.3	31.07	24.17	0.218
5B	8.4	29.84	23.20	0.436
5C				
6A				
6B	8.2	29.30	22.80	0.436
6C	8.5	30.44	23.65	0.436
7A	9.0	29.65	22.96	0.327
7B	9.5	28.54	22.02	0.436
7C				
8A	9.5	29.65	22.89	0.763
8B	9.0	29.86	23.13	0.218
8C				

5.1.4 Conclusions

There is nothing dramatic revealed by the temperature, salinity, and density data.

The more dense water fills the deeper depths of the Cove. This would be consistent with the existence of a current through the Cove.

There is no indication of an effect by the Callahan Mine outfall on the temperature, salinity or density patterns in Holbrook Cove during the period of this study.

5.1.5 Recommendations

More electronic analyzing equipment is needed. Titrating is an especially long, tedious operation which leads to error.

A greater quantity of data is required to build a better picture of Holbrook Cove temperature, salinity and density patterns. Priority should be given to a number of samplings of the same area at different times of day. Then the variance of the data with respect to time could be related to water motion.

5.1.6 Detailed Procedure

5.1.6.1 Sampling Plan

To facilitate relating the temperature and salinity data to the biological accuracy results, an identical sampling grid was used for both projects (see Figure 5.2).

5.1.6.2 Sampling Technique

The sampling was accomplished using the water sampling bottles built in conjunction with this project. Once at the sampling position, determined by sighting angles on shore landmarks, the depth was determined using the fathometer on R.V. LOBSTER, the boat from which the samples were collected. It was then decided how many bottles spaced at depth intervals of three meters could be lowered.

Once this had been ascertained, the bottles were readied on the rear deck of the boat along with labeled, plastic-capped storage containers. The sampling bottles were attached to the heavy line at intervals of three meters as the line was lowered.

The bottles were triggered at the desired depths. They were then hauled up and the water in each bottle was emptied into a labeled container.

Figure 5.2

Sampling Grid

At the same station, the bathythermograph was lowered and retrieved. Its data slide was then removed and stored for later analysis.

5.1.6.3 Sampling Analysis

Once back at the laboratory, the water samples were titrated to determine chlorine content, using the silver nitrate method. The data were then converted to total salinity using the general formula:

$$S = 0.03 + 1.8050 \text{ cl} \quad \text{(where the units are parts per thousand)}$$

The salinity was then tabulated according to station and depth.

The temperature data were drawn from the bathythermograph slides. For each station, the correct slide was read for the water sampling depths. The resulting temperature corresponded to the depths of each sample, and was tabulated next to salinity.

Using this temperature and salinity data, the U.S. Navy Hydrographic Tables were used to compute σ_t. σ_t is a parameter relating the density (ρ) of a water sample to the density of pure water (pure water has a density, ρ, of 1.0000).* The density of the water sample is related to pure water by using the equation

$$\sigma_t = (\rho - 1)1000$$

If ρ equals 1.02575, then σ_t equals 25.75. It should be noted that the effect of pressure on density was not included because it is minimal for the depths in the Cove.

5.2 Chlorophyll Patterns in Holbrook Cove

5.2.1 Objective

This portion of the ecological survey is designed to quantitatively measure the distribution pattern of chlorophyll in the Holbrook Cove sampling area. A marked increase in chorophyll concentration with increased distance from the Callahan mine

*For a detailed description, see Sverdrup, H. U., M. W. Johnson, and R. H. Fleming, 1942, The Oceans, Prentice-Hall, Inc., N.J.

outfall would suggest that the effluent from the outfall is harmful to the diatom population and therefore has an unbalancing effect on the entire ecosystem, since diatoms are a major source of food for the Cove inhabitants.

5.2.2 <u>Background</u>

Gentile and Erickson (1971)[1] in their study of the Goose Pond area were able to make a direct correlation between the effluent, rich in heavy metals (notably copper), and the growth inhibition of a particular diatom, <u>Cyclotella nana</u>. The ability of the water to support <u>Cyclotella</u> decreased as the mine outfall was approached. When a chelator was added to the samples, rendering the copper inert, the diatom population increased. Although this was not conclusive evidence, it does suggest that heavy metal pollution from the outfall is upsetting the plankton community.

The method used by this experimenter was to collect samples at various depths from stations upstream and downstream of the outfall, giving a fairly accurate cross section of the entire sampling area. Tests were made for a specific chlorophyll concentration, referred to as Chlorophyll 'A,' which is the major green component of the particular diatom in question.

5.2.3 <u>Results</u>

Using water bottles, 106 samples were taken. 105 were analyzed, one being lost. The results are found in Figures 5.3, 5.4 and 5.5 as well as in Tables 5.1, 5.2 and 5.3. The data in the tables are the Chlorophyll 'A' concentrations in micrograms per liter (μg/ℓ) for each sample. The station numbers 1A, 1B, 1C, etc., refer to the stations in Figure 5.2.

5.2.4 <u>Conclusions</u>

One of the major assumptions about which this research project was planned was that the flow from the Callahan mine outfall would be continuous throughout the sampling period. Based upon observations made by the sampling team, it appears that no flow occurred during the entire month of July. This circumstance casts doubt upon the hypothesis that the heavy metal ion concentration would be the greatest near the mouth of the outfall, since the waters of the Cove are either ebbing or

Holbrook Cove

Chlorophyll 'A' Contained in Water Samples Taken

at Stations 1A Through 8A

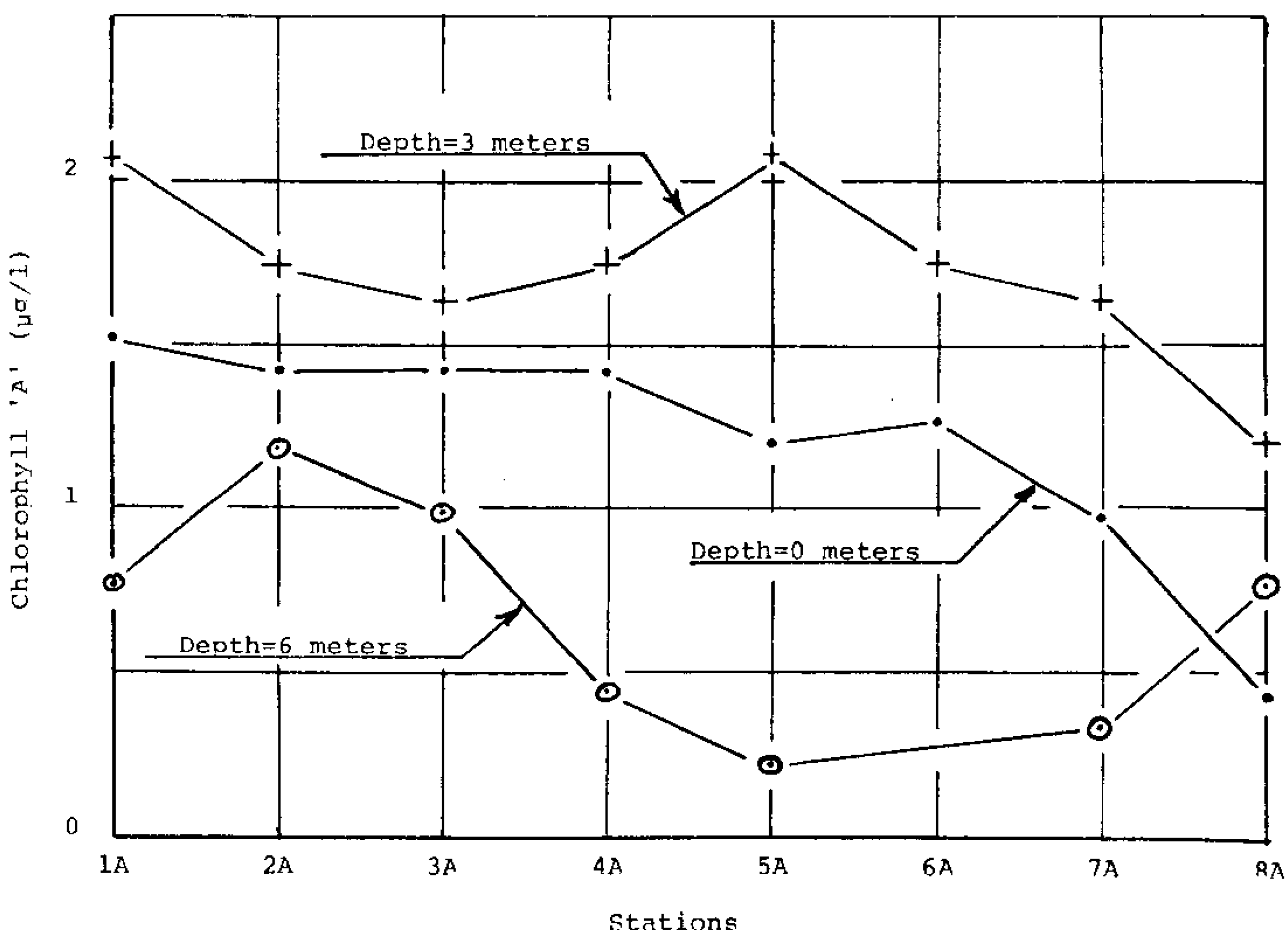


FIGURE 5.3

Holbrook Cove

Chlorophyll 'A' Contained in Water Samples

Taken at Stations 1B Through 8B

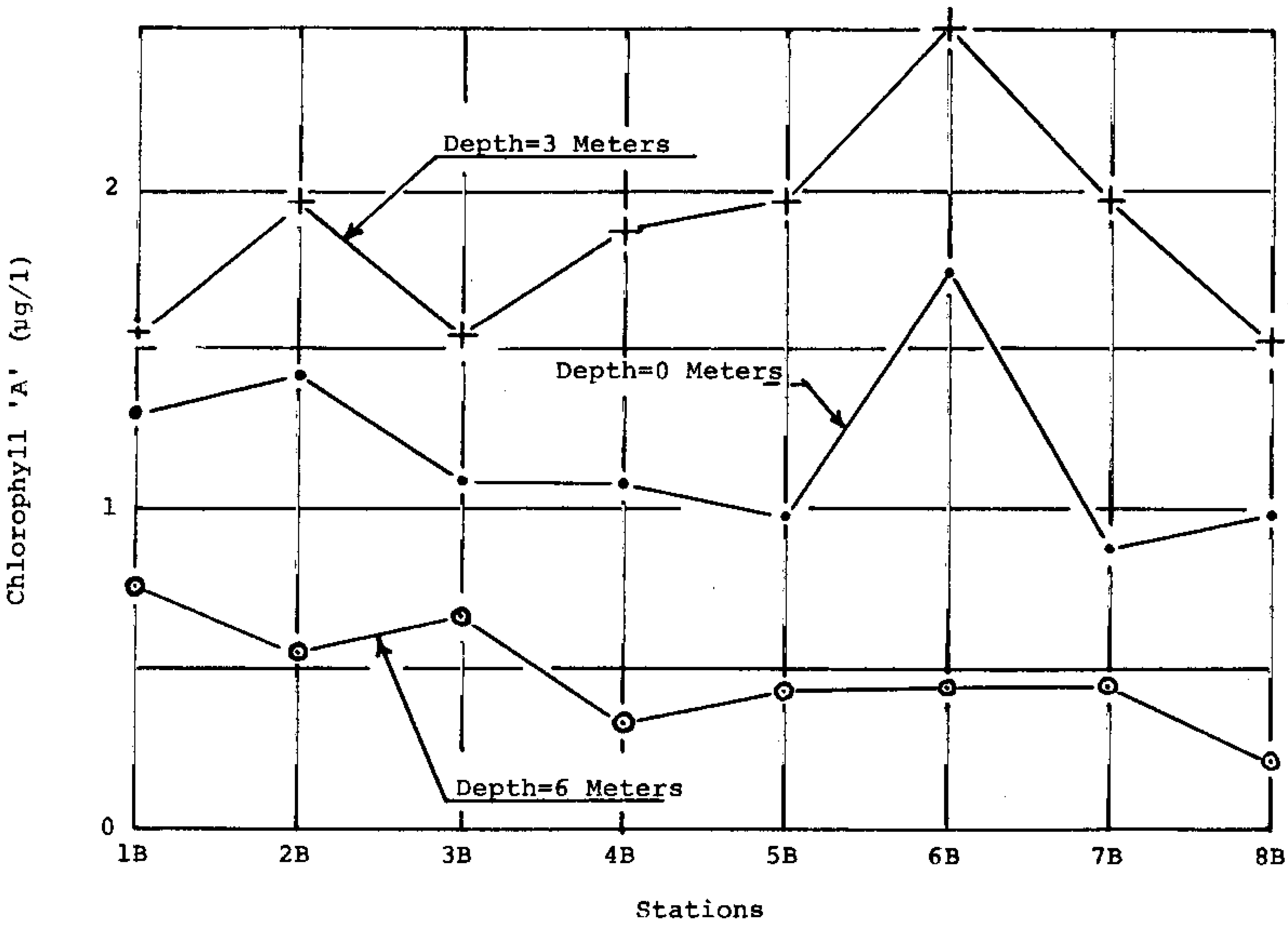


FIGURE 5.4

Holbrook Cove

Chlorophyll 'A' Contained in Water Samples

Taken at Stations 1C Through 8C

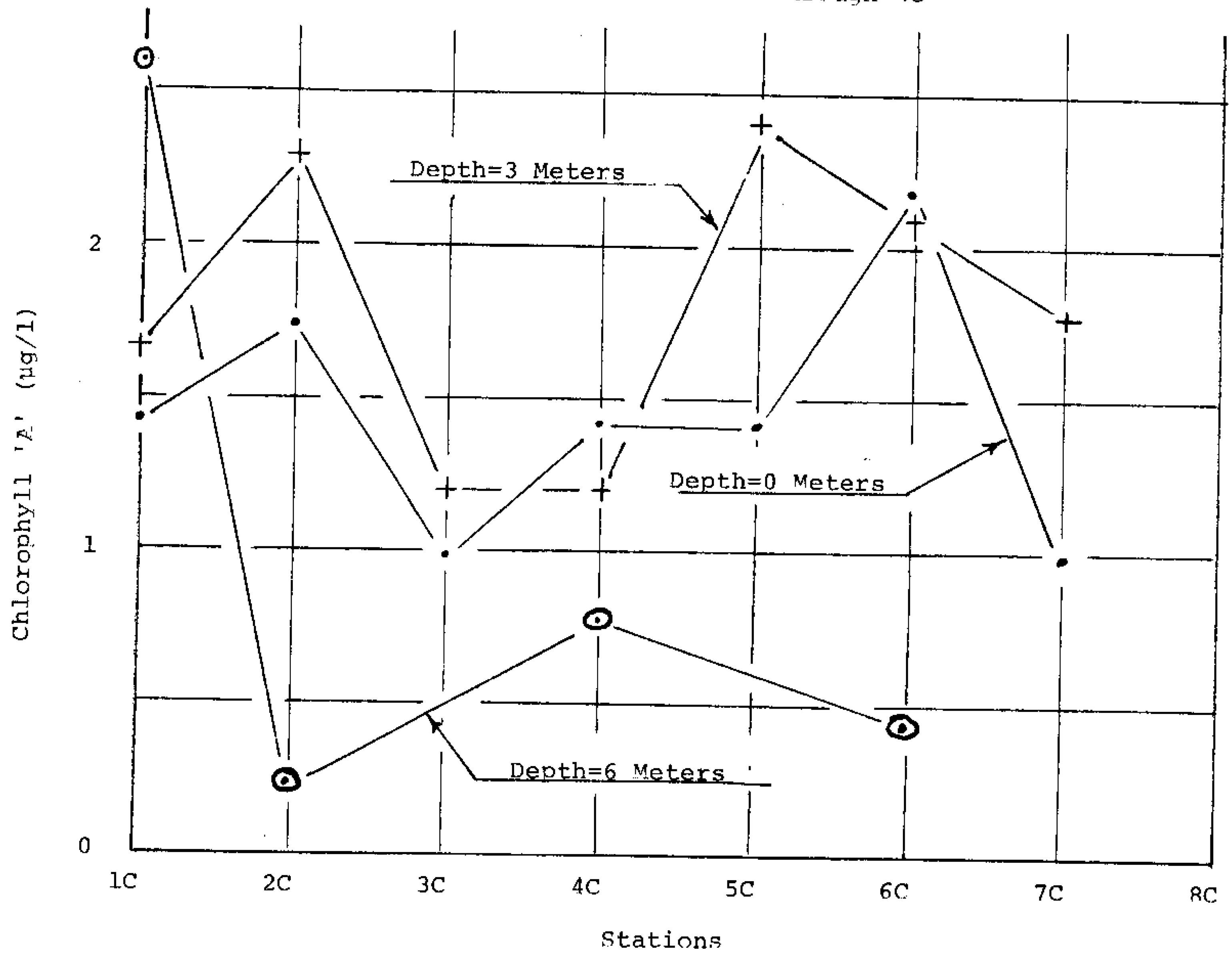


FIGURE 5.5

flooding most of the time. It seems more logical that, if heavy metals are concentrated in the area, the effects would be most noticeable in the deep water pockets north and south of the outfall.

In examining Figures 5.3, 5.4 and 5.5, it appears that Chlorophyll 'A' concentrations are greatest at a depth of about three meters and least at depths of six meters or more. There does not appear to be a significant variation related to distance from the Callahan mine outfall.

It should be noted that the samples were all collected during a flood tide. The samples for stations 1A, 1B, 1C, 2A, 2B, 2C, 3A, and 3B were collected during the morning of July 26. The samples for stations 3C, 4A, 4B and 4C were collected during the evening of July 26. The samples for the remainder of the stations were collected during the morning of July 27.

Due to the violation of the basic assumption relating to continuous flow from the Callahan mine outfall, it is impossible to draw any conclusions with respect to the effect of the outfall upon the Chlorophyll 'A' patterns in Holbrook Cove.

5.2.5 Recommendations

In future attempts to determine the effects of a source of heavy metal concentrations (as the Callahan mine outfall may be), the water samples should be analyzed for the concentration of heavy metal ions present. This will be difficult since the concentration will be extremely low, but it would appear to be essential if the effect of heavy metals on Chlorophyll 'A' is to be determined with confidence.

Sampling plans should be expanded to permit collection of at least three water samples at three different times at each depth and location. The size of the sampling team should be expanded to permit collection of water samples over the entire grid in a period of not more than six hours (the approximate extent of either a flooding or ebbing tide). This implies that at least three students will be required to analyze the samples.

5.2.6 Procedure (see references 2 and 3)

As soon as possible 25 milliliters of each sample were filtered through a one-inch Gelman Glass Fiber filter and frozen.

The filters carrying the chlorophyll were then homogenized and extracted with 90% acetone solution and fluorated, giving a reading "f_o." Each sample was then acidified and another reading taken, "f_a." The amount of chlorophyll "a" per sample in micrograms per liter (μg/ℓ) was derived from the equation "$chl_a = 0.109(f_o-f_a)$."

REFERENCES

1. Dow and Hurst, Jr., Rehabilitation Problems of the Cape Rosier Open Pit Mine, Dept. of Sea and Shore Fisheries, Augusta, Maine, Nov. 1971.

2. Duxbury and Yentsch, Plankton Pigment Nomographs, J. Marine Res. 15, 1956, pp. 92-101.

3. Richards and Thompson, A Spectrophotometric Method for the Estimation of Plankton Pigments, J. Marine Res. 11, 1952, pp. 156-172.

6.0 BIOLOGICAL EFFECT OF HEAVY METAL POLLUTANTS

6.1 Objective

At Cape Rosier, Maine, a copper-zinc open pit mine has been discharging effluent rich in heavy metals into Holbrook Cove. Recent studies have shown that this type of metal pollutant is harmful to marine organisms, and probably to human health.[1] In planning this study, it was felt that actual measurements of metal ion concentration in water and sediment at various stations might lead to a better understanding of the effects of these pollutants when correlated with benthic faunal population distributions and photosynthetic primary production in the area. The purpose of this facet of the overall study was to gather data concerning the distribution of the heavy metals (Cu, Pb, Zn, and Cd) in the sediments near the outfall, and to correlate these data with the distribution of benthic infauna (in terms of species diversity, abundance of individuals in each species, and biomass) in the sediments.

6.2 Background

In 1968, operations were undertaken by the Callahan Mining Corporation in the area near Goose Pond on Cape Rosier, Maine, to exploit local deposits of copper and zinc ore. The mouth of Goose Pond (Figure 6.1) was dammed, the pond pumped dry, and a large open pit excavation was begun. Sea water is used in the aqueous flotation and ore separation process. This water is pumped from Holbrook Cove from a site adjacent to the outfall (Figure 6.2), and used to the mill processing. It is then dumped into a settling pond, where theoretically all suspended matter is removed. The effluent is pumped into Holbrook Cove through a subsurface outfall pipe. Sump pumps which keep the open pit free of ground seepage also empty into Holbrook Cove. During the four years of operation of the mine, fine sediment suspended in the effluent has entered the Cove and large portions have probably settled there.

It must be noted, however, that the mining operation is not the only source of heavy metal ions. Surface runoff and seasonal

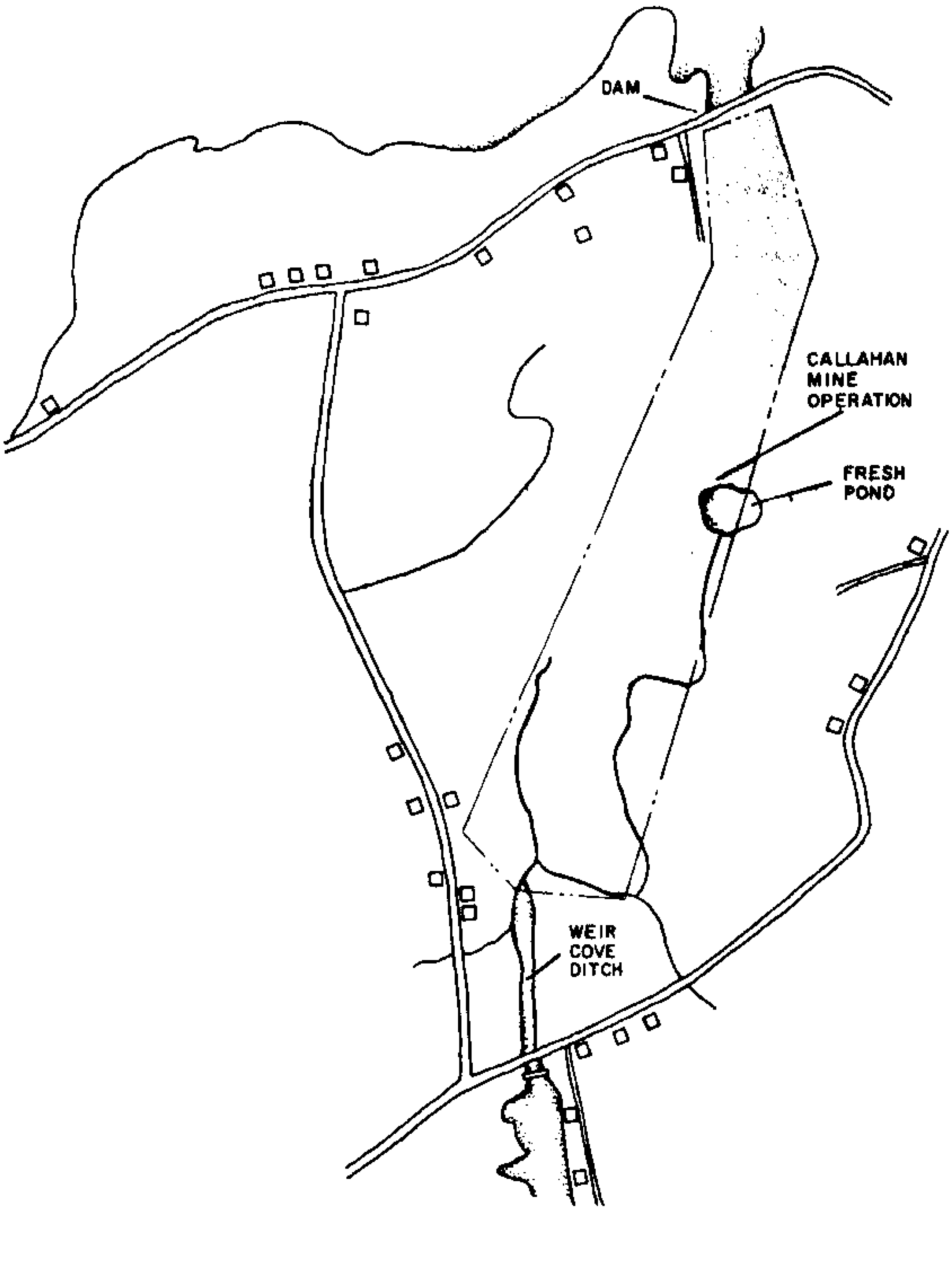


Figure 6.1

Callahan Mine Location

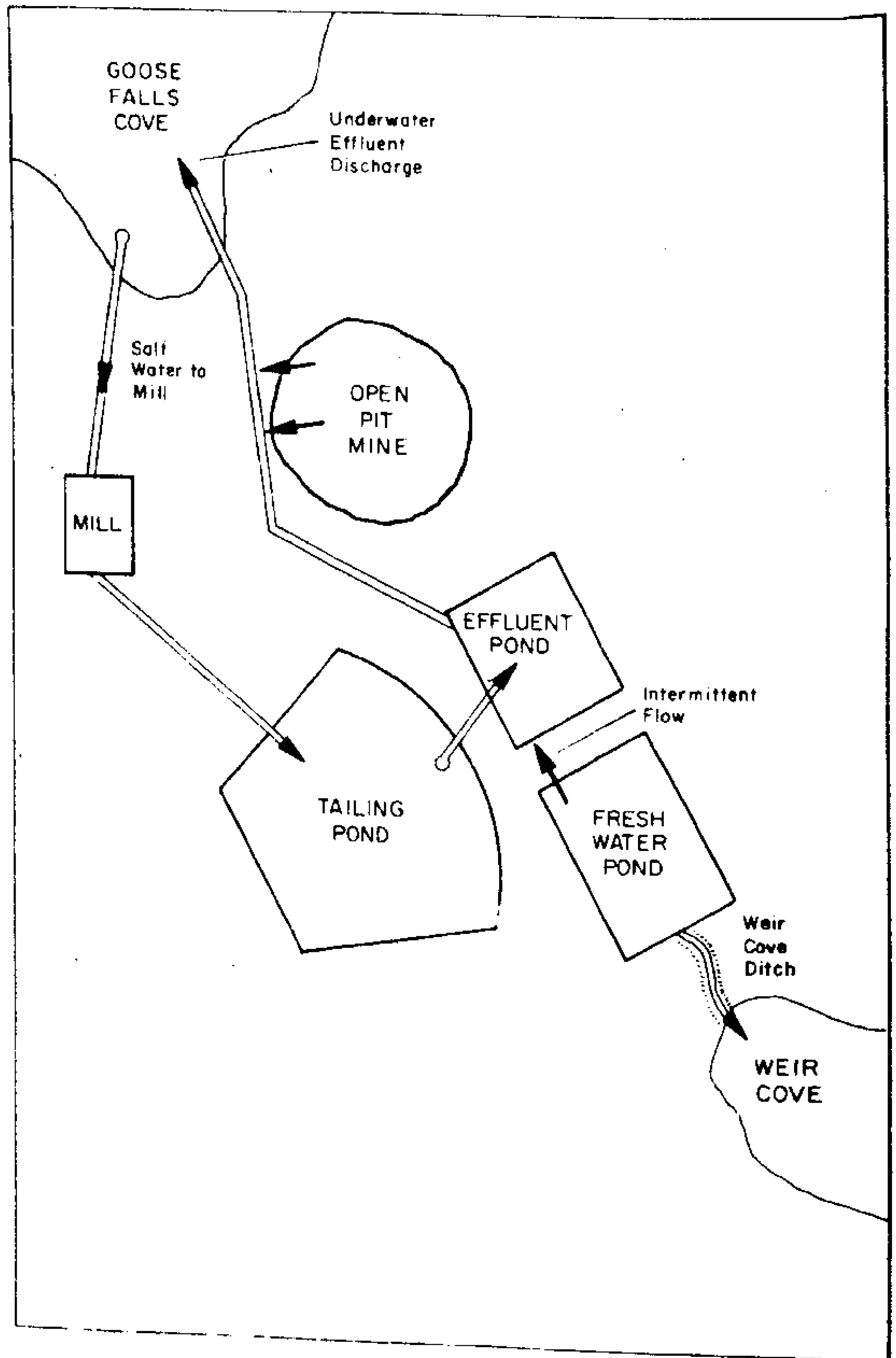


Figure 6.2

Callahan Mine Complex

APPENDIX C

AN EXAMPLE OF THE USE OF FIGURE 7.11

Example:

Find Height of Tide at 1125 Hours, July 5, 1972.

Date: July 5, 1972

Time: 1125 EDT   1025 EST

Barometer: 30.30"

From Tide Table (See Appendix B)

Previous Tide Level = +9.2 ft (High) @ 0605 Hours

Next Subsequent Tide Level = +0.2 ft (Low) @ 1212 Hours

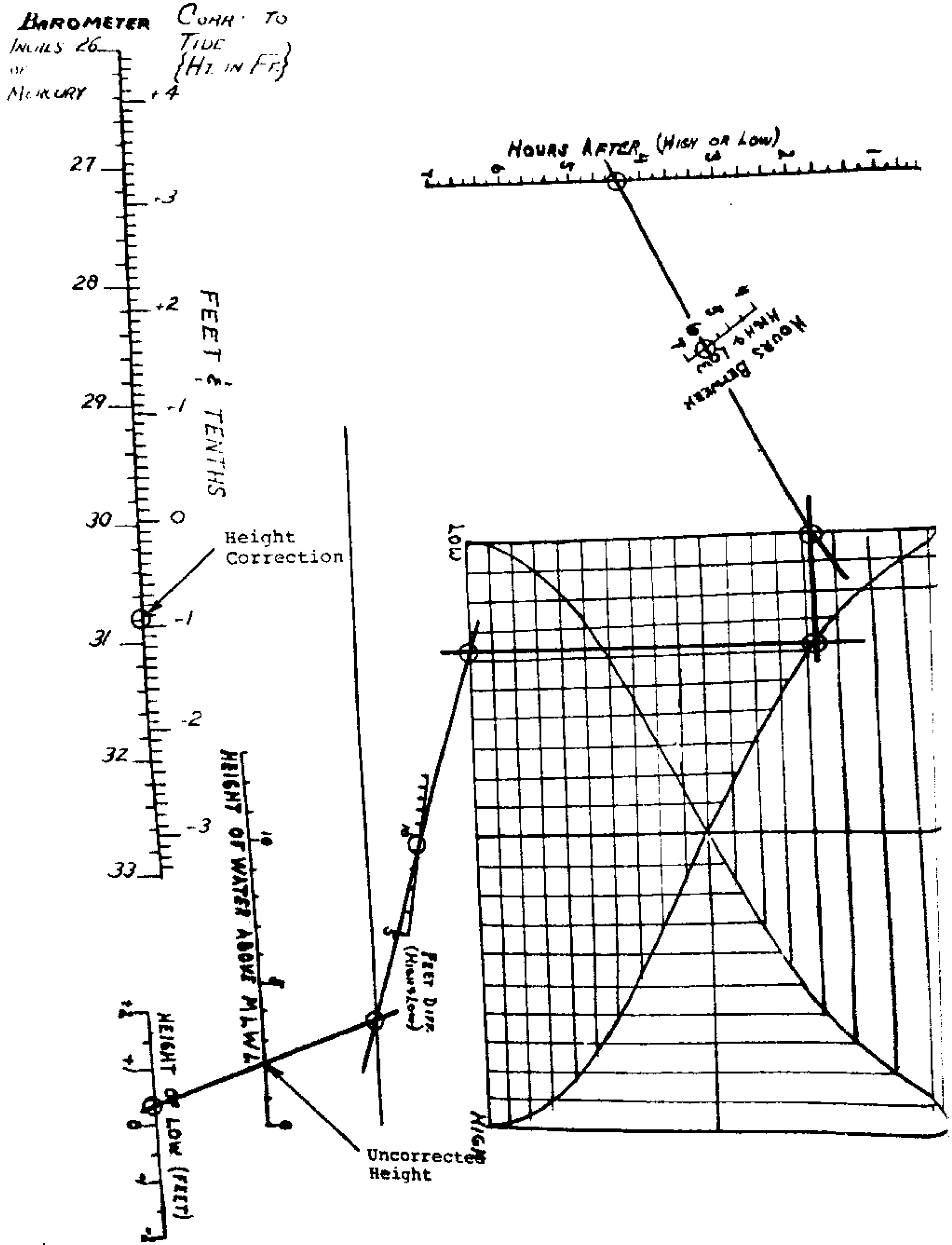
Hours Between High and Low = (1212 - 0605) = 6^h07^m

Feet Diff Between High and Low = (9.2 - 0.3) = 9.5 ft

Hours After High Tide = (1025 - 0605) = 4^h20^m

From Nomogram:

Uncorrected Ht	=		+2.1 ft
Correction for 30.80"	=	-0.95 ft	-0.95 ft
Corrected Ht	=	+0.55 ft	+1.15 ft



BAROMETER
INCHES OF MERCURY
CORR. TO TIDE {HT. IN FT.}
FEET & TENTHS
Height Correction
HOURS AFTER (HIGH OR LOW)
HOURS BETWEEN HIGH & LOW
LOW
HIGH
HEIGHT OF WATER ABOVE M.L.W.L.
FEET DIFF. (HIGH & LOW)
HEIGHT OF LOW (FEET)
Uncorrected Height

drainage fluctuations will alter the erosion of nearby natural ore deposits, and also the resultant metal ion concentrations in the waters of Holbrook Cove. The exact pattern of effluent distributions as driven by currents and tides has not yet been determined, although sampling stations (Figure 5.2) were selected to encompass all possible effluent paths.

Of all the animals in the immediate area, only the benthic infauna have been continually subjected to the heavy metals present in the mine effluent. These animals cannot move appreciably, and thus have had to adapt to the environment of Holbrook Cove. In general, the animals that have evolved to survive in a particular environment (the boreal waters of the Gulf of Maine in this case) have the ability to successfully adapt to the range of environmental variations which occur naturally. However, even these "historical stresses" are occasionally exceeded and individual species succumb. After this stress has passed, the species may either recolonize the area, or another species may nove in and take over the first species ecological niche. The fewer of these overturns there are, the more stable is the biological community. In areas where the "predictability" of the environment is high (few abnormal stresses beyond the tolerance of all the species present), there are many species, each with a small number of individuals, and each adapted to deal with its own narrow range of ideal conditions. Where predictability is relatively low, each species must adapt to a wide range of possible environmental conditions. Since the range of ideal conditions (the niche) of each species cannot overlap with the niche of the species next to it on the spectrum of environmental factors, it is evident that there will be more niches, and thus more species, present in a high predictability environment.

In Holbrook Cove, the influx of heavy metal pollutants can be viewed as an "unpredictable" environmental stress from the point of view of the benthic community. If the community is capable of adapting to this stress, there should be no obvious change in the species composition of this community. This is the "null hypothesis" of this investigation. In order to test this hypothesis, some quantitative measure of the species diversity must be employed. Several are in use at present. The rarefaction analysis method of Sanders[2] shows the diversity graphically, although computation and data presentation are cumbersome and tedious. The information function of Shannon[3] is simpler. The number of individuals of each species in the community is calculated as a fraction of the total number of individuals in the community. This fraction, p_i, is then iterated over all species, and then the value of $\Sigma\ p_i \log_2 p_i$ is calculated for the community. This gives a value which is sample size-independent. The application of this function to biological systems has recently been questioned by Hurlburt,[4] who proposes several alternate diversity indices. Once all data are assembled in this investigation, both Shannon's and Hurlburt' indices will be employed.

All organisms present in each sample must be identified and counted. For practical purposes, this is impossible. The sediment must be sieved to remove very small sediment (some small animals are obviously lost in the process). Reish[5] calculated the optimum screen mesh size to maximize animal retention and minimize the extensive labor necessary to sort the samples. In practice, there is also an optimum number of grab samples to be taken at each station to assure that all species in the community are represented in each station sample. This must be determined *in situ*, after a few samples have been sorted.

In Holbrook Cove, a grid of sampling stations was laid out (Figure 5.2) in the waters near the outfall based on the sediment metal concentrations determined by the Federal Water Quality Administration[6] in the immediate area. One objective is to duplicate the FWQA study in more detail for a small area. Hopefully, contour charts for the levels of copper, zinc, lead and cadmium, as well as charts of the species diversity indices may be drawn from the data resulting from sampling the stations on the grid. Correlation tests on these data may yield interesting results.

Since species diversity in this case may be influenced by other factors, these must be investigated and their influence on the community assessed, the 1971 Summer Laboratory report

(MITSG 72-3) investigated temperature, salinity, nutrients, dissolved oxygen and currents. No abnormalities were evident. Other phases of this investigation (Sections 5.1 and 5.2) duplicated portions of those studies, again revealing no abnormalities. Sediment particle size distribution does play a significant role in determining benthic community structure.[7] Most samples in the area were composed of 60% silt, 20% clay and 20% fine sand. However, several stations were located on bare rock, or on the shallow sill of glacial sand and gravel that forms the western end of Holbrook Cove. This is a biological community very different from that found in the mud of deeper water, and therefore will not be included in the forthcoming discussion of the biological data with reference to heavy metals.

Cadmium, lead, copper, and zinc were chosen to be sampled because they exist in large enough concentrations to be measured with available Atomic Absorption Spectrophotometry equipment and are thought to be major pollutants in the area.[8] Chromium falls below AAS detection limits. However, once data has been collected, it is difficult to draw any conclusions as to significant patterns in flow or toxicity or even the relation to the mine effluent. Robert Dow, Director of Research, Maine Department of Sea and Shore Fisheries, reports "Since exploratory drilling, stockpiling of ore-bearing rock, de-watering of the old mine shaft, and pumping out of the rain-filled pit behind the newly constructed dam at Goose Falls, heavy metal levels in clams, sediments, and rock weeds cannot be interpreted as background only. This significant and dramatic increase in all three media after ore separation can be wholly attributed to the plant operation and the discharge of effluents into Goose Cove."[9] The Federal Water Quality Administration, now the Environmental Protection Agency, is more conservative in its correlation between toxic metal concentration and the mine effluent, but recommends that public water supplies in the area be monitored due to high lead concentration at two of their sample stations.[6] It should be noted here that this report has been criticized by Dow and other Maine state officials.[10] Tidal stage, climate and geological makeup affect concentrations of trace metals, but it is not yet fully understood how and to what degree. In addition, agreement as to whether sediments adsorb toxic ions, rendering them inert or whether they are a continuing source of contamination has not been reached.

It has been found that heavy metals do not concentrate along trophic levels.[11] In that particular survey of the Illinois River, the order of concentration magnitudes of Cu, Ni, Fe, Pb, Cr, Li, Co, Cd was as follows: sediments > worms > clams > fish > water. Zinc was found in greater concentration in clams than in worms. According to a report by Dow on "Estuarine Communities and Pollution,"[12] "Evidence does not support the assumption that heavy metals in estuarine sediments, marine algae, and shellfish are directly related to the level of these metals in the overlying waters." It is important, therefore, to measure metal concentrations in mud and organic samples as well as in the water. The sand worm, second only to the blood worm in economic value per unit weight to the Maine fishing industry, has a reported toxicity threshold of about 0.1 parts per million copper (Raymont and Shields, cited by Dow).[8]

A previous study of the waters around Cape Rosier showed copper concentrations ranging from 0.1 to 0.4 PPM.[8] Dow believes that lead is probably the most hazardous metal pollutant at the mine site for both humans and commercial shellfish.[12] A study of the effect of cadmium upon humans is being conducted intermittently by M.I.T. Human intake of toxic metals comes through drinking water sources and consumption of shellfish. In particular, bivalves have the ability to concentrate heavy metals to levels greater than those found in their environment.

6.3 Results

The analysis of the 25 Holbrook Cove sediment and water samples for heavy metal concentrations and benthic fauna has not been completed at this writing. Shortages of equipment availability (mostly an inability to gain access to AAS equipment) and difficulties with impurity interference (Section 6.6) have hindered the determination of heavy metal concentrations. It is expected that these difficulties will have been overcome to allow completion of AAS analysis by March 1973.

Benthic faunal sorting and species identification is also proceeding slowly. The 0.25 mm screen mesh size, as determined from Reish's[5] analysis, used in sieving the grab samples causes the retention of a large volume of materials, which must be picked through under a dissecting microscope. Average sorting times have been in excess of 20 hours for each of the three samples sorted thus far.

A basic difficulty in the faunal analysis concerns species identification. Of the 52 positively identified polychaete worm species taken in Holbrook Cove in the FWQA study,[6] only 24 are named in Knowlton's[13] checklist. Knowlton acknowledged that his checklist is not "all-inclusive," even though he, his co-workers and his students have sampled along the whole Maine coast for a number of years. Significantly, the two dominant polychaete species, Aricidea jeffreysii and Nephthys incisa, representing 38% and 17% respectively of all individuals taken in Holbrook Cove, have never been found by TRIGOM researchers and are thus not included in Knowlton's checklist.

The most abundant polychaete species in the samples sorted thus far has not been identified as yet. There is some internal disagreement about whether two species are being considered as one in this case. Until this is resolved, no species diversities can be calculated.

Some trends are apparent, however. Biomass and number of individuals appear to be at a minimum at the station closest to the mine outfall; i.e., there are fewer individuals and the individuals appear to be smaller near the outfall. This could indicate an adverse influence of the effluent on the biota, but it is obviously too early to draw any correlations.

Other data would be valuable in addition to sediment faunal data. An attempt will be made to analyze locally collected bloodworms[14] (Glycera dibranchiata), sand worms[14] (Nereis virens), and clams (Mya arenaria) for heavy metals in their tissues. Several attempts were made to raise Nereis virens in aquariums in the laboratory, with the ultimate intention of studying the effects of various concentrations of heavy metal ions introduced into the sea water. However, each time, high natural worm mortality was observed due to high ambient temperatures, and it was finally concluded that the necessary refrigeration was not available, so the project was abandoned.

6.4 Conclusions

As stated before, sample analysis is not yet complete, so no conclusions are possible at present.

6.5 Recommendations

During July 1972, the Callahan Mining Corporation was beginning to raise salmon in a fish trap floating in Holbrook Cove. They planned to monitor the metal concentration in the salmon flesh, with the ultimate intention of marketing the salmon on a large scale. In their proposal, the deep open pit would be filled with sea water and used for fish culture. Considering the remarks made by Dr. Ruth Patrick,[15] this would be highly undesirable.

As of July 1972, the mining operation had apparently been closed down. Weir Ditch, which had poured effluents into Weir Cove on the southern side of Cape Rosier, had been another major source of heavy metal contamination. As of July 28, its seaward end had been filled in. Although monitoring of the site should be continued, it is probably not within the capabilities of the Student Summer Ocean Engineering Laboratory to continue the systematic sediment monitoring on a large scale, recognizing the difficulties which were encountered attempting to use analytical techniques and equipment and the great amount of time necessary to sort benthic sediment samples. However, monitoring of metals in worms and clams in the Cove is relatively simpler, and should be continued if AAS equipment is available.

6.6 Detailed Procedure

6.6.1 Sampling Plan

A grid pattern consisting of 24 stations was selected on the basis of previous sampling and analysis done by the FWQA.[6] Basically, a 3 x 8 pattern was laid out in the channel separating Holbrook Island and Cape Rosier. If time allowed, multiple sediment samples would be taken at each station, assuring adequate sampling of the benthos.

6.6.2 Sampling Technique

Samples were taken with a modified Petersen grab sampler at most stations. Some stations were coarse gravel or bare rock, preventing adequate grab sampling. The grab was hand-operated from the deck of the lobster boat.

All samples were sieved as soon as possible after return (usually within 6 hours) through 0.25 mm sieves, preserved with 10% formalin, and buffered to saturation with sodium borate (preventing calcareous shell decomposition). Subsamples for AAS analysis were placed in acid-rinsed containers and preserved with 2-3 ml concentrated HNO_3.

6.6.3 Sample Analysis

Sorting of benthic samples was accomplished under low magnification microscopy. All animals retained by the sieve were transferred to a methyl alcohol preservative. Identification was accomplished using standard available keys.

Analysis of sediment and water samples will be done by atomic absorption spectrometry using Jarrell Ash instrumentation. The method followed will be the standard methods used by the Environment Protection Agency,[16] with minor alteration by the M.I.T. lab. Although metal ion concentrations of some of the Goose Falls Stations probably fall quite low, previous surveys of the area (FWQA)[6] have not found it necessary to use special low detection limit methods of analysis, especially since interferences are more common with these methods.

Interferences known as matrix interferences occur when there are high concentrations of acids or dissolved salts, as would be the case with the samples considered here. These are controlled by dilution or by matching the concentrations of major constituents in samples and standards. When there is no way of matching concentrations, the method of additions[17] is used. For analysis of the samples taken from Holbrook Cove, a rinse to remove sodium interference will be adequate. Several runs will be made to determine statistical confidence intervals.

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7.0 INSTRUMENTATION

7.1 Karman Vortex Trail Current Meter

7.1.1 Objective

The basic goal of this project is the evolution of a compact and reliable current velocity measuring device utilizing the regular velocity-dependent oscillation of vortices behind a blunt object in a moving fluid. Several general design criteria were established: (1) The instrument must be capable of being set and monitored without diver assistance; (2) the output of the instrument must be recordable on magnetic tape; (3) data reduction should be convenient.

7.1.2 Background

Work was carried out during the 1971 M.I.T. Sea Grant Summer Laboratory based on similar objectives (see M.I.T. Sea Grant Report Number 72-3). These attempts were unsuccessful. The experience gained at that time allowed the successful redesign of the instrument during the 1972 Summer Lab. The basis of operation of the instrument is the velocity-dependent vortex shedding of a blunt object moving with respect to a fluid. The wake pattern generated by this object is known as a Karman Vortex Trail. This wake pattern is characterized by periodic shedding of vortices from alternate sides of the blunt object. Each shed vortex moves downstream causing lateral movement of the fluid in the wake of the object. The instrument is based on the detection of this movement. Here the magnitude of movement is not important, but rather the frequency of the change in direction of the fluid behind the blunt object is desired and, thus, the frequency of vortex shedding. This frequency is then empirically related to the velocity of fluid flow, through the calibration of the meter.

7.1.3 Results

The final results, based on a rather short testing period of one day off the dock at Castine and three days at varying locations in Holbrook Cover, were in general successful. The instrument, coupled with a simple oscillator, recorder and timer on the surface, provided data at half-hour intervals over most of the test period. The circuit interfacing the instrument with the recorder, however, was unreliable and created a large amount of unreadable data. Data reduction, while intended to be accomplished electronically, was easily handled aurally, each twenty-four hours worth of collected data requiring approximately forty-five minutes to put into tabular or graphic form. Graphical results of several periods of monitoring are shown in Figures 4.2 and 7.1. The validity of the data is difficult to determine. At present, there is no other tabulated data concerning current flow in the test areas. The results do show fair correlation with times of high and low tide. For example, in Figure 7.1 no current was evident shortly before high tide at 2324 hours and low tide at 0554 hours, the times being appropriate for dockside at Castine. The irregularity of the current profile presented for Holbrook Cove may well represent the apparent current surges which were noted on several occasions by the observers of the current drogues used in this area, as described in Section 3.0 of this report.

7.1.4 Conclusions

Although the test period was too short to allow conclusive evaluation of the instruments reliability, sensitivity and range in open water, the results would indicate that the meter offers a valid substitute for impeller-type current meters, when measuring low velocity currents. The instrument holds up well under rough treatment and requires no diver assistance in mooring.

7.1.5 Recommendations

The success achieved, though limited, would recommend further work on the development of this instrument as a component of a complete system for current monitoring. Most seriously needed would be the perfection of the interfacing electronics. Completion of the digital recording system which was undertaken during the lab would offer considerable advantages and possibilities in the area of data reduction. Concerning the meter itself, one could use pressure transducers as the means of converting the fluid motion to a modulated electric signal, replacing the present arrangement of fin and photocell.

7.1.6 Detailed Procedure

Preliminary design of the instrument took place in the months after the 1971 Summer Lab, and was based on experience

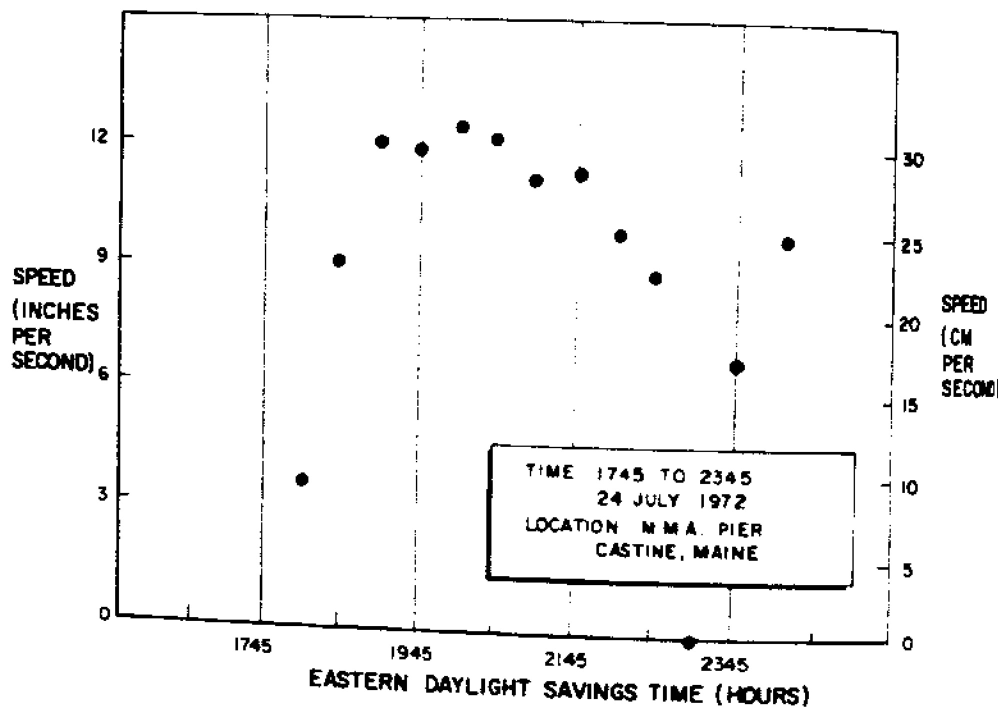


Figure 7.1

Karman Vortex Trail Current Meters Results at Castine gained during the lab. An attempt was made to build a current meter using the vortex shedding phenomenon. The attempt involved trying to sense the frequency of vibration of a wire placed in a fluid flow. The presence of the wire caused the development of a Karman Vortex Trail. In simplified terms, the periodic lateral displacement of the fluid caused the wire to vibrate at the frequency of the vortex shedding. The attempt was then made to sense this vibration using electromechanical means. Due to the very small displacements and energy transfers involved, little success was achieved. It was decided to increase the dimensions to afford greater ease in detection of the movement of the fluid. A one-inch cylinder was used to generate the vortex trail. Sensing of the frequency of vortex shedding was done by a fin mounted on needle bearings in the flow behind the cylinder. Electrical pickup was accomplished by placing a magnet on the fin and positioning a reed switch close enough to be activated by the magnet. This version provided linear response from three-tenths of a knot to just below two knots with sensitivity to one-tenth of a knot. The instruments' dimensions were approximately two inches by three and one-half inches by six inches.

The primary shortcoming of the instrument was that its range of operation was too high to be considered for use in tidal current surveys. Several things were done in an attempt to lower the range of response. First, the effective Reynolds number of the instrument was increased by providing a venturi at the intake of the meter, thus increasing the current velocity seen by the instrument over that of the ambient flow. Little improvement was noted. It is believed that the force imparted to the sensing fin by the fluid movement was of the same order as the force exerted by the magnet on the reed switch, so the sensing of the movement of the fin was relegated to a photo cell rather than the proximity switch and magnet. Tests demonstrated an extension in the effective range of instrument down to about three inches per second. It was still apparent that more energy must be imparted to the wake to obtain greater sensitivity. To achieve this end, an ellipse replaced the cylinder. It was oriented with the major axis perpendicular to the flow. It had been observed that the ellipse generates a wake that is wider than its greatest dimension whereas the wake of a cylinder is roughly the same width as its diameter. The meter now showed a response down to one inch per second (1/20 of a knot) under test tank conditions.

7.1.7 Fabrication

The physical layout of the meter is shown in Figure 7.2. The fin in the wake of the cylinder responds to the movement of the fluid. This lateral movement becomes a rotational movement of the wires used to support the fin. The interposer, rigidly attached to the upper supporting wire moves back and forth between the photocell and light source, which modulates the output of the oscillator. The prototype instrument had dimensions of two inches by six inches by twenty inches. The large length was provided in an attempt to reduce turbulence encountered by the ellipse caused by the leading edges of the duct. All electronics, except the photocell and light source, are designed to be on the surface, thus limiting the amount of waterproofing that must be accomplished. The light source and photocell were cast in plexiglass with their individual leads connected to a four-wire hydrophone cable to the surface. These connections were sealed by simply dipping the soldered joints in fiberglass resin. No trouble was encountered in this method of waterproofing. The original system design called for the meter to be connected to an analog-to-digital converter which would feed digital data to a recorder. This equipment was not ready for use, however, so a simpler method of providing recordable signals was used. The photocell, having a change in resistance which was dependent on the change in light to which it was exposed, was used as part of an astable multivibrator. As the resistance changed, the output frequency of the multivibrator changed. All frequencies were in the audio range and were easily recorded. As was mentioned earlier, the data was readily reduced aurally. This configuration results in a signal which is frequency-modulated at the rate with which the ellipse sheds vortices.

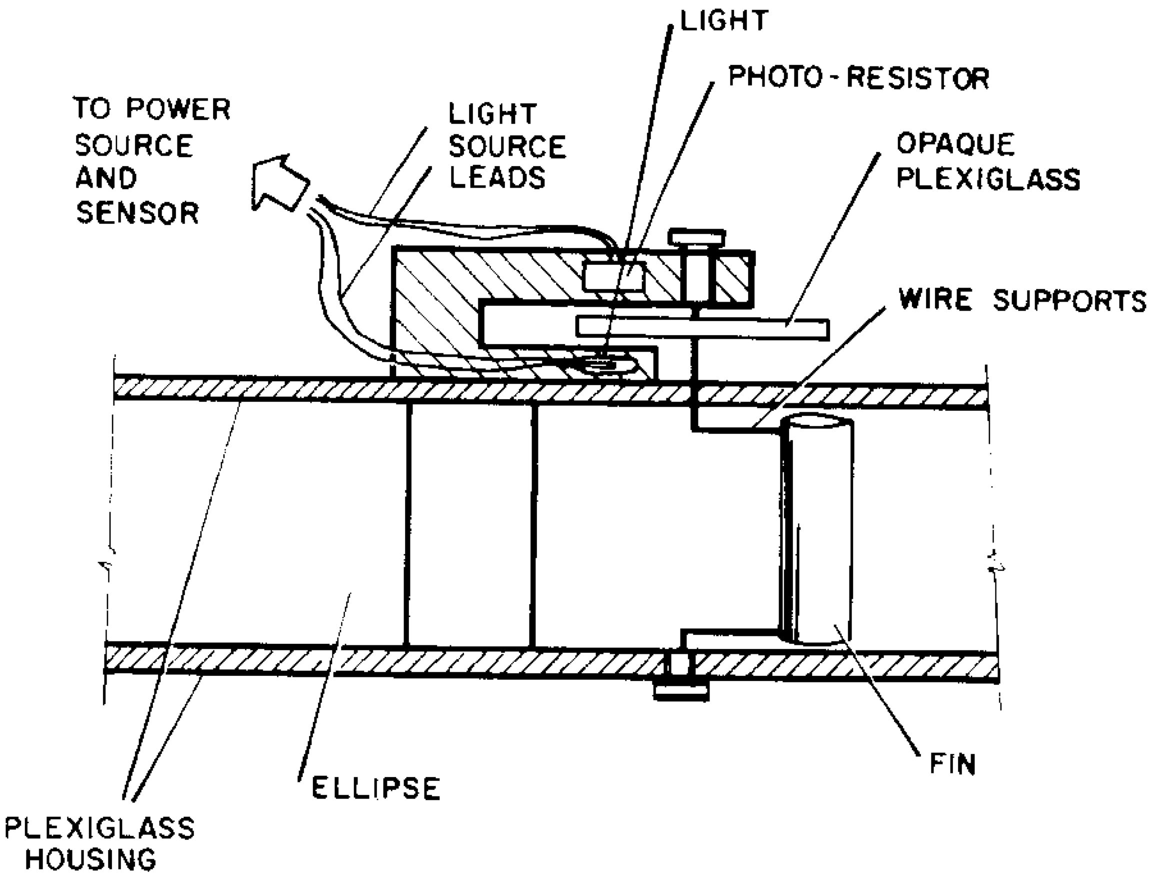


Figure 7.2

Karman Vortex Trail Meter Layout

7.1.8 Calibration

Calibration was carried out, using the instrument towing carriage of the wave tank in the Hydrodynamics Lab at M.I.T. This was used in preference to the ship model towing tank, due to the very low control speeds which could be achieved. Response of the meter from one inch per second to twelve inches per second was obtained. Calibration data is shown in Figure 7.3 along with a curve showing theoretical response. The theoretical curve is based on the following empirical formula relating frequency of vortex shedding to fluid velocity:

$$n = \frac{SV}{d}$$

where n is frequency, S is the Strouhal number, V is the velocity and d is the characteristic diameter (the major axis of the ellipse, 1-7/16"). The Strouhal number is constant in this regime of Reynolds number (greater than 1000). After the conclusion of operations in Castine, the ship model towing tank was used to determine the angular response of the unit to test the feasibility of using the instrument as a current direction indicator. It was hoped that the response would be such as to allow two of the instruments to be mounted in a fixed position at right angles to each other to give vectoral information as well as data about the magnitude of the current. Tests showed that the response of the instrument intercepting the current flow at angles of greater than thirty degrees was too poor to allow such a configuration.

7.1.9 Meter Implacement

The mooring of the current meter is designed to be as simple as possible. To maintain a stationary position a fifty-pound weight is used at the bottom. A line runs directly up to the meter at the desired height above the bottom and is fastened rigidly to the housing about eight inches from the leading edge, on the underside of the instrument. Leading upward from the same position on the top of the housing is a line to a submerged float. This float maintains the vertical position of the meter. A short line is attached on the float line and leads to the tail of the instrument to keep it horizontal. The electrical cable

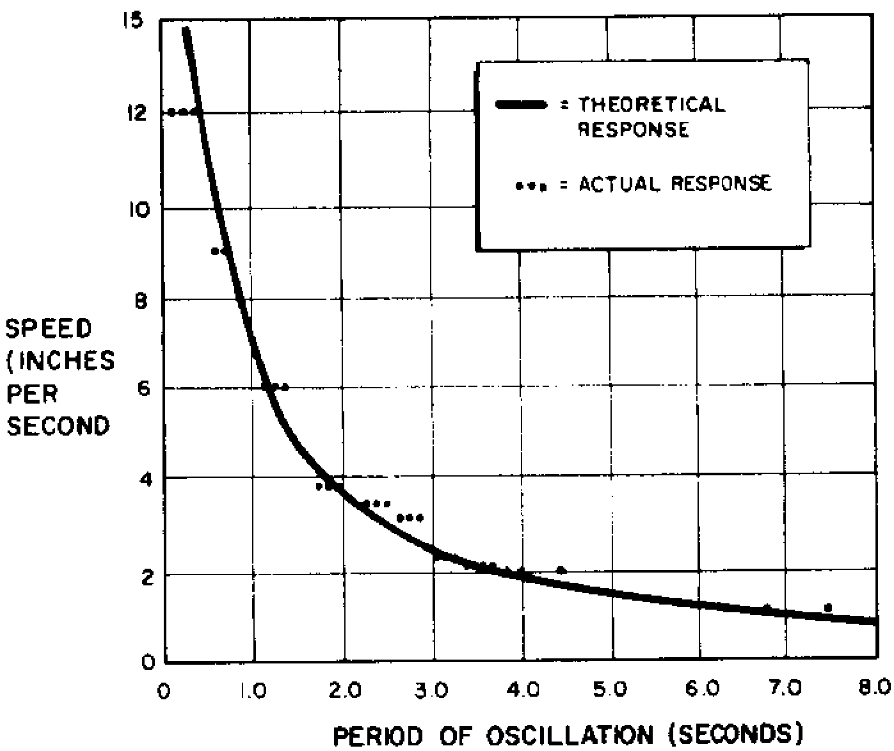


Figure 7.3

Karman Vortex Trail Current Meter
Calibration Curve

(for power and data transmission) is attached at various points to the instrument support cable and is supported at the surface by its own float and a five-quart pressure cooker which provides the watertight housing for the electronics and recorder. A retrieving line is attached to the submerged float and again supported by a surface buoy. No trouble was experienced with this mooring for this instrument. It appeared to allow adequate freedom for the instrument to orient itself with the current flow and showed no sign of drifting off station.

7.2 Impeller-Driven Current Meter

7.2.1 Objective

The objective of this project is the development of a compact and reliable current velocity measuring device utilizing an impeller. Several general design criteria were established: (1) The instrument must be capable of being set and monitored without diver assistance; (2) the output of the instrument must be recordable on magnetic tape; and (3) data reduction must be convenient.

7.2.2 Background

An impeller current velocity measuring device was designed for the 1971 Summer Ocean Engineering Laboratory (see Figure 7.4). This device consisted of a seven-inch-diameter cylindrical housing made of plexiglas tubing, a 24-inch-diameter impeller fashioned from fiberglas, a plexiglas shaft which was driven by the impeller and turned a 5-inch-diameter disc (also fabricated of plexiglas) in which 60 small holes had been drilled at equal intervals on a circumference of four and one-half inches. The disc was used to alternately shadow and expose a photocell to a light source. The unit proved to be cumbersome and unreliable; hence a redesign was undertaken.

The design of the 1972 impeller current velocity meter incorporates many improvements. These include: reduction in size and bulk, an improved impeller, and a better harness (used in securing the meter to the mooring). In the redesign a light source and sensing device (photocell) are sealed in the flanges fore and aft of the impeller hub. The impeller hub has several holes drilled parallel to its axis through which light passes

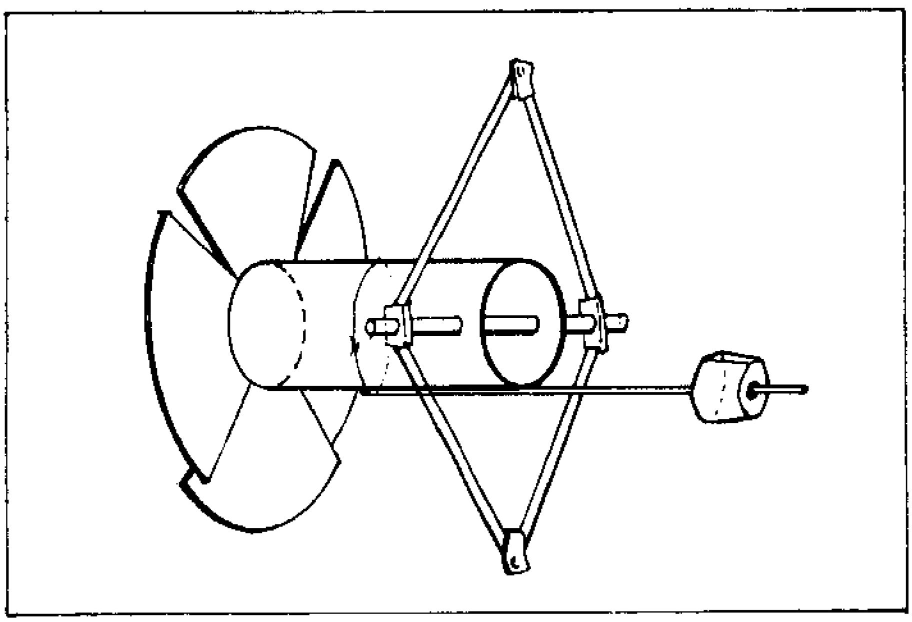


Figure 7.4 Impeller Current Meter
(1971 Version)

when one of the holes is lined up with the light source and the sensing device. In this way several pulses are received from the meter for each revolution of the impeller, permitting accurate readings at low current velocities. The leads from the light source and the sensing device are led into a hydrophone cable, and through the cable to the surface instrument package. The instrumentation package was placed in a pressure cooker which also served as a float. The pressure cooker contained a motorcycle battery, a small amplifier for the signal from the meter, a clock, and a cassette recorder.

7.2.3 Calibration of the Impeller Current Meters

The current meters were calibrated in the M.I.T. towing tank. The major problem which had to be overcome was that the fluorescent lighting in the towing tank interfered with the photocells in the transparent current meters. This was rectified by shutting off the lights in the towing tank during calibration runs. The current meters were painted black before they were shipped to Castine, Maine, to prevent the ambient light from interfering with the operation of the meters when they were moored at the test sites.

The calibration procedure for the three meters constructed in preparation for the 1972 Summer Ocean Engineering Laboratory consisted of towing the meter at speeds of from 0.2 knots to 1.5 knots and employing a frequency counter to ascertain the pulses per second received from the photocells for each speed. It should be noted that the calibration results from all three meters are identical. The empirical correlation between the pulses per second and the speed is:

$$\text{speed (knots)} = 0.25 + 0.53 \text{ (pulses/second)}$$

7.2.4 Mooring

The mooring of the current meter is fairly simple (see Figures 7.5 and 7.6). A 50-pound block is used as an anchor. A line is passed up from the anchor to the meter and then to a float with 25 pounds of buoyancy moored just beneath the surface. Thus there is a 25-pound tension in the line at all times. A slack line attached to the hydrophone cable is led to the instrument package floating on the surface. A buoy is attached to the

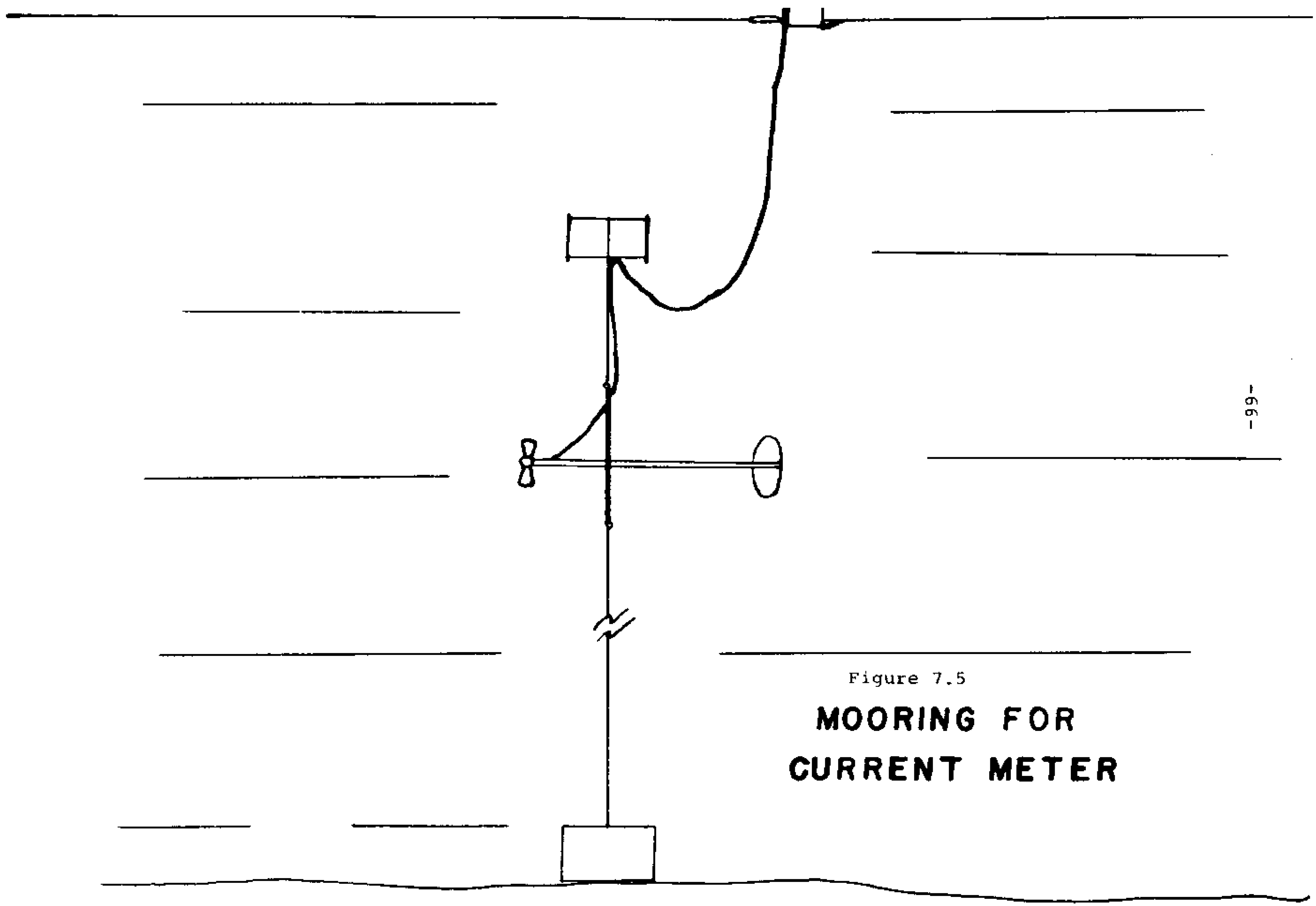


Figure 7.5

MOORING FOR CURRENT METER

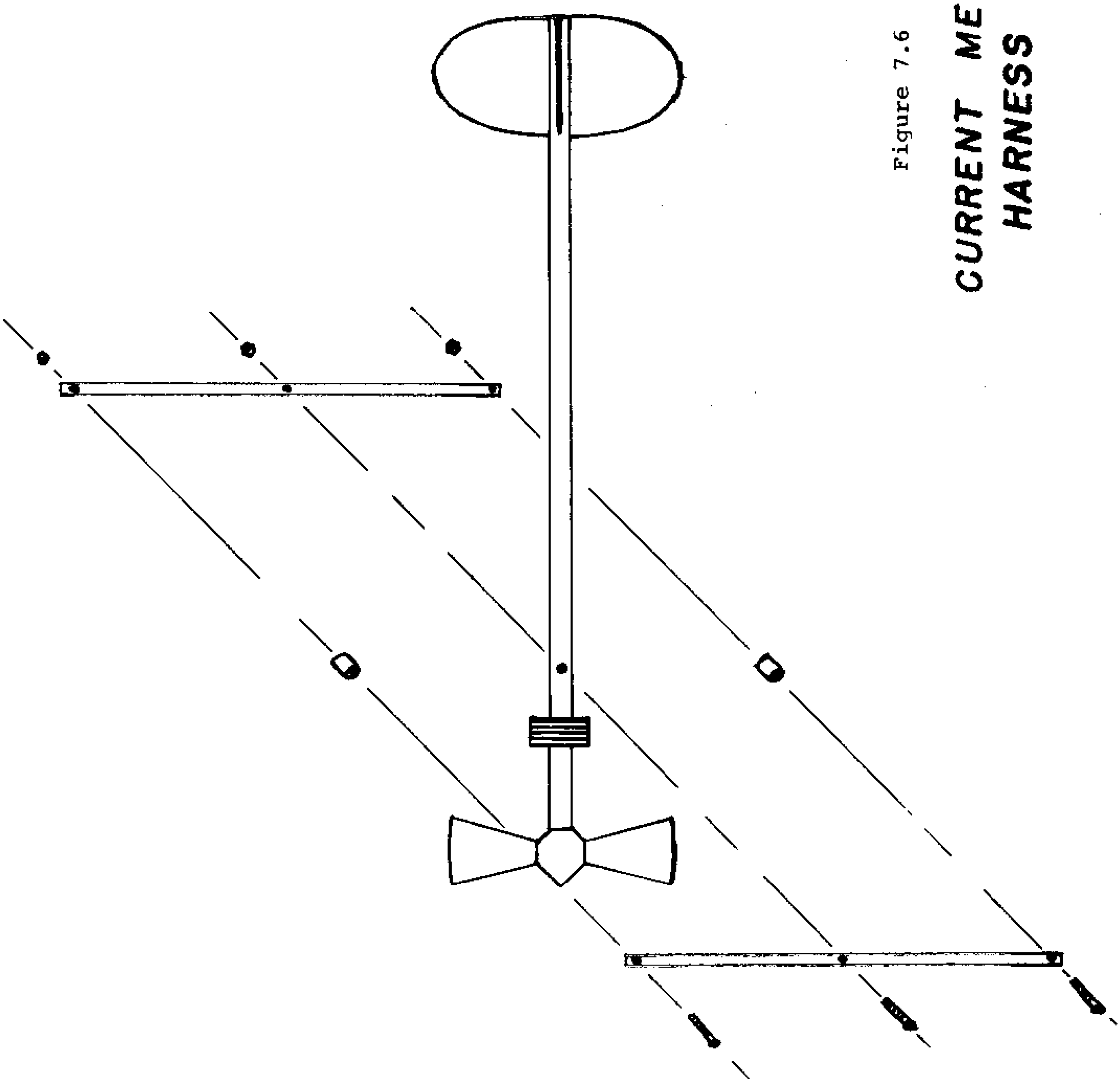


Figure 7.6

CURRENT METER HARNESS

subsurface float to mark the meter. This arrangement permits the cassette to be changed without disturbing the current meter.

7.2.5 Conclusions

The meters performed as designed. The problem with ambient light interfering with the photocells was overcome by making the flanges and impeller hub opaque. A problem developed with mooring harness in that the meter was attached at its center of gravity and when it was raised or lowered it tended to try to rotate until its axis lined up with the mooring line. In one such case the impeller of one meter was broken.

7.2.6 Recommendations

The mooring arrangement should be redesigned to correct the deficiency exhibited when the meter is raised or lowered during implantation or retrieval. A device that will measure current direction should be devised to act as a companion instrument so that both current direction and velocity can be measured at any given instant and recorded.

7.3 Current Direction Indicator

7.3.1 Objective

The major inadequacy of the current metering equipment became apparent during the initial weeks of the project. This inadequacy lay in the inability of the meters to distinguish current direction. It was decided that a companion instrument capable of yielding data on current direction was required. Two basic criteria were established: (1) The instrument should not require diver assistance; and (2) the output should be compatible with the digital recorder which was under development for use with the current meters.

7.3.2 Background

During the 1971 Summer Ocean Engineering Laboratory, construction of a current direction indicator was attempted using a variable capacitor which tuned an oscillator circuit whose output was recorded in analog form (see Sea Grant Report No. MITSG 72-3). The instrument housing and capacitor were moored in a fixed position and a vane (which was allowed to swing with the current) varied the capacitor position. This proved very cumbersome, since it required a three-point moor, a buoying system to maintain the indicator's position vertical, pressurization of the instrument, and considerable diver assistance. The large frictional resistance between the capacitor's shaft and the watertight seals caused problems.

The requirement that the direction indicator be a companion to the current velocity metering devices caused a drastic departure from the concept of the current direction indicator attempted in 1971. The primary changes in design criteria were as follows:

1) Since the housings of current velocity meters rotate to maintain their alignment with the current, then the housing of the current direction indicator must also rotate and the sensing device must maintain a constant orientation (as the sensing device in a gyro or magnetic compass). In the 1971 design the housing maintained a constant orientation and the sensing device oriented itself to align with current.
2) Since the data transmitted from the current velocity metering devices are in digital format, the data transmitted from the current direction indicator must also be in digital format to permit the use of the same recording and data reduction equipment. In the 1971 design the data were transmitted in an analog format.
3) Since the designs of the current velocity meters were based upon a criterion of minimal diver involvement, this criterion must also be invoked in the design of the current direction indicator. As has been previously stated, the 1971 design required extensive diver services.

7.3.3 Results

To meet the design criterion that the housing of the current direction indicator must rotate and the sensing element must maintain a constant orientation, the principle of the magnetic compass card was utilized. It was recognized that four binary bits will permit the transmission of sixteen digital information bits. This characteristic can be utilized to identify digitally sixteen 22-1/2° sectors. It is believed that, for this application, further refinement of current direction would not be sufficiently useful to justify the additional complexity of additional binary bits.

A magnetic compass card was fabricated. Four concentric circles were drawn on the card and interrupted slots were cut on the concentric circles such that rotation of the compass card with respect to the housing would alternately interrupt or pass light from one side of the card to one or more of the four photocells located in a radial line on the opposite side of the card and spaced to coincide with the four concentric circles. The sixteen sectors are identified digitally by determining which of the four photocells are exposed to the light source.

The instrument did not reach the test stage due to the late starting date. The housing is a four-inch i.d. plexiglas tube with end caps three-quarters of an inch thick fitted with O-ring seals. The final version of the compass card uses two permanent alnico magnets and is mounted on needle bearings. The sensing unit's functional resistance to rotation was very small, but it was sufficient to affect the reliability of the orientation of the card with respect to the earth's magnetic field. The light-sensing unit was put together and tested in the housing. No problems were found in sensing the card position using this method. However, it was discovered that a small amount of iron in one of the photocells affected the magnets on the card.

7.3.4 Conclusion and Recommendations

The success of the sensing method makes further attempts at development of this instrument attractive. A compass card with stronger magnetic units and less rotational friction is required. If fabrication proves too difficult, a commercial compass card can be adapted. If photocells which do not affect the compass card cannot be obtained, then perhaps light pipes can be used in the proximity of the card. Completion and testing of the digital recorder and the interfacing circuitry is yet to be accomplished.

7.4 Oxygen and pH Meters

7.4.1 Objective

The ambitious sampling project encompassed by the Holbrook Cove Survey made the automation of the measurement of the environmental factors extremely attractive. The objective of this project is to provide instrumentation that will make the measurement of the oxygen content and pH of water samples a simple, accurate procedure.

7.4.2 Background

During the 1971 Summer Ocean Engineering Laboratory, preliminary measurement of dissolved oxygen concentrations were made using the Winkler iodometric titration method. This proved to be time-consuming and laborious. In planning the biological investigation related to determining the effect of the Callahan mine outfall upon the ecology of Holbrook Cove, it became apparent that it would be necessary to monitor all environmental conditions including the concentrations of dissolved oxygen in and the pH of each water sample. It was therefore decided to obtain a polarographic oxygen electrode and to construct an oxygen meter for use with this electrode. In addition, a simple design for a pH meter was noted in the November 1968 edition of Popular Electronics and it was decided to construct this device for use in the survey.

7.4.3 Results

Both the oxygen and pH meters were constructed. Due to limitations of time, the oxygen meter was not used. The pH meter was constructed, but the proper microammeter was not available and the project's volt-ohm meter was substituted. This substitution proved unsatisfactory due to the high impedance of the volt-ohm meter rendering the meter deflections too small to permit determination of the pH of the water samples to the desired limits of accuracy. The meter was tested in buffer solutions whose pH values were 4.0, 7.0 and 10.0 and the readings appeared to be correct within the limits of accuracy permitted by the volt-ohm meter.

7.4.4 Conclusions

Both meters appear to be operational and require only minor modification (in the case of the pH meter) for increased accuracy, and calibration (in the case of the oxygen meter). They will greatly simplify the measurements of oxygen content and pH.

7.4.5 Detailed Description of the Oxygen Meter and Probe

The polarographic oxygen probe consists of a silver tube whose diameter is one centimeter which acts as an anode and contains a gold cathode at its center. This cathode is maintained at a constant voltage of -0.8 volts with respect to the anode. Both the anode and cathode are coated with either teflon or polyethylene which permits only the gaseous oxygen to diffuse through the coating to the electrodes. This coating prevents the other ions present in sea water from coming in contact with the electrodes. The space between the teflon (or polyethylene) film and the cathode is filled with a fifty percent normal solution of potassium hydroxide.

Conductance between the anode and cathode is produced by the following chemical reaction:

At the gold cathode

4 electons + O_2 -- 4 OH

(Thus, one mole of oxygen produces the flow of four electrons)

At the silver anode

4 Ag + 4 OH -- 2 Ag_2O + 2 H_2O + 4 electrons

(Thus, the conductivity between the anode and cathode is proportional to the oxygen concentration)

The purpose of the oxygen meter is to translate the conductance at the oxygen meter probe to a voltage which can then be read on a standard voltmeter. The operation of the oxygen meter is a follows (see Figure 7.7).

1) A reference voltage is obtained by adding in series a silicon diode and a germanium diode forming a voltage drop of 1.0 volts, which is nearly independent of current flow.

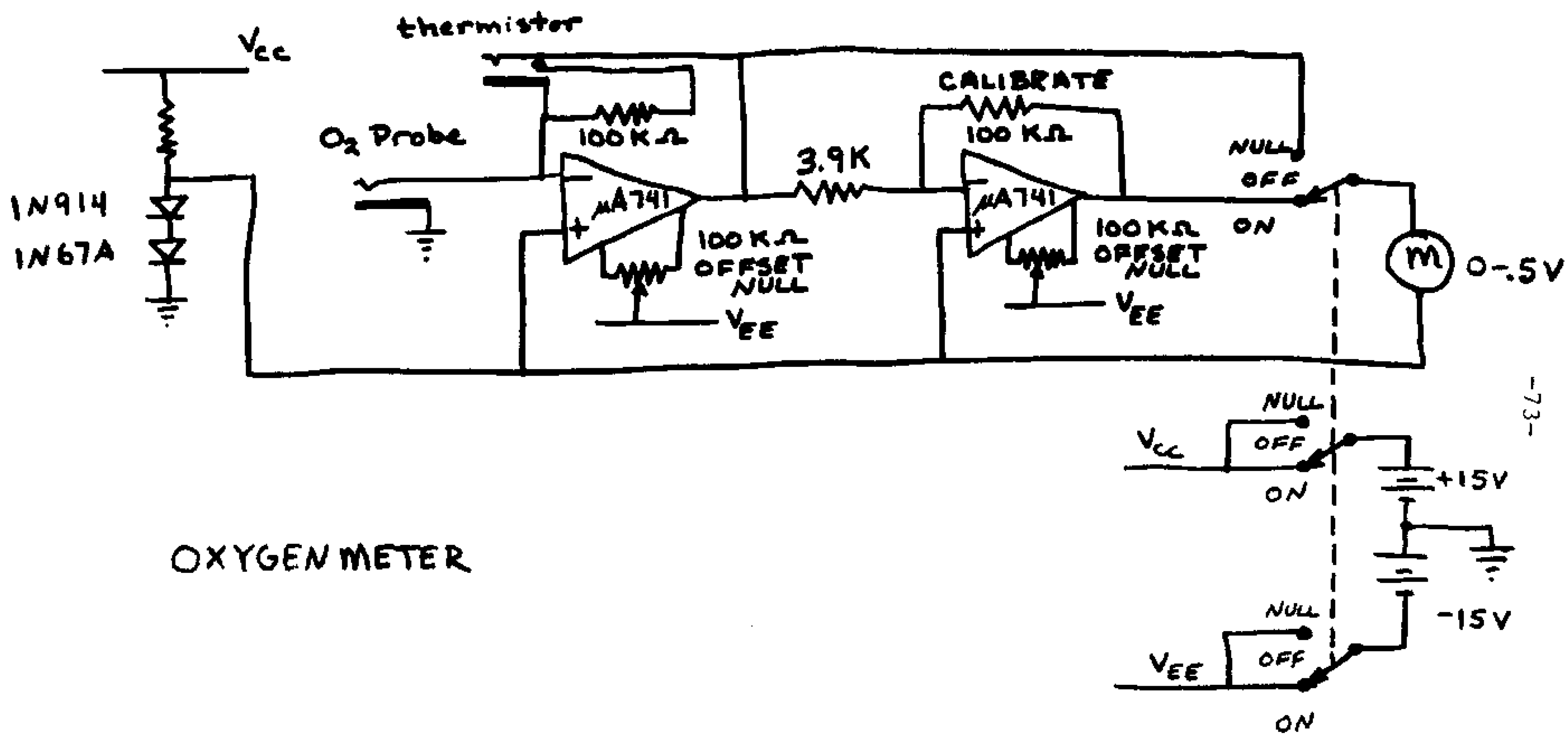


Figure 7.7

Oxygen Meter Circuit Diagram

2) The reference voltage (1.0 volts) is maintained at the inverting input of the first stage of the operational amplifier by virtue of its high gain (200,000) and using negative feedback.
3) An output voltage is developed when the conductance of the probe permits current to flow through the thermistor. The output voltage is directly proportional to the current flow and hence to the oxygen concentration at the probe.

In order to calibrate the oxygen meter, the following procedure is used:

1) Disconnect the oxygen probe from the oxygen meter and check to be sure the voltmeter readout indicates zero voltage. If the voltmeter does not indicate zero voltage, place the oxygen meter switch in the "null" position and adjust the first stage offset-null variable resistance pot until the voltmeter indicates zero volts.
2) Place the oxygen meter switch in the "on" position and adjust the second stage offset-null variable resistance pot until the voltmeter again indicates zero volts.
3) Plug the oxygen probe into the oxygen meter. Check to be sure that the oxygen meter switch is in the "on" position. Place the probe in a solution of known oxygen concentration and adjust the calibration variable resistance pot until the voltmeter indicates a voltage that corresponds to the oxygen concentration of the solution being used for calibration.

7.5 Automated Data Recorder

7.5.1 Objective

The objective of this project is the design and construction of an automated system to: a) convert analog data to digital format; b) record the converted data on magnetic tape; and c) automatically transcribe the recorded data onto IBM cards for data processing. The system is to have the capability of receiving, converting and recording from several sensors during any given time span.

7.5.2 Background

Plans for the Holbrook Cove Survey called for the deploy- ment of current velocity meters at several locations and to leav these instruments in place to measure current data over consid- erable time spans. It did not appear practicable to expect an operator to man these instruments and record the data manually. In addition, it was anticipated that a great many observations were to be recorded and the time and effort involved in tran- scribing this information from analog format into machine- readable digital format seemed prohibitive.

7.5.3 Results

The automated data recorder is designed and various of the elements have been constructed and tested. The concept appears attractive and feasible although there are still techni- cal difficulties to be overcome.

The automated system consists of several units. These incl

1) Encoder (one for each sensor)
2) Decoder (one for each automated system)
3) Recorder (one for each automated system)
4) Power Supply (one for each automated system)

The encoder circuit has two major states: analog to digit conversion and data recording. The encoder is designed as a "bus" instrument to allow for general multiplexing of any numbe of sensors. During the first major state, the time (in seconds since the initializing pulse which cleared all counters and flip-flops is displayed on the "bus" lines. Each sensor's output has its own counter which keeps a running count of the sensor's impulses until the end of an interval determined by the time signals on the "bus" and a gate. Near the end of MS1 (majo state 1), a tape recorder is turned on to allow the tape to come up to speed. By the beginning of MS2 all analog to digital con- versions are complete and the recording on the cassette tape recorder can begin. The method chosen is based on the standard technique involved in low-speed remote computer terminals. The data from each sensor's counter is sampled in turn and converted to the serial form: start bit, 8 data bits (msb first), 2 stop bits. The bits are recorded on the tape by the method of

Frequency Shift Keying (FSK) in which one tone indicates a zero, a second tone indicates a one. This transmission is terminated by a data word of 377octal which serves as an end-of-record mark.

The decoder is in two sections. The first is a standard teletype line receiver similar to the one used by Digital Equipment Corporation in their Logic Handbook. The second part converts the eight bits derived from the first part to two hexidecimal characters in Hollerith format. These characters are sent to the relay drivers which cause the relays to simulate a person punching the keys of an IBM 029 keypunch.

No special requirements are imposed on the magnetic tape recorder by the encoder and decoder. The application of the automated data recording system, however, makes it mandatory that it be compact, reliable, and conserve electrical energy. The speed of the capstan drives should be independent of the power supply voltage.

The power supply is any 12-volt dc electrical source. A motorcycle battery was utilized during the 1972 Summer Ocean Engineering Laboratory.

Since the automated system was not completed, a substitute circuit was designed and utilized (see Figure 7.8). This circuit is a standard astable multivibrator, except that one of the timing resistors is replaced by a photoresistor. In addition, a resistor has been added in series with the photoresistor to prevent the resistance in this path from becoming such a small value that oscillation ceases. Astable multivibrators will not commence oscillation if both transistors are saturated. To prevent this condition from occurring, the timing components were selected to insure that they were extremely asymmetrical. The purpose of this circuit is to convert the electrical pulse (generated when the current velocity meter photocell is exposed to its light source) into a voltage which oscillates in the audio range. This oscillating voltage was then used by the magnetic tape recorder to record the pulse as an audible tone on the magnetic tape.

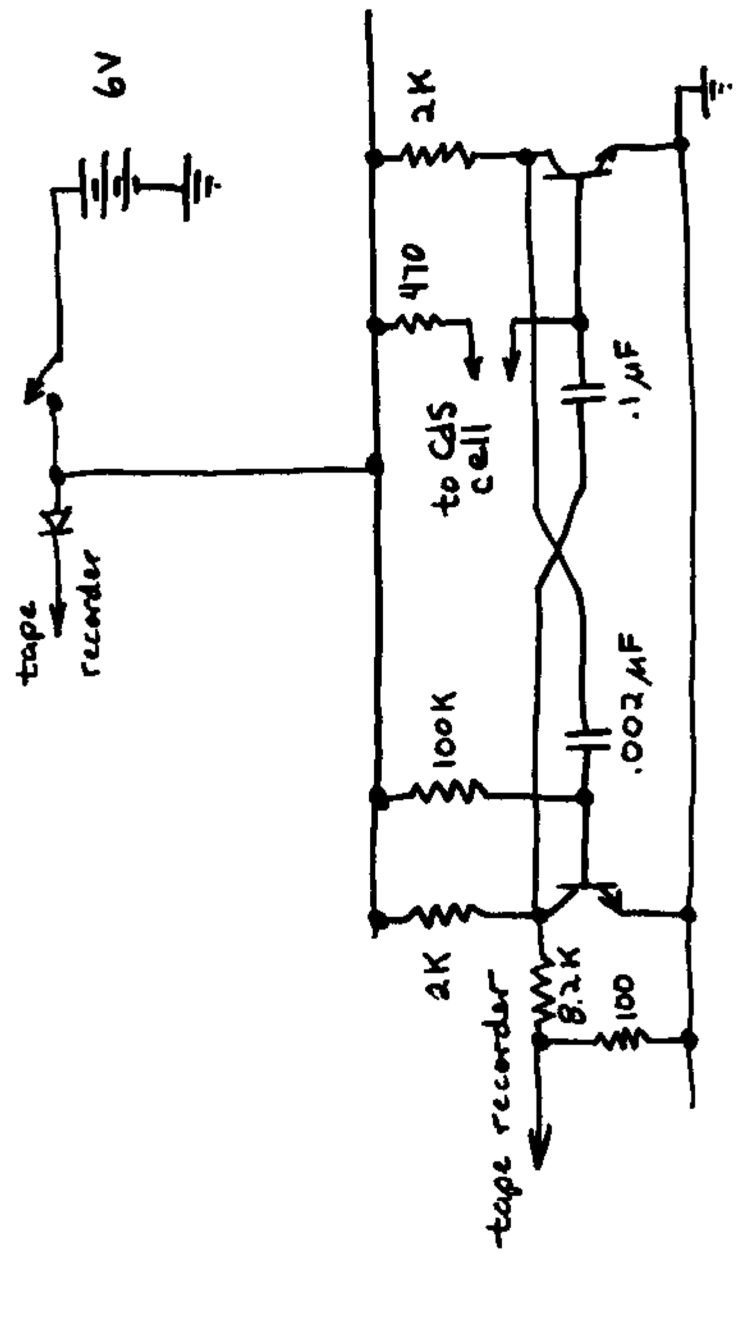


Figure 7.8

Astable Multivibrator Circuit Diagram

7.5.4 Conclusions

The automated data recorder system is technically feasible. The primary problems encountered are fairly mundane. The power consumption must be decreased if the system is to be operated over the time spans envisioned. The timing and recording components must be reduced in physical size.

The FSK transcriber requires additional design work. Its major problem is that a scheme to generate signals to activate the "skip" and "card release" functions on the IBM 029 keypunch must be worked out.

The substitute astable multivibrator circuit worked, but was not problem-free. The primary problems centered about the photoresistor, which was affected by ambient light conditions. This sometimes caused a frequency change in the audible tone and on other conditions it prevented oscillations.

7.5.5 Recommendations

It is believed that perfection of the automated data recording system will make a significant contribution to the oceanographic data-gathering effort. For this reason, it is recommended that this project be continued.

It is recommended that a redesign substituting MOS logic for the existing TTL logic be undertaken to reduce power consumption. This redesign will also make the recorder less sensitive to the power supply voltage.

A review of the frequency and time length of data samples should be made since both affect the power consumption of the data recorder system.

7.6 Tide Gauge

7.6.1 Objective

The objective of this project is to design and construct an instrument which will accurately measure and record the fluctuations in the water height during the tidal cycle. This instrument is to be capable of continuous operation for at least 24 hours and is to be able to operate in all weather conditions.

7.6.2 Background

In conjunction with the measurements of current flows in Holbrook Cove, it was desirable to obtain a measurement of the water height at both the southern and northwestern entrances to the Cove simultaneously. These measurements, which would require the construction of two instruments, would then be used to determine the relative importance of each entrance during the ebbing and flooding tides. After this was determined, it was planned to move one instrument to various sites within the Cove in an effort to further establish the tidal flood and ebb patterns of the Cove.

7.6.3 Results

Due to time limitations, only one instrument was machined in time for field testing. These tests, which occurred during the final days at Maine Maritime Academy, were disappointing because they yielded no accurate data and demonstrated that the machine, as designed and constructed, did not meet the design criteria.

The data obtained from these tests more closely approximated a step function than the expected sine function. A possible explanation for this behavior is that the internal friction of the machine could not be overcome by the small forces generated by the minute tidal changes. Thus, only when the summation of these forces became greater than some critical value, determined by the frictional forces of the apparatus, would the machine begin to scribe, rapidly dissipating the accumulated tidal force.

7.6.4 Conclusions

While the initial results obtained from this machine were unacceptable, the prototype did indicate many specific areas of the design which, if modified, would allow an instrument capable of performing the desired function to be produced. Fundamental to these changes is the consideration of internal friction and the selection of best methods to minimize this force.

7.6.5 Recommendations

The design of this apparatus is best considered as comprised of two components: The first component utilizes a Westclox clock mechanism to power a rotating drum upon which a continuous graph may be scribed; and the second component which reduces (scales) the vertical displacement of the tide and uses the tidal energy to drive a scribe which marks upon the rotating drum. To shield this entire component from the weather, it is entirely encased in a plexiglas case.

The details of the first component, which are found in Figure 7.9, show the rotating drum mounted on a combination thrust and radial bearing and driven by a pulley/belt arrangement by the clock mechanism. A better design would be to utilize a horizontal drum mounted by radial bearings on both ends of the drum. This double mounting will prevent any radial displacement of the drum when subjected to the pressure of the scribe and the consequent binding which occurs when only one bearing is used. Another improvement which suggests itself is the utilization of microchain and sprockets to rotate the drum. This will overcome the slippage inherent in a pulley/belt arrangement at very small angular velocities. A further time check could be provided by a clock-activated scribe, activated at regular time intervals.

The second component, as shown by Figure 7.9, is comprised of a weight and a float suspended from a large sprocket by a chain. The weight and float are designed to travel vertically with the tide, rotating the sprocket wheel, which subsequently drives a small pinion gear against a movable rack which is displaced vertically one-fifteenth the amount of the displacement caused by the tide. Affixed to this rack is a scribe which stays in contact with the drum continuously. If the vertical rotating drum is replaced by a horizontal rotating drum, the rack and pinion assembly can be replaced by an assembly utilizing a screw-activated scribe, which should be an improvement.

As was previously indicated, the primary obstacle to the machine functioning properly is that insufficient energy is generated by small tidal displacements to cause the machine to scribe continuously. As shown in Figure 7.9, the weight and float are both suspended within tubes for the purpose of damping out any local surface disturbances on the water surface. As shown, a float is placed in a tube open to the sea, while a counterweight is placed in a tube sealed to the sea. This arrangement allows the float to rise and fall with the water admitted to its tube. It is apparent that the top and bottom positions of the float during slack tide define the conditions critical to the proper functioning of the tide gauge. These

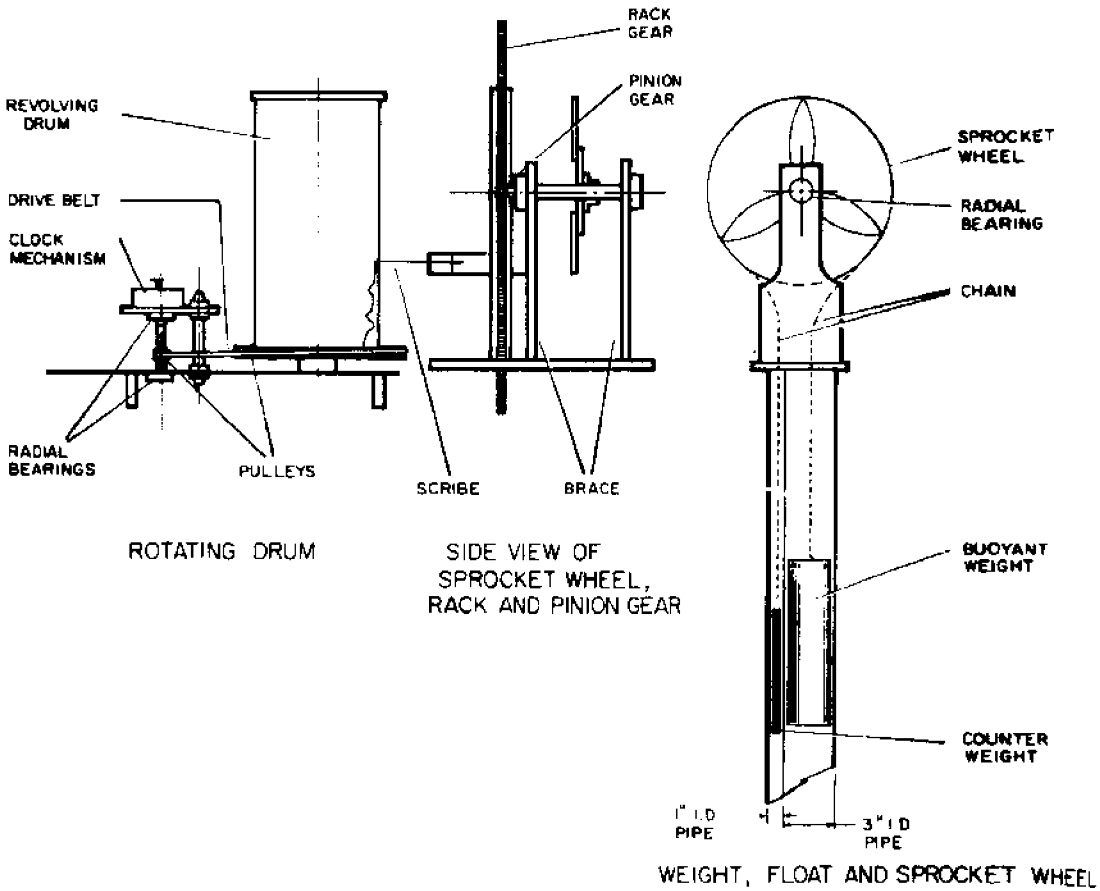


Figure 7.9

Tide Gauge Construction

critical conditions are summarized in Figure 7.10. The results of the tests during the Summer Ocean Engineering Laboratory and careful examination of Figure 7.10 lead to the conclusion that both the float and the weight must be increased in size if the gauge is to function as designed. An obvious method of accomplishing this is to utilize a large doughnut-shaped float circumscribing a large sealed tube in which a counterweight is suspended. This improvement would tend to minimize the nonlinearity of the system indicated by the equations in Figure 7.12. The nonlinearity can also be eliminated by properly calibrating the tide gauge.

7.7 Detailed Bottom Topography of Holbrook Cove

7.7.1 Objective

The objective of this project is to obtain the data required to build a detailed topographical model of the bottom configuration in Holbrook Cove. As a first step it is necessary to define the water height above mean lower low water as a function of time.

7.7.2 Background

It has been noted that some of the prominent bottom features such as rocks and shoals are not indicated on the charts of Holbrook Cove. In order to rectify this deficiency, a careful and systematic program of taking and recording soundings, using a small boat and lead line, is planned.

7.7.3 Results

During the 1972 Summer Ocean Engineering Laboratory there was time to complete only the first step, i.e., prepare a nomogram (see Figure 7.11) that will permit the prediction of water height above mean lower low water as a function of time. During the process of checking this nomogram against observed tide heights at the dock of the Maine Maritime Academy, it was discovered that the scope of the tide was about 12 inches greater than would be predicted using the Coast and Geodetic Survey Tide Tables. An example of the use of Figure 7.11 is in Appendix C.

7.7.4 Conclusions

The tide height observations at the dock at the Maine Maritime Academy agreed with the predictions calculated using

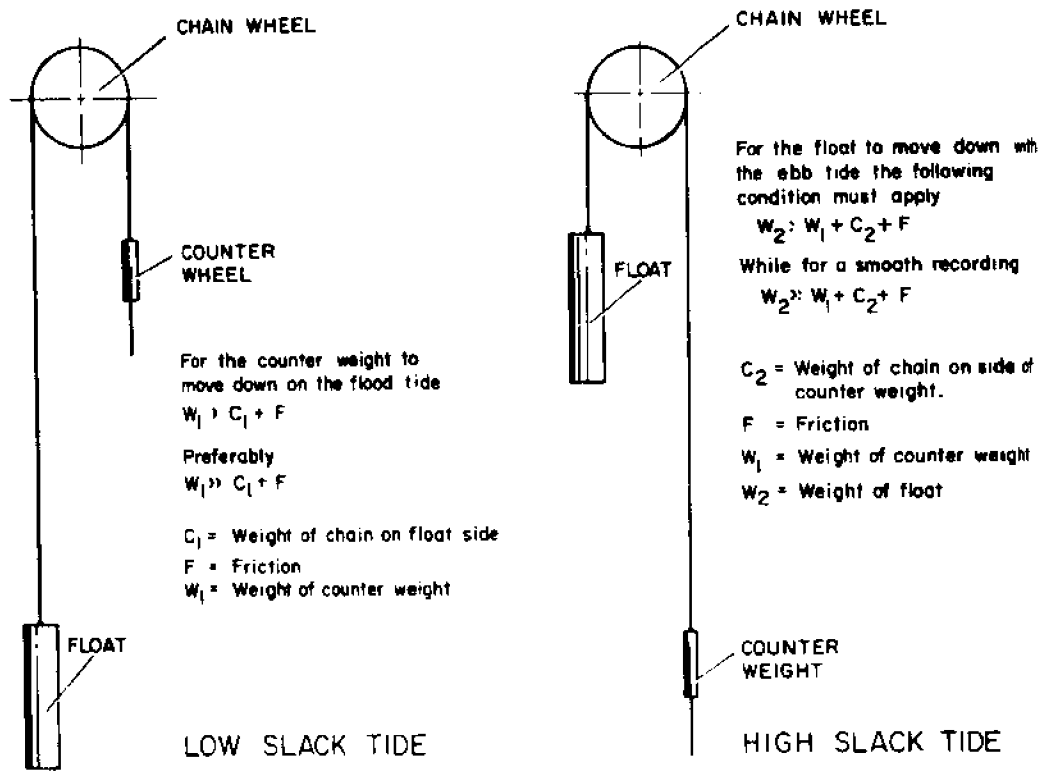


Figure 7.10

Tide Gauge Critical Conditions

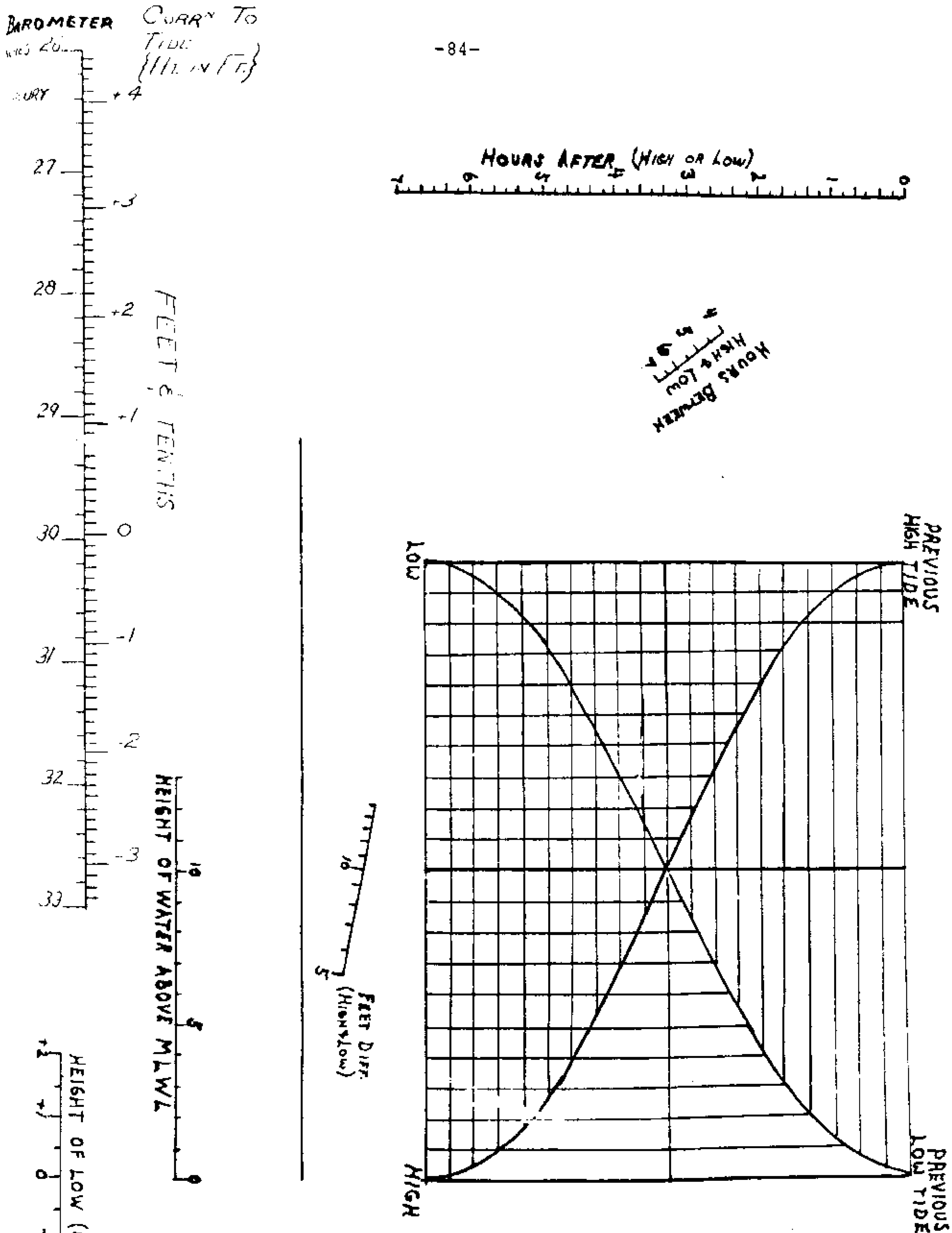


Figure 7.11

Nomogram

the nomogram. Based upon the observations, it appears that the corrections to tide height for Castine, Maine (as indicated in the Coast and Geodetic Survey Tide Tables), are in error. The correction for High water should read +1.7 vice +0.7.

7.7.5 Recommendations

The first step in the process of building the topographical model of the bottom configuration of Holbrook Cove is completed with the preparation of the nomogram. It is recommended that the nomogram be used to correct soundings taken in the subsequent phases of the project to obtain water heights corresponding to mean lower low water depths.

7.8 Bottom Sample Corer

7.8.1 Objective

The purpose of this project is to design, build, and test a corer to obtain bottom mud samples. The corer should be inexpensive and easy to operate.

7.8.2 Background

There were two reasons for choosing this project. One was to obtain experience in designing and building a piece of oceanographic equipment; the second was to produce a corer that would be available for use in the ocean engineering program at Maine Maritime Academy.

7.8.3 Results

In the actual test in Holbrook Cove, the unit was lowered into the water to check the balance. It was then lowered until the messenger hit bottom, allowing the corer to fall. When the corer was released, it was observed that the line holding the tripping device, corer and messenger became taut and then went slack. When the unit was retrieved, it was discovered that the line attaching the corer to the tripping device had been severed. The boat used for this test had not been moored and the test site was not buoyed. All attempts to locate the corer failed.

7.8.4 Conclusions

Judging from the observations of the line holding the tripping device, corer and messenger, the corer penetrated the bottom and would have permitted the retrieval of a core if it had not been lost. The design of the corer should be modified to provide for a steel wire leader for attachment of the corer to the tripping device.

7.8.5 Recommendations

Future tests of this device should be conducted only after the boat has been moored and the site suitably marked so that, in the case of severed lines, the lost units may be located and retrieved. The basic design appears sound, although it is not possible to state whether or not the samples retrieved using the corer would be sufficiently undisturbed to permit an accurate reconstruction of the boundaries and depths of the sedimentary layers.

7.8.6 Detailed Procedure

The corer consists of a body composed of an internal pipe and an external pipe. On the ends of these pipes are two fittings called the head and tail. These fittings are threaded to fit on the ends of both pipes. They are designed in such a manner that the outer pipe will take the stress and the internal pipe will retrieve the sample. Once obtained, the sample is removed by pushing the sediment out with a push rod which consists of a wooden tip the same diameter as the internal pipe and a rod longer than the pipe.

On one end of the tripping device is a messenger and on the other side, the corer. The tripping mechanism and arm are all designed so that the whole device, with corer and messenger, will balance in the water. When the device is lowered, the messenger, which has 35 feet of line extended ahead of the corer, touches the bottom and allows the tripping arm to rotate and the corer to fall to the bottom a distance equal to the messenger line length plus four feet (the length of the corer). Once the corer hits the bottom, the whole unit is raised and the sample removed.

Figure 7.12 Corer

BODY

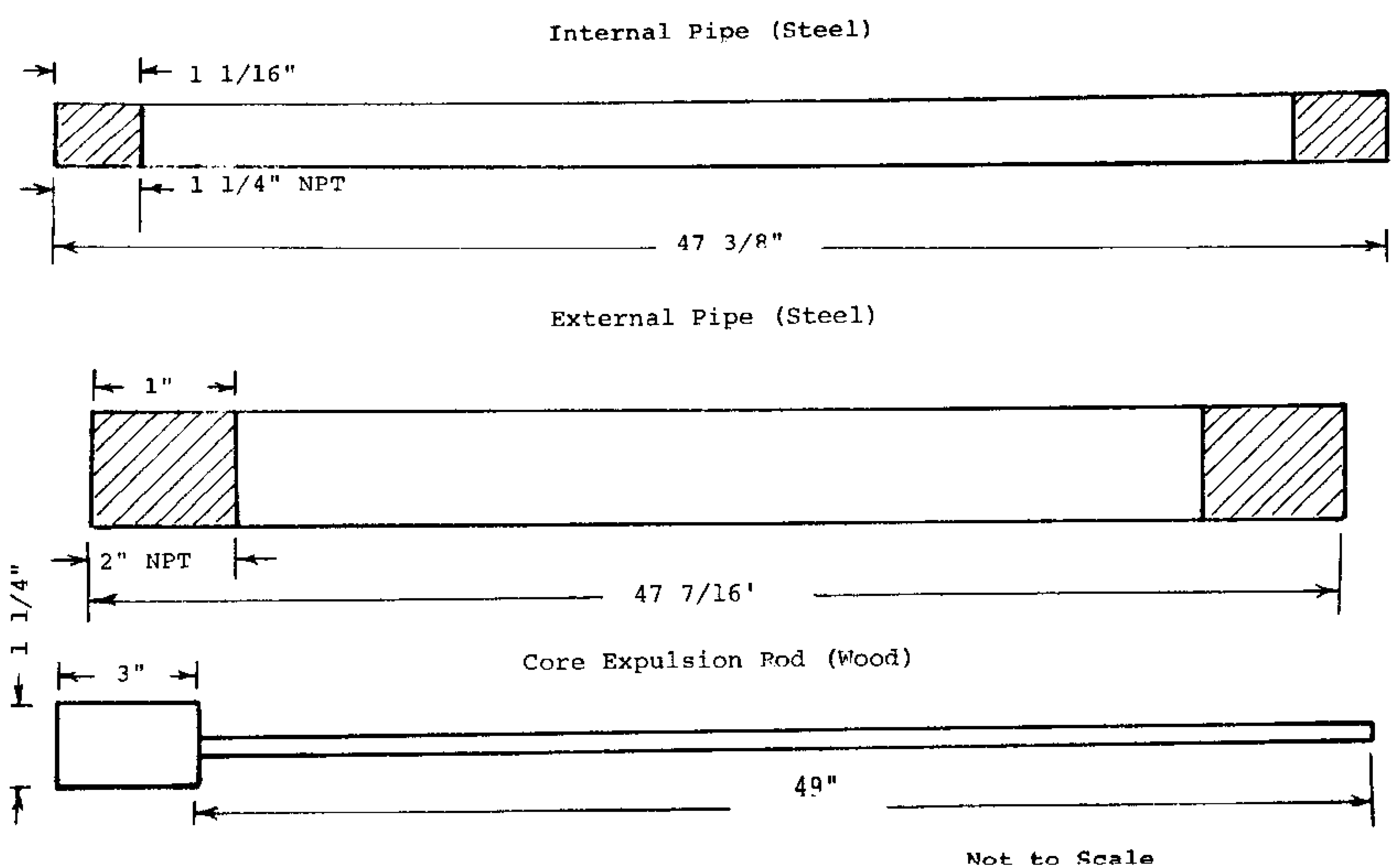


Figure 7.13 Corer

Tripping Mechanism

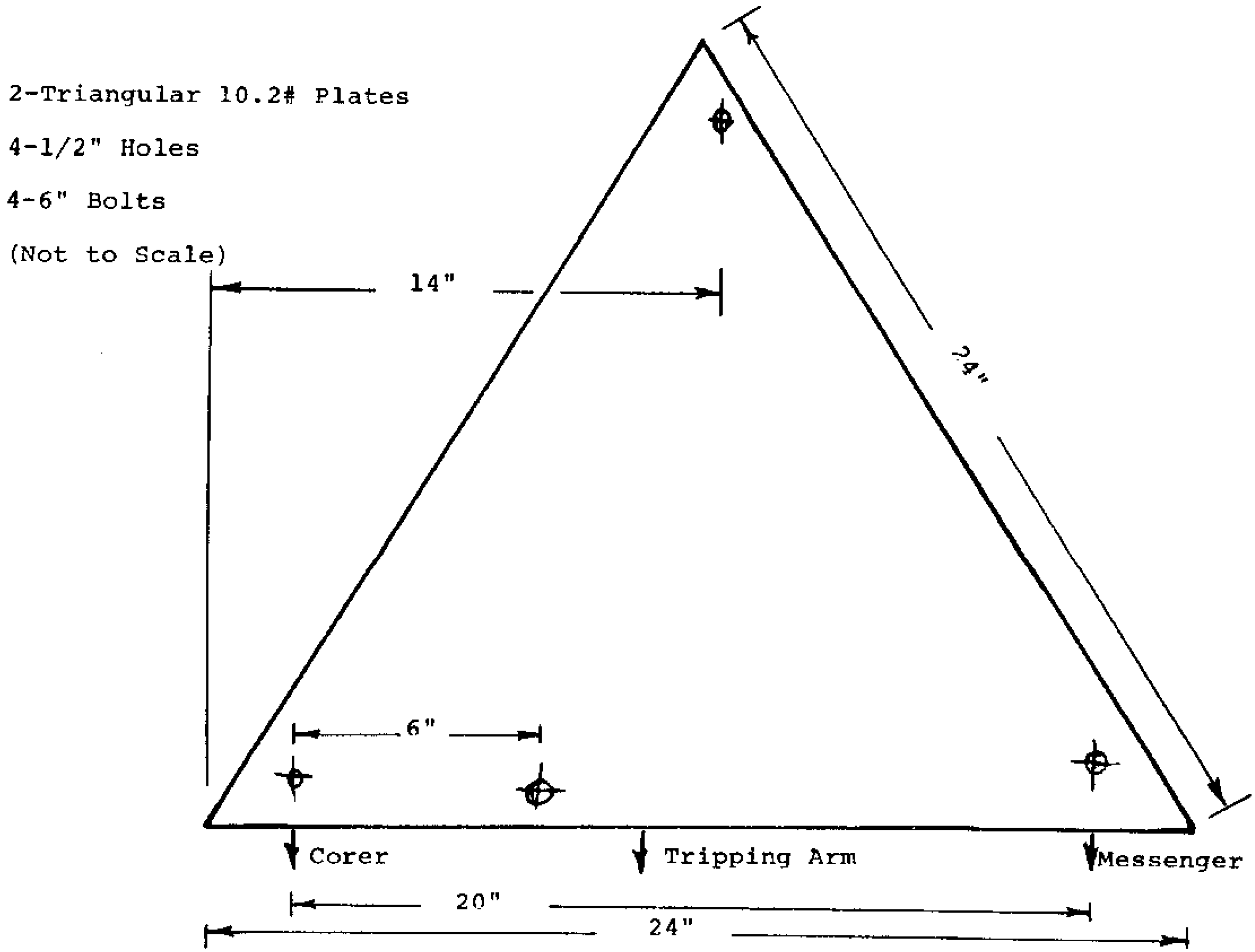
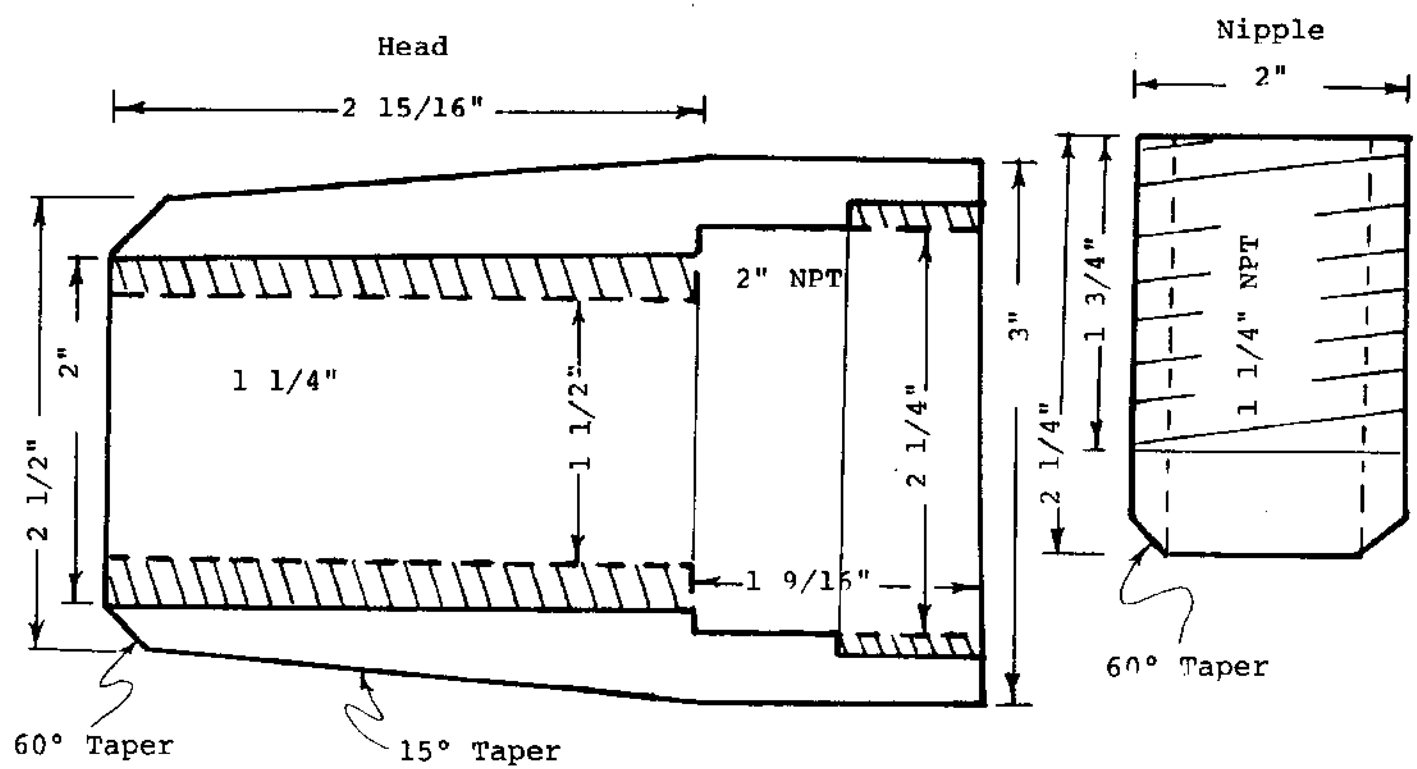


Figure 7.14

Head and Nipple Insert



Note: Nipple fits in front of head and is replacable in the event cutting edge is damaged on a rock.

APPENDIX A

DROGUE BODY COMPUTER PROGRAMS

APPENDIX A

The first computer program is modified solely by input data. There is no need for a modification of the source program.

One of the first data cards is a parameter decision card specifying which options the user of the program wishes to utilize. This is stated in the program listing. The flow chart points out the various combinations of options possible. Comment cards are permitted at certain points to keep track of special data.

One possible option is the use of data-smoothing subroutines. The preferred smoothing subroutine is spline fit. Spline fit approximates an idealized drafting spline curve through the data positions. If the number of equations (positions) is too small to permit the use of a spline, a least-squares fit subroutine is used.

Another important option is the IAXIS parameter which rotates the axis such that the X coordinates can be plotted and calculated as a function of the Y coordinates.

The spline and least-squares subroutines compute the Y coordinates as a function of the X coordinates. A reversal in buoy velocity will cause infinite looping in the spline and least-squares subroutines since they will yield two or more values of Y for one value of X. If a buoy reverses direction, the program will terminate the buoy path and restart it in the opposite direction. In cases of vorticity (in the Holbrook Cove Survey), many restarted paths resulted. In those cases, it was specified on the decision card that no interpolated values were desired and that all broken segments should be connected. Because the spline fit subroutine allows the user to specify the placement of the constraints on the equations, the user sometimes supplied cards listing the position of constraints and/or position of output points desired. If the user wished to place the constraint or position of output points, he specified a positive number of constraints and output points, with the positions given in X coordinates. If the user wished the program to pick the positions, a negative number was specified. If a buoy back-tracked, the program itself decided on a number of constraints and output points, and the placement of each.

In order to graphically represent velocities in addition to pathlines, two subroutines placed either a tickmark for times or a line through two or more buoy paths, depending on user specification (e.g., if the distance between ten-minute tick-marks decreased, the buoy was traveling slower. If the distance increased, the buoy was traveling faster).

In the numerical printout part of the program, two types of velocities were computed: a backwards difference velocity and a centered difference velocity. The backwards difference velocity is computed by dividing the distance between the position under consideration and the position at the previous observation by the difference between the time of the observation of the position under consideration and the time of the previous observation. The centered difference velocity is computed by dividing the sum of the distances between the position under consideration and the positions of the previous observation and the next subsequent observation by the sum of the differences between the times of observation of the position under consideration and the times of the previous and next subsequent observations. The subroutine STOREC could be further modified to allow a least-squares or other velocity approximation if the user wished to modify the source.

All sorts, with the exception of TSORT, are interchange sorts, as the number of sorted items cannot exceed 99. The limit on the number of buoys' segments is explained by the fact that the program considers each buoy segment caused by backtracking to be a separate and equal segment (e.g., in the case of vorticity, a buoy input with 99 points may be composed of 20 or more segments, etc.). TSORT takes an already sorted list and puts them in ascending order, in the event that they were originally in descending order.

There are a few limits and constraints that are intrinsic in the source program, and to be changed require the source to be modified. Numerical limits are listed. Other major limits not listed follow. The IWARN array is a controlling factor in the dumping of input constraints and output positions for the interpolation routines and timelines. If a buoy backtracks, IWARN for that particular buoy is activated. This means that all input constraints are dumped and replaced and that timelines are not allowed on any of the segments (tickmarks are).

Spline is used in all cases except where the number of points is too close to the number of equations. Then, and only then, is least squares used.

DROGUE BODY COORDINATE

AND VELOCITY CALCULATION

COMPUTER PROGRAM

```
      COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINO(99),
     2YINO(99),XOUT(500),YCLT(500),NIN,ITMARK,ICONET,ISTRLN,IADICH,XINT,
     3YINT,INCRCT,JUSIN,IMLINE
      COMMON /AREA1/ IHELP
      COMMON /AREA2/ XMAX,XMIN,YMAX,YMIN
      COMMON /AREA7/ TCHAR,NWSTAR
      REAL*8 CHAR1,CHAR2,CHAR3,CHAR4,CHAR5,TCHAR,CHAR21,CHAR22,CHAR23,
     1CHAR24,CHAR25
      LOGICAL*1 MIWSAR(9),IFLT(9)
C     CHARACTER VARIABLES
C
C
C     COMMON/AREA1/  EMERGENCY ESCAPE CLAUSE
C     COMMON/AREA2/  MAXIMUM DIMENSION SIZES
C     COMMON/AREA7/  HIGH OR LOW TIDE CHARACTERS AND TIME
C
C     SUBROUTINES AND FUNCTION LIST
C     TIMELS  CALCULATES CURVES THAT INTERSECT POSITIONS AT GIVEN TIMES
C     TIMEMK CALCULATES TICKMARKS ON THE POSITIONS FOR GIVEN TIMES
C     DUCK A SPLINE FIT CURVE
C     GLSQ SOLVES EQUATIONS GIVEN TO IT BY DUCK IN A LEAST SQUARES WAY
C     AUTOD PLACES THE POSITION OF THE CONSTRAINTS FOR CURVES BY DUCK
C     DUCKT EXAMINES THE POSITIONS OF THE CONSTRAINTS  WILL VOID THEM
C     PRITOK WILL PRINT OUT THE POSITIONS OF THE CONSTRAINTS
C     INTERP PREPARES EQUATIONS AND SOLVES FOR A LEAST SQUARES FIT
C     GLSQXZ  M.I.T. COMPUTER MATHLIB  LEAST SQUARES FIT
C     SIMEQ IBM SSP FOR THE SOLUTIONS OF SIMULTANEOUS EQUATIONS
C     COEF PRINTS OF THE EQUATION COEFFICIENTS USED IN SPLINE AND LEAST
C     SQUARES
C     XOUTER CALCULATES AT REGULAR INTERVALS THE OUTPUT POSITIONS
C     TSORT SPECIAL SORT PLACES INPUT POINTS IN ASCENDING ORDER IF THEY
C     ARE INPUTTED IN DESCENDING ORDER
C     SORT  A STANDARD INTERCHANGE SORT
C     RSORT INTERCHANGE SORT WITH A TAG-A-LONG ARRAY
C     PRAPN PUNCHES AND/OR PRINTS INPUT POINTS
```

```
C      CUTER PUNCHES OR PRINTS OUTPUT POINTS
C      DEGREE OUTPUTS A DEGREE.MINUTE NUMBER FROM INPUT DEGREES  OUTPUT +
C      STOREC CALCULATES CENTERED VELOCITIES AND FUTHER IMPROVEMENTS
C
C      LIMITATIONS
C      FINAL NO. OF BUOY SEGMENTS <= 40
C      MAX. NO. INPUT POINTS  99
C      CONSTRAINTS ON SPLINE  MUST BE <= INPUT POINTS -4
C      MAX. OF CONSTRAINTS  20
C      MAX. NO.  OUTPUT POINTS  500
C      POSITIONS OF CONSTRAINTS MUST BE INPUTTED IF  +CONSTRAINTS INPUT
C      POSITION OF OUTPUT MUST BE INPUT IF +OUTPUT POINTS INPUTTED
C      IF OUTPUT OR CONSTRAINTS NEGATIVE PROGRAM CALCULATES ABS() NO.
C      POSITIONS MUST BE INPUTTED IN TERMS OF X AND Y COORDINATES
C      ORIGIN IS STATION OF FIRST ANGLES +X IS IN DIRECTION OF NEXT STAT.
C      UNITS ARE:
C                 DEGREES.MINUTES
C      IF TRANSITS USED 0-90-0 SCALES THEN INPUT 2 DEGREES.MINUTES FOR
C      ANGLES GREATER THAN 90 BUT READING LESS THAN 90
C                 METERS.METER
C                 HOURHOURMINUTEMINUTESECONDSECOND
C
C
C      INITIALIZATION OF VALUES
C
       F=.0001
       XMAX=0.0
       XMIN=0.0
       YMAX=0.0
       YMIN=0.0
       IHELP=0
       KIN=5
       KOT=6
       KPUT=7
       IFIRST=1
       NORMAL=2
```

```
      ILAST1=3                                                          MAIN0073
      JOBNUM=0                                                          MAIN0074
      ILOOP=0                                                           MAIN0075
      XSIGNI=1.0                                                        MAIN0076
      DO 7777 IMESS=1,40                                                MAIN0077
C                                                                       MAIN0078
C     IWARN IS TO SAVE THE MEMORY OF WHICH JOBS HAD BROKEN BUCY PATHS   MAIN0079
C     THIS INFO  IS USED FOR DESTROYING CONSTRAINT AND OUTPUT DATA AND  MAIN0080
C     AND FOR STOPPING TIMELINES ON THE REASON THAT IT WILL BACKTRACK   MAIN0081
C     TO FAR TO ALLOW A FUNCTION(X) TO EXIST  PREVENTS A BLOW-UP        MAIN0082
      IWARN(IMESS)=0                                                    MAIN0083
 7777 CONTINUE                                                          MAIN0084
C                                                                       MAIN0085
C     FIRST CARD IS A CHARACTER COMMENT CARD  ANY COMMENT ON IT WILL    MAIN0086
C     PRINTED AND/OR PUNCHED IN THE OUTPUT                              MAIN0087
      READ(KIN,1795)CHAR1,CHAR2,CHAR3,CHAR4,CHAR5,CHAR21,CHAR22,CHAR23, MAIN0088
     1CHAR24,CHAR25                                                     MAIN0089
C                                                                       MAIN0090
C     PARAMETER INPUT CHOICES                                           MAIN0091
C     IPUN=1 PUNCHING                                                   MAIN0092
C     INOROT=1  PUNCH OUTPUT ONLY                                       MAIN0093
C     JUSIN=1  DONOT CALCULATE INTERPOLATION OUTPUT POINTS              MAIN0094
C     ICONET=1  CONNECT BROKEN SEGMENTS CAUSED BY BUCY BACKTRACKING     MAIN0095
C     IAXIS=1  X AXIS=-Y AXIS    Y AXIS= X AXIS                         MAIN0096
C     ITMARK=1 CALCULATE TIME TICKMARKS                                 MAIN0097
C     IMLINE=1 CALCULATE A SMOOTH TIMELINE BY USING SPLINE OR LEAST SQU.MAIN0098
C     ISTRLN=1  SEGMENTED TIMELINE NO SPLINE OR LSFIT CALCULATIONS      MAIN0099
C                                                                       MAIN0100
      READ(KIN,1000)IPUN,INOROT,JUSIN,ICONET,IAXIS,ITMARK,IMLINE,ISTRLN MAIN0101
C                                                                       MAIN0102
      WRITE(KOT,1022)                                                   MAIN0103
      WRITE(KOT, 1101)                                                  MAIN0104
      WRITE(KOT,1796)CHAR1,CHAR2,CHAR3,CHAR4,CHAR5,CHAR21,CHAR22,CHAR23,MAIN0105
     1CHAR24,CHAR25                                                     MAIN0106
      IF(IPUN.NE.0)WRITE(KPCT,1101)                                     MAIN0107
      IF(IPUN.NE.0)WRITE(KPCT,1796)CHAR1,CHAR2,CHAR3,CHAR4,CHAR5 ,CHAR21 MAIN0108
```

```
      1,CHAR22,CHAR23,CHAR24,CHAR25
       WRITE(KOT ,1050)IPUN,INOROT,JUSIN,ICONET,IAXIS,ITMARK,IMLINE,
      1ISTRLN
       IF(IPUN.NE.0)
      1WRITE(KPCT,1050)IPUN,INOROT,JUSIN,ICONET,IAXIS,ITMARK,IMLINE,
      2ISTRLN
       IF(IAXIS.EQ.1)XSIGNI=-1.0
C
C      INPUT NUMBER OF BUOY GROUPS
C      INPUT DEGREES.MINUTES THAT THE BASELINE FROM ORIGIN IS OFF TRUE N
C      INPUT LENGHT OF BASELINE IN METERS.METER
C      INPUT  "HIGHTIDE"  OR  " LOWTIDE"
C      INPUT TIME OF HIGH OR LOW TIDE
C     OPTIONAL INPUT OF ANGLES FOR MAX DIMENSICN IN Y DIRECTION
C     OPTIONAL IS NON-CONSTRAINING ON REST OF INPUT
      READ(KIN,1100)NOJOBS
      READ(KIN,1200)DEGTN,BASLN,TCHAR,MWHOUR,MWMIN,MWSEC,NSECA,ANGA,NSEC
     1B,ANGB
C
C     CHECK ON CORRECT INPUT FOR MAX DIMENSIONS
      IF((ANGA+ANGB).LT.1.0) GOTO 1911
      IF(NSECA.EQ.2)ANGA=180.00-ANGA
      IF(NSECB.EQ.2)ANGB=180.00-ANGB
      IANGA=ANGA
      IANGB=ANGB
      XTEMP=(IANGA+ (ANGA-IANGA)*1.66666)*.0174533
      YTEMP=(IANGB+ (ANGB-IANGB)*1.66666)*.0174533
      IF((XTEMP+YTEMP).GE.3.14159)WRITE(KOT,1301)JOBNUM,ILCOP,ANGA,ANGB
      IF((XTEMP+YTEMP).GE.3.14159)GOTO 1911
      YMAX=(BASLN*SIN(XTEMP)*SIN(YTEMP))/SIN(XTEMP+YTEMP)
      IF(IAXIS.EQ.1)YMAX=(YMAX*COS(XTEMP))/SIN(XTEMP)
C
C     CONVERSION OF TRUE NORTH DEGREES.MINUTES TO RADIANS
 1911 NDEGTN=DEGTN+E
      NMINT=(DEGTN-NDEGTN+E)*100.
      NADDD=NMINT/60
```

```
      NDEGTN=NDEGTN+NADDO                                                MAIN0145
      NDEGTN=NDEGTN-(NDEGTN/360)*360                                     MAIN0146
      NMINT=NMINT-NADDO*60                                               MAIN0147
      DEGTN=(NDEGTN+NMINT/60.)*.0174533                                  MAIN0148
C                                                                        MAIN0149
      WRITE(KOT,1001)NDEGTN,NMINT,BASLN ,TCHAR,MWHOUR,MWMIN,MWSEC,YMAX   MAIN0150
      NOJOBA=IABS(NOJOBS)                                                MAIN0151
      JOBNUM=1                                                           MAIN0152
 6000 IB1=1                                                              MAIN0153
      WRITE(KOT, 1888)JOBNUM                                             MAIN0154
      ISTIMO=0                                                           MAIN0155
C                                                                        MAIN0156
C     INPUT NO. OF SIGHTINGS FOR BUOY AND A MESSAGE                      MAIN0157
      READ(KIN,1300)NIN,CHAR1,CHAR2,CHAR3,CHAR4,CHAR5,CHAR21,CHAR22,     MAIN0158
     1CHAR23                                                             MAIN0159
C                                                                        MAIN0160
      WRITE(KOT,1598)CHAR1 ,CHAR2,CHAR3,CHAR4,CHAR5,CHAR21,CHAR22,CHAR23 MAIN0161
C                                                                        MAIN0162
      WRITE(KOT,1201)TCHAR                                               MAIN0163
      NINA=IABS(NIN)                                                     MAIN0164
      ICHECK=0                                                           MAIN0165
 7000 IB=IB1                                                             MAIN0166
      KOUNT=0                                                            MAIN0167
      NINAC=NINA                                                         MAIN0168
      DO 5000 ILOOP=IB,NINAC                                             MAIN0169
      IADICH=0                                                           MAIN0170
      ICHECK=ICHECK+1                                                    MAIN0171
C                                                                        MAIN0172
C     SECTOR FOR TRANSIT ANGLE ONE                                       MAIN0173
C     TRANSIT ANGLE ONE                                                  MAIN0174
C     SECTOR FOR TRANSIT ANGLE TWO                                       MAIN0175
C     TRANSIT ANGLE TWO                                                  MAIN0176
C     TIME OF SIGHTING HOURS                                             MAIN0177
C     TIME OF SIGHTING MINUTES                                           MAIN0178
C     TIME OF SIGHTING SECONDS                                           MAIN0179
C     SECTOR IS BLANK IF INPUTTING  FROM FULL 360 DEGREES                MAIN0180
```

```
      READ(KIN,1400)NSEC1,ANG1,NSEC2,ANG2,IHOUR,MINUT,NSEC
C
      NSUBT=(IHOUR*3600 + MINUT*60 + NSEC) - (MWHOUR*3600 + MWMIN*60 +
     1MWSEC)
      CALL TIMEPH(NSUBT,MIWSAR)
      IF(NSEC1.EQ.2)ANG1=180.00-ANG1
      IF(NSEC2.EQ.2)ANG2=180.00-ANG2
      IANG1=ANG1
      IANG2=ANG2
C
C     DEGREES--> RADIANS
      XTEMP=(IANG1+ (ANG1-IANG1)*1.66666)*.0174533
      YTEMP=(IANG2+ (ANG2-IANG2)*1.66666)*.0174533
C
C     CHECK FOR BLANK CARDS  ANGLES =0 OR > 180
      IF(((ABS(XTEMP+YTEMP)).LT.3.14159).AND.(XTEMP.NE.0.0).AND.(YTEMP
     1.NE.0.0))GOTO 5500
      KOUNT=KOUNT+1
      ILOKI=ILOOP-KOUNT
      IF(ILOOP.NE.NINAD)GOTO 5679
      J=ILOOP-1
C
C     CLEAN OUT STOREC
      CALL STOREC(ILAST1,J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,MIWSAR,
     1ILAP,IELT,DIST,VEL,VELOC,DIRCT)
      WRITE(KOT,1601)J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(L),
     1L=1,9),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT
 5679 WRITE(KOT,1301) JOBNUM,ILOOP,ANG1,ANG2
      IF(ILOOP.NE.NINAD)WRITE(KOT,1201)TCHAR
      GOTO 5000
 5500 ILOKI=ILOOP-KOUNT
      IETIM=IHOUR*3600+MINUT*60+NSEC
      YINT=(BASLN*SIN(XTEMP)*SIN(YTEMP))/SIN(XTEMP+YTEMP)
      XINT=(YINT*COS(XTEMP))/SIN(XTEMP)
C
C     CHANGE OF AXIS
```

```
      IF(IAXIS.NE.1)GOTO 1912                                           MAIN0217
      STORAG=YINT                                                       MAIN0218
      YINT=XINT                                                         MAIN0219
      XINT=-STORAG                                                      MAIN0220
C                                                                       MAIN0221
 1912 IF(ILOKI.LE.1)GOTO 5505                                           MAIN0222
C                                                                       MAIN0223
C     CHECK FOR IDENTICAL POINTS                                        MAIN0224
      IF(XINT.NE.XIN(JOBNUM,(ILOKI-1)))GOTO 5505                        MAIN0225
      KOUNT=KOUNT + 1                                                   MAIN0226
      ILOKI=ILOOP-KOUNT                                                 MAIN0227
      IF(ILOOP.NE.NINAD)GOTO 5976                                       MAIN0228
      J=ILOOP-1                                                         MAIN0229
C                                                                       MAIN0230
C     CLEAN OUT STOREC                                                  MAIN0231
      CALL STOREC(ILASTI,J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,MIWSAR, MAIN0232
     1ILAP,IELT,DIST,VEL,VELOC,DIRCT)                                   MAIN0233
      WRITE(KOT,1601)J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(L), MAIN0234
     1L=1,3),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT                       MAIN0235
 5976 WRITE(KOT,4344)ANG1,ANG2,XINT,YINT,JOBNUM,ILOOP                   MAIN0236
      IF(ILOOP.NE.NINAD)WRITE(KOT,1201)TCHAR                            MAIN0237
      GOTO 5000                                                         MAIN0238
C                                                                       MAIN0239
 5505 IF(ILOKI.LT.3)GOTO 5600                                           MAIN0240
C                                                                       MAIN0241
C                                                                       MAIN0242
C     CHECK ON POSSIBLE CHANGE OF DIRECTION  BACKWARDS                  MAIN0243
C     IF TRUE THEN CUT OFF OLD SEGMENT AND BEGIN NEW                    MAIN0244
      IF(((XINT.GE.XINO(ILOKI-1)).AND.(XINO(ILOKI-1).GE.XINO(ILOKI-2))) MAIN0245
     1.OR.((XINT.LE.XINO(ILOKI-1)).AND.(XINO(ILOKI-1).LE.XINO(ILOKI-2)))MAIN0246
     2)GOTO 5600                                                        MAIN0247
      J=0                                                               MAIN0248
      ILAP=IETIM-IETIMO                                                 MAIN0249
      DIST=SQRT(((XIN(JOBNUM,(ILOKI-1))-XINT)**2)+ ((YIN(JOBNUM,        MAIN0250
     1(ILOKI-1))-YINT)**2))                                             MAIN0251
      XNUMER=(YIN(JOBNUM,(ILOKI-1)) - YINT)*(-1.)                       MAIN0252
```

```
      XDENOM=-(XIN(JOBNUM,(ILOKI-1))-XINT)*XSIGNI                       MAIN0253
      IF(IAXIS.EQ.0)DIRCT=(-ATAN2(XNUMER,XDENOM) + DEGTN)/.0174533      MAIN0254
      IF(IAXIS.EQ.1)DIRCT=(-ATAN2(XDENCM,XNUMER) + DEGTN)/.0174533      MAIN0255
      CALL TIMEPH(ILAP,IELT)                                            MAIN0256
      VELOC=0.00                                                        MAIN0257
      VEL=0.00                                                          MAIN0258
      IF(ILAP.NE.0)VEL=DIST/FLOAT(ILAP) *100.0                          MAIN0259
      NDIRC=DIRCT                                                       MAIN0260
      TMINN=( DIRCT-NDIRC)*.6                                           MAIN0261
      DIRCT=NDIRC                                                       MAIN0262
      CIRCT=DIRCT + TMINN                                               MAIN0263
      CIRCT=DEGREE(DIRCT)                                               MAIN0264
      CALL STOREC(NORMAL,J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,MIWSAR, MAIN0265
     1ILAP,IELT,DIST,VEL,VELCC,DIRCT)                                   MAIN0266
      WRITE(KOT,1601)J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(L),LMAIN0267
     1=1,9),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT                        MAIN0268
C                                                                       MAIN0269
C     CLEAN OUT STCREC                                                  MAIN0270
      CALL STOREC(ILAST1,J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,MIWSAR  MAIN0271
     1,ILAP,IELT,DIST,VEL,VELOC,DIRCT)                                  MAIN0272
      WRITE(KOT,1601)J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(L),LMAIN0273
     1=1,9),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT                        MAIN0274
      WRITE(KOT,1401)JOBNUM,ILOOP                                       MAIN0275
      IWARN(JOBNUM)=1                                                   MAIN0276
C                                                                       MAIN0277
C     CHECK ON INTERPOLATICN  POINTS                                    MAIN0278
      IF(JUSIN.EQ.1)WRITE(KCT,1201)                                     MAIN0279
      IF(JUSIN.EQ.1)GOTO 5600                                           MAIN0280
C                                                                       MAIN0281
C                                                                       MAIN0282
      LEN(JOBNUM)=ILOKI-1                                               MAIN0283
      WRITE(KOT,1518)                                                   MAIN0284
C                                                                       MAIN0285
C     AVERAGE CIRECTION ANC VELCOITY                                    MAIN0286
      ADIST=SQRT(((XIN(JOBNUM,LEN(JOBNUM))-XIN(JOBNUM,1))**2)+          MAIN0287
     1((YIN(JOBNUM,LEN(JOBNUM))-YIN(JOBNUM,1))**2))                     MAIN0288
```

```
      IATIME=ITIME(JOBNUM,LEN(JOBNUM))-ITIME(JCBNUM,1)
      IF(IATIME.EQ.0)AVEL=C.00
      IF(IATIME.NE.0)AVEL=ADIST/FLOAT(IATIME) *100.0
      ADIRCT=0.00
      IF(ADIST.NE.C.0)ADIRCT=(-ATAN2((YIN(JOBNUM,LEN(JOBNUM))-YIN(JOBNUM
     1,1)),(XIN(JCBNUM,LEN(JCBNUM))-XIN(JOBNUM,1)))+CEGTN)/.0174533
      IF(IAXIS.EQ.C)GOTO 7372
      IF(ADIST.NE..0)ADIRCT=(-ATAN2((-XIN(JOBNUM,LEN(JOBNUM))+XIN(JOBNUM
     1,1)),(YIN(JOBNUM,LEN(JCBNUM))-YIN(JOBNUM,1)))+CEGTN)/.0174533
 7372 CALL TIMEPH(IATIME,IELT)
      NDIRC=ADIRCT
      TMINN=(ADIRCT-NDIRC)*.6
      ADIRCT=NCIRC
      ADIRCT=ADIRCT+TMINN
      ADIRCT=DEGREE(ADIRCT)
      WRITE(KOT,1517)ADIST,(IELT(IZ),IZ=1,9),AVEL,ADIRCT
      NDK=(ILOKI-1)/3
      IF(NCK.GT.6)NDK=6
      NDKA=NDK
      NOUT=(ILOKI-1)*3
      IF(ICCNET.EQ.1)IADICH=1
      IF((IPUN.NE.C).AND.(INCRCT.EQ.0)) CALL FRAPN
      IF((IPUN.EQ.C).OR.(INCROT.NE.0))CALL PRINTO
      IF(JLSIN.NE.0)GOTO 5C50
C
      IF(LEN(JCBNUM).GT.1)GCTO 5501
C
      WRITE(KOT,1333)JOBNUM,LEN(JOBNUM)
      IF(IPUN.NE.0)WRITE(KPCT,1333)JOBNUM,LEN(JCBNUM)
      GOTO 505C
 5501 CALL XOUTER
C
C     DECISION ON WHICH INTERPOLATION TO USE
      IF(LEN(JCBNUM).GT.4)GCTO 5502
      IARITY=1
      CALL INTERP(LEN(JOBNUM),IARITY,NOUT)
```

```
      GOTO 5503
 5502 CALL AUTOD
C
C     ESCAPE CLAUSE CAUSED IN CALCULATING THE POSITIONS OF CONSTRAINTS
      IF(IHELP.EQ.1)GOTO 9587
      IARITY=1
      CALL DUCK(LEN(JOBNUM),XINO,YINO,NDK,XDK,NOUT,XOUT,YOUT,IARITY)
 5503 IF(IPUN.NE.0)CALL OUTER
      IF(IPUN.EQ.0)CALL PRCT
 5050 JOBNUM=JOBNUM+1
      NOJOBA=NOJOBA+1
      IWARN(JOBNUM)=1
      VELOC=0.00
      VEL=0.00
      DIRCT=0.00
      DIST=0.00
      ILAP=0
      CALL TIMEPH(ILAP,IELT)
      ITIME(JOBNUM,1)=IETIM
      XIN(JOBNUM,1)=XINT
      YIN(JOBNUM,1)=YINT
      XINO(1)=XINT
      YINO(1)=YINT
      IB1=2
      NINA=NINAD-ILOOP+1
      J=1
      WRITE(KOT, 1888)JOBNUM
      WRITE(KOT,1201)TCHAR
      CALL STOREC(IFIRST,J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,MIWSAR,
     1ILAP,IELT,DIST,VEL,VELOC,DIRCT)
      IETIMO=IETIM
C     IF MORE POINTS IN THIS GROUP RESTART BROKEN SEGMENT
      IF(ICHECK.LT.IABS(NINA))GOTO 7000
      LEN(JOBNUM)=1
      WRITE(KOT,1601)J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(L),L
     1=1,9),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT
```

```
      GOTO 5423
C
C     PREVIOUS BLOCK       FOR BACKTRACKING BUOYS AND ALL MEASURES FOR
C     RESTARTING THE NEXT SEGMENT
C
C
C     STORAGE OF TIMES FOR USE IN TIMELINES OR TIME MARKS
 5600 ITIME(JOBNUM,ILOKI)=IETIM
      XINC(ILOKI)=XINT
      YINC(ILOKI)=YINT
      XIN(JOBNUM,ILOKI)=XINT
      YIN(JOBNUM,ILOKI)=YINT
      IF(ILOKI.GT.1)GOTO 5800
      ILAP=0
      DIST=0.00
      VEL=0.00
      VELCC=0.00
      ISTORE=1
      DIRCT=0.00
      GOTO 5900
 5800 IL=ILOKI-1
      ILAP=IETIM-IETIMO
      DIST=SQRT(ABS((XINT-XINC(IL))**2+(YINT-YINC(IL))**2))
      VEL=0.00
      IF(ILAP.NE.0)VEL=DIST/FLOAT(ILAP)*100.0
      DIRCT=0.00
      IF(DIST.NE.0)DIRCT=(-ATAN2((YINT-YINC(IL)),(XINT-XINC(IL)))+DEGTN)
     1/.0174533
      IF(IAXIS.EQ.0)GOTO 8389
      IF(DIST.NE.0)DIRC=(-ATAN2((-XINT+XINC(IL)),(YINT-YINC(IL)))+DEGTN)
     1/.0174533
      DIRCT=DIRC
 8389 NDIRC=DIRCT
      TMINN=(DIRCT-NDIRC)*.6
      DIRCT=NDIRC
      DIRCT=DIRCT+TMINN
```

```
      DIRCT=DEGREE(DIRCT)
      ISTORE=2
 5500 CALL TIMEPH(ILAP,IELT)
      N=3
      ILUUP=ILOOP
      CALL STOREC(ISTORE,ILUUP,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,
     1MIWSAR,ILAP,IELT,DIST,VEL,VELOC,DIRCT)
      IF(ILOKI.GT.1)
     1WRITE(KOT,1601)ILUUP,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(
     1L),L=1,9),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT
C
C     CLEAN OUT STOREC
      IF(ILOOP.EQ.NINAD)CALL STOREC(N,ILUUP,ANG1,ANG2,XINT,YINT,IHOUR,
     1MINUT,NSEC,MIWSAR,ILAP,IELT,DIST,VEL,VELOC,DIRCT    )
      IF(ILOOP.EQ.NINAD)
     1WRITE(KOT,1601)ILUUP,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(
     1L),L=1,9),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT
      IETIMO=IETIM
 5000 CONTINUE
      LEN(JOBNUM)=ILOKI
      WRITE(KOT,1518)
C
C     CALCULATION OF TOTAL DISTANCE  AND AVERAGED VELOCITY AND TIME
C     BY USING FIRST AND LAST POINTS
      ADIST=SQRT(((XIN(JOBNUM,LEN(JOBNUM))-XIN(JOBNUM,1))**2)+
     1((YIN(JOBNUM,LEN(JOBNUM))-YIN(JOBNUM,1))**2))
      IATIME=ITIME(JOBNUM,LEN(JOBNUM))-ITIME(JOBNUM,1)
      IF(IATIME.EQ.0)AVEL=0.00
      IF(IATIME.NE.0)AVEL=ADIST/FLOAT(IATIME) *100.0
      ADIRCT=0.00
      IF(ADIST.NE.0.0)ADIRCT=(-ATAN2((YIN(JOBNUM,LEN(JOBNUM))-YIN(JOBNUM
     1,1)),(XIN(JOBNUM,LEN(JOBNUM))-XIN(JOBNUM,1)))+DEGTN)/.0174533
      IF(IAXIS.EQ.0)GOTO 9369
      IF(ADIST.NE..0)ADIRCT=(-ATAN2((-XIN(JOBNUM,LEN(JOBNUM))+XIN(JOBNUM
     1,1)),(YIN(JOBNUM,LEN(JOBNUM))-YIN(JOBNUM,1)))+DEGTN)/.0174533
 9369 CALL TIMEPH(IATIME,IELT)
```

```
      NDIRC=ADIRCT
      TMINN=(ADIRCT-NDIRC)*.6
      ADIRCT=NDIRC
      ADIRCT=ADIRCT+TMINN
      ADIRCT=DEGREE(ADIRCT)
      WRITE(KOT,1517)ADIST,(IELT(IZ),IZ=1,9),AVEL,ADIRCT
C
 5423 IF((IPUN.NE.C).AND.(INORCT.EQ.0)) CALL PRAPN
      IF((IPUN.EQ.C).OR.(INCRCT.NE.0))CALL PRINTO
      IF(JUSIN.NE.C)GOTO 4CC0
C
C     IF ANY BUOY GROUP HAD TO BE DIVIDED BECALSE CF BACKTRACKING BUOYS
C     THEN THE PRCGRAM WILL CESTROY ALL INPUT FOR CONSTRAINTS AND OUTPUT
C     IT WILL THEN REPLACE THEM
      IF(IWARN(JOBNUM).EQ.C)GOTO 5950
      READ(KIN,130C)NDK
      NDKA=IABS(NDK)
      IF(NDKA.GE.(LEN(JOBNUM)-3))NDKA=(LEN(JOBNUM))/3
      ND1=(NDK+7)/8
C
C     DUMP INPUT PCINTS
      IF(NDK.GT.0)READ(KIN,1700)(DUMP,I=1,ND1)
      IF((-NDK).GE.(LEN(JOBNUM)-3))NDK=-LEN(JOBNUM)/3
      IF((NDK.LE.0).AND.(IABS(NDK).GT.6))NDK=-6
      IF(NDKA.GT.6)NDKA=6
      NDKA=IABS(NDK)
      READ(KIN,130C)NOUT
      NOUTA=IABS(NOUT)
      NOUT1=(NOUT+7)/8
C
C     DUMP INPUT PCINTS
      IF(NOUT.GT.0)READ(KIN,1700)(DUMP,I=1,NOUT1)
      IF(NOUT.EQ.0)NOUT=-LEN(JOBNUM)*3
      NOUTA=IABS(NOUT)
C
      IF(LEN(JOBNUM).GT.1)GOTO 5601
```

```
C
      WRITE(KOT,1333)JOBNUM,LEN(JOBNUM)
      IF(IPUN.NE.0)WRITE(KPCT,1333)JOBNUM,LEN(JCBNUM)
      GOTC 4000
 5601 CALL XOUTER
      IF(LEN(JCBNUM).GT.4)GCTO 5602
      IARITY=1
      CALL INTERP(LEN(JOBNUM),IARITY,NCUTA)
      GOTO 5603
 5602 CALL AUTOD
      IF(IHELP.EQ.1)GOTO 9967
      IARITY=1
      CALL DUCK(LEN(JOBNUM),XINO,YINO,NDKA,XDK,NOUTA,XCUT,YOUT,IARITY)
 5603 IF(IPUN.NE.0)CALL CUTER
      IF(IPUN.EQ.0)CALL PRC1
      GOTO 4000
 5950 READ(KIN,1300)NDK
      IF(NDK.EQ.0)NDK=LEN(JCBNUM)/3
      IF((-NDK).LT.(LEN(JOBNUM)-3))GOTC 6969
      NDK=-LEN(JOBNUM)/3
      IF((NDK.LE.0).AND.(IABS(NDK).GT.6))NDK=-6
 6969 NDKA=IABS(NDK)
      IF(NDK.GT.0)READ(KIN,1500)(XDK(I),I=1,NDK)
      IF(LEN(JOBNUM).LT.5)GCTO 5957
      IF(NDK.LT.0)CALL AUTCE
      IF(IHELP.EQ.1)GOTO 9967
      IF(NCKA.LT.(LEN(JOBNUM)-3    ))GOTO 5701
      NDK= LEN(JOBNUM)/3
      IF(NCK.GT.6)NDK=6
      NDKA=NDK
      CALL AUTOD
      IF(IHELP.EQ.1)GOTO 9967
 5701 IF(NDK.GT.0)CALL DUCKT
 5957 READ(KIN,1300)NOUT
      IF(NCUT.EQ.0)NOUT=-LEN(JCBNUM)*3
      NOUTA=IABS(NOUT)
```

```
      IF(NCUT.LT.0)CALL XCUTER                                          MAIN0505
      NOUTA=IABS(NCUT)                                                  MAIN0506
      IF(NCUT.GT.0)READ(KIN,1500)(XOUT(I),I=1,NOUT)                     MAIN0507
C                                                                       MAIN0508
      IF(LEN(JOBNUM).GT.1)GOTO 5702                                     MAIN0509
C                                                                       MAIN0510
      WRITE(KOT,1333)JOBNUM,LEN(JOBNUM)                                 MAIN0511
      IF(IPUN.NE.0)WRITE(KPCT,1333)JOBNUM,LEN(JOBNUM)                   MAIN0512
      GOTO 4000                                                         MAIN0513
 5702 IF(NCUT.GT.0)CALL SORT(XCUT,NCUT)                                 MAIN0514
      IF(LEN(JOBNUM).GT.4)GOTO 5703                                     MAIN0515
      IARITY=1                                                          MAIN0516
      CALL INTERP(LEN(JOBNUM),IARITY,NCUTA)                             MAIN0517
      GOTO 5704                                                         MAIN0518
 5703 IARITY=1                                                          MAIN0519
      CALL DUCK(LEN(JOBNUM),XINO,YINO,NOKA,XOK,NOUTA,XCUT,YOUT,IARITY)  MAIN0520
 5704 IF(IPUN.EQ.0)CALL PRCT                                            MAIN0521
      IF(IPUN.NE.0)CALL CUTER                                           MAIN0522
 4000 JOBNUM=JOBNUM+1                                                   MAIN0523
C                                                                       MAIN0524
C     IF NO. OF BUOY SEGMENTS LESS THAN INPUT DO MORE                   MAIN0525
      IF(JOBNUM.LE.NCJOBA)GOTO 6000                                     MAIN0526
C                                                                       MAIN0527
C                                                                       MAIN0528
      IF((IMLINE.EQ.0).AND.(ITMARK.EQ.0))GOTO 9998                      MAIN0529
C                                                                       MAIN0530
C                                                                       MAIN0531
C                                                                       MAIN0532
C     ISTART MUST BE LESS THAN IFIN. THEREFORE IF THE BOUYS ARE TIMED   MAIN0533
C     FOR A PERIOD OVER 24 HOURS OR IF THEY ARE TIMED THROUGH A NEW DAY MAIN0534
C     IE.  START AT 230000 TO 000100 THEN  TIME MUST BE ADJUSTED        MAIN0535
C                                                                       MAIN0536
C     TIME OF STARTING HOURS                                            MAIN0537
C     TIME OF STARTING MINUTES                                          MAIN0538
C     TIME OF STARTING SECONDS                                          MAIN0539
C     TIME OF FINISH HOURS                                              MAIN0540
```

```
C       TIME OF FINISH MINUTES                                                MAIN0541
C       TIME OF FINISH SECONDS                                                MAIN0542
C       DT OF TIME HOURS                                                      MAIN0543
C       DT OF TIME MINUTES                                                    MAIN0544
C       DT OF TIME SECONDS                                                    MAIN0545
        READ(KIN,1600)NSHOUR,NSMIN,NSSEC,NFHOUR,NFMIN,NFSEC,IHDT,IMDT,ISDT    MAIN0546
C                                                                             MAIN0547
C                                                                             MAIN0548
        IDT=IHDT*3600+IMDT*60+ISDT                                            MAIN0549
        MWSTAR=MWHOUR*3600+MWMIN*60+MWSEC                                     MAIN0550
        ISTART=NSHOUR*3600+NSMIN*60+NSSEC                                     MAIN0551
        IFIN=NFHOUR*3600+NFMIN*60+NFSEC                                       MAIN0552
        IF(((IMLINE.NE.0).AND.(IABS(NOJOBS).GT.1)).OR.(ISTRLN.NE.0))CALL      MAIN0553
       1TIMELS                                                                MAIN0554
        IF((IMLINE.EQ.0).AND.(ITMARK.NE.0).AND.(ISTRLN.EQ.0))CALL TIMEMK      MAIN0555
 9998   NOJOBS=((JOBNUM-1)*NOJOBS)/IABS(NOJOBS)                               MAIN0556
        WRITE(KOT,1112)XMAX,XMIN,YMAX,YMIN                                    MAIN0557
C                                                                             MAIN0558
C       OUTPUT NUMBER OF SEGMENTS                                             MAIN0559
        IF(IPUN.NE.0)WRITE(KPCT,1115)XMAX,XMIN,YMAX,YMIN                      MAIN0560
C       OUTPUT MAXIMUN DIMENSIONS                                             MAIN0561
        WRITE(KOT,1801)NOJOBS                                                 MAIN0562
        IF(IPUN.NE.0)WRITE(KPCT,1901)NOJOBS                                   MAIN0563
C                                                                             MAIN0564
        GOTO 9999                                                             MAIN0565
C       ESCAPE CLAUSE                                                         MAIN0566
 9987   WRITE(KOT,1784)JOBNUM                                                 MAIN0567
        IF(IPUN.NE.0)WRITE(KPCT,1784)JOBNUM                                   MAIN0568
 9999   STOP                                                                  MAIN0569
 1795   FORMAT(10A8)                                                          MAIN0570
 1112   FORMAT('-','      XMAX=',F10.3,'      XMIN=',F10.3,'      YMAX=',     MAIN0571
       1F10.3,'      YMIN=',F10.3///)                                         MAIN0572
 1115   FORMAT(' REMOVE THIS CARD. PUT THE NEXT CARD RIGHT AFTER PARAMETER    MAIN0573
       1 CHECK CARD.'/'      XMAX=',F10.3,'      XMIN=',F10.3,'      YMAX=',  MAIN0574
       2F10.3,'      YMIN=',F10.3)                                            MAIN0575
 1796   FORMAT(10A8)                                                          MAIN0576
```

```
      GOTO 800
  666 DXNCR=(XINO(INCO)-XINO(1))/(FLOAT(INCO)+1.)
      DXNCR=(DXNCR*(FLOAT(INCO)+1.))/100.
      J=100
      NPTS=100
      XOUT(1)=XINO(1)
      DO 802 M=2,99
      XOUT(M)=XOUT(M-1)+DXNCR
  802 CONTINUE
      WRITE(KOT,888)
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      IF(INCO.GT.4)GOTO 808
C
C     TYPE OF CURVE  LEAST SQUARES
C
      NDEGX=INCO
      IARITY=0
      CALL INTERP(NDEGX,IARITY,NPTS)
      GOTO 805
C
  808 INCA=INCO-4
C
C     TYPE OF CURVE  SPLINE
C
      XDK(1)=XINO(1)+DXNCR
      DO 801 M=2,INCA
      XDK(M)=XDK(M-1)+DXNCR
  801 CONTINUE
      IARITY=0
      CALL DUCK(INCO,XINO,YINO,INCA,XDK,100,XOUT,YOUT,IARITY)
  805 IF(IPUN.EQ.0)GOTO 803
      WRITE(KPOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      WRITE(KPOT,854)
      WRITE(KPOT,860)(YOUT(L),L=1,100)
      WRITE(KPOT,870)
      WRITE(KPOT,860)(XOUT(L),L=1,100)
```

```
      MBAK=MBAK + 1
      WRITE(KOT,877)
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      WRITE(KOT,377)
      WRITE(KOT,855)
      DO 704 L=1,J
      WRITE(KOT,865) YOUT(L),XOUT(L)
  704 CONTINUE
      IF(IPUN.EQ.0)GOTO 800
      WRITE(KPOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      WRITE(KPOT,854)
      WRITE(KPOT,860)(YOUT(L),L=1,J)
      WRITE(KPOT,870)
      WRITE(KPOT,860)(XOUT(L),L=1,J)
      GOTO 800
C
C
  647 MBAK=MBAK+1
      CALL RSORT(XINO,YINO,INCO)
C
C     SEGMENTED TIMELINE OR NOT
      IF(((ISTRLN.EQ.0).OR.(IMLINE.EQ.1)).AND.(INCO.GT.2))GOTO 666
C
      J=INCO
      WRITE(KOT,877)
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      IF(IPUN.EQ.0)GOTO 777
      WRITE(KPOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      WRITE(KPOT,854)
      WRITE(KPOT,860)          (YINO(L),L=1,INCO)
      WRITE(KPOT,870)
      WRITE(KPOT,860)       (XINO(L),L=1,INCO)
  777 WRITE(KOT,855)
      DO 555 L=1,INCO
      WRITE(KOT,865) YINO(L),XINO(L)
  555 CONTINUE
```

```
1683 FORMAT('1',' *********** JOBNUMBER  ',I4,'   START **************')    MAIN0577
1000 FORMAT(8I2)                                                               MAIN0578
1C50 FORMAT(' PARMS IPUN=',I1,'INCRCT=',I1,'JUSIN=',I1,'ICONET=',I1,'IA        MAIN0579
    1XIS=',I1,'ITMARK=',I1,'IMLINE=',I1,'ISTRLN=',I1)                          MAIN0580
4344 FORMAT('-','CUPLICATE POINTS FOR ANGLES ',2F7.2/' POSITICNS IS (',        MAIN0581
    1F10.2,',',F1C.2,')'/' IN JOBNUMBER ',I3,'  ILCCP EQUALS  ',I3///)         MAIN0582
1100 FORMAT(I2)                                                                MAIN0583
1200 FORMAT(2F10.C,A8,2X,3I2,4X,I1,F9.0,I1,F9.0)                               MAIN0584
1C01 FORMAT(//' DEGREES THAT THE BASELINE IS CFF TRUE NORTH ',I4,'  MIN        MAIN0585
    1UTES',I3//' THE LENGHT OF THE BASELINE IS ',F10.2,'  METERS'//            MAIN0586
    2' ',A8,'  TIME =  ',1),I3,':',I2,':',I2,' HH:MM:SS'//' Y MAXIMUM          MAIN0587
    3INPUTTED AS  ',F10.2,' METERS'///)                                        MAIN0588
1300 FORMAT(I10,8A8)                                                           MAIN0589
1598 FORMAT(/8A8//)                                                            MAIN0590
1518 FORMAT(//' AVERAGES FOR GROUP:     TOTAL DISTANCE     TOTAL TIME          MAIN0591
    1   AVEG. VEL.     AVERG. DIRCT.'/'                                        MAIN0592
    3 METERS          HH:MM:SS          CM/SEC              DEG.MIN')          MAIN0593
1517 FORMAT(23X,F10.2,6X,S/1,5X,F10.2,8X,F1C.2)                                MAIN0594
1500 FORMAT(8F10.C)                                                            MAIN0595
1101 FORMAT(' *********************** MAIN JCB START ***************')         MAIN0596
1600 FORMAT(3I2,4X,3I2,4X,3I2)                                                 MAIN0597
1401 FORMAT('-',' ***** BACKTRACKING BUOY ***** JOBNUMBER ',I2,' POSITI        MAIN0598
    1CN ',I4,///)                                                              MAIN0599
1301 FORMAT('-',' ANGLE > PI CR =0.0      JOBNUMBER',I5,'  ILCOP POSITI        MAIN0600
    1CN ',I5,'  ANGLE 1 IS ',F6.2,'  ANGLE 2 IS  ',F6.2///)                    MAIN0601
1691 FORMAT(1X,I1C,2F10.2,2F10.1,I4,':',I2,':',I2,5X,9A1,2X,9A1,1F11.2,        MAIN0602
    12F11.1,F11.2)                                                             MAIN0603
1201 FORMAT('-','  POSIT.NC','   ANGLE 1','   ANGLE 2','   X CCORD',           MAIN0604
    1'   Y COORD','  START TM',6X,A8        ,'  TIM ELPT','  DISTANCE          MAIN0605
    2','  BACK.VEL.','  CENT.VEL.','  DIRCT(N).'/                              MAIN0606
    3             1X,13X,'DEG.MIN   DEG.MIN    METERS    METERS  HH',          MAIN0607
    3':MM:SS     HH:MM:SS   HH:MM:SS     METERS     CM/SEC     CM/SEC          MAIN0608
    4','   DEG.MIN')                                                           MAIN0609
1784 FORMAT(' ************* WARNING THIS JOB, NUMBER ',I4,' HAS SLIPPED        MAIN0610
    1BY ALL'   /' PROTECTICNS SO IT WAS CANCELLED IN AUTOC **********'/        MAIN0611
    2' EXAMINE WHATEVER DATA IS PRINTED OUT CR PUNCHED CUT BEFORE USING        MAIN0612
```

```
    3 IT'                    /' ********* MAIN JOB END ***************')          MAIN0613
1400 FORMAT(I1,F9.0,I1,F9.C,3I2)                                                   MAIN0614
1700 FORMAT(F10.0)                                                                 MAIN0615
1801 FORMAT('                  TCTAL NUMBER CF JCBS ECUALS',I3,'                   MAIN0616
    1          '////' ****************** MAIN JOB END ***************')            MAIN0617
1333 FORMAT(  '0000 JCB NUMBER ',20X,I2,' NCT DONE INSUFFICIENT INPUT P            MAIN0618
    1CINTS =',I3)                                                                  MAIN0619
1C22 FORMAT('1')                                                                   MAIN0620
1501 FCRMAT(' REMCVE THIS CARD. PUT THE NEXT CARD RIGHT AFTER X AND Y M            MAIN0621
    1IN AND MAX CARD '/' TCTAL NUMBER OF JOBS DONE =  ',I3/' **********            MAIN0622
    2************** MAIN JCB END **********************************')             MAIN0623
     END                                                                           MAIN0624
```

```
C      TIMELINES SUBROUTINE ************************
C      CALCULATES A SMOOTH  OR SEGMENTED TIMELINE
       SUBROUTINE TIMELS
       COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),ICT,
      1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XIND(99),
      2YIND(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IADICH,XINT,
      3YINT,INCROT,JUSIN,IMLINE
       COMMON /AREA2/ XMAX,XMIN,YMAX,YMIN
       COMMON /AREA7/ TCHAR,MWSTAR
       LOGICAL*1 MTIME(9),NTIME(9),MISTAR(9),MIFIN(9),MIDT(9),MMWSTA(9)
       REAL*8 TCHAR
       RANGE=(YMAX-YMIN)/40.
       XRANGE=RANGE/4.
       MBAK=0
       WRITE(KOT,888)
       WRITE(KOT,890)
       IF(IPUN.NE.0)WRITE(KPOT,890)
       CALL TIMEPH(ISTART,MISTAR)
       CALL TIMEPH(IFIN,MIFIN)
       CALL TIMEPH(IDT,MIDT)
       CALL TIMEPH(MWSTAR,MMWSTA)
       WRITE(KOT,895)(MISTAR(L),L=1,9),(MIFIN(L),L=1,9),(MIDT(L),L=1,9)
      1,(MMWSTA(L),L=1,9)
       IF(IPUN.NE.0)WRITE(KPOT,895)(MISTAR(L),L=1,9),(MIFIN(L),L=1,9),
      1(MIDT(L),L=1,9),(MMWSTA(L),L=1,9)
       NIDTS=(IFIN-ISTART)/IDT +1
       DO 800 N=1,NIDTS
       I=ISTART+IDT*(N-1)
       CALL TIMEPH(I,NTIME)
       IZ=ISTART-MWSTAR+ IDT*(N-1)
       CALL TIMEPH(IZ,MTIME)
       NDEGX=0
       INCO=0
       JOBNNN=JOBNUM-1
C
C      CALCULATES POSITION OF A TIMEMARK BY SEARCHING ALL ARRAYS FOR
```

```
C      ALL TIMES    DOES A LINEAR INTERPOLATICN IF TIME IN THE MIDDLE
C      CF INPUTTED TIMES
       CO 810 JCB=1,JOBNNN
       IF((IWARN(JOB).NE.0).AND.(ISTRLN.NE.1))GCTO 81C
       LENJ1=LEN(JOB)-1
       IF(LENJ1.LT.1)GOTO 81C
       DO 820 K=1,LENJ1
       IF(I.EQ.ITIME(JOB,K))COTO 830
       IF(((I.GT.ITIME(JOB,K)).AND.(I.LT.ITIME(JCB,K+1))).OR.((I.LT.
      1ITIME(JOB,K)).AND.(I.CT.ITIME(JOB,K+1))))GOTC 840
   820 CONTINUE
       GOTO 810
   830 INCC=INCC+1
       XINO(INCC)=YIN(JOB,K)
       YINO(INCO)=XIN(JOB,K)
       GOTC 810
   840 INCO=INCO+1
       IDENCM=ITIME(JOB,K+1)-ITIME(JOB,K)
       NUMER=I-ITIME(JOB,K)
       RATIO=FLOAT(NUMER)/FLCAT(IDENCM)
       XINO(INCC)=YIN(JOB,K) + (YIN (JOB,K+1)-YIN (JCB,K))*RATIC
       YINC(INCO)=XIN(JOB,K) + (XIN (JOB,K+1)-XIN (JOB,K))*RATIC
   810 CONTINUE
C
       IF(INCO.GT.1)GOTO 847
C
C      CHECK ON WHETHER A TIMEMARK IS TC BE DONE IF INSUFFICIENT POINTS
C      CALCULATIONS BELOW
       IF((INCC.LT.1).OR.(ITMARK.NE.1))GOTO 80C
       XOUT(1)=XINC(1)-RANGE
       YOUT(1)=YINO(1)
       CO 10 I9=2,5
       XOUT(I9)=XOUT(I9-1) + XRANGE
       YOUT(I9)=YINC(1)
    10 CONTINUE
       J=5
```

```
      MBAK=MBAK + 1                                                     TIML0073
      WRITE(KOT,877)                                                    TIML0074
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK      TIML0075
      WRITE(KOT,377)                                                    TIML0076
      WRITE(KOT,855)                                                    TIML0077
      DO 704 L=1,J                                                      TIML0078
      WRITE(KOT,865) YOUT(L),XOUT(L)                                    TIML0079
  704 CONTINUE                                                          TIML0080
      IF(IPUN.EQ.0)GOTO 800                                             TIML0081
      WRITE(KPOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK     TIML0082
      WRITE(KPOT,854)                                                   TIML0083
      WRITE(KPOT,860)(YOUT(L),L=1,J)                                    TIML0084
      WRITE(KPOT,870)                                                   TIML0085
      WRITE(KPOT,860)(XOUT(L),L=1,J)                                    TIML0086
      GOTO 800                                                          TIML0087
C                                                                       TIML0088
C                                                                       TIML0089
  647 MBAK=MBAK+1                                                       TIML0090
      CALL RSORT(XIND,YIND,INCO)                                        TIML0091
C                                                                       TIML0092
C     SEGMENTED TIMELINE OR NOT                                         TIML0093
      IF(((ISTRLN.EQ.0).OR.(IMLINE.EQ.1)).AND.(INCO.GT.2))GOTO 666      TIML0094
C                                                                       TIML0095
      J=INCO                                                            TIML0096
      WRITE(KOT,877)                                                    TIML0097
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK      TIML0098
      IF(IPUN.EQ.0)GOTO 777                                             TIML0099
      WRITE(KPOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK     TIML0100
      WRITE(KPOT,854)                                                   TIML0101
      WRITE(KPOT,860)          (YIND(L),L=1,INCO)                       TIML0102
      WRITE(KPOT,970)                                                   TIML0103
      WRITE(KPOT,860)       (XIND(L),L=1,INCO)                          TIML0104
  777 WRITE(KOT,855)                                                    TIML0105
      DO 555 L=1,INCO                                                   TIML0106
      WRITE(KOT,865) YIND(L),XIND(L)                                    TIML0107
  555 CONTINUE                                                          TIML0108
```

```
      GOTO 800                                                          TIML0109
  666 DXNCR=(XINO(INCO)-XINO(1))/(FLOAT(INCO)+1.)                       TIML0110
      DXNCR=(DXNCR*(FLOAT(INCO)+1.))/100.                               TIML0111
      J=100                                                             TIML0112
      NPTS=100                                                          TIML0113
      XOUT(1)=XINO(1)                                                   TIML0114
      DO 802 M=2,99                                                     TIML0115
      XOUT(M)=XOUT(M-1)+DXNCR                                           TIML0116
  802 CONTINUE                                                          TIML0117
      WRITE(KOT,888)                                                    TIML0118
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK      TIML0119
      IF(INCO.GT.4)GOTO 808                                             TIML0120
C                                                                       TIML0121
C     TYPE OF CURVE  LEAST SQUARES                                      TIML0122
C                                                                       TIML0123
      NDEGX=INCO                                                        TIML0124
      IARITY=0                                                          TIML0125
      CALL INTERP(NDEGX,IARITY,NPTS)                                    TIML0126
      GOTO 805                                                          TIML0127
C                                                                       TIML0128
  808 INCA=INCO-4                                                       TIML0129
C                                                                       TIML0130
C     TYPE OF CURVE  SPLINE                                             TIML0131
C                                                                       TIML0132
      XDK(1)=XINO(1)+DXNCR                                              TIML0133
      DO 801 M=2,INCA                                                   TIML0134
      XDK(M)=XDK(M-1)+DXNCR                                             TIML0135
  801 CONTINUE                                                          TIML0136
      IARITY=0                                                          TIML0137
      CALL DUCK(INCO,XINO,YINO,INCA,XDK,100,XOUT,YOUT,IARITY)           TIML0138
  805 IF(IPUN.EQ.0)GOTO 803                                             TIML0139
      WRITE(KPOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK     TIML0140
      WRITE(KPOT,854)                                                   TIML0141
      WRITE(KPOT,860)(YOUT(L),L=1,100)                                  TIML0142
      WRITE(KPOT,870)                                                   TIML0143
      WRITE(KPOT,860)(XOUT(L),L=1,100)                                  TIML0144
```

```
803 WRITE(KOT,855)                                                          TIML0145
    DO 804 L=1,100                                                          TIML0146
    WRITE(KOT,865) YOUT(L),XOUT(L)                                          TIML0147
804 CONTINUE                                                                TIML0148
800 CONTINUE                                                                TIML0149
    IF(IPUN.NE.0)WRITE(KPCT,885)MBAK                                        TIML0150
    IF(IPUN.NE.0)WRITE(KPCT,880)                                            TIML0151
    WRITE(KOT,885)MBAK                                                      TIML0152
    WRITE(KOT, 880)                                                         TIML0153
    RETURN                                                                  TIML0154
895 FORMAT(' STARTING TIME= ' ,9A1,  '   FINISHING TIME= ' ,9A1/ '  DT     TIML0155
   1CF TIME=  ',9A1,'  WATER OR MOONTIME =  ',9A1)                          TIML0156
888 FORMAT('1')                                                             TIML0157
890 FORMAT(' ****************TIMELINES START **********************')        TIML0158
950 FORMAT(' TIMELINES NORMAL TIME=  ',9A1,'   TIME AFTER ',A8,'=',9A1      TIML0159
   1/'  OUTPUT POINTS=  ',I4,'   TIMELINES NO.=  ',I4)                      TIML0160
854 FORMAT(' XOUTS IBM 1130 *****************************************')     TIML0161
860 FORMAT(8F10.3)                                                          TIML0162
870 FORMAT(' YOUTS IBM 1130 *****************************************')     TIML0163
865 FORMAT(F10.3,5X,F10.3)                                                  TIML0164
880 FORMAT(' *********************** TIMELINES END *****************')      TIML0165
855 FORMAT(' IBM XOUTS',5X,' IBM YOUTS')                                    TIML0166
885 FORMAT(' NO. OF TIMELINES ',I3,'   PUT THIS CARD JUST AFTER TIMELI     TIML0167
   1NES START')                                                             TIML0168
877 FORMAT('-')                                                             TIML0169
    END                                                                     TIML0170
```

```
C      TIMEMARK SUBROUTINE ************************
C      SUBROUTINE TC CALCULATE TIMEMARKS(TICKLIKE)ONLY
       SUBROUTINE TIMEMK
       COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPCT,KOT,KIN,XIN(40,99),IDT,
      1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XIND(99),
      2YINC(99),XOUT(500),YCUT(500),NIN,ITMARK,ICONET,ISTRLN,IACICH,XINT,
      3YINT,INDRCT,JUSIN,IMLINE
       COMMON /AREA2/ XMAX,XMIN,YMAX,YMIN
       COMMON /AREA7/ TCHAR,MWSTAR
       LOGICAL*1 MTIME(9),NTIME(9),MISTAR(9),MIFIN(9),MIDT(9),MMWSTA(9)
       REAL*8 TCHAR
       JOBNNN=JOBNUM-1
       INCC=1
       MBAK=0
       J=5
       RANGE=(YMAX-YMIN)/40.
       XRANGE=RANGE/5.
       WRITE(KOT,666)
       WRITE(KOT,890)
       IF(IPUN.NE.0)WRITE(KPCT,890)
       CALL TIMEPH(ISTART,MISTAR)
       CALL TIMEPH(IFIN,MIFIN)
       CALL TIMEPH(IDT,MIDT)
       CALL TIMEPH(MWSTAR,MMWSTA)
       WRITE(KOT,895)(MISTAR(L),L=1,9),(MIFIN(L),L=1,9),(MIDT(L),L=1,9)
      1,(MMWSTA(L),L=1,9)
       IF(IPUN.NE.0)WRITE(KPCT,895)(MISTAR(L),L=1,9),(MIFIN(L),L=1,9),
      1(MIDT(L),L=1,9),(MMWSTA(L),L=1,9)
       NIDTS=(IFIN-ISTART)/IDT +1
C
C      CALCULATIONS OF TIMEMARKS  DOES A LINEAR  APPRCX.  IF INBETWEEN
       DO 800 N=1,NIDTS
       I=ISTART+IDT*(N-1)
       CALL TIMEPH(I,NTIME)
       IZ=ISTART-MWSTAR+ IDT*(N-1)
       CALL TIMEPH(IZ,MTIME)
```

```
      DO 810 JOB=1,JOBNNN
      LENJ1=LEN(JOB)-1
      IF(LENJ1.LT.1)GOTO 810
      DO 820 K=1,LENJ1
      IF(I.EQ.ITIME(JOB,K))GOTO 830
      IF(((I.GT.ITIME(JOB,K)).AND.(I.LT.ITIME(JOB,K+1))).OR.(((I.LT.
     1ITIME(JOB,K)).AND.(I.GT.ITIME(JOB,K+1))))GOTO 840
  820 CONTINUE
      GOTO 810
  830 XINO(INCO)=YIN(JOB,K)
      YINO(INCO)=XIN(JOB,K)
      GOTO 815
  840 IDENOM=ITIME(JOB,K+1)-ITIME(JOB,K)
      NUMER=I-ITIME(JOB,K)
      RATIO=FLOAT(NUMER)/FLOAT(IDENOM)
      XINO(INCO)=YIN(JOB,K) + (YIN (JOB,K+1)-YIN (JOB,K))*RATIO
      YINO(INCO)=XIN(JOB,K) + (XIN (JOB,K+1)-XIN (JOB,K))*RATIO
  815 XOUT(1)=XINO(1)-RANGE
      YOUT(1)=YINO(1)
      DO 816 I9=2,J
      XOUT(I9)=XOUT(I9-1) + XRANGE*(I9-1)
      YOUT(I9)=YINO(1)
  816 CONTINUE
      MBAK=MBAK + 1
      WRITE(KOT,888)
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      WRITE(KOT,877)
      WRITE(KOT,855)
      DO 804 L=1,J
      WRITE(KOT,865) YOUT(L),XOUT(L)
  804 CONTINUE
      IF(IPUN.EQ.0)GOTO 810
      WRITE(KPCT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      WRITE(KPCT,854)
      WRITE(KPCT,860)(YOUT(L),L=1,J)
      WRITE(KPCT,870)
```

```
      WRITE(KPCT,860)(XOUT(L),L=1,J)                                     TIMK0073
  810 CONTINUE                                                           TIMK0074
  800 CONTINUE                                                           TIMK0075
C                                                                        TIMK0076
      IF(IPUN.NE.0)WRITE(KPCT,885)MBAK                                   TIMK0077
      IF(IPUN.NE.0)WRITE(KPCT,880)                                       TIMK0078
      WRITE(KOT,885)MBAK                                                 TIMK0079
      WRITE(KOT, 880)                                                    TIMK0080
      RETURN                                                             TIMK0081
  666 FORMAT('1')                                                        TIMK0082
  895 FORMAT(' STARTING TIME= ' ,9A1,  '  FINISHING TIME= ' ,9A1/ '  DT  TIMK0083
     1CF TIME=  ',9A1,'  WATER OR MOONTIME =  ',9A1)                     TIMK0084
  888 FORMAT('-')                                                        TIMK0085
  890 FORMAT(' *****************TIMEMARKS START ***********************') TIMK0086
  850 FORMAT(' TIMEMARKS NORMAL TIME=  ',9A1,'   TIME AFTER ',A8,'=',9A1 TIMK0087
     1/'  OUTPUT POINTS=  ',I4,'   TIMEMARKS NO.=  ',I4)                 TIMK0088
  854 FORMAT(' XOUTS IBM 1130 ******************************************') TIMK0089
  860 FORMAT(8F10.3)                                                     TIMK0090
  870 FORMAT(' YOUTS IBM 1130 ******************************************') TIMK0091
  865 FORMAT(F10.3,5X,F10.3)                                             TIMK0092
  880 FORMAT(' *********************** TIMEMARKS END *****************') TIMK0093
  855 FORMAT(' IBM XOUTS',5X,' IBM YOUTS')                               TIMK0094
  885 FORMAT(' NO. OF TIMEMARKS ',I3,'   PUT THIS CARD JUST AFTER TIMEMA TIMK0095
     1RKS START')                                                        TIMK0096
  877 FORMAT(/)                                                          TIMK0097
      END                                                                TIMK0098
```

```
C      DUCK SUBROUTINE ****************************           DUCK0001
C      SPLINE CURVE SUBROUTINE                                 DUCK0002
       SUBROUTINE DUCK(NIN,XIN,YIN,NDK,XDK,NOUT,XOUT,YOUT,IARITY)  DUCK0003
       DIMENSION XIN(1),YIN(1),XOUT(1),YOUT(1),XDK(1),XN(105),XD(25)  DUCK0004
      1 ,H(105,25),C(27),EXTRA(105)                            DUCK0005
       COMMON /AREA2/ XMAX,XMIN,YMAX,YMIN                      DUCK0006
       DR(XX,SS)=(1.-XX)*((1.-SS**2)-(1.-XX)**2)/(2.*SS*(1.-SS)**2)  DUCK0007
       DL(XX,SS)=XX*(SS*(2.-SS)-XX**2)/(2.*SS**2*(1.-SS))      DUCK0008
       NEQ=NDK+2                                               DUCK0009
       DEL=XIN(NIN)-XIN(1)                                     DUCK0010
       DO 3 N=1,NIN                                            DUCK0011
 3     XN(N)=(XIN(N)-XIN(1))/DEL                               DUCK0012
       DO 7 N=1,NDK                                            DUCK0013
 7     XD(N)=(XDK(N)-XIN(1))/DEL                               DUCK0014
       DO 1 M=1,NIN                                            DUCK0015
       H(M,NDK+1)=1.0                                          DUCK0016
       H(M,NDK+2)=XN(M)                                        DUCK0017
       H(M,NDK+3)=YIN(M)                                       DUCK0018
       DO 1 N=1,NDK                                            DUCK0019
       IF(XN(M).GT.XD(N)) GO TO 2                              DUCK0020
       H(M,N)=DL(XN(M),XD(N))                                  DUCK0021
       GO TO 1                                                 DUCK0022
 2     H(M,N)=DR(XN(M),XD(N))                                  DUCK0023
 1     CONTINUE                                                DUCK0024
       CALL GLSQ(H,C,EXTRA,NIN,NEQ,BUG,0.00001,0.00001)        DUCK0025
       ITIPE=1                                                 DUCK0026
C      PRINT COEFFICIENTS OF SPLINE FIT                        DUCK0027
       CALL COEF(C    ,NDK,ITIPE)                              DUCK0028
       DO 4 M=1,NOUT                                           DUCK0029
       XQ=(XOUT(M)-XIN(1))/DEL                                 DUCK0030
       YOUT(M)=C(NDK+1)+C(NDK+2)*XQ                            DUCK0031
       DO 4 N=1,NDK                                            DUCK0032
       IF(XQ.GT.XD(N)) GO TO 5                                 DUCK0033
       YOUT(M)=YOUT(M)+C(N)*DL(XQ,XD(N))                       DUCK0034
       GO TO 4                                                 DUCK0035
 5     YOUT(M)=YOUT(M)+C(N)*DR(XQ,XD(N))                       DUCK0036
```

```
 4    CONTINUE                                                              DUCK0037
C                                                                           DUCK0038
C     DO DIMENSION SCAN  IARITY CHECKS ON FROM WHERE THE DIMENSIONS CAME    DUCK0039
C     TIMELINES INVOLVES A ROTATION OF AXIS                                 DUCK0040
      DO 17 M=1,NCUT                                                        DUCK0041
      IF(IARITY.EQ.0)GOTO 100                                               DUCK0042
      IF(XCUT(M).GT.XMAX)XMAX=XOUT(M)                                       DUCK0043
      IF(XCUT(M).LT.XMIN)XMIN=XOUT(M)                                       DUCK0044
      IF(YCUT(M).GT.YMAX)YMAX=YOUT(M)                                       DUCK0045
      IF(YCUT(M).LT.YMIN)YMIN=YOUT(M)                                       DUCK0046
      GOTO 17                                                               DUCK0047
  100 IF(YCUT(M).GT.XMAX)XMAX=YOUT(M)                                       DUCK0048
      IF(YCUT(M).LT.XMIN)XMIN=YOUT(M)                                       DUCK0049
   17 CONTINUE                                                              DUCK0050
      RETURN                                                                DUCK0051
      END                                                                   DUCK0052
```

```
C     GLSQ SUBROUTINE ****************************               GLSQ0001
C     AUGMENTED MATRIX TO SOLVE SIMULTANEOUS EQUATIONS               GLSQ0002
      SUBROUTINE GLSQ(A,X,IL,N,M,ALPHA,E1,E2)                        GLSQ0003
      DIMENSION A(105,25),X(1),IL(1)                                 GLSQ0004
      MM=M+1                                                         GLSQ0005
      LL=1                                                           GLSQ0006
      DO 60 J=1,MM                                                   GLSQ0007
   60 IL(J)=0                                                        GLSQ0008
      I=1                                                            GLSQ0009
      DO 3 K=1,MM                                                    GLSQ0010
      II=I+1                                                         GLSQ0011
      DO 4 J=II,N                                                    GLSQ0012
      IF(ABS(A(J,K))-E1)4,4,6                                        GLSQ0013
    6 T1=SQRT((A(J,K))**2+(A(I,K))**2)                               GLSQ0014
      S=A(J,K)/T1                                                    GLSQ0015
      C=A(I,K)/T1                                                    GLSQ0016
      DO 5 L=K,MM                                                    GLSQ0017
      T2=C*A(I,L)+S*A(J,L)                                           GLSQ0018
      A(J,L)=-S*A(I,L)+C*A(J,L)                                      GLSQ0019
    5 A(I,L)=T2                                                      GLSQ0020
      LL=LL+1                                                        GLSQ0021
    4 CONTINUE                                                       GLSQ0022
      IF(ABS(A(I,K))-E2)3,3,8                                        GLSQ0023
    8 IL(K)=I                                                        GLSQ0024
      I=I+1                                                          GLSQ0025
    3 CONTINUE                                                       GLSQ0026
      X(MM)=-1.0                                                     GLSQ0027
      II=M                                                           GLSQ0028
      DO 35 I=1,M                                                    GLSQ0029
   35 X(I)=0.0                                                       GLSQ0030
      DO 30 J=1,M                                                    GLSQ0031
      IF(IL(II))30,30,31                                             GLSQ0032
   31 S=0.0                                                          GLSQ0033
      LL=II+1                                                        GLSQ0034
      I=IL(II)                                                       GLSQ0035
      DO 32 K=LL,MM                                                  GLSQ0036
```

```
 32   S=S+A(I,K)*X(K)                                   GLSQ0037
      X(II)=-S/A(I,II)                                  GLSQ0038
 3C   II=II-1                                           GLSQ0039
      IF(IL(MM))50,51,50                                GLSQ0040
 51   ALPHA=0.C                                         GLSQ0041
      GO TO 52                                          GLSQ0042
 5C   I=IL(MM)                                          GLSQ0043
      ALPHA=A(I,MM)                                     GLSQ0044
 52   RETURN                                            GLSQ0045
      END                                               GLSQ0046
```

```
C     AUTOC SUBROUTINE ****************************                  AUDK0001
C     SUBROUTINE TO PLACE POSITIONS OF CONSTRAINTS IF  -CONSTRAINTS   AUDK0002
C     INPUTTED.                                                       AUDK0003
C     PLACES CONSTRAINTS AT AREAS OF GREATEST CURVATURE   IE 2ND DERIVAT AUDK0004
      SUBROUTINE ALTOC                                                AUDK0005
      COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT, AUDK0006
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINC(99), AUDK0007
     2YINC(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IACICH,XINT, AUDK0008
     3YINT,INDROT,JUSIN,IMLINE                                        AUDK0009
      COMMON /AREA1/ IHELP                                            AUDK0010
      DIMENSION ACURS(97)                                             AUDK0011
      NXNDK=IABS(NDKA)                                                AUDK0012
C                                                                     AUDK0013
C     ESCAPE CLAUSE                                                   AUDK0014
      IF(NXNDK.GE.(LEN(JOBNUM)-3    ))GOTO 298                        AUDK0015
      NIN2=LEN(JOBNUM)-2                                              AUDK0016
      SUMAC=0.                                                        AUDK0017
      DO 200 I=1,NIN2                                                 AUDK0018
C                                                                     AUDK0019
C     CALCULATION OF SECOND  DERIVATIVE                               AUDK0020
      ACURS(I)=((((YIN (JOBNUM,I)-YIN (JOBNUM,I+1)) / (XIN (JOBNUM,I)- AUDK0021
     1XIN (JOBNUM,I+1))) -((YIN (JOBNUM,I+1)-YIN (JOBNUM,I+2)) / (XIN  AUDK0022
     2(JOBNUM,I+1)-XIN (JOBNUM,I+2)))) / ((XIN (JOBNUM,I)-XIN (JOBNUM, AUDK0023
     3I+2))/ 2.))                                                     AUDK0024
      SUMAC=SUMAC+ABS(ACURS(I))                                       AUDK0025
  200 CONTINUE                                                        AUDK0026
      NOLD=0                                                          AUDK0027
      TEMP=0.                                                         AUDK0028
      CURPD=SUMAC/FLOAT(NXNDK)                                        AUDK0029
      INDEX1=1                                                        AUDK0030
  225 DO 210 K=INDEX1,NIN2                                            AUDK0031
      XNDK=ABS((ABS(ACURS(K))+TEMP) / CURPD)                          AUDK0032
      NNDK=XNDK+.501                                                  AUDK0033
      DIF=(XNDK-FLOAT(NNDK))+.002                                     AUDK0034
      IF(NNDK.LT.1)GOTO 220                                           AUDK0035
      JKL=K                                                           AUDK0036
```

```
      XNDK=NNDK                                                          AUDK0037
      TEMP=DIF*CURPD                                                     AUDK0038
      XNCR=(XIN (JCBNUM,K+2)  -XIN (JOBNUM,K))/(XNDK+1.)                 AUDK0039
      TXINC=0.                                                           AUDK0040
      CO 230 I=1,NNDK                                                    AUDK0041
      NOLD=NCLD+1                                                        AUDK0042
      TXINC=TXINC+XNCR                                                   AUDK0043
      IF(NCLD.GT.NXNDK)GOTC 240                                          AUDK0044
      XDK(NOLD)=XIN (JOBNUM,K)+TXINC                                     AUDK0045
  230 CONTINUE                                                           AUDK0046
      GOTC 210                                                           AUDK0047
  220 TEMP=TEMP+DIF*CURPD                                                AUDK0048
  210 CONTINUE                                                           AUDK0049
      IF(NCLD.GE.NXNDK)GOTC 240                                          AUDK0050
      IF((JKL+1).LT.NIN2)INCEX1=JKL+1                                    AUDK0051
      IF((JKL+1).GE.NIN2)INCEX1=1                                        AUDK0052
      CURPD=CURPD/2.0                                                    AUDK0053
      GOTO 225                                                           AUDK0054
  240 CO 235 MNK=1,NXNDK                                                 AUDK0055
      CO 238 MNM=1,NXNDK                                                 AUDK0056
      IF(MNK.EQ.MNM)GOTO 238                                             AUDK0057
      IF(ABS(XCK(MNK)-XDK(MNM)).GE.(XNCR*.66))GOTO 238                   AUDK0058
      XDK(MNM)=(XIN(JOBNUM,(LEN(JOBNUM)))-XCK(MNM))/3.0   +XDK(MNM)      AUDK0059
      GOTC 240                                                           AUDK0060
  238 CONTINUE                                                           AUDK0061
  235 CONTINUE                                                           AUDK0062
C                                                                        AUDK0063
C     CALLING A TEST OF ITS VALUES                                       AUDK0064
      CALL DUCKT                                                         AUDK0065
      GOTC 299                                                           AUDK0066
  298 IHELP=1                                                            AUDK0067
  299 RETURN                                                             AUDK0068
```

```
C      DUCKT SUBROUTINE ****************************
C      CHECKS ON POSITIONS OF CONSTRAINTS
C      WILL VOID THEM IF POSITIONED TO CLOSE TO END
       SUBROUTINE DUCKT
       COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,
      1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINO(99),
      2YINO(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IADICH,XINT,
      3YINT,INORCT,JLSIN,IMLINE
       CALL SORT(XDK,NDKA)
       J1=0
       NINA=LEN(JOBNUM)
  989  DO 990 I=1,NDKA
       J1=J1 + 1
       XLOW=XDK(I)-XINO(1)
       HIGH=XINO(NINA)-XDK(I)
       IF((XLOW.GT.3.).OR.(HIGH.LT.3.))GOTO 990
       IF(XLOW.GT.3.)GOTO 991
       ADD=(XINO(2)-XINO(1))/2. +XINO(1)
       WRITE(KOT,981)I,XDK(I),ADD
       XDK(I)=ADD
C
C      TEST TO PREVENT INFINITE LOOP
       IF(J1.GT.2)GOTO 95
       GOTO 989
  991  SUB=(XINO(NINA)-XINO(NINA-1))/2. +XINO(NINA-1)
       WRITE(KOT,981)I,XDK(I),SUB
       XDK(I)=SUB
C
C      TEST TO PREVENT INFINITE LOOP
       IF(J1.GT.2)GOTO 95
       GOTO 989
  990  CONTINUE
   95  XDK(I)=(XINO(NINA)-XINO(1))/2.
       CALL PRITCK
       RETURN
  981  FORMAT('-','DUCK NUMBER  ',I3,' PRESENT VALUE ',F10.3,'  HAS NOW
```

```
1BEEN SUBSTITLED WITH THE VALUE ',F10.3///)                            DUKT0037
 END                                                                   DUKT0038
```

```
C       PRITCK SUBROUTINE ***************************
C       PRINTS OUT POSITIONS OF CONSTRAINTS ON SPLINE CURVE
        SUBROUTINE PRITDK
        COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,
       1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XIND(99),
       2YIND(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IACICH,XINT,
       3YINT,INDRCT,JUSIN,INLINE
        WRITE(KOT,250)NDKA,JOBNUM
        NXNDK=IABS(NDKA)
        DO 245 I=1,NXNDK
        WRITE(KOT,260)XDK(I)
  245   CONTINUE
        RETURN
  250   FORMAT('-',I4,' IS THE NUMBER OF DUCKS USED FOR JOB NUMBER ',I4/
       1//' XDK COORDINATES')
  260   FORMAT(F10.3)
        END
```

```
C      INTERP SUBROUTINE ***************************
C      SUBROUTINE THAT PREPARES ARGUEMENTS FOR GLSQXZ
C      ALSO OUTPUTS POINTS USING GLSQXZ'S COEFFICIENTS
       SUBROUTINE INTERP(NDEGX,IARITY,NPTS)
       COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,
      1ISTART,IFIN,YIN(40,99),ITIME(40,99),NCKA,NOUT,XDK(20),XINO(99),
      2YINO(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IALICH,XINT,
      3YINT,INORCT,JUSIN,IMLINE
       COMMON /AREA2/ XMAX,XMIN,YMAX,YMIN
       DIMENSION PARAM(4)
       IF(NDEGX.GE.3)NODX=3
       IF(NDEGX.EQ.2)NODX=2
       CALL GLSQXZ(NODX,PARAM,NDEGX)
       DO 99 K=1,NPTS
       YOUT(K)=0.0
       DO 111 I=1,NODX
       NPOWER=I-1
       YOUT(K)=YOUT(K) + PARAM(I)*XOUT(K)**NPOWER
  111  CONTINUE
C
C      DIMENSION CHECK  ON FROM WHERE VALUES CAME FROM  TIMELINES RCT.AXS
       IF(IARITY.EQ.0)GOTO 100
       IF(XOUT(K).GT.XMAX)XMAX=XOUT(K)
       IF(XOUT(K).LT.XMIN)XMIN=XOUT(K)
       IF(YOUT(K).GT.YMAX)YMAX=YOUT(K)
       IF(YOUT(K).LT.YMIN)YMIN=YOUT(K)
       GOTO 99
  100  IF(YOUT(K).GT.XMAX)XMAX=YOUT(K)
       IF(YOUT(K).LT.XMIN)XMIN=YOUT(K)
   99  CONTINUE
       WRITE(KOT,250)
       ITIPE=0
       C
C      WRITE COEFFICIENTS FOR LEAST SQUARES FIT
       CALL COEF(PARAM,NODX,ITIPE)
       RETURN
```

```
250 FORMAT(//' LISTING OF COEFFICIENTS OF LEAST SQUARES METHOD'/)    INTP0037
    END                                                              INTP0038
```

```
C     GLSQXZ SUBROUTINE ****************************
C     LEAST SQUARES ROUTINE  M.I.T.  COMPUTER MATHLIB.
      SUBROUTINE GLSQXZ(NPARAM,PARAM,NPTS)
C
C     NPARAM IS THE NUMBER OF COEFFICIENTS YOU WANT RETURNED
C     PARAM IS A VECTOR CONTAINING THE COEFFICIENTS
C
      COMMON IPUN,JOBNUM,IWRN(40),LEN(40),KPCT,KOT,KIN,XIN(40,99),IDT,
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINO(99),
     2YINO(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IADICH,XINT,
     3YINT,INOROT,JUSIN,IMLINE
      DIMENSION A(100),PARAM(1),XPOWER(6)
C  ZERO ARRAYS BEFORE SUMMING.
   10 DO 20 I = 1, NPARAM
   20    PARAM(I) = 0.0E0
C
      IXPMAX=2*(NPARAM-1)
      DO 30 I = 1, IXPMAX
   30    XPOWER(I) = 0.0E0
C
C  COMPUTE SUMS OF POWERS OF X AND OF POWERS OF X TIMES Y.
      DO 50 K = 1, NPTS
         XP = 1.0E0
      XK=XINO(K)
      YK=YINO(K)
         DO 40 I = 1, IXPMAX
            IF (I .LE. NPARAM) PARAM(I) = PARAM(I) + XP * YK
            XP = XP * XK
            XPOWER(I) = XPOWER(I) + XP
   40    CONTINUE
   50 CONTINUE
C
C  COMPUTE COEFFICIENTS OF NORMAL EQUATIONS.  THE COEFFICIENT MATRIX
C  HAS A BANDED STRUCTURE.
      A(1) = NPTS
      IF (NPARAM .EQ. 1) GO TO 90
```

```
C
      DO 80 I = 2, NPARAM
         XP = XPOWER(I - 1)
         DO 60 K = 1, I
C
C
            A(K, I + 1 - K) = XP
            A(K + NPARAM * (I - K)) = XP
   60    CONTINUE
C
         XP = XPOWER(NPARAM + I - 2)
         DO 70 K = I, NPARAM
C
C
            A(NPARAM + I - K, K) = XP
            A(I + (NPARAM - 1) * K) = XP
   70    CONTINUE
   80 CONTINUE
C
C  SOLVE NORMAL EQUATIONS.
   90 CALL SIMEQ(A,PARAM,NPARAM,IERR)
      IF (IERR .NE. 0) WRITE (6, 1002)
      RETURN
C
 1002 FORMAT(39H LSFIT:  NORMAL EQUATIONS ARE SINGULAR.)
      END
```

```
C     SIMEQ SUBROUTINE ****************************
C     IBM  SSP SUBROUTINE TO SOLVE SIMULTANEOUS EQUATIONS FOR LSFIT
      SUBROUTINE SIMEQ(A,B,N,KS)
C
C        DESCRIPTION OF PARAMETERS
C           A - MATRIX OF COEFFICIENTS STORED COLUMNWISE.  THESE ARE
C               DESTROYED IN THE COMPUTATION.  THE SIZE OF MATRIX A IS
C               N BY N.
C           B - VECTOR OF ORIGINAL CONSTANTS (LENGTH N). THESE ARE
C               REPLACED BY FINAL SOLUTION VALUES, VECTOR X.
C           N - NUMBER OF EQUATIONS AND VARIABLES. N MUST BE .GT. ONE.
C           KS - OUTPUT DIGIT
C                0 FOR A NORMAL SOLUTION
C                1 FOR A SINGULAR SET OF EQUATIONS
C
      DIMENSION A(1),B(1)
C
C        FORWARD SOLUTION
C
      TOL=0.001
      KS=0
      JJ=-N
      DO 65 J=1,N
      JY=J+1
      JJ=JJ+N+1
      BIGA=0
      IT=JJ-J
      DO 30 I=J,N
C
C        SEARCH FOR MAXIMUM COEFFICIENT IN COLUMN
C
      IJ=IT+I
      IF(ABS(BIGA)-ABS(A(IJ))) 20,30,30
   20 BIGA=A(IJ)
      IMAX=I
   30 CONTINUE
```

```
C
C        TEST FOR PIVOT LESS THAN TOLERANCE (SINGULAR MATRIX)          SIMQ0037
C                                                                      SIMQ0038
      IF(ABS(BIGA)-TOL) 35,35,40                                       SIMQ0039
   35 KS=1                                                             SIMQ0040
      RETURN                                                           SIMQ0041
C                                                                      SIMQ0042
C        INTERCHANGE ROWS IF NECESSARY                                 SIMQ0043
C                                                                      SIMQ0044
   40 I1=J+N*(J-2)                                                     SIMQ0045
      IT=IMAX-J                                                        SIMQ0046
      DO 50 K=J,N                                                      SIMQ0047
      I1=I1+N                                                          SIMQ0048
      I2=I1+IT                                                         SIMQ0049
      SAVE=A(I1)                                                       SIMQ0050
      A(I1)=A(I2)                                                      SIMQ0051
      A(I2)=SAVE                                                       SIMQ0052
C                                                                      SIMQ0053
C        DIVIDE EQUATION BY LEADING COEFFICIENT                        SIMQ0054
C                                                                      SIMQ0055
   50 A(I1)=A(I1)/BIGA                                                 SIMQ0056
      SAVE=B(IMAX)                                                     SIMQ0057
      B(IMAX)=B(J)                                                     SIMQ0058
      B(J)=SAVE/BIGA                                                   SIMQ0059
C                                                                      SIMQ0060
C        ELIMINATE NEXT VARIABLE                                       SIMQ0061
      IF(J-N) 55,70,55                                                 SIMQ0062
   55 IQS=N*(J-1)                                                      SIMQ0063
      DO 65 IX=JY,N                                                    SIMQ0064
      IXJ=IQS+IX                                                       SIMQ0065
      IT=J-IX                                                          SIMQ0066
      DO 60 JX=JY,N                                                    SIMQ0067
      IXJX=N*(JX-1)+IX                                                 SIMQ0068
      JJX=IXJX+IT                                                      SIMQ0069
   60 A(IXJX)=A(IXJX)-(A(IXJ)*A(JJX))                                  SIMQ0070
   65 B(IX)=B(IX)-(B(J)*A(IXJ))                                        SIMQ0071
                                                                       SIMQ0072
```

```
C                                                                       SIMQ0073
C        BACK SCLUTICN                                                  SIMQ0074
C                                                                       SIMQ0075
   70 NY=N-1                                                            SIMQ0076
      IT=N*N                                                            SIMQ0077
      CO 8C J=1,NY                                                      SIMQ0078
      IA=IT-J                                                           SIMQ0079
      IB=N-J                                                            SIMQ0080
      IC=N                                                              SIMQ0081
      CO 80 K=1,J                                                       SIMQ0082
      B(IB)=B(IB)-A(IA)*B(IC)                                           SIMQ0083
      IA=IA-N                                                           SIMQ0084
   80 IC=IC-1                                                           SIMQ0085
      RETURN                                                            SIMQ0086
      END                                                               SIMQ0087
```

```
C      COEF SUBROUTINE ****************************
C      OUTPUT COEFFICIENTS FOR BOTH SPLINE AND LEAST SQUARES FIT
       SUBROUTINE COEF(ZIN,NCK,ITIPE)
       DIMENSION ZIN(1)
C
C      THIS INSTALLATION REQUIRES LOGICAL UNIT 6 AS THE PRINTER
C
       KOT=6
C
C
       IF(ITIPE.EQ.0)GOTO 750
       WRITE(KOT,500)
  750  DO 766 I=1,NCK
       WRITE(KOT,600)ZIN(I)
  766  CONTINUE
       WRITE(KOT,800)
       RETURN
  500  FORMAT(  //' LISTING OF COEFFICIENTS USED IN SUBROUTINE DUCK'/)
  600  FORMAT(F13.3)
  800  FORMAT( / )
       END
```

```
C     XOUTER SUBROUTINE **************************
C     ROUTINE TO PLACE OUTPUT POINTS IF NOUT INPUTTED AS <=0
      SUBROUTINE XOUTER
      COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPCT,KOT,KIN,XIN(40,99),IDT,
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINC(99),
     2YINC(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IADICH,XINT,
     3YINT,INORCT,JUSIN,INLINE
      NOUTA=IABS(NOUT)
      XNCR=(XIN (JOBNUM,LEN(JOBNUM)) -XIN (JOBNUM,1))/FLOAT(NOUTA)
      XOUT(1)=XIN (JOBNUM,1)
      XOUT(NOUTA)=XIN (JOBNUM,LEN(JOBNUM))
      NOUTA1=NOUTA-1
C
C     PLACES THEM AT REGULAR INTERVAL
      DO 300 I=2,NOUTA1
      XOUT(I)=XOUT(I-1) +XNCR
  300 CONTINUE
      RETURN
      END
```

```
C     OUTER SUBROUTINE WITH OPTIONAL ENTRY PROT ************
C     PUNCHED AND/OR PRINTED OUTPUT POINTS
      SUBROUTINE OUTER
      COMMON IPUN,JCHNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XIND(99),
     2YIND(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IADICH,XINT,
     3YINT,INDRCT,JUSIN,INLINE
      COMMON/ONE/IANS
C
C     ICONET ADDITIONAL POINTS
      LX=NCUT + IADICH
      WRITE(KPOT,450)LX , JCHNUM
      NOUTA=IABS(NOUT)
      WRITE(KPOT,455)
      IF(IADICH.NE.1)
     1WRITE(KPOT,460)(XOUT(I),I=1,NOUTA)
C
C     DECISION ON POSITION OF ICONET POINT
      IF((IADICH.EQ.1).AND.(IANS.NE.1))WRITE(KPOT,460)(XOUT(I),I=1,NOUTA
     1),XINT
      IF((IADICH.EQ.1).AND.(IANS.EQ.1))WRITE(KPOT,460)XINT,(XOUT(I),I=1,
     1NOUTA)
      WRITE(KPOT,470)
      IF(IADICH.NE.1)
     1WRITE(KPOT,460)(YOUT(I),I=1,NOUTA)
      IF((IADICH.EQ.1).AND.(IANS.NE.1))WRITE(KPOT,460)(YOUT(I),I=1,NOUTA
     1),YINT
      IF((IADICH.EQ.1).AND.(IANS.EQ.1))WRITE(KPOT,460)YINT,(YOUT(I),I=1,
     1NOUTA)
      ENTRY PROT
C
C     PRINTED ONLY
C
C     ICONET ADDITIONAL POINT
      LX=NCUT + IADICH
      WRITE(KOT,450)LX,JCHNUM
```

```
      NOUTA=IABS(NCUT)
      WRITE(KOT,475)
      IF((IADICH.EQ.1).AND.(IANS.EQ.1))WRITE(KOT,465)XINT,YINT
      DO 400 I=1,NCUTA
      WRITE(KOT,465) XOUT(I),YOUT(I)
  400 CONTINUE
      IF((IADICH.EQ.1).AND.(IANS.NE.1))WRITE(KOT,465)XINT,YINT
      WRITE(KOT,480)JOBNUM
      WRITE(KOT,490)
  490 FORMAT('1')
  450 FORMAT(I4,'  OUTPUT POINTS FOR JOB NUMBER  ',I2)
  460 FORMAT(8F10.3)
  455 FORMAT(' XOUTS FOLLOW ********************************************')
  470 FORMAT(' YOUTS FOLLOW ********************************************')
  480 FORMAT('-',' ************ END OF JOBNUMBER ',I4,'***************')
  465 FORMAT(3X,F10.3,5X,F10.3)
  475 FORMAT('-',' XOUTS COORD    YOUTS COORD')
      RETURN
      END
```

```
C      PRAPN SUBROUTINE WITH OPTIONAL ENTRY PRINTO **********
C      PUNCHED AND/OR PRINTED INPUT POINTS
       SUBROUTINE PRAPN
       COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,
      1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINO(99),
      2YINO(99),XOUT(500),YOUT(500),NIN,ITMAPK,ICONET,ISTRLN,IADICH,XINT,
      3YINT,INOROT,JUSIN,IMLINE
       COMMON /AREA2/ XMAX,XMIN,YMAX,YMIN
       COMMON/ONE/IANS
C      COMMON/ONE/  FOR ICONET POSITION IF A TSORT HAS BEEN DONE
C
C
C      SORT INPUT POINTS IN SPECIAL SORT
       CALL TSORT
C      ICONET ADDITIONAL POINT
       LX=LEN(JOBNUM) + IADICH
       WRITE(KPOT,150) LX,JOBNUM
       LENT=LEN(JOBNUM)
       WRITE(KPOT,155)
       IF(IADICH.NE.1)
      1WRITE(KPOT,160)(XIN (JOBNUM,I),I=1,LENT)
C
C      DECISION OF WHERE CONNECTION POINT GOES
       IF((IADICH.EQ.1).AND.(IANS.NE.1))WRITE(KPOT,160)(XIN(JOBNUM,I),I=1
      1,LENT),XINT
       IF((IADICH.EQ.1).AND.(IANS.EQ.1))WRITE(KPOT,160)XINT,(XIN(JOBNUM,I
      1),I=1,LENT)
       WRITE(KPOT,170)
       IF(IADICH.NE.1)
      1WRITE(KPOT,160)(YIN (JOBNUM,I),I=1,LENT)
       IF((IADICH.EQ.1).AND.(IANS.NE.1))WRITE(KPOT,160)(YIN(JOBNUM,I),I=1
      1,LENT),YINT
       IF((IADICH.EQ.1).AND.(IANS.EQ.1))WRITE(KPOT,160)YINT,(YIN(JOBNUM,I
      1),I=1,LENT)
       ENTRY PRINTO
C
```

```
C     PRINTED ONLY                                                      PRAP0037
      IF((IPUN.NE.1).OR.(INCROT.EQ.1))CALL TSORT                        PRAP0038
      LX=LEN(JOBNUM) + IADICH                                           PRAP0039
      IF(LEN(JOBNUM).EQ.1)LX= LEN(JOBNUM)                               PRAP0040
      WRITE(KOT,150)LX,JOBNUM                                           PRAP0041
      LENT=LEN(JOBNUM)                                                  PRAP0042
      WRITE(KOT,175)                                                    PRAP0043
      IF(LEN(JOBNUM).EQ.1)GOTO 600                                      PRAP0044
      IF((IADICH.EQ.1).AND.(IANS.EQ.1))WRITE(KOT,165)XINT,YINT          PRAP0045
  600 DO 100 I=1,LENT                                                   PRAP0046
      WRITE(KOT,165)XIN (JOBNUM,I),YIN (JOBNUM,I)                       PRAP0047
C                                                                       PRAP0048
C     MAX DIMENSION CHECK                                               PRAP0049
      IF(XMAX.LT.XIN(JOBNUM,I))XMAX=XIN(JOBNUM,I)                       PRAP0050
      IF(XMIN.GT.XIN(JOBNUM,I))XMIN=XIN(JOBNUM,I)                       PRAP0051
      IF(YMAX.LT.YIN(JOBNUM,I))YMAX=YIN(JOBNUM,I)                       PRAP0052
      IF(YMIN.GT.YIN(JOBNUM,I))YMIN=YIN(JOBNUM,I)                       PRAP0053
  100 CONTINUE                                                          PRAP0054
      IF(LEN(JOBNUM).EQ.1)GOTO 700                                      PRAP0055
      IF((IADICH.EQ.1).AND.(IANS.NE.1))WRITE(KOT,165)XINT,YINT          PRAP0056
  700 RETURN                                                            PRAP0057
  150 FORMAT(I3,' POINTS IN FOR JOB NUMBER ',I2)                        PRAP0058
  155 FORMAT(' XIN POINTS FOLLOW ****************************************')PRAP0059
  160 FORMAT(8F10.2)                                                    PRAP0060
  165 FORMAT(2X,F10.3,5X,F10.3)                                         PRAP0061
  170 FORMAT(' YIN POINTS FOLLOW ****************************************')PRAP0062
  175 FORMAT('-',' XINS COORD ','     YINS COORD')                      PRAP0063
      END                                                               PRAP0064
```

```
C      TSORT SUBROUTINE ***************************                     TSRT0001
C      SPECIAL SORT PUTS THE LEAST MEMBER FIRST IN CASE POINTS          TSRT0002
C      INPUTTED IN DESCENDING  ORDER                                    TSRT0003
       SUBROUTINE TSORT                                                 TSRT0004
       COMMON IPLN,JCBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT, TSRT0005
      1ISTART,IFIN,YIN(40,99),ITIME(40,99),NOKA,NOUT,XOK(20),XINO(99),  TSRT0006
      2YINO(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONFT,ISTRLN,IADICH,XINT, TSRT0007
      3YINT,INORCT,JUSIN,IMLINE                                         TSRT0008
       COMMON/ONE/IANS                                                  TSRT0009
       IANS=0                                                           TSRT0010
       IF(XIN (JCBNUM,1).LE.XIN (JOBNUM,LEN(JCBNUM)))GOTO 640           TSRT0011
       IANS=1                                                           TSRT0012
       MEND=LEN(JCBNUM)/2                                               TSRT0013
       DO 600 I=1,MEND                                                  TSRT0014
       TEMPX=XIN (JCBNUM,I)                                             TSRT0015
       TEMPY=YIN (JCBNUM,I)                                             TSRT0016
       ITEMP=ITIME(JOBNUM,I)                                            TSRT0017
       NUM=LEN(JCBNUM)+1-I                                              TSRT0018
       XIN (JOBNUM,I)=XIN (JCBNUM,NUM)                                  TSRT0019
       YIN (JCBNUM,I)=YIN (JCBNUM,NUM)                                  TSRT0020
       ITIME(JCBNUM,I)=ITIME(JCBNUM,NUM)                                TSRT0021
       XIN (JOBNUM,NUM)=TEMPX                                           TSRT0022
       YIN (JCBNUM,NUM)=TEMPY                                           TSRT0023
       ITIME(JOBNUM,NUM)=ITEMP                                          TSRT0024
   600 CONTINUE                                                         TSRT0025
   640 RETURN                                                           TSRT0026
       END                                                              TSRT0027
```

```
C     SORT SUBROUTINE ****************************                  SORT0001
C     INTERCHANGE  SORT                                              SORT0002
      SUBROUTINE SORT(ARRAY,NUM)                                     SORT0003
      DIMENSION ARRAY(1)                                             SORT0004
      DO 700 I=1,NUM                                                 SORT0005
      HOLD=-2.**32                                                   SORT0006
      IHOLD=-2**32                                                   SORT0007
      NUM2=NUM-I +1                                                  SORT0008
      DO 710 J=1,NUM2                                                SORT0009
      IF(HOLD.GT.ARRAY(J))GOTO 710                                   SORT0010
      HOLD=ARRAY(J)                                                  SORT0011
      IHOLD=J                                                        SORT0012
  710 CONTINUE                                                       SORT0013
      ARRAY(IHOLD)=ARRAY(NUM2)                                       SORT0014
      ARRAY(NUM2)=HOLD                                               SORT0015
  700 CONTINUE                                                       SORT0016
      RETURN                                                         SORT0017
      END                                                            SORT0018
```

```
C     RSORT SUBROUTINE ******************************            RSRT0001
C     INTERCHANGE SORT WITH TAG-A-LONG ARRAY                       RSRT0002
      SUBROUTINE RSORT(XISC,YISC,INC)                               RSRT0003
      DIMENSION XISC(1),YISC(1)                                     RSRT0004
      DO 900 I=1,INC                                                RSRT0005
      HOLD=-2.**32                                                  RSRT0006
      IHOLD=-2**32                                                  RSRT0007
      NUM2=INC-I +1                                                 RSRT0008
      DO 910 J=1,NUM2                                               RSRT0009
      IF(HOLD.GT.XISC(J))GOTO 910                                   RSRT0010
      HOLD=XISC(J)                                                  RSRT0011
      IHOLD=J                                                       RSRT0012
      YOLD=YISC(J)                                                  RSRT0013
  910 CONTINUE                                                      RSRT0014
      XISC(IHOLD)=XISC(NUM2)                                        RSRT0015
      YISC(IHOLD)=YISC(NUM2)                                        RSRT0016
      XISC(NUM2)=HOLD                                               RSRT0017
      YISC(NUM2)=YOLD                                               RSRT0018
  900 CONTINUE                                                      RSRT0019
      RETURN                                                        RSRT0020
      END                                                           RSRT0021
```

```
C      STOREC SUBROUTINE   ************************
C      CALCULATES VALUES FOR CENTERED VELOCITY AND FOR FUTHER IMPROVEMENT
       SUBROUTINE STOREC(ICEC,ICOUNT,ANG1,ANG2,XCORD,YCORD,IHOUR,MINUT,
      1NSEC,MIWSAR,ILAP,IELT,DIST,VEL,VELOC,DIRCT)
       LOGICAL*1 IIELT(9),ICELT(9),IELT(9),NIWSAR(9),MIWSAR(9),KIWSAR(9)
       GO TO (900,100,200), ICEC
  100 CXEMP=FLOAT(ILAP) + FLOAT(IOLAP)
       CVELOC=OVEL*FLOAT(IOLAP)/DXEMP + VEL*FLOAT(ILAP)/DXEMP
       IF(ICOUNT.EQ.2)CVELOC=0.00
       GOTO 800
C
C      TRANSFER STATION
  200 CVELOC=OVEL
  800 IXCOUN=ICCOUN
       XANG1=OANG1
       XANG2=CANG2
       XXCORD=CXCORD
       XYCORD=OYCORD
       IXHOUR=IIHOUR
       IXMIN=IMINUT
       IXNSEC=INSEC
       IXLAP=IOLAP
       DO 905 JB=1,9
       IIELT(JB)=ICELT(JB)
  905 NIWSAR(JB)=KIWSAR(JB)
       XDIST=ODIST
       XVEL=OVEL
       XVELOC=OVELOC
       XDIRCT=ODIRCT
  900 IOCOUN=ICOUNT
       CANG1=ANG1
       CANG2=ANG2
       CXCORD=XCORD
       CYCORD=YCORD
       IIHOUR=IHOUR
       IMINUT=MINUT
```

```
      INSEC=NSEC
      IDLAP=ILAP
      DO 910 JB=1,9
      KIWSAR(JB)=MIWSAR(JB)
  910 IDELT(JB)=IELT(JB)
      CDIST=DIST
      CVEL=VEL
      CVELOC=VELOC
      CDIRCT=DIRCT
      IF(IDEC.EQ.1)RETURN
      ICOUNT=IXCOUN
      ANG1=XANG1
      ANG2=XANG2
      XCORD=XXCORD
      YCORD=XYCORD
      IHOUR=IXHOUR
      MINUT=IXMIN
      ILAP=IXLAP
      NSEC=IXNSEC
      DO 920 JB=1,9
      MIWSAR(JB)=NIWSAR(JB)
  920 IELT(JB)=IIELT(JB)
      DIST=XDIST
      VEL=XVEL
      VELOC=XVELOC
      DIRCT=XDIRCT
C
      RETURN
      END
```

```
      FUNCTION DEGREE(ANGLEZ)
C     FUNCTION TO CHANGE DEGREES TO POSITIVE DEGREES.MINUTES FOR OUTPUT
      NANGLE=IFIX(ANGLEZ)
      MANGLE=IFIX(ANGLEZ-FLOAT(NANGLE))
      MAD=MANGLE/60
      NANGLE=NANGLE+MAD
      MANGLE=MANGLE-MAD*60
      NANGLE=NANGLE-(NANGLE/360)*360
C
C     NEGATIVE ANGLE FIX
      IF(NANGLE.GE.0)GOTO 100
      ISUB=0
      IF(MANGLE.NE.0)ISUB=-1
      IF(MANGLE.NE.0)MANGLE=60 + MANGLE
      NANGLE=360 + ISUB +NANGLE
C
  100 DEGREE=FLOAT(NANGLE) +FLOAT(MANGLE)/100
      RETURN
      END
```

```
      SUBROUTINE TIMEPH(NSECS,FIELD)
C     OUTPUTS A HH:MM:SS CHARACTER(ARRAY) FROM INPUT TIME IN SECONDS
      LOGICAL*1 FIELD(1),DIGITS(13)
      DATA DIGITS/'0','1','2','3','4','5','6','7','8','9','-',':',' '/
C
C     COMPARISON OF BYTES
      IF(NSECS.LT.0)FIELD(1)=DIGITS(11)
      IF(NSECS.GE.0)FIELD(1)=DIGITS(13)
      FIELD(4)=DIGITS(12)
      FIELD(7)=DIGITS(12)
      IHOUR=NSECS/3600
      IMINUT=(NSECS-IHOUR*3600)/60
      ISEC=NSECS-IHOUR*3600-IMINUT*60
      I        =IABS(IHOUR/10)
      FIELD(2)=DIGITS(I+1)
      I        =IABS(IHOUR-(IHOUR/10)*10)
      FIELD(3)=DIGITS(I+1)
      I=IABS(IMINUT/10)
      FIELD(5)=DIGITS(I+1)
      I        =IABS(IMINUT-(IMINUT/10)*10)
      FIELD(6)=DIGITS(I+1)
      I        =IABS(ISEC/10)
      FIELD(8)=DIGITS(I+1)
      I        =IABS(ISEC-(ISEC/10)*10)
      FIELD(9)=DIGITS(I+1)
C
      RETURN
      END
```

SAMPLE OUTPUT

FOR DROGUE BODY COORDINATE

AND VELOCITY CALCULATION

COMPUTER PROGRAM

```
********************** MAIN JOB START ***************
JOB  LOWTIDE   7/24/72  MAIN-DECK      WIND GD
PARMS IPUN=0INDRCT=0JUSIN=0ICONST=1IAXIS=1ITMARK=1IMLINE=0ISTRLN=0

DEGREES THAT THE BASELINE IS OFF TRUE NORTH  -71  MINUTES-39

THE LENGHT OF THE BASELINE IS     366.20  METERS

 LOWTIDE  TIME =     5:54: 0 HH:MM:SS

Y MAXIMUM  INPUTTED AS        0.0  METERS
```

*********** JOBNUMBER 1 START ***********

C1B LOWTIDE

POSIT.NO	ANGLE 1 DEG.MIN	ANGLE 2 DEG.MIN	X COORD METERS	Y COORD METERS	START TM HH:MM:SS	LOWTIDE HH:MM:SS	TIM ELPT HH:MM:SS	DISTANCE METERS	BACK.VEL. CM/SEC	CENT.VEL. CM/SEC	DIRCT(N). DEG.MIN
1	53.50	99.45	-500.7	365.0	5:36: 0	-00:18:00	00:00:00	0.0	0.0	0.0	0.0
2	52.00	90.00	-471.3	368.2	5:43:40	-00:10:20	00:07:40	29.51	6.4	4.3	14.00
3	51.30	90.15	-465.4	370.2	5:48:10	-00:05:50	00:04:30	6.17	2.3	2.3	0.0
4	51.00	91.15	-467.3	378.4	5:54: 0	00:00:00	00:05:50	8.37	2.4	2.4	276.00

***** BACKTRACKING BUOY ***** JOBNUMBER 1 POSITION 4

AVERAGES FOR GROUP:	TOTAL DISTANCE METERS	TOTAL TIME HH:MM:SS	AVEG. VEL. CM/SEC	AVERG. DIRCT. DEG.MIN
	35.52	00:12:10	4.87	11.00

4 POINTS IN FOR JOB NUMBER 1

XINS COORD	YINS COORD
-500.707	365.019
-471.274	368.199
-465.442	370.229
-467.279	378.395

LISTING OF COEFFICIENTS OF LEAST SQUARES METHOD

-432.961
-3.499
-0.004

10 OUTPUT POINTS FOR JOB NUMBER 1

XOUTS COORD	YOUTS COORD
-500.707	365.940
-496.788	366.677
-492.870	367.401
-488.951	368.010
-485.033	368.505
-481.114	368.886
-477.196	369.152
-473.277	369.307
-465.442	369.245
-467.279	378.395

*********** END OF JOBNUMBER 1 ***********

POSIT.NO	ANGLE 1 DEG.MIN	ANGLE 2 DEG.MIN	X COORD METERS	Y COORD METERS	START TM HH:MM:SS	LGHTIME HH:MM:SS	TIM ELPT HH:MM:SS	DISTANCE METERS	BACK.VEL. CM/SEC	CENT.VEL. CM/SEC	DIRCT(N). DEG.MIN
1	51.00	91.15	-407.3	378.4	5:50: 0	00:00:00	00:00:00	0.0	0.0	0.0	0.0
2	47.30	91.00	-409.6	375.3	6:13:55	00:19:55	00:19:55	57.74	4.8	5.2	21.00
3	46.30	91.15	-397.1	376.9	6:16:40	00:22:40	00:02:45	12.58	7.6	8.1	11.00
4	45.00	90.15	-369.8	369.8	6:22:20	00:28:20	00:05:40	28.21	8.3	8.6	32.00
5	44.15	90.00	-358.7	368.2	6:24:20	00:30:20	00:02:00	11 25	9.4	10.9	26.00
6	39.45	97.45	-276.5	356.5	6:33:45	00:39:45	00:09:25	83.23	11.2	11.7	28.00
7	38.15	97.00	-278.7	353.6	6:35:55	00:41:55	00:02:10	18 03	13.9	15.5	27.00
8	34.15	93.00	-231.4	339.8	6:41: 0	00:47:00	00:05:05	49 36	16.2	16.7	34.00
9	30.00	79.45	-192.5	333.4	6:44:45	00:50:45	00:03:45	39.40	17.5	17.1	27.00
10	27.15	78.15	-171.3	332.6	6:46:55	00:52:55	00:02:10	21 21	16.3	15.0	20.00
11	20.00	73.00	-120.6	331.3	6:52:45	00:58:45	00:05:50	50.71	14.5	16.0	19.00
12	13.00	57.45	-74.2	321.4	6:57:10	01:03:10	00:04:25	47 45	17.9	16.8	30.00
13	2.30	16.00	-14.0	319.5	7: 3:25	01:09:25	00:06:15	60 27	16.1	15.7	20.00
14	-6.45	-34.30	37.2	314.1	7: 9: 0	01:15:00	00:05:35	51.42	15.3	14.2	24.00
15	-13.30	-49.00	73.1	304.6	7:13:50	01:19:50	00:04:50	37 19	12.8	12.5	33.00
16	-17.30	-54.45	94.9	301.1	7:16:55	01:22:55	00:03:05	22 09	11.9	12.2	27.00
17	-22.05	-58.00	119.2	293.7	7:20:20	01:26:20	00:03:25	25.33	12.4	9.8	35.00
18	-26.15	-60.15	141.7	287.2	7:25:10	01:31:10	00:04:50	23 40	8.1	6.1	34.00
19	-27.15	-60.00	146.2	283.8	7:28:15	01:34:15	00:03:05	5 67	3.1	3.1	55.00

AVERAGES FOR GROUP:	TOTAL DISTANCE METERS	TOTAL TIME HH:MM:SS	AVEG. VEL. CM/SEC	AVERG. DIRCT. DEG.MIN
	620.70	01:34:15	10.98	27.00

19 POINTS IN FOR JOB NUMBER 2

XINS COORD	YINS COORD
-407.279	378.395
-409.622	375.349
-397.132	376.864
-369.815	369.812
-358.684	368.199
-276.558	356.549
-278.749	353.591
-231.397	339.793
-192.465	333.393
-171.286	332.572
-120.574	321.330
-74.197	321.395
-13.952	319.544
37.177	314.106
73.134	304.626
94.936	301.104
119.173	293.732
141.651	287.240
146.171	283.809

4 IS THE NUMBER OF DUCKS USED FOR JOB NUMBER 2

XDK COORDINATES
-369.717
-263.948

-18.510
306.725

LISTING OF COEFFICIENTS USED IN SUBROUTINE DUCK

65.829
-156.311
-26.712
-188.205

-20 OUTPUT POINTS FOR JOB NUMBER 2

XOUTS COORD	YOUTS COORD
-467.279	378.201
-436.607	377.606
-405.934	375.960
-375.261	372.947
-344.589	366.393
-313.916	359.292
-283.244	351.944
-252.571	345.303
-221.899	339.959
-191.226	335.433
-160.554	331.922
-129.881	328.796
-99.209	325.110
-68.536	323.573
-37.864	320.953
-7.191	318.027
23.481	314.469
54.154	309.906
84.826	303.553
146.171	294.390

*********** END OF JOBNUMBER 2***************

```
*********** TIMEMARKS START ****************
STARTING TIME=  05:35:00  FINISHING TIME=  07:25:00
UF UF TIME=   00:10:00  WATER OR MOONTIME =   05:54:00


TIMEMARKS NORMAL TIME=   05:45:00   TIME AFTER  LOWTIDE=-00:09:00
 OUTPUT POINTS=     5   TIMEMARKS NO.=     1


IBM XOUTS       IBM YOUTS
 -469.540         359.341
 -469.540         361.232
 -469.540         365.016
 -469.540         370.592
 -469.540         378.260


TIMEMARKS NORMAL TIME=   05:55:00   TIME AFTER  LOWTIDE= 00:01:00
 OUTPUT POINTS=     5   TIMEMARKS NO.=     2


IBM XOUTS       IBM YOUTS
 -464.384         369.782
 -464.384         370.674
 -464.384         374.458
 -464.384         380.133
 -464.384         397.701


TIMEMARKS NORMAL TIME=   06:05:00   TIME AFTER  LOWTIDE= 00:11:00
 OUTPUT POINTS=     5   TIMEMARKS NO.=     3


IBM XOUTS       IBM YOUTS
 -435.435         367.252
 -435.435         369.144
 -435.435         372.928
 -435.435         378.604
 -435.435         396.172


TIMEMARKS NORMAL TIME=   06:15:00   TIME AFTER  LOWTIDE= 00:21:00
 OUTPUT POINTS=     5   TIMEMARKS NO.=     4


IBM XOUTS       IBM YOUTS
 -404.701         365.486
 -404.701         368.378
 -404.701         372.162
 -404.701         377.837
 -404.701         395.405


TIMEMARKS NORMAL TIME=   06:25:00   TIME AFTER  LOWTIDE= 00:31:00
```

OUTPUT POINTS= 5 TIMEMARKS NO.= 5

IBM XOUTS	IBM YOUTS
-354.284	357.914
-354.284	359.806
-354.284	363.590
-354.284	369.266
-354.284	376.833

TIMEMARKS NORMAL TIME= 06:35:00 TIME AFTER LOWTIDE= 00:41:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 6

IBM XOUTS	IBM YOUTS
-286.275	345.382
-286.275	347.274
-286.275	351.058
-286.275	356.734
-286.275	364.302

TIMEMARKS NORMAL TIME= 06:45:00 TIME AFTER LOWTIDE= 00:51:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 7

IBM XOUTS	IBM YOUTS
-190.039	323.839
-190.039	325.730
-190.039	329.514
-190.039	335.190
-190.039	342.758

TIMEMARKS NORMAL TIME= 06:55:00 TIME AFTER LOWTIDE= 01:01:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 8

IBM XOUTS	IBM YOUTS
-96.958	316.903
-96.958	318.695
-96.958	322.479
-96.958	329.155
-96.958	335.723

TIMEMARKS NORMAL TIME= 07:05:00 TIME AFTER LOWTIDE= 01:11:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 9

IBM XOUTS	IBM YOUTS
0.548	308.542
0.548	310.434
0.548	314.218
0.548	327.462

```
0.043        327.462

TIMEMARKS NORMAL TIME=   07:15:00   TIME AFTER  LOWTIDE= 01:21:00
 OUTPUT POINTS=     5   TIMEMARKS NO.=    10

IPM XOUTS      IPM YOUTS
   81.384        293.833
   81.384        295.725
   81.384        299.505
   81.384        305.195
   81.384        312.752

TIMEMARKS NORMAL TIME=   07:25:00   TIME AFTER  LOWTIDE= 01:31:00
 OUTPUT POINTS=     5   TIMEMARKS NO.=    11

IPM XOUTS      IPM YOUTS
  140.576        278.003
  140.576        275.855
  140.576        283.675
  140.576        289.355
  140.576        296.923
NO. OF TIMEMARKS  11   PUT THIS CARD JUST AFTER TIMEMARKS START
******************** TIMEMARKS END ******************

    XMAX=   146.171     XMIN=  -500.707     YMAX=   378.395     YMIN=     0.0

            TOTAL NUMBER OF JOBS EQUALS  2

****************** MAIN JOB END ****************
```

OUTPUT POINTS= 5 TIMEMARKS NO.= 5

IBM XOUTS	IBM YOUTS
-354.284	357.914
-354.284	359.806
-354.284	363.550
-354.284	369.266
-354.284	376.833

TIMEMARKS NORMAL TIME= 06:35:00 TIME AFTER LOWTIDE= 00:41:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 6

IBM XOUTS	IBM YOUTS
-286.275	345.382
-286.275	347.274
-286.275	351.058
-286.275	356.734
-286.275	364.302

TIMEMARKS NORMAL TIME= 06:45:00 TIME AFTER LOWTIDE= 00:51:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 7

IBM XOUTS	IBM YOUTS
-190.039	323.838
-190.039	325.730
-190.039	329.514
-190.039	335.190
-190.039	342.758

TIMEMARKS NORMAL TIME= 06:55:00 TIME AFTER LOWTIDE= 01:01:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 8

IBM XOUTS	IBM YOUTS
-96.558	316.903
-96.558	319.[illegible]
-96.558	322.479
-96.558	328.155
-96.558	335.723

TIMEMARKS NORMAL TIME= 07:05:00 TIME AFTER LOWTIDE= 01:11:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 9

IBM XOUTS	IBM YOUTS
0.548	308.542
0.548	310.434
0.548	314.218
0.548	327.462

```
TIMEMARKS NORMAL TIME=   07:15:00   TIME AFTER  LOWTIDE= 01:21:00
OUTPUT POINTS=     5   TIMEMARKS NO.=    10

IBM XOUTS       IBM YOUTS
   81.384         293.833
   81.384         295.725
   81.384         299.505
   81.384         305.195
   81.384         312.752


TIMEMARKS NORMAL TIME=   07:25:00   TIME AFTER  LOWTIDE= 01:31:00
OUTPUT POINTS=     5   TIMEMARKS NO.=    11

IBM XOUTS       IBM YOUTS
  140.576         278.003
  140.576         279.895
  140.575         283.675
  140.576         289.355
  140.576         296.923
NO. OF TIMEMARKS  11   PUT THIS CARD JUST AFTER TIMEMARKS START
********************** TIMEMARKS END **********************

     XMAX=   146.171     XMIN=  -500.707     YMAX=   378.395     YMIN=     0.0


             TOTAL NUMBER OF JOBS EQUALS  2


****************** MAIN JOB END ****************
```

DROGUE BUOY PLOTTING

COMPUTER PROGRAM LISTING

```
C
C     PROGRAM: TAKES FIXED DATA PUNCHED DECK AND THEN PLOTS IT.
C     IN THE DATA DECK ITSELF ARE THE INSTRUCTIONS.  NOTHING NORMALLY
C     HAS TO BE CHANGED BY THE PROGRAM USER .
C
      DIMENSION X(100),Y(100 ),XSCL(4),XLAB(20),TEMP1(20)
C
C       X    Y     COORDINATES OF POINTS.
C     XSCL    SCALING FOR MAX AND  MIN    POINTS
C     XLAB    MESSAGE FOR IDENTIFICATION OF POINTS.
C     TEMP1    PRINTING STORAGE FOR INFORMATION(ALPHA FORM) ON INPUT .
C
C
C     I/O  LOGICAL DEVICE NUMBERS. PRINTER=5,PLOTTER=7,CARD=8
C     CONSOLE OUT=1,CONSOLE IN=6.
      KIN=9
      KEYO=1
      KEYI=6
C
C     PAUSE FOR TURNING DATA SWITCHES AND HARD COPY ON SCOPE.
      PAUSE 16
C
C     WIPES PREVIOUS SCOPE COPY
      CALL ERASE
C
C     IF DATA SWITCH  0  DOWN  PLOTS ON SCOPE ONLY.
      CALL DATSW(0,MODE)
      IF(MODE.EQ.2)CALL LOOK
C
C     IF DATA SWITCH 15  UP OUTPUT COMES OUT ON PRINTER. ELSE ON CONSOL
      CALL DATSW (15,KOT)
      KOT = KOT - ((KOT/2)*2)
      KOT = (KOT*4) + 1
C
      READ(KIN,500)WASTE
      READ(KIN,510)XLAB
```

```
C                                                                        PLOT0037
C     PARAMETERS FROM MAIN PROGRAM.                                      PLOT0038
      READ (KIN,520)IRUN,INORD,JUSIN,ICONE,IAXIS,ITMAR,IMLIN,ISTRL       PLOT0039
C                                                                        PLOT0040
      WRITE(KOT,525)IRUN,INORD,JUSIN,ICONE,IAXIS,ITMAR,IMLIN,ISTRL       PLOT0041
C                                                                        PLOT0042
C     XMAX,XMIN,YMAX,YMIN                                                PLOT0043
      READ(KIN,530)XSCL(2),XSCL(1),XSCL(4),XSCL(3)                       PLOT0044
C                                                                        PLOT0045
C                                                                        PLOT0046
C     IJOBS=NUMBER OF JOBS IN THIS CALLUP OF PROGRAM.                    PLOT0047
      READ(KIN,540)(TEMP1(K),K=1,7),IJOBS                                PLOT0048
C                                                                        PLOT0049
      WRITE(KOT,700)                                                     PLOT0050
      WRITE(KOT,540)(TEMP1(K),K=1,7),IJOBS                               PLOT0051
C                                                                        PLOT0052
C     INITIALIZATION OF SCOPE AND PLOTTER SCALES AND COORDINATES.        PLOT0053
C     SYMBOLS PUT AT   (0,0)  (XMIN,0)  (XMAX,0)  (0,YMIN)   (0,YMAX)    PLOT0054
      CALL SCALE(1.,1.,0.,0.)                                            PLOT0055
      CALL FPLOT (1,12.0,-11.0)                                          PLOT0056
      CALL FPLOT (1,0.0,-10.0)                                           PLOT0057
      CALL BEAM(-3.5,-2.5)                                               PLOT0058
C                                                                        PLOT0059
C     .005308  IS TO SCALE METERS TO  .01 INCHES IN A  1:7422  CHART.    PLOT0060
      CALL SCALE(.005308,.005308,XSCL(1),XSCL(3))                        PLOT0061
C                                                                        PLOT0062
      CALL FPLOT(-2,0.0,0.0)                                             PLOT0063
      CALL POINT(-6)                                                     PLOT0064
      CALL FPLOT(-2,0.0,XSCL(3))                                         PLOT0065
      CALL POINT(-5)                                                     PLOT0066
      CALL FPLOT(-2,XSCL(1),0.0)                                         PLOT0067
      CALL POINT(-1)                                                     PLOT0068
      CALL FPLOT(-2,0.0,XSCL(4))                                         PLOT0069
      CALL POINT(-2)                                                     PLOT0070
      CALL FPLOT(-2,XSCL(2),0.0)                                         PLOT0071
      CALL POINT(-1)                                                     PLOT0072
```

```
C
      DO 1100 I=1,IJOBS
C
C     INPOUT CHECK FROM PARAM. LIST.
      IF(INPORD .NE.0)GOTO 1200
C
C
C     NPTS=NUMBER OF POINTS.
      READ(KIN,560)NPTS,(TEMP1(K),K=1,9)
C
      WRITE(KOT,700)
C
C     IF DATA SWITCH 15  UP OUTPUT COMES OUT ON PRINTER. ELSE ON CONSOL
      CALL DATSW (15,KOT)
      KOT = KOT - ((KOT/2)*2)
      KOT = (KOT*4) + 1
C
      WRITE(KOT,560)NPTS,(TEMP1(K),K=1,9)
      READ(KIN,500)WASTE
      READ(KIN,570)(X(K),K=1,NPTS)
      READ(KIN,500)WASTE
      READ(KIN,570)(Y(K),K=1,NPTS)
C
C     IF DATA SWITCH 1  DOWN SKIPS INPUT POINTS.
      CALL DATSW(1,IB)
      IF(IB.EQ.2)GOTO 1200
C
                    CALL FORAF(X,Y,NPTS,+1,-1)
C
C     JUSTN CHECK FROM PARAM LIST
 1200 IF(JUSTN.NE.0)GOTO 1100
C
      READ(KIN,580)NPTS,(TEMP1(K),K=1,9)
      WRITE(KOT,700)
      WRITE(KOT,580)NPTS,(TEMP1(K),K=1,9)
      IF(NPTS.EQ.0)GOTO 1100
```

```
      NPTS=IABS(NPTS)                                                   PLOT0109
      READ(KIN,500)WASTE                                                PLOT0110
      READ(KIN,570)(X(K),K=1,NPTS)                                      PLOT0111
      READ(KIN,500)WASTE                                                PLOT0112
C                                                                       PLOT0113
C     NPTS=NUMBER OF POINTS.                                            PLOT0114
      READ(KIN,570)(Y(K),K=1,NPTS)                                      PLOT0115
C                                                                       PLOT0116
C                                                                       PLOT0117
C     IF DATA SWITCH 2  DOWN SKIPS OUTPUT POINTS.                       PLOT0118
      CALL DATSW(2,I7)                                                  PLOT0119
      IF(I7.EQ.2)GOTO 1100                                              PLOT0120
C                                                                       PLOT0121
                    CALL FGRAF(X,Y,NPTS,+1,-1)                          PLOT0122
 1100 CONTINUE                                                          PLOT0123
C                                                                       PLOT0124
C     CHECK TO SEE IF A TIME PROGRAM MAY HAVE BEEN USED.                PLOT0125
      IF((IMLIN.EQ.0).AND.(ITMAR.EQ.0).AND.(ISTPL.EQ.0))GOTO 9999       PLOT0126
C                                                                       PLOT0127
      READ(KIN,500)WASTE                                                PLOT0128
C                                                                       PLOT0129
C     ITNUM=NUMBER OF TIME MARKS AND LINES FOR BATCH.                   PLOT0130
      READ(KIN,590)(TEMP1(K),K=1,4),ITNUM                               PLOT0131
C                                                                       PLOT0132
      WRITE(KOT,700)                                                    PLOT0133
      WRITE(KOT,590)(TEMP1(K),K=1,4),ITNUM                              PLOT0134
      IF(ITNUM.EQ.0)GOTO 9999                                           PLOT0135
      WRITE(KOT,700)                                                    PLOT0136
      READ(KIN,510)(TEMP1(K),K=1,20)                                    PLOT0137
      WRITE(KOT,510)(TEMP1(K),K=1,20)                                   PLOT0138
      READ(KIN,510)(TEMP1(K),K=1,20)                                    PLOT0139
      WRITE(KOT,510)(TEMP1(K),K=1,20)                                   PLOT0140
      DO 2000 I=1,ITNUM                                                 PLOT0141
      WRITE(KOT,700)                                                    PLOT0142
      READ(KIN,510)(TEMP1(K),K=1,20)                                    PLOT0143
      WRITE(KOT,510)(TEMP1(K),K=1,20)                                   PLOT0144
```

```
C                                                                       PLOT0145
C     NPT=NUMBER OF POINTS.                                             PLOT0146
      READ (KIN,505)(TEMP1(K),K=1,4),NPT,TEMP1(5),TEMP1(6),TEMP1(7),    PLOT0147
     1TEMP1(8),TEMP1(9),TEMP1(10),TEMP1(11),TEMP1(12),TEMP1(13),        PLOT0148
     2TEMP1(14),TEMP1(15),TEMP1(16),TEMP1(17),TEMP1(18)                 PLOT0149
C                                                                       PLOT0150
      WRITE(KOT,505)(TEMP1(K),K=1,4),NPT,TEMP1(5),TEMP1(6),TEMP1(7),    PLOT0151
     1TEMP1(8),TEMP1(9),TEMP1(10),TEMP1(11),TEMP1(12),TEMP1(13),        PLOT0152
     2TEMP1(14),TEMP1(15),TEMP1(16),TEMP1(17),TEMP1(18)                 PLOT0153
      READ(KIN,500)WASTE                                                PLOT0154
      READ(KIN,570)(X(K),K=1,NPT )                                      PLOT0155
      READ(KIN,500)WASTE                                                PLOT0156
      READ(KIN,570)(Y(K),K=1,NPT )                                      PLOT0157
C                                                                       PLOT0158
C     IF DATA SWITCH 3 DOWN SKIPS TIMELINES AND TIMEMARKS.              PLOT0159
      CALL DATSW(3,I6)                                                  PLOT0160
      IF(I6.EQ.2)GO TO 2000                                             PLOT0161
C                                                                       PLOT0162
                   CALL  FGRAF(X,Y,NPT ,+1,-1)                          PLOT0163
 2000 CONTINUE                                                          PLOT0164
 9998 READ(KIN,500)WASTE                                                PLOT0165
 9999 READ(KIN,500)WASTE                                                PLOT0166
C                                                                       PLOT0167
C     MESSAGE WRITING PART.                                             PLOT0168
C     POSITIONING OF MESSAGE TO APPEAR ON CHART.                        PLOT0169
      XEMP=XSCL(1)-80.0                                                 PLOT0170
      YEMP=XSCL(3)-150.0                                                PLOT0171
                   CALL  FCHAR(XEMP,YEMP    ,.10,.10,0.0)               PLOT0172
C                                                                       PLOT0173
                   WRITE(7,599)(XLAB(I),I=1,20)                         PLOT0174
C                                                                       PLOT0175
C                                                                       PLOT0176
      CALL EXIT                                                         PLOT0177
C                                                                       PLOT0178
C                                                                       PLOT0179
C                                                                       PLOT0180
```

```
  500 FORMAT(A4)                                                              PLOT0181
  510 FORMAT(20A4)                                                            PLOT0182
  520 FORMAT(12X,I1,7X,I1,6X,I1,7X,I1,6X,I1,7X,I1,7X,I1,7X,I1)                PLOT0183
  525 FORMAT(12X,I1,7X,I1,6X,I1,7X,I1,6X,I1,7X,I1,7X,I1,7X,I1)                PLOT0184
  530 FORMAT(10X,F10.0,10X,F10.0,10X,F10.0,10X,F10.0)                         PLOT0185
  540 FORMAT(7A4,3X,I2)                                                       PLOT0186
  560 FORMAT(I3,9A4,40X,I1)                                                   PLOT0187
  570 FORMAT(8F10.0)                                                          PLOT0188
  580 FORMAT(I4,9A4,32X,I1)                                                   PLOT0189
  590 FORMAT(4A4,2X,I3)                                                       PLOT0190
  700 FORMAT('0')                                                             PLOT0191
  595 FORMAT(4A4,3X,I5,14A4)                                                  PLOT0192
  599 FORMAT(10A4)                                                            PLOT0193
      END                                                                     PLOT0194
```

APPENDIX B

TIDES AT CASTINE, MAINE

JULY 4, 1972 THROUGH JULY 28, 1972

NOTE:

	Castine
L.44	24' N
68	48' W

H.W.	-4 Min on Portland
L.W.	-1 Min on Portland

H.W.	+0.7 FT
L.W.	+0.0 FT

Ranges
MEAN 9.7 FT
SPRING 11.1 FT

MEAN TIDE LEVEL 4.8 FT

ALL HOURS EASTERN DAYLIGHT SAVINGS TIME

	TIDES	
	TIME	HT
July 4, 1972	0503	9.4
	1115	0.1
	1732	10.2
	2356	0.1
July 5	0605	9.2
	1212	0.3
	1834	10.4
July 6	0103	-0.1
	0710	9.1
	1314	0.4
	1932	10.6
July 7	0210	-0.4
	0820	9.1
	1417	0.4
	2035	10.9
July 8	0312	-0.7
	0922	9.3
	1518	0.2
	2137	11.2
July 9	0413	1.0
	1019	9.5
	1616	0.1
	2232	11.4

TIDES

	TIME	HT
July 10	0510	-1.3
	1116	9.0
	1714	-0.1
	2328	10.8
July 11	0601	1.4
	1209	9.8
	1808	-0.2
July 12	0019	11.4
	0651	-1.3
	1258	9.9
	1759	-0.1
July 13	0110	11.1
	0738	-1.1
	1346	9.9
	1950	0.0
July 14	0159	10.7
	0823	-0.7
	1434	9.8
	2039	0.2
July 15	0247	10.1
	0910	-0.2
	1520	9.3
	2130	0.5
July 16	0335	9.5
	0953	0.3
	1606	9.4
	2223	0.8
July 17	0427	8.3
	1041	0.8
	1655	9.2
	2315	1.0
July 18	0520	8.4
	1130	1.2
	1746	9.1
July 19	0013	1.2
	0619	8.1
	1221	1.6
	1839	9.0

TIDES

	TIME	HT
July 20	0109	1.2
	0718	7.9
	1316	1.7
	1935	9.0
July 21	0210	1.1
	0814	7.8
	1411	1.8
	2027	9.1
July 22	0305	0.9
	0909	8.0
	1502	1.7
	2118	9.3
July 23	0354	0.7
	0958	8.2
	1550	1.5
	2204	9.3
July 24	0437	0.4
	1041	8.4
	1635	1.2
	2245	9.9
July 25	0517	0.1
	1122	8.7
	1716	0.9
	2324	10.7
July 26	0554	-0.2
	1158	9.0
	1752	0.6
July 27	0003	10.4
	0630	-0.4
	1236	9.4
	1835	0.3
July 28	0041	10.5
	0707	-0.6
	1313	9.7
	1916	0.0

HOLBROOK COVE SURVEY

A 1972 Student Summer Ocean Engineering Laboratory

Research Project

Report No. MITSG 72-19
Date: December 31, 1972

Index No. 72-119-Nkw

Administrative Statement

A fundamental educational experience for undergraduate students of Ocean Engineering is the opportunity to design, construct and operate equipment in the marine environment in a coordinated attack upon some real-world problem. This is the primary objective of the Holbrook Cove Survey. The research objective is to gain a better understanding of the hydraulics and ecology of this small cove and to determine what effect the effluent that a mining operation discharges into this relatively confined estuary may have upon its ecological community. This is one of the projects of the 1972 Summer Ocean Engineering Laboratory.

A companion report, "The Search for DEFENCE and Other Projects of Students During the 1972 Summer Ocean Engineering Laboratory," (MITSG 72-20), describes the other Ocean Engineering projects undertaken by the students.

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Individual	Organization
Professor A. D. Carmichael	M.I.T.
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Professor Ira Dyer	M.I.T.
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Professor Dean Mayhew	Maine Maritime Academy
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The list of faculty and staff at both the Maine Maritime Academy and the Massachusetts Institute of Technology who contributed to the success of the 1972 Summer Ocean Engineering Laboratory would be lengthy and nearly impossible to compile without inadvertent omissions, so to these individuals the participants express their sincere appreciation.

1972 Summer Ocean Engineering Laboratory

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1.0 INTRODUCTION

This report is the first of two volumes concerning the accomplishments of the 1972 M.I.T./Maine Maritime Academy Sea Grant Summer Ocean Engineering Laboratory. It describes the investigations students conducted in an oceanographic and biological survey of Holbrook Cove in July 1972. The second report deals with their successful search for the remains of a Revolutionary War privateer, the design and construction of equipment for use in future Summer Ocean Engineering Laboratories, and other activities.

The Summer Ocean Engineering Laboratory provides undergraduate ocean engineering students an opportunity to combine theory and practice when they design simple equipment and test and operate this equipment in the real environment for which the students must prepare themselves.

We selected two major projects in which all the students' equipment could be utilized in coordinated efforts; thus each student had an opportunity to contribute useful results to a real-world ocean engineering project. These two major projects are a comprehensive survey of Holbrook Cove and a systematic search for the remains of American Revolutionary War ship hulks.

For the students, the Summer Laboratory demonstrated that there is more to ocean engineering than just conceptual design and theoretical analysis. They dealt first-hand with Murphy's Law. They experienced the rigors of the marine environment, including the limitations of weather, the swift devastation of corrosion, and the exacting demands of hydrostatics.

Their benefits, judging from the students' post-Summer Lab interests and activities, include: a better perspective of their academic experiences; an enhanced appreciation for the relevance of the various elements that comprise an ocean engineering curriculum; an intensified curiosity directed toward unfamiliar facets of ocean engineering; and, in some cases, an inspiration for a special project or thesis.

In the report of the 1971 Summer Ocean Engineering Laboratory we stated:

The opinion of all who were involved with this project, students and faculty of both M.I.T. and Maine Maritime Academy, visiting faculty, and consultants, was that this program served an educational purpose that is essential early in the students' Ocean Engineering education. All hands were exposed to the myriad of problems encountered in attempting to apply theory and classroom experience to equipment and procedures that must work at sea without the enormous expense and pressure of full-scale industrial or government projects. The usual mistakes were made in an environment where they could be dealt with without cost or loss of essential data and the lessons were learned.

Our experience during this second Summer Ocean Engineering Laboratory reinforces our faith in the value of this educational experience.

2.0 SUMMARY

2.1 Objective

The objective of the Holbrook Cove Survey is to gain an understanding of its hydraulics and ecology in order to ascertain the effect which the effluent from the Callahan mine outfall has upon the Cove.

Holbrook Cove is located approximately one-half mile southwest of Castine, Maine, and appears on U.S. Coast & Geodetic Survey Chart number 311, as well as the Department of Interior/ Department of the Army topographical map of Castine, Maine.

2.2 Background

This project permitted the M.I.T. and Maine Maritime Academy students to design, construct and utilize individual equipment and employ them in the marine environment in a coordinated attack upon a real problem. It had come to the attention of those participating in the 1972 Summer Ocean Engineering Laboratory that heavy metal pollution is a problem in the coastal areas of Maine and that a relatively new mining operation had opened in Holbrook Cove. It is deemed possible that the effluent from the outfall of this mining operation has a profound effect upon the ecology. The following research projects were planned and coordinated to study this problem.

PROJECT	STUDENT PARTICIPANTS
Tidal Current Streamlines and Velocity	Cebelius, Kennedy and Lukens
Temperature and Salinity	Murphy
Chlorophyll 'A' Content	Chertow
Benthic Infauna Distribution	Dwyer, Lee, Seo
Tidal Height Fluctuations	Barnes
Detailed Bottom Topography	Cameron, Cianchette and Sautter
Bottom Soil Structure	Barriault
Water Oxygen Content	Murphy

2.3 Results

The results of the individual projects are as follows:

Project	Results
Tidal Currents	Streamlines at various tidal phases have been established. Current velocities have been calculated. Current velocities have been measured on a real-time basis at the northwestern and southern entrances to the Cove. Fluctuations indicate a seiche in the Cove has a profound effect upon the velocity at any given time.
Temperature and Salinity	These measurements were made. The results are contained in Tables 5.1, 5.2 and 5.3.
Chlorophyll 'A' content	These measurements were made. The results are contained in Figures 5.3, 5.4 and 5.5 and Tables 5.1, 5.2 and 5.3.
Benthic Infauna Distribution	Still being analyzed. Initial trends indicate that the biomass and numbers of individuals are at a minimum at the sampling station nearest the outfall. This may indicate that the effluent has an adverse effect on the biota.
Tidal Height Fluctuations	A tide gauge has been built and tested, but the scribe mechanism and the magnitude of frictional forces did not permit the gauge to give useful results.
Detailed Bottom Topography	A nomogram was prepared to permit the soundings to be related to the MLLW datum. In testing the nomogram against observed tidal heights at Castine, it was noted that the scope of tide appears to be about one foot greater than indicated in the tide tables. Time precluded the detailed sounding program execution.

Project	Results
Bottom Soil Structure	A corer and release mechanism were designed and built. During the first *in situ* test the messenger line used for retrieval was severed and the unit could not be relocated for recovery.
Oxygen Content of Cove Water	An oxygen meter was designed and constructed for use with an oxygen probe borrowed from the Woods Hole Oceanographic Institution. Time precluded calibration. No measurements of oxygen content of Cove water were made.

2.4 Conclusions

It is apparent that the educational objectives of this project were met. All of the rigors of the marine environment were apparent from the restrictions of weather to the effects of corrosion. The constraints of time demonstrated that careful planning is necessary if this priceless commodity is to be conserved and that, if it is not conserved, the entire effort up to the deadline may end in frustration. The loss of the corer dramatically demonstrated the need for failure analysis and provision of safeguards to handle those failures which may occur if an entire project is not to be jeopardized by some malfunction. Finally, the students received practical training in boat handling, safety at sea, navigation and the discipline these activities imply.

The research objectives were partially met. The results of the investigations into the hydraulics of the Cove indicate that there may be a seiche that significantly affects the current velocity magnitudes. Sampling of data at thirty-minute intervals does not give a meaningful result in this instance since the sampling intervals must be less than half the period of the seiche to obtain a meaningful real-time result. The gross flow patterns in the Cove have been defined particularly in the vicinity of the three entrances. Finally, the results suggest that the variation of current velocity with respect to depth is significant and should be investigated.

The results of the temperature and salinity survey reveal no anomalies in the absence of flow from the mine outfall.

The chlorophyll 'A' measurements do not suggest any effect upon chlorophyll 'A' distributions in the vicinity of mine outfall. In the absence of a constant effluent flow, none would be expected.

The preliminary results in the study of the benthic infauna distribution suggest that there is a detectable adverse effect upon the ecology in the vicinity of the mine outfall.

2.5 Recommendations

The Holbrook Cove Survey is incomplete as of this writing. From the research point of view, there is still a great deal to be learned in this relatively small geographical area. A better and more complete survey could and should be conducted, taking advantage of the lessons and mistakes of the 1972 effort. Certainly, the equipment not used in the 1972 survey should be employed to complete those research objectives not carried out in this effort because of the limitations of time.

A determination of the period and magnitude of the seiche in Holbrook Cove and its effect upon the flow patterns is a very intriguing project and the most effective means appears to be through the use of current meters. A second study which suggests itself is the determination of the variation of current with respect to depth. Both of these projects would be enhanced by the design and construction of a device that will establish current direction for use with the current magnitudes as measured by the current meters.

If the Callahan mine outfall is discharging effluent, a repetition of the study of the chlorophyll 'A' distribution seems indicated. Perfection of a method to measure the concentration of heavy metal ions to correlate with the clorophyll 'A' pattern is highly desirable.

From the educational viewpoint, the efforts in surveying the Cove are ideal. The project is of necessity interdisciplinary and careful coordination is required if the results are to be meaningful. This coordination imposes the discipline of scheduling, which is one of the very real constraints not adequately imposed by any other form of educational experience. It is therefore recommended that the survey effort be considered for future Summer Ocean Engineering Laboratory projects.

3.0 DETERMINATION OF THE CURRENT PATTERNS IN HOLBROOK COVE

3.1 Objective

This project has as its objective the determination of the current velocities and streamlines in the Holbrook Cove estuary as a function of time and tide. Data were obtained by the use of drogue buoys (see Figure 3.1). By recording the geographical position of each buoy and the associated time, velocities and positions have been calculated.

Figure 3.1

Drogue Buoys

3.2 Procedure

Measurement of buoy positions and the related times were made at various locations in the Cove over the complete spectrum of tide states. Although it was originally planned to cover the entire area of the Cove, limitations of time forced the project to select those areas which appeared to be most crucial to the understanding of the Cove's current patterns, and concentrate the data-gathering efforts only in those areas.

Geographical measurements of buoy positions were made by establishing a baseline between two transits and recording both its length and line of bearing. Using the transits at the ends of the baseline, simultaneous measurements of the relative angle between the baseline and the line of sight from each transit to a buoy were made and recorded. The units of measure employed were:

Directions and angles--degrees and minutes
Baseline length--meters
Time--hours, minutes and seconds

3.3 Limitations of Accuracy

Factors affecting data accuracy were both natural and mechanical. The natural factor that was of concern was the effect of the wind upon the paths and velocities of the buoys. Wind velocities in excess of two knots were considered to measurably affect data accuracy, and wind velocities in excess of five knots were considered unacceptable. In reducing the data, all measurements taken in conditions involving wind velocities in excess of two knots were discarded. In reducing the data, it appears that there may be some measurable wind effect at velocities of one to two knots. This fact led the team to concentrate the data-gathering effort into the very early morning hours in which there is generally no measurable wind.

Mechanical factors affecting the accuracy of the data were the limitations equipment imposed upon the measurements of the baseline lengths, line-of-sight angles with respect to the baseline and the times of each measurement. The end positions of the baselines were established by locating them on a chart of the estuary with respect to landmarks depicted thereon. Lengths of the baselines were determined by first calculating the length by means of triangulation and then measuring the distance between the two end positions as located on the Coast and Geodetic Survey Charts. Table 3.1 contains a comparison of the length of the baselines as determined by triangulation and by measurement from the Coast and Geodetic Survey Charts.

It is estimated that the line-of-sight angles with respect to baseline were measured with limits of accuracy of about $\pm$one-half degree of arc. Time was measured to the nearest tenth of a minute (six seconds).

Table 3.1

COMPARISON OF LENGTH OF BASELINES AS DETERMINED BY TRIANGULATION AND MEASUREMENT (CGS CHARTS)

BASELINE	LENGTH MEASURED FROM CHART	LENGTH MEASURED BY TRIANGULATION
015/195	823	950
026/206	311	321
108/288	347	368
122/302	293	246
146/326	329	333
174/354	466	397

3.4 Data Reduction

The large volume of data collected made the use of a computer highly desirable. The quality of the data was carefully examined and several series of observations were disregarded because they appeared to have been severely affected by wind. The remainder of the data was then sorted first by utilizing a computer program to calculate buoy velocities and then discarding all inconsistent observations. For example, if a buoy's velocity changed drastically between observations and then appeared to return on succeeding observations to values consistent with earlier observations and the buoy's position was inconsistent with those established by preceding and succeeding observations, the data corresponding to the nonconforming observation was discarded. This procedure was adopted after it was noted that the paths of the buoys were linear or involved only slight degrees of curvature, except for a very few instances in which buoys came under the influence of a vortex. In those instances, only the most erratic cases were disregarded.

The data reduction required solutions of two equations of the form:

$$P_n = f(x, y)$$
$$V_n = g(P_n, P_{(n-1)}, \Delta T)$$

where

P_n and $P_{(n-1)}$ are buoy positions at times n and (n-1) respectively;

f and g are functions involving the parameters contained within the parentheses which follow them;

x and y are orthogonal coordinates in a two-dimensional grid system with the x coordinate measured parallel to the observation baseline;

ΔT is the time interval between the observations establishing the positions P_n and $P_{(n-1)}$.

In order to define the positions of the buoys in terms of the coordinate system, x and y, using the baseline as the base of a triangle and the lines of sight from the ends of the baseline to the buoy as its other two legs, the computer was utilized. The known quantities are the length of the baseline and the two included angles between the lines of sight and the baseline. Establishing one end of the baseline as the origin of the coordinate system, the calculation of the orthogonal projection of the leg formed by the line of sight from that end of the baseline to the buoy defines the x coordinate. The calculation of the altitude of the vertex, formed by the intersection of the two lines of sight, with respect to the baseline defines the y coordinate. The computer was programmed to calculate the x and y coordinates using the law of sines. No attempt was made to utilize a single coordinate system for the entire estuary, but rather a different one was used for each baseline. If desired, a set of transformation equations could have been derived, but it would have unnecessarily complicated the problem. Streamlines were represented graphically on a chart of the Cove.
As a matter of expediency two Fortran IV programs were written. The first calculated the x and y coordinates and the velocities punching the calculated data onto cards which served as data

for the second program. The latter program plotted the streamlines on a mechanical plotter. These streamlines were then positioned on a chart of the Cove and a reproduction made from the result.

A listing of each of the two programs is found in Appendix A. A description of the first program is also included in the appendix, but, since the second program merely reads Cartesian coordinates and calls an IBM-supplied plotting subroutine, no description seems to be required.

3.5 Results

Figure 3.2 is a reproduction of the chart of Holbrook Cove showing its major physical features and the surrounding landmarks. The features which appear to have the greatest effect upon the flow patterns of the Cove are three entrances: the sandbar (northern entrance), the Nautilus Rock Channel (northwestern entrance) and the Goose Falls Channel (southern entrance) The sandbar is submerged from zero to eight feet, varying from three hours before high tide to three hours after high tide. Since the drogue buoys used in this project required at least five feet of water depth, little data was obtained in the vicinity of the sandbar. It should be noted that all times in the figures which follow are recorded in hours and minutes from the High or Low tide. The times of High and Low tide were calculated based upon the U.S. Department of Commerce Tide Tables using the correction factors for Castine, Maine (see Appendix B)

The data have been grouped into six time periods, each corresponding to approximately a two-hour phase in the Tidal Cycle. The names and approximate time limits of each phase are contained in Table 3.2.

Figures 3.3 and 3.4 contain the streamlines and flow velocities. Tables 3.3 through 3.8 list the dates of the observations, initial and final observation times (recorded with respec to the hours and minutes before or after the high/low tide) and the baseline from which the observations were made. The baselines are identified in Figure 3.2.

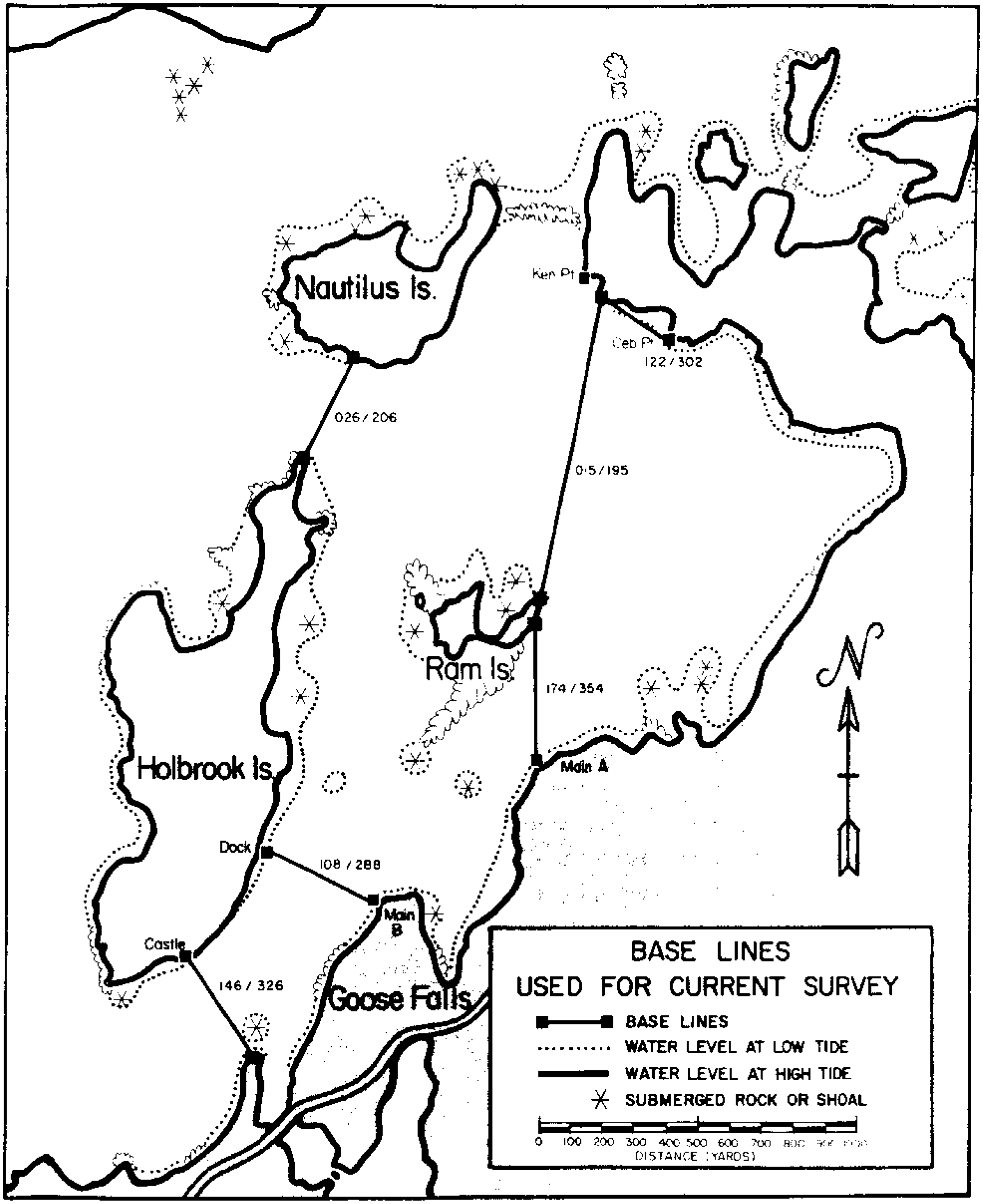


Figure 3.2

Holbrook Cove

Table 3.2

NAME AND APPROXIMATE TIME BOUNDARIES OF TIDAL PHASES

NAME	BEGINNING	END
Pre-High Phase	3 hours before high tide	1 hour before high tide
High Phase	1 hour before high tide	1 hour after high tide
Post-High Phase	1 hour after high tide	3 hours after high tide
Pre-Low Phase	3 hours before low tide	1 hour before low tide
Low Phase	1 hour before low tide	1 hour after low tide
Post-Low Phase	1 hour after low tide	3 hours after low tide

3.6 Conclusions

The streamline and velocity charts for the pre-high phase (Figures 3.3 and 3.4) reveal that buoy direction reversals begin with those buoys located closest to the southern entrance. The tidal flows appear to initiate approximately 45 minutes earlier at the southern end than at the northern end of the Cove. There appears to be a tidal phase gradient in the area of the Cove bounded by the southern entrance and by Ram Island. The streamline chart (Figure 3.3) for the pre-low phase indicates slack water about one hour before the predicted low tide at Castine, Maine. The velocity chart (Figure 3.4) for the low phase indicates rather high velocities at the times of predicted slack water at Castine, Maine. It is noted that buoy velocities appear to decrease as they approach Ram Island.

The basin north of Ram Island can be pictured as a large tank with four inlets/outlets (one of which is open for about three hours before and after high tide). The currents through the northwestern and southern entrances to the Cove in post-low and pre-high phases are in opposition in the shallow channel west of Ram Island. The current from the southern entrance is predominant and forces water back toward the northwestern entrance.

As the current in the southern entrance begins to shift from flood to ebb, water continues to fill the basin. By the time the current at the northern entrance (the sandbar) begins

Table 3.3

TIDE PHASE: PRE-HIGH

DATE	BUOY	TIME START	TIME END	OBSERVATION BASELINE
7/25	F3R	-3:00	-2:29	026/206
7/25	F4R	-2:10	-1:07	026/206
7/25	F3O	-3:56	+0:36	026/206
7/19	K3B	-5:05	-3:36	108/288
7/19	K2RB	-5:00	-3:04	108/288
7/19	K3RB	-2:41	-1:48	108/288
7/19	K3R	-2:43	-1:55	108/288
7/19	K3W	-2:42	-1:48	108/288
7/19	K3WG	-2:39	-1:50	108/288
7/25	E3W	-1:53	+0:08	146/326
7/26	C2R	-2:22	-1:54	108/288
7/26	C3W	-3:03	-2:25	108/288
7/26	C2B	-4:10	-2:55	108/288
7/26	C3B	-2:30	-2:20	108/288
7/26	D2O	-2:08	-1:21	174/354
7/26	D2R	-3:19	-2:58	174/354
7/25	E3Y	-2:40	-2:12	146/326
7/25	E4Y	-1:54	-0:50	146/326
7/25	E3RB	-2:35	-2:09	146/326
7/25	E2W	-2:41	-2:14	146/326
7/25	F3B	-3:35	-3:00	026/206

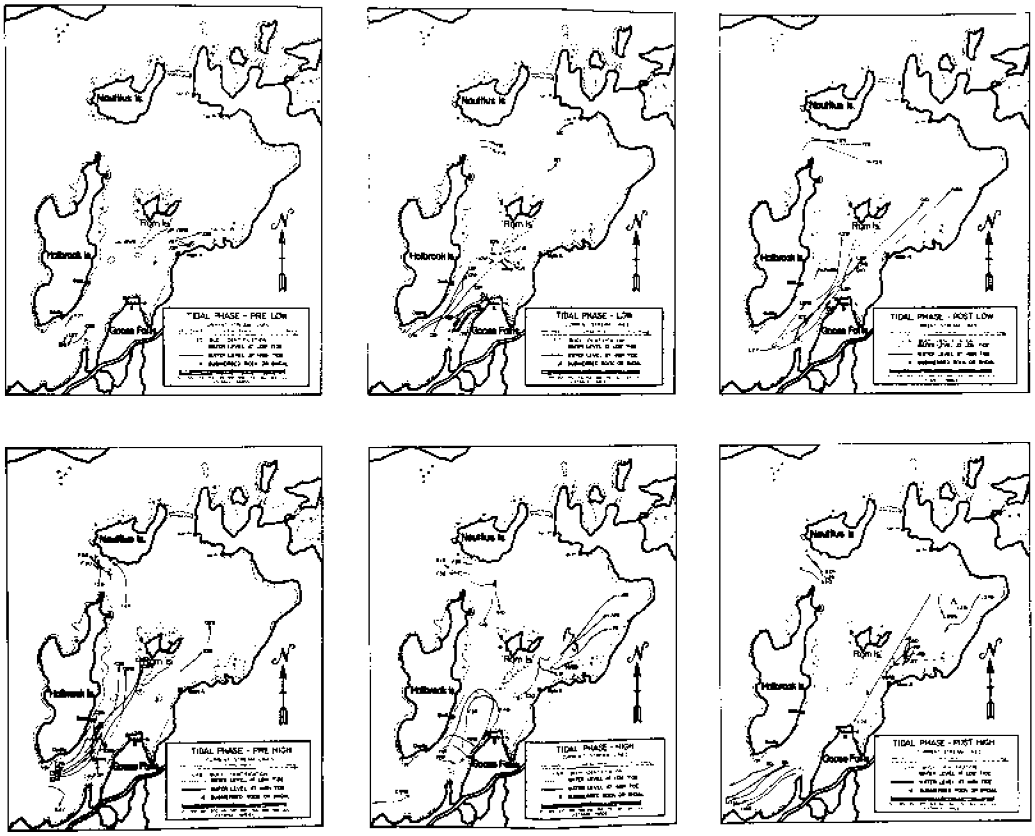


Figure 3.3 Pre-High, High and Post-High Streamlines and Current Velocities

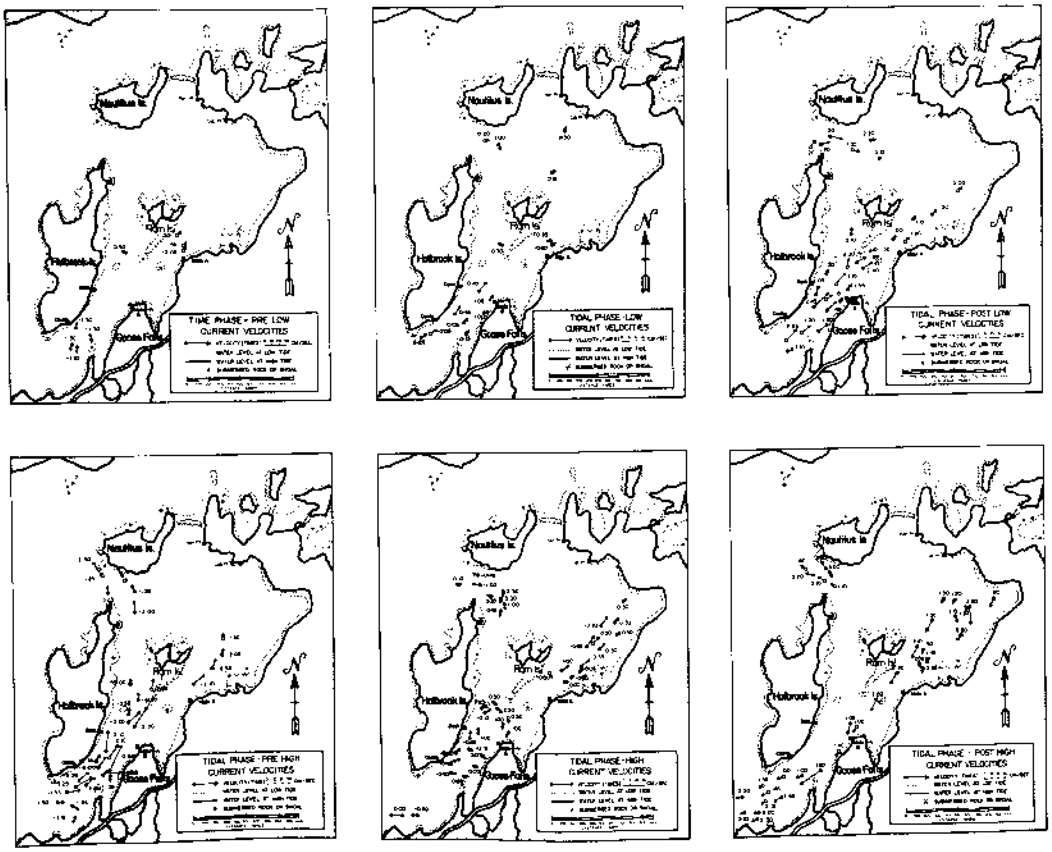


Figure 3.4 Pre-Low, Low and Post-Low Streamlines and Current Velocities

Table 3.4

TIDE PHASE: HIGH

DATE	BUOY	TIME START	TIME END	OBSERVATION BASELINE
7/26	D1Y	-2:06	+2:03	174/354
7/26	D3O	-0:59	+1:57	174/354
7/26	D2RB	-1:00	+0:41	174/354
7/26	C3R	-1:31	+1:40	108/288
7/26	C4B	-1:56	+1:50	108/288
7/24	G1O	-0:04	+1:45	015/195
7/24	G1R	-0:06	+1:42	015/195
7/25	F5B	-1:03	+0:35	026/206
7/25	F5R	-0:59	+0:37	026/206
7/24	G1B	-0:04	+1:38	015/195
7/24	H1W	-0:42	+0:22	146/326
7/24	H1RB	-0:45	+0:25	146/326
7/11	L1R	-1:03	+0:25	122/302
7/11	L1W	-1:04	+0:27	122/302
7/11	L1WG	-1:06	+0:30	122/302
7/11	L1RB	-1:05	+0:31	122/302

to ebb, the basin has begun to empty. The current through the northern entrance (the sandbar) begins to flow into the basin and the currents through the outlets formed by the northwestern entrance and the channels east and west of Ram Island flow out of the basin. When the water level falls below the sandbar in the northern entrance, blocking flow, the currents through the remaining three outlets continue to flow out of the basin until the next current reversal at low tide.

3.7 Recommendations

The use of buoys and transits is subject to many limitations. First and foremost is the restriction on their use to periods of

Table 3.5

TIDE PHASE: POST HIGH

DATE	BUOY	TIME START	TIME END	OBSERVATION BASELINE
7/23	I1RB	+0:51	+2:32	015/195
7/23	I1W	+0:52	+2:32	015/195
7/23	I1B	+1:00	+2:34	015/195
7/23	I1O	+0:57	+2:31	015/195
7/24	G2O	+2:54	+3:22	015/195
7/24	G2R	+2:53	+3:21	015/195
7/24	G2B	+2:56	+3:20	015/195
7/24	H2RB	+1:17	+3:12	146/326
7/24	H2Y	+1:16	+3:13	146/326
7/24	H2W	+1:20	+3:09	146/326
7/8	M1RB	+2:07	+2:42	122/302
7/8	M2RB	+3:12	+3:44	122/302
7/11	L2R	+1:26	+3:17	174/354
7/11	L2WG	+1:20	+2:20	174/354
7/11	L2W	+1:21	+2:21	174/354
7/22	J1W	+1:45	+2:51	108/288
7/11	L2RB	+1:20	+2:20	174/354
7/22	J2R	+1:43	+2:49	108/288
7/22	J1B	+1:44	+2:50	108/288
7/22	J1Y	+1:44	+2:36	108/288
7/22	J1O	+1:57	+5:26	108/288
7/26	D3RB	+1:08	+1:55	174/354
7/23	I1Y	+0:53	+3:20	015/195

Table 3.6

TIDE PHASE: PRE-LOW

DATE	BUOY	TIME START	TIME END	OBSERVATION BASELINE
7/22	J2Y	-2:27	-0:15	108/288
7/22	J2R	-2:30	-0:52	108/288
7/22	J2B	-2:32	-0:27	108/288
7/22	J2RB	-2:33	-0:42	108/288
7/24	H3Y	-2:09	-1:25	146/326
7/24	H3W	-2:14	-1:26	146/326
7/23	I2Y	-1:43	-1:23	015/195
7/23	I2O	-1:41	-1:22	015/195
7/19	K1WG	-1:19	-0:31	108/288

little or no wind. This severely limits the time available for gathering data. In addition, the buoys proved to be difficult to place in position, transport and store.

The transits require rather large crews since two transits are required per baseline and two or three men are needed at each station to communicate, man the transit, and record data.

The communications and recording duties can often be combined but, since at one of the transit stations a person must coordinate the sighting by the two stations, it is difficult to operate with less than four persons manning the two transits, while five persons appear to be optimum. There is also the added problem that, since buoys often run aground and in order to understand the currents, buoys must be frequently repositioned, an additional person is required to man a boat. Fatigue will also begin to take its toll, if a station is to be run over four or five hours and a replacement crew will be required. In short, buoy and transit stations require too many people to be an optimum solution.

Table 3.7

TIDE PHASE: LOW TIDE

DATE	BUOY	TIME START	TIME END	OBSERVATIC BASELINE
7/27	A1O	-3:03	+1:30	026/306
7/27	A1Y	+0:09	+1:29	026/306
7/26	C1B	-0:18	0:00	108/288
7/27	B3W	+0:33	+1:21	108/288
7/22	J3RB	+0:03	+1:08	108/288
7/22	J2O	+0:05	+1:07	108/288
7/22	J3R	-0:01	+0:47	108/288
7/22	J3B	+0:02	+1:08	108/288
7/22	J3Y	0:00	+1:15	108/288
7/22	J3W	-0:02	+0:38	108/288
7/19	K1W	-1:16	-0:02	108/288
7/19	K1RB	-1:17	+0:04	108/288
7/19	K1R	-1:18	+0:03	108/288
7/25	F1R	+0:14	+0:59	026/206
7/25	F1B	+0:12	+1:02	026/206
7/26	C1R	-0:22	+1:52	108/288
7/26	C1W	+0:06	+1:37	108/288

Before buoys are employed in future projects, they should be redesigned to permit operation under unfavorable wind condi- tions. The visible part of the buoy should be made more easil identifiable and less dependent on lighting conditions, so in- creased distance and bad weather will not hamper tracking. The operational maximum was six buoys with a sighting period of approximately six minutes. The optimum was four buoys with a three-minute tracking period. Acoustical tracking by means of sonar might be an alternative.

The use of stationary current meters would eliminate many of the problems of buoy tracking, but would raise new ones. As

Table 3.8

TIDE PHASE: POST-LOW

DATE	BUOY	TIME START	TIME END	OBSERVATION BASELINE
7/26	D1RB	+0:14	+3:05	174/354
7/26	D1O	+0:15	+3:00	174/354
7/26	K2W	+1:13	+3:12	108/288
7/26	K2R	+1:15	+3:15	108/288
7/26	K2WGS	+2:01	+2:28	108/288
7/25	F2O	+1:09	+1:55	026/206
7/25	F2R	+1:18	+3:14	026/206
7/25	F2B	+1:16	+2:19	026/206
7/25	E1W	+1:10	+2:43	146/326
7/25	E2RB	+2:22	+2:47	146/326
7/25	E2Y	+2:02	+2:45	146/326
7/26	C1O	-0:19	+2:43	108/288
7/26	C2W	+1:53	+2:44	108/288
7/25	E1Y	+1:13	+1:44	146/326

it stands now, most current meters provide a current magnitude, but a current direction would also have to be obtained. Another limitation of current meters is the fact that they are difficult to moor and reposition.

An optimum approach might be the use of a combination of buoys and current meters. The buoys, of course, utilize a Lagrangian type of coordinate system, while the current meters use a Eulerian type of system, but with the information from both, an exceptional picture of the hydrodynamics of the Cove could be obtained.

4.0 DETERMINATION OF CURRENT VELOCITIES VERSUS REAL TIME IN THE SOUTHERN AND NORTHWESTERN ENTRANCES OF HOLBROOK COVE

4.1 Objective

The objective of this project is to measure current velocities in the center of the channel at the southern and northwestern entrances of Holbrook Cove over a complete tidal cycle.

4.2 Procedure

The current meters were moored in approximately the center of the southern and northwestern channels at a depth of approximately 10 feet at low tide. A clock-timing device was used to record the current meter pulses on magnetic tape for a period of four minutes at half-hour intervals, on the hour and half-hour. The magnetic recorders were later retrieved. An operator rewound the tape, placed the tape recorder in the "play" mode and counted the number of pulses over a 10-second interval. Current velocities were then determined using the pulses per second to enter the calibration curves.

4.3 Results

Figures 4.1 and 4.2 are plots of current velocities at 30-minute intervals. The tidal phase noted at the bottom of the figures relate the time to the tidal phase at Castine. Figures 4.3 and 4.4 compare buoy velocities calculated from observations taken in the vicinity of the current meter positions with the results of the current meters. It should be noted that the buoy observations were not made on the same day that the current meters were implanted and that the buoy positions are in the same general area, but not identical to the positions of the current meter. It should also be noted that the current meters were placed a fixed distance from the bottom of the Cove and their depths therefore vary with the height of the tides. It is estimated that the depth of the current meters varied from approximately 10 feet to approximately 20 feet over the complete tidal cycle.

4.4 Conclusions

In comparing the results of the current meters and the buoys, it appears that there may be a periodic velocity fluctuation that significantly affects the magnitudes of the currents

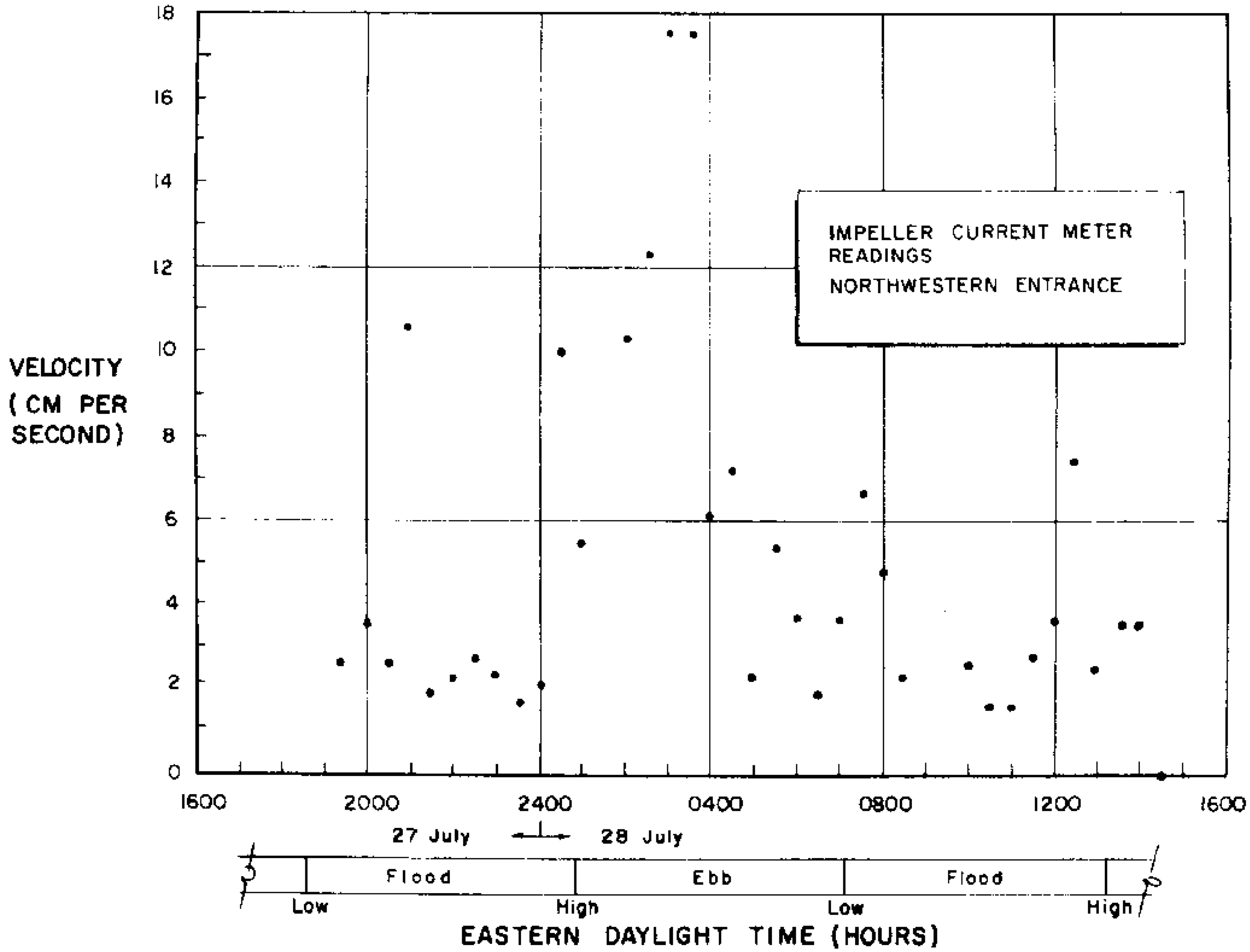


Figure 4.1

Impeller Current Meter Results in
Northwest Entry to Holbrook Cove

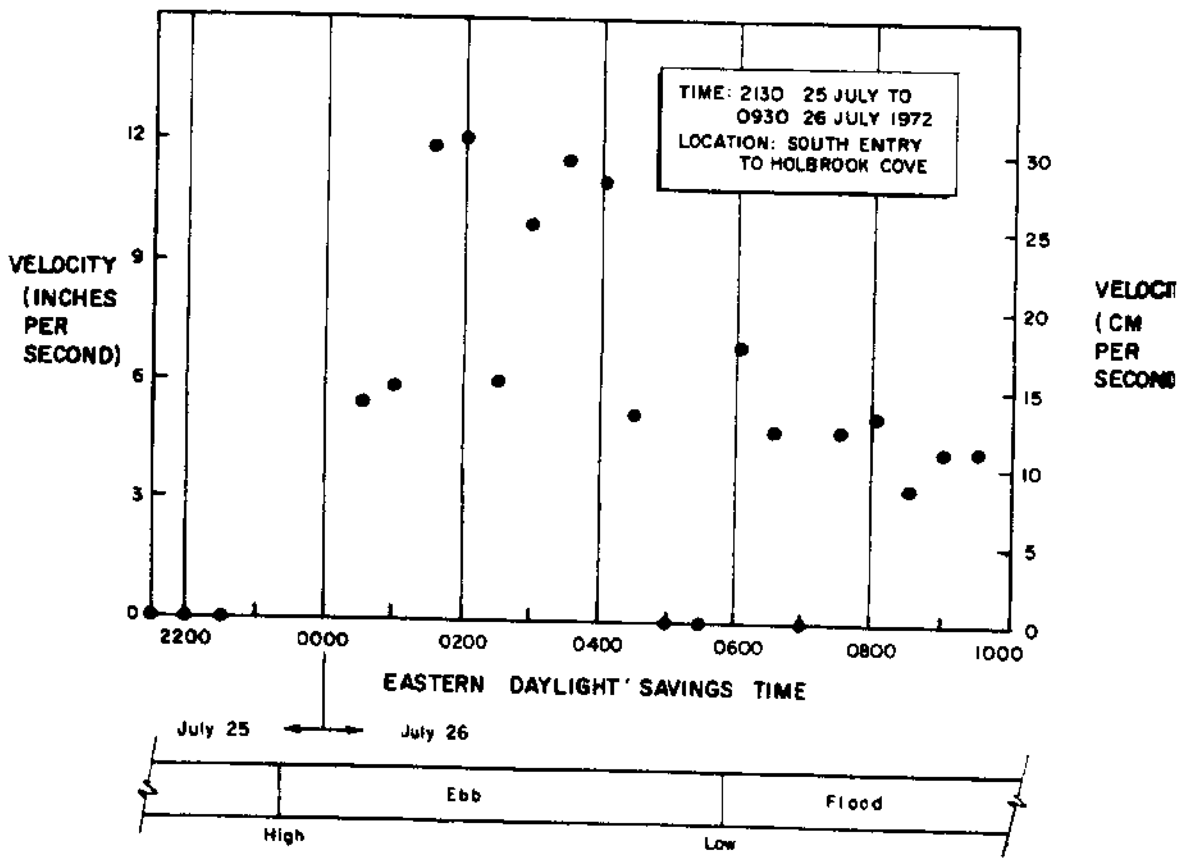


Figure 4.2

Karman Vortex Trail Current Meter Results
in South Entry to Holbrook Cove

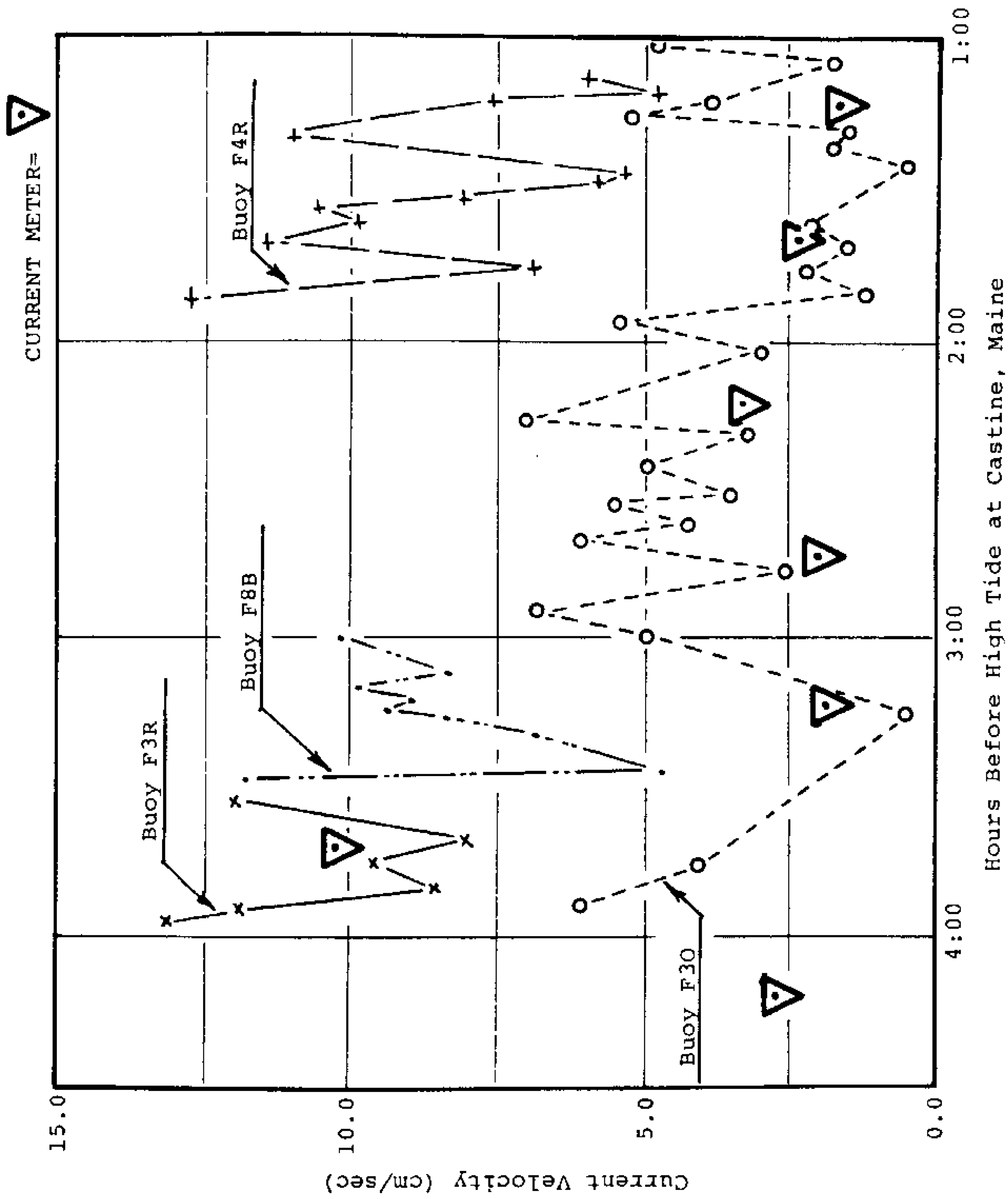


Figure 4.3

Comparison of Buoy Velocities and Current Meter Results
Northwestern Entrance to Holbrook Cove

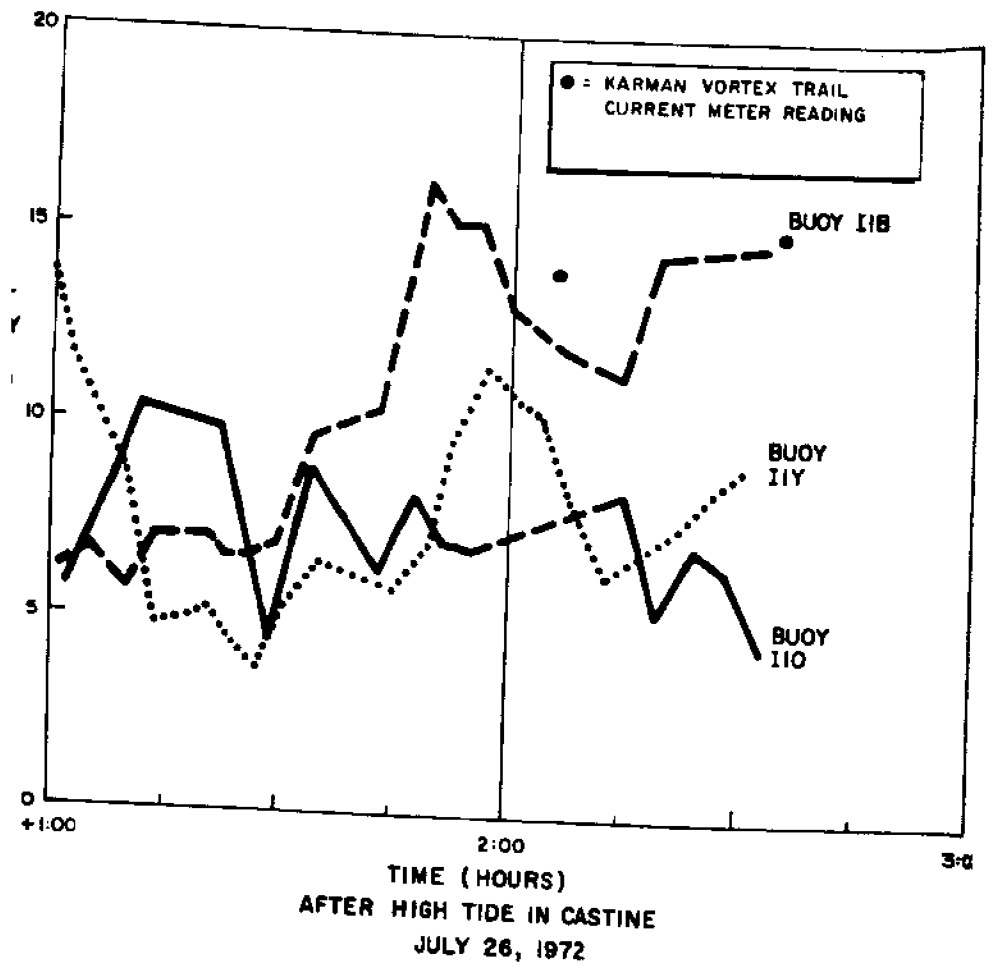


Figure 4.4

Comparison of Current Meter and Body Velocity Results in South Entry to Holbrook Cove in the Cove. The results suggest that the period of this oscillation is about 8 to 12 minutes and the velocity variations may be as much as plus or minus 30 percent around some mean value.

Based upon the results of both the current meters and the buoy velocities, it is concluded that the tidal currents in Holbrook Cove are significantly affected by a seiche. In planning the project, this result was not anticipated and the time intervals selected for recording currents was arbitrarily set at 30 minutes. In addition, it appears that there is a significant reduction in the current velocities recorded by the current meter when the depths are greatest, i.e., near high tide.

4.5 Recommendations

While it appears that the current meter and recording system functioned properly, the reduction of data by counting the number of "beeps" over a time interval as a means of establishing velocity is far too time-consuming. It is therefore recommended that a means of recording velocity that will permit a more automated reduction of data be devised.

It is also recommended that any future projects consider the possibilities of a seiche and velocity measurements be made continuously over longer time spans or, if intermittent current velocity measurements are made, the interval between measurements be shortened to a period that is less than half the period of the estimated seiche.

Finally, it is recommended that a vertical array of current meters be deployed to establish the velocity profile as a function of depth.

5.0 TEMPERATURE, SALINITY AND CHLOROPHYLL

5.1 Temperature and Salinity Patterns

5.1.1 Objective

The purpose in studying temperature and salinity in Holbrook Cove is to obtain baseline data usable in density analysis. This data will be useful in establishing the prevailing conditions in Holbrook Cove, and how these conditions may affect biology and water movement. The design of inexpensive water sampling bottles and their construction was required to achieve the primary objective (see Figure 5.1).

5.1.2 Background

Salinity and temperature analysis is a standard practice in physical oceanography. Salinity gives a good idea of the horizontal and vertical extent of dilution in the Holbrook mic[ro-] estuary. Presumably, fresh water from both the Bagaduce and Penobscot Rivers dilute sea water in the area of the Cove. Rain water also has a day-to-day effect, although sampling was not extensive enough to draw any conclusions about this effect.

Temperature is of equal value to the oceanographer. Within any geographical basin, one generally finds more than one water type. Temperature tends to be the prime indication of a transition from one water type to another; and the word thermocline denotes just such a boundary. Temperature is seasonal, and has a controlling effect on the biological community.

Finally, temperature and salinity, coupled with the depth at which the sample was taken, can be combined to calculate the density of the water sample. Density, also a characteristic of the particular water, determines the physics of that water body to some extent. Statically, more dense water will lie at the bottom of basins. Dynamically, the forces on waters of different density are the cause of water movement.

5.1.3 Results

The results of this investigation are tabulated in Tables 5.1, 5.2 and 5.3. The column headed "Chlorophyll 'A'" is discussed in Section 5.2.

Figure 5.1

Sampling Bottles

TABLE 5.1

TEMPERATURE, SALINITY, DENSITY AND CHLOROPHYLL 'A'

AT DEPTH = 0 METERS

STATION	TEMPERATURE (DEGREES CENTIGRADE)	SALINITY	SIGMA 'T'	CHLOROPHYLL 'A' (MICROGRAMS PER LITER)
1A	17.5	26.18	19.22	2.071
1B	17.5	25.44	18.12	1.526
1C	17.5	25.30	18.02	1.417
2A	17.0	25.66	18.40	1.417
2B	15.0	25.22	18.49	1.417
2C	17.0	24.34	17.78	1.744
3A	17.0	25.30	18.13	1.417
3B	17.0	25.30	18.13	1.090
3C	18.0	25.02	17.96	0.931
4A	17.5	24.65	17.79	1.417
4B	17.5	24.88	17.70	1.990
4C	18.0	25.44	18.01	1.417
5A	17.0	25.37	18.56	1.199
5B	14.0	26.20	19.44	0.981
5C	17.2	27.10	19.45	1.417
6A	17.0	25.66	18.40	1.398
6B	13.0	21.05	16.20	1.744
6C	14.0	26.92	19.99	2.130
7A	17.0	26.13	18.80	0.931
7B	17.5	25.93	18.50	0.872
7C	17.0	25.33	18.15	0.931
8A	17.5	[illegible]	18.61	0.436
8B	18.0	26.40	18.74	0.991
8C				

TABLE 5.2

TEMPERATURE, SALINITY, DENSITY AND CHLOROPHYLL 'A'

AT DEPTH = 3 METERS

STATION	TEMPERATURE (DEGREES CENTIGRADE)	SALINITY	SIGMA 'T'	CHLOROPHYLL 'A' (MICROGRAMS PER LITER)
1A	15.0	28.72	20.62	1.526
1B	16.0	26.20	19.03	1.308
1C	14.0	26.29	19.51	1.635
2A	17.0	25.82	18.52	1.744
2B	11.5	26.11	19.82	1.962
2C	15.0	26.38	19.38	2.239
3A	12.0	27.46	20.78	1.635
3B	10.0	27.28	20.97	1.526
3C	10.0	29.07	22.36	1.199
4A	10.5	27.39	20.97	1.744
4B	10.0	27.08	21.03	1.853
4C	10.5	26.18	20.03	1.199
5A	12.5	28.51	21.50	2.071
5B	9.5	28.18	21.74	1.962
5C	11.0	28.87	22.04	2.398
6A	11.0	28.29	21.59	1.744
6B	9.5	29.00	21.78	2.507
6C	10.0	28.91	22.23	2.071
7A	12.0	27.10	20.50	1.635
7B	12.0	29.03	21.98	1.962
7C	12.0	28.54	21.54	1.744
8A	12.0	26.96	20.39	1.199
8B	11.5	28.42	21.61	1.526
8C				

TABLE 5.3

ATURE, SALINITY, DENSITY AND CHLOROPHYLL 'A'

AT DEPTH = 6 METERS

PERATURE EGREES IGRADE)	SALINITY	SIGMA 'T'	CHLOROPHYLL 'A' (MICROGRAMS PER LITER)
3.5	29.54	22.92	0.763
9.5	29.34	22.64	0.763
10.0	28.56	21.96	2.616
11.0	29.90	22.84	1.199
9.0	29.72	23.02	0.545
11.0	29.32	22.39	0.218
9.0	29.90	23.16	0.931
8.5	29.90	23.23	0.654
3.5	29.61	23.00	0.436
9.5	29.61	22.78	0.327
9.5	29.63	22.87	0.763
3.3	31.07	24.17	0.218
8.4	29.34	23.20	0.436
8.2	29.30	22.80	0.436
9.5	30.44	23.65	0.436
9.0	29.65	22.96	0.327
9.5	28.54	22.02	0.436
9.5	29.65	22.89	0.762
9.0	29.86	23.13	0.218

5.1.4 Conclusions

There is nothing dramatic revealed by the temperature, salinity, and density data.

The more dense water fills the deeper depths of the Cove. This would be consistent with the existence of a current through the Cove.

There is no indication of an effect by the Callahan Mine outfall on the temperature, salinity or density patterns in Holbrook Cove during the period of this study.

5.1.5 Recommendations

More electronic analyzing equipment is needed. Titrating is an especially long, tedious operation which leads to error.

A greater quantity of data is required to build a better picture of Holbrook Cove temperature, salinity and density patterns. Priority should be given to a number of samplings of the same area at different times of day. Then the variance of the data with respect to time could be related to water motion.

5.1.6 Detailed Procedure

5.1.6.1 Sampling Plan

To facilitate relating the temperature and salinity data to the biological accuracy results, an identical sampling grid was used for both projects (see Figure 5.2).

5.1.6.2 Sampling Technique

The sampling was accomplished using the water sampling bottles built in conjunction with this project. Once at the sampling position, determined by sighting angles on shore landmarks, the depth was determined using the fathometer on R.V. LOBSTER, the boat from which the samples were collected. It was then decided how many bottles spaced at depth intervals of three meters could be lowered.

Once this had been ascertained, the bottles were readied on the rear deck of the boat along with labeled, plastic-capped storage containers. The sampling bottles were attached to the heavy line at intervals of three meters as the line was lowered.

The bottles were triggered at the desired depths. They were then hauled up and the water in each bottle was emptied into a labeled container.

Figure 5.2

Sampling Grid

At the same station, the bathythermograph was lowered and retrieved. Its data slide was then removed and stored for later analysis.

5.1.6.3 Sampling Analysis

Once back at the laboratory, the water samples were titrated to determine chlorine content, using the silver nitrate method. The data were then converted to total salinity using the general formula:

$S = 0.03 + 1.8050\ cl$ (where the units are parts per thousand)

The salinity was then tabulated according to station and depth.

The temperature data were drawn from the bathythermograph slides. For each station, the correct slide was read for the water sampling depths. The resulting temperature corresponded to the depths of each sample, and was tabulated next to salinity.

Using this temperature and salinity data, the U.S. Navy Hydrographic Tables were used to compute σ_t. σ_t is a parameter relating the density (ρ) of a water sample to the density of pure water (pure water has a density, ρ, of 1.0000).* The density of the water sample is related to pure water by using the equation

$$\sigma_t = (\rho - 1)1000$$

If ρ equals 1.02575, then σ_t equals 25.75. It should be noted that the effect of pressure on density was not included because it is minimal for the depths in the Cove.

5.2 Chlorophyll Patterns in Holbrook Cove

5.2.1 Objective

This portion of the ecological survey is designed to quantitatively measure the distribution pattern of chlorophyll in the Holbrook Cove sampling area. A marked increase in chorophyll concentration with increased distance from the Callahan mine

*For a detailed description, see Sverdrup, H. U., M. W. Johnson, and R. H. Fleming, 1942, The Oceans, Prentice-Hall, Inc., N.J.

outfall would suggest that the effluent from the outfall is harmful to the diatom population and therefore has an unbalancing effect on the entire ecosystem, since diatoms are a major source of food for the Cove inhabitants.

5.2.2 Background

Gentile and Erickson (1971)[1] in their study of the Goose Pond area were able to make a direct correlation between the effluent, rich in heavy metals (notably copper), and the growth inhibition of a particular diatom, Cyclotella nana. The ability of the water to support Cyclotella decreased as the mine outfall was approached. When a chelator was added to the samples, rendering the copper inert, the diatom population increased. Although this was not conclusive evidence, it does suggest that heavy metal pollution from the outfall is upsetting the plankton community.

The method used by this experimenter was to collect samples at various depths from stations upstream and downstream of the outfall, giving a fairly accurate cross section of the entire sampling area. Tests were made for a specific chlorophyll concentration, referred to as Chlorophyll 'A,' which is the major green component of the particular diatom in question.

5.2.3 Results

Using water bottles, 106 samples were taken. 105 were analyzed, one being lost. The results are found in Figures 5.3, 5.4 and 5.5 as well as in Tables 5.1, 5.2 and 5.3. The data in the tables are the Chlorophyll 'A' concentrations in micrograms per liter (μg/ℓ) for each sample. The station numbers 1A, 1B, 1C, etc., refer to the stations in Figure 5.2.

5.2.4 Conclusions

One of the major assumptions about which this research project was planned was that the flow from the Callahan mine outfall would be continuous throughout the sampling period. Based upon observations made by the sampling team, it appears that no flow occurred during the entire month of July. This circumstance casts doubt upon the hypothesis that the heavy metal ion concentration would be the greatest near the mouth of the outfall, since the waters of the Cove are either ebbing or

Holbrook Cove

Chlorophyll 'A' Contained in Water Samples Taken

at Stations 1A Through 8A

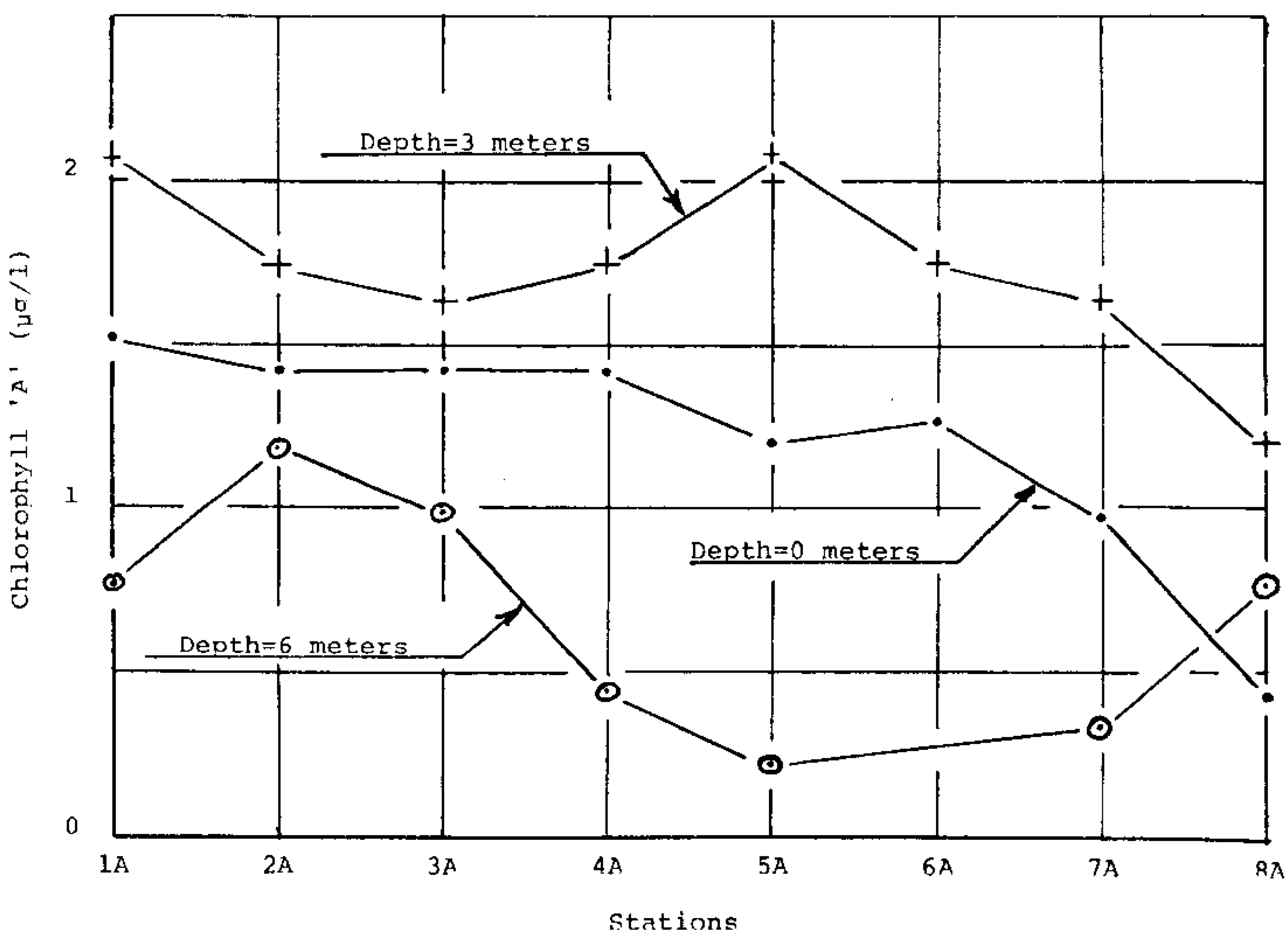
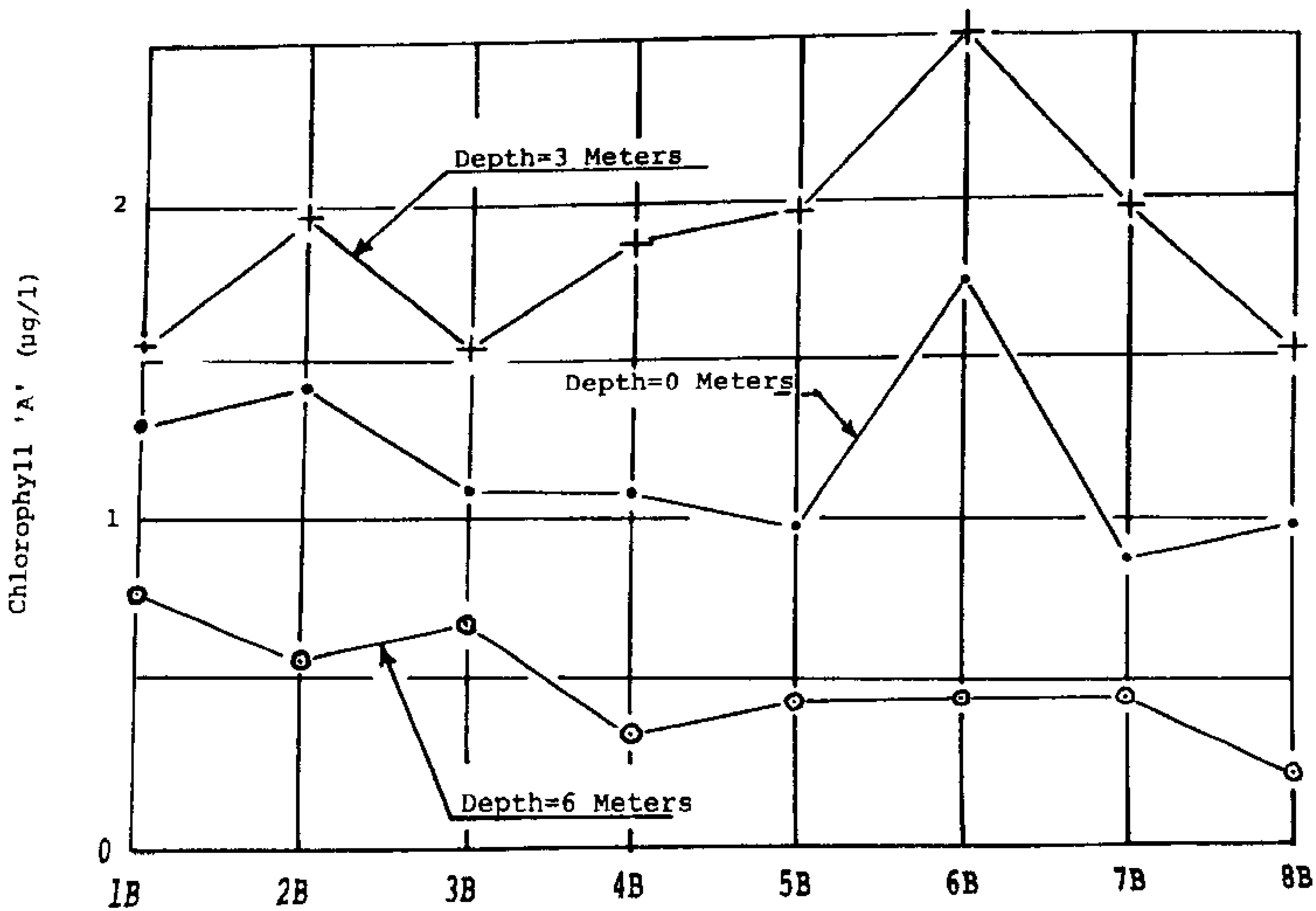


FIGURE 5.3

Holbrook Cove

Chlorophyll 'A' Contained in Water Samples

Taken at Stations 1B Through 8B



Chlorophyll 'A' Contained in Water Samples

Taken at Stations 1C Through 8C

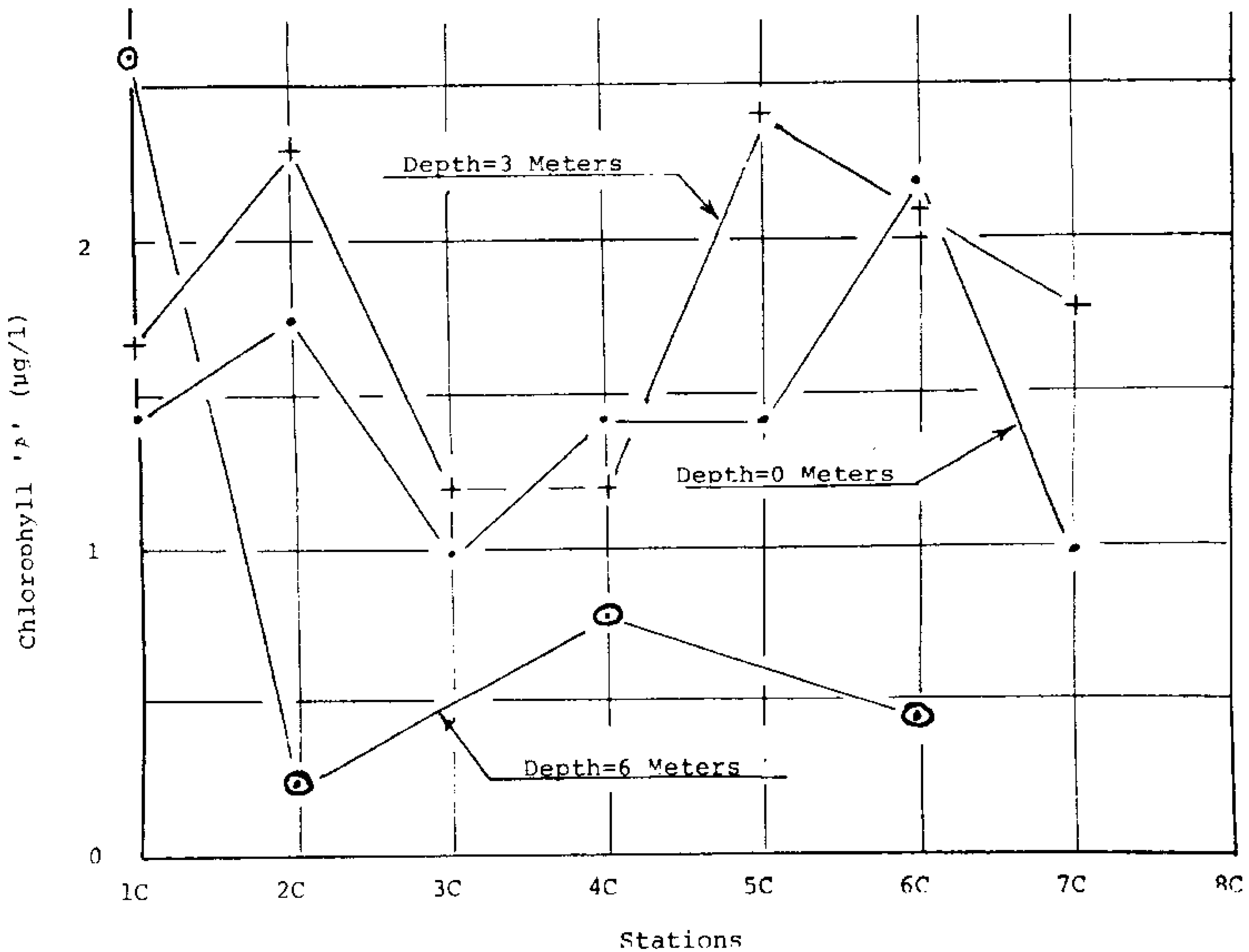


FIGURE 5.5

flooding most of the time. It seems more logical that, if hea metals are concentrated in the area, the effects would be most noticeable in the deep water pockets north and south of the outfall.

In examining Figures 5.3, 5.4 and 5.5, it appears that Chlorophyll 'A' concentrations are greatest at a depth of abou three meters and least at depths of six meters or more. There does not appear to be a significant variation related to distance from the Callahan mine outfall.

It should be noted that the samples were all collected during a flood tide. The samples for stations 1A, 1B, 1C, 2A, 2B, 2C, 3A, and 3B were collected during the morning of July 2 The samples for stations 3C, 4A, 4B and 4C were collected duri the evening of July 26. The samples for the remainder of the stations were collected during the morning of July 27.

Due to the violation of the basic assumption relating to continuous flow from the Callahan mine outfall, it is impossibl to draw any conclusions with respect to the effect of the outf upon the Chlorophyll 'A' patterns in Holbrook Cove.

5.2.5 Recommendations

In future attempts to determine the effects of a source of heavy metal concentrations (as the Callahan mine outfall may be), the water samples should be analyzed for the concentratio of heavy metal ions present. This will be difficult since the concentration will be extremely low, but it would appear to be essential if the effect of heavy metals on Chlorophyll 'A' is to be determined with confidence.

Sampling plans should be expanded to permit collection of at least three water samples at three different times at each depth and location. The size of the sampling team should be expanded to permit collection of water samples over the entire grid in a period of not more than six hours (the approximate extent of either a flooding or ebbing tide). This implies that at least three students will be required to analyze the samples

5.2.6 Procedure (see references 2 and 3)

As soon as possible 25 milliliters of each sample were filtered through a one-inch Gelman Glass Fiber filter and froze

The filters carrying the chlorophyll were then homogenized and extracted with 90% acetone solution and fluorated, giving a reading "f_o." Each sample was then acidified and another reading taken, "f_a." The amount of chlorophyll "a" per sample in micrograms per liter (μg/ℓ) was derived from the equation "$chl_a = 0.109(f_o - f_a)$."

REFERENCES

1. Dow and Hurst, Jr., Rehabilitation Problems of the Cape Rosier Open Pit Mine, Dept. of Sea and Shore Fisheries, Augusta, Maine, Nov. 1971.

2. Duxbury and Yentsch, Plankton Pigment Nomographs, J. Marine Res. 15, 1956, pp. 92-101.

3. Richards and Thompson, A Spectrophotometric Method for the Estimation of Plankton Pigments, J. Marine Res. 11, 1952, pp. 156-172.

6.0 BIOLOGICAL EFFECT OF HEAVY METAL POLLUTANTS

6.1 Objective

At Cape Rosier, Maine, a copper-zinc open pit mine has been discharging effluent rich in heavy metals into Holbrook Cove. Recent studies have shown that this type of metal pollutant is harmful to marine organisms, and probably to human health.[1] In planning this study, it was felt that actual measurements of metal ion concentration in water and sediment at various stations might lead to a better understanding of the effects of these pollutants when correlated with benthic faunal population distributions and photosynthetic primary production in the area. The purpose of this facet of the overall study was to gather data concerning the distribution of the heavy metals (Cu, Pb, Zn, and Cd) in the sediments near the outfall, and to correlate these data with the distribution of benthic infauna (in terms of species diversity, abundance of individuals in each species, and biomass) in the sediments.

6.2 Background

In 1968, operations were undertaken by the Callahan Mining Corporation in the area near Goose Pond on Cape Rosier, Maine, to exploit local deposits of copper and zinc ore. The mouth of Goose Pond (Figure 6.1) was dammed, the pond pumped dry, and a large open pit excavation was begun. Sea water is used in the aqueous flotation and ore separation process. This water is pumped from Holbrook Cove from a site adjacent to the outfall (Figure 6.2), and used to the mill processing. It is then dumped into a settling pond, where theoretically all suspended matter is removed. The effluent is pumped into Holbrook Cove through a subsurface outfall pipe. Sump pumps which keep the open pit free of ground seepage also empty into Holbrook Cove. During the four years of operation of the mine, fine sediment suspended in the effluent has entered the Cove and large portions have probably settled there.

It must be noted, however, that the mining operation is not the only source of heavy metal ions. Surface runoff and seasonal

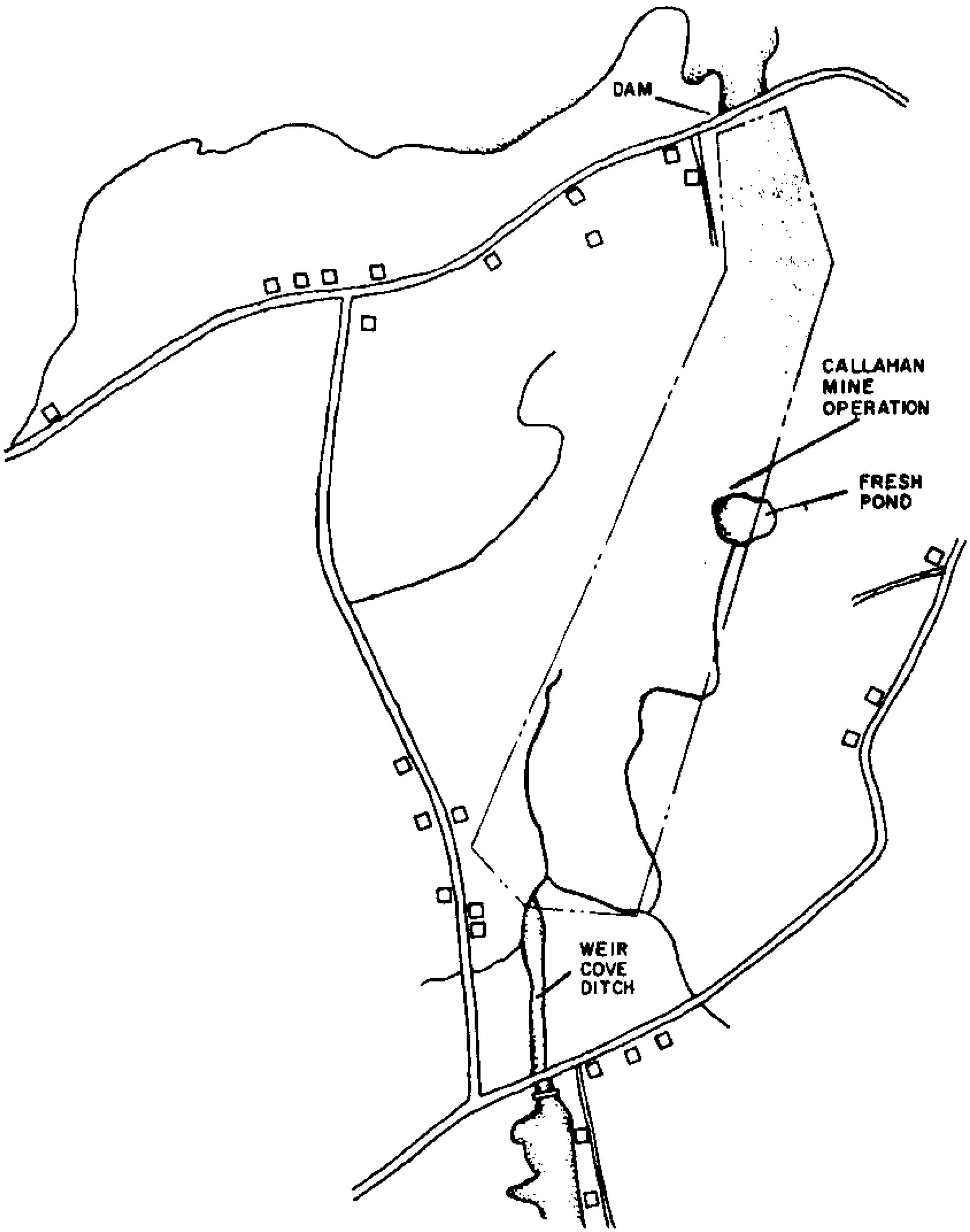


Figure 6.1

Callahan Mine Location

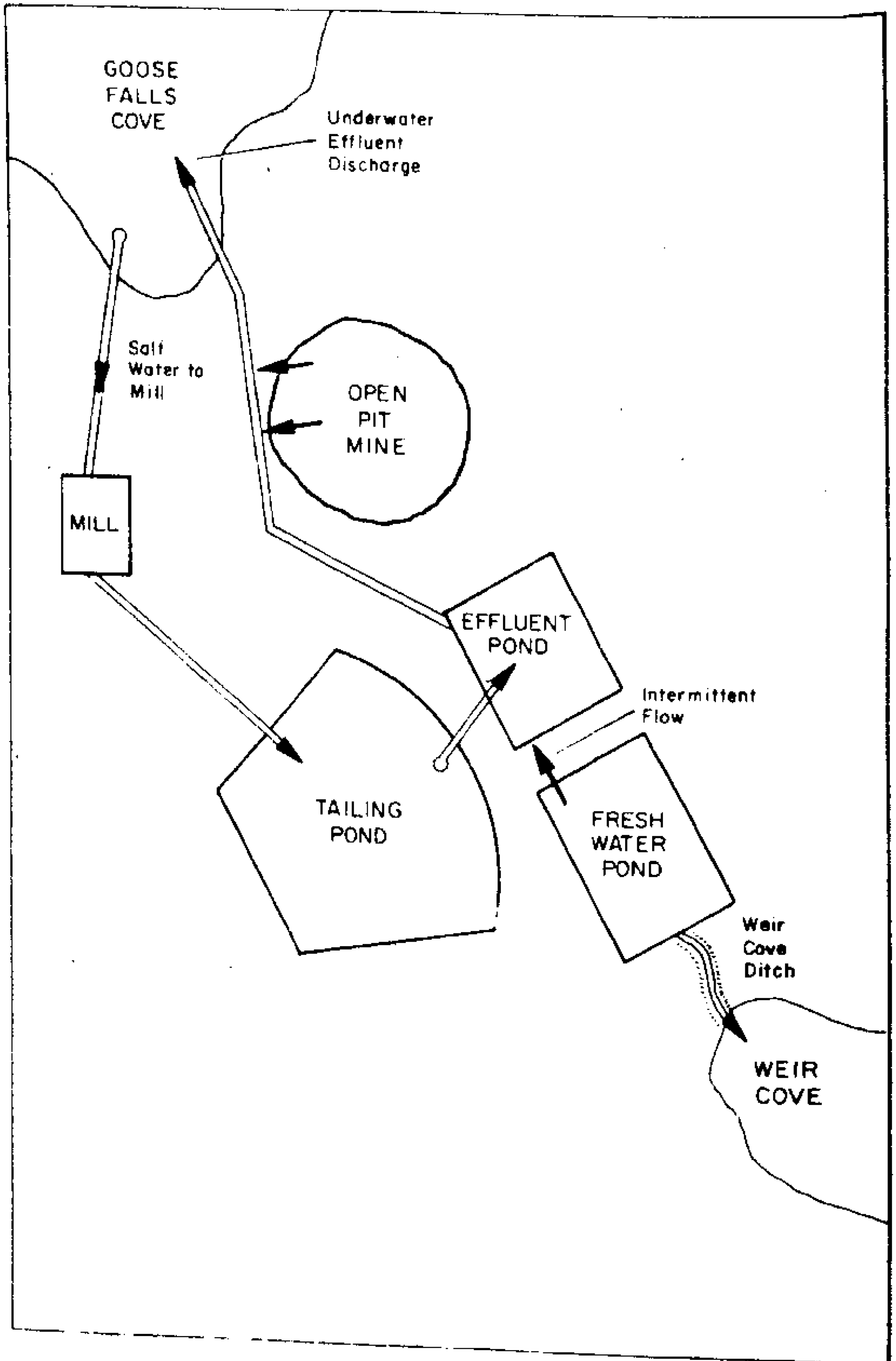


Figure 6.2

Callahan Mine Complex

APPENDIX C

AN EXAMPLE OF THE USE OF FIGURE 7.11

Example:

Find Height of Tide at 1125 Hours, July 5, 1972.

Date: July 5, 1972

Time: 1125 EDT 1025 EST

Barometer: 30.30"

From Tide Table (See Appendix B)

Previous Tide Level = +9.2 ft (High) @ 0605 Hours

Next Subsequent Tide Level = +0.2 ft (Low) @ 1212 Hours

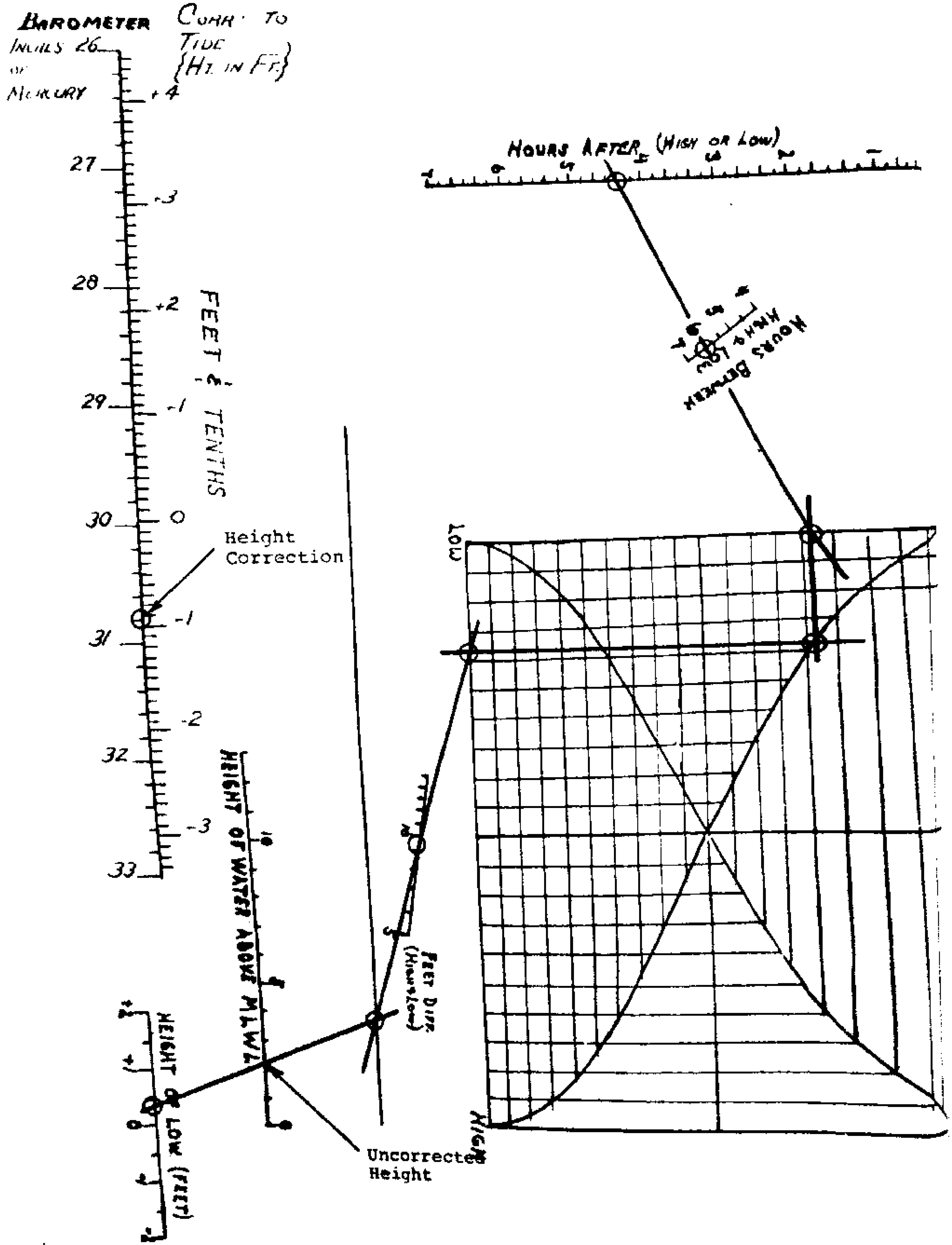
Hours Between High and Low = (1212 - 0605) = 6^h07^m

Feet Diff Between High and Low = (9.2 - 0.3) = 9.5 ft

Hours After High Tide = (1025 - 0605) = 4^h20^m

From Nomogram:

Uncorrected Ht	=		+2.1 ft
Correction for 30.80"	=	-0.95 ft	-0.95 ft
Corrected Ht	=	+0.55 ft	+1.15 ft



BAROMETER
INCHES OF MERCURY
CORR. TO TIDE {HT. IN FT.}
FEET & TENTHS
Height Correction
HOURS AFTER (HIGH OR LOW)
HOURS BETWEEN HIGH & LOW
LOW
HIGH
HEIGHT OF WATER ABOVE M.L.W.L.
FEET DIFF. (High-Low)
HEIGHT OF LOW (FEET)
Uncorrected Height

drainage fluctuations will alter the erosion of nearby natural ore deposits, and also the resultant metal ion concentrations in the waters of Holbrook Cove. The exact pattern of effluent distributions as driven by currents and tides has not yet been determined, although sampling stations (Figure 5.2) were selected to encompass all possible effluent paths.

Of all the animals in the immediate area, only the benthic infauna have been continually subjected to the heavy metals present in the mine effluent. These animals cannot move appreciably, and thus have had to adapt to the environment of Holbrook Cove. In general, the animals that have evolved to survive in a particular environment (the boreal waters of the Gulf of Maine in this case) have the ability to successfully adapt to the range of environmental variations which occur naturally. However, even these "historical stresses" are occasionally exceeded and individual species succumb. After this stress has passed, the species may either recolonize the area, or another species may move in and take over the first species ecological niche. The fewer of these overturns there are, the more stable is the biological community. In areas where the "predictability" of the environment is high (few abnormal stresses beyond the tolerance of all the species present), there are many species, each with a small number of individuals, and each adapted to deal with its own narrow range of ideal conditions. Where predictability is relatively low, each species must adapt to a wide range of possible environmental conditions. Since the range of ideal conditions (the niche) of each species cannot overlap with the niche of the species next to it on the spectrum of environmental factors, it is evident that there will be more niches, and thus more species, present in a high predictability environment.

In Holbrook Cove, the influx of heavy metal pollutants can be viewed as an "unpredictable" environmental stress from the point of view of the benthic community. If the community is capable of adapting to this stress, there should be no obvious change in the species composition of this community. This is the "null hypothesis" of this investigation. In order to test this hypothesis, some quantitative measure of the species diversity must be employed. Several are in use at present. The rarefaction analysis method of Sanders[2] shows the diversity graphically, although computation and data presentation are cumbersome and tedious. The information function of Shannon[3] is simpler. The number of individuals of each species in the community is calculated as a fraction of the total number of individuals in the community. This fraction, p_i, is then iterated over all species, and then the value of $\Sigma\ p_i \log_2 p_i$ is calculated for the community. This gives a value which is sample size-independent. The application of this function to biological systems has recently been questioned by Hurlburt,[4] who proposes several alternate diversity indices. Once all data are assembled in this investigation, both Shannon's and Hurlburt' indices will be employed.

All organisms present in each sample must be identified and counted. For practical purposes, this is impossible. The sediment must be sieved to remove very small sediment (some small animals are obviously lost in the process). Reish[5] calculated the optimum screen mesh size to maximize animal retention and minimize the extensive labor necessary to sort the samples. In practice, there is also an optimum number of grab samples to be taken at each station to assure that all species in the community are represented in each station sample. This must be determined *in situ*, after a few samples have been sorted.

In Holbrook Cove, a grid of sampling stations was laid out (Figure 5.2) in the waters near the outfall based on the sediment metal concentrations determined by the Federal Water Quality Administration[6] in the immediate area. One objective is to duplicate the FWQA study in more detail for a small area. Hopefully, contour charts for the levels of copper, zinc, lead and cadmium, as well as charts of the species diversity indices may be drawn from the data resulting from sampling the stations on the grid. Correlation tests on these data may yield interesting results.

Since species diversity in this case may be influenced by other factors, these must be investigated and their influence on the community assessed, the 1971 Summer Laboratory report

(MITSG 72-3) investigated temperature, salinity, nutrients, dissolved oxygen and currents. No abnormalities were evident. Other phases of this investigation (Sections 5.1 and 5.2) duplicated portions of those studies, again revealing no abnormalities. Sediment particle size distribution does play a significant role in determining benthic community structure.[7] Most samples in the area were composed of 60% silt, 20% clay and 20% fine sand. However, several stations were located on bare rock, or on the shallow sill of glacial sand and gravel that forms the western end of Holbrook Cove. This is a biological community very different from that found in the mud of deeper water, and therefore will not be included in the forthcoming discussion of the biological data with reference to heavy metals.

Cadmium, lead, copper, and zinc were chosen to be sampled because they exist in large enough concentrations to be measured with available Atomic Absorption Spectrophotometry equipment and are thought to be major pollutants in the area.[8] Chromium falls below AAS detection limits. However, once data has been collected, it is difficult to draw any conclusions as to significant patterns in flow or toxicity or even the relation to the mine effluent. Robert Dow, Director of Research, Maine Department of Sea and Shore Fisheries, reports "Since exploratory drilling, stockpiling of ore-bearing rock, de-watering of the old mine shaft, and pumping out of the rain-filled pit behind the newly constructed dam at Goose Falls, heavy metal levels in clams, sediments, and rock weeds cannot be interpreted as background only. This significant and dramatic increase in all three media after ore separation can be wholly attributed to the plant operation and the discharge of effluents into Goose Cove."[9] The Federal Water Quality Administration, now the Environmental Protection Agency, is more conservative in its correlation between toxic metal concentration and the mine effluent, but recommends that public water supplies in the area be monitored due to high lead concentration at two of their sample stations.[6] It should be noted here that this report has been criticized by Dow and other Maine state officials.[10] Tidal stage, climate and geological makeup affect concentrations of trace metals, but it is not yet fully understood how and to what degree. In addition, agreement as to whether sediments adsorb toxic ions, rendering them inert or whether they are a continuing source of contamination has not been reached.

It has been found that heavy metals do not concentrate along trophic levels.[11] In that particular survey of the Illinois River, the order of concentration magnitudes of Cu, Ni, Fe, Pb, Cr, Li, Co, Cd was as follows: sediments > worms > clams > fish > water. Zinc was found in greater concentration in clams than in worms. According to a report by Dow on "Estuarine Communities and Pollution,"[12] "Evidence does not support the assumption that heavy metals in estuarine sediments, marine algae, and shellfish are directly related to the level of these metals in the overlying waters." It is important, therefore, to measure metal concentrations in mud and organic samples as well as in the water. The sand worm, second only to the blood worm in economic value per unit weight to the Maine fishing industry, has a reported toxicity threshold of about 0.1 parts per million copper (Raymont and Shields, cited by Dow).[8]

A previous study of the waters around Cape Rosier showed copper concentrations ranging from 0.1 to 0.4 PPM.[8] Dow believes that lead is probably the most hazardous metal pollutant at the mine site for both humans and commercial shellfish.[12] A study of the effect of cadmium upon humans is being conducted intermittently by M.I.T. Human intake of toxic metals comes through drinking water sources and consumption of shellfish. In particular, bivalves have the ability to concentrate heavy metals to levels greater than those found in their environment.

6.3 Results

The analysis of the 25 Holbrook Cove sediment and water samples for heavy metal concentrations and benthic fauna has not been completed at this writing. Shortages of equipment availability (mostly an inability to gain access to AAS equipment) and difficulties with impurity interference (Section 6.6) have hindered the determination of heavy metal concentrations. It is expected that these difficulties will have been overcome to allow completion of AAS analysis by March 1973.

Benthic faunal sorting and species identification is also proceeding slowly. The 0.25 mm screen mesh size, as determined from Reish's[5] analysis, used in sieving the grab samples causes the retention of a large volume of materials, which must be picked through under a dissecting microscope. Average sorting times have been in excess of 20 hours for each of the three samples sorted thus far.

A basic difficulty in the faunal analysis concerns species identification. Of the 52 positively identified polychaete worm species taken in Holbrook Cove in the FWQA study,[6] only 24 are named in Knowlton's[13] checklist. Knowlton acknowledged that his checklist is not "all-inclusive," even though he, his co-workers and his students have sampled along the whole Maine coast for a number of years. Significantly, the two dominant polychaete species, Aricidea jeffreysii and Nephthys incisa, representing 38% and 17% respectively of all individuals taken in Holbrook Cove, have never been found by TRIGOM researchers and are thus not included in Knowlton's checklist.

The most abundant polychaete species in the samples sorted thus far has not been identified as yet. There is some internal disagreement about whether two species are being considered as one in this case. Until this is resolved, no species diversities can be calculated.

Some trends are apparent, however. Biomass and number of individuals appear to be at a minimum at the station closest to the mine outfall; i.e., there are fewer individuals and the individuals appear to be smaller near the outfall. This could indicate an adverse influence of the effluent on the biota, but it is obviously too early to draw any correlations.

Other data would be valuable in addition to sediment faunal data. An attempt will be made to analyze locally collected bloodworms[14] (Glycera dibranchiata), sand worms[14] (Nereis virens), and clams (Mya arenaria) for heavy metals in their tissues. Several attempts were made to raise Nereis virens in aquariums in the laboratory, with the ultimate intention of studying the effects of various concentrations of heavy metal ions introduced into the sea water. However, each time, high natural worm mortality was observed due to high ambient temperatures, and it was finally concluded that the necessary refrigeration was not available, so the project was abandoned.

6.4 Conclusions

As stated before, sample analysis is not yet complete, so no conclusions are possible at present.

6.5 Recommendations

During July 1972, the Callahan Mining Corporation was beginning to raise salmon in a fish trap floating in Holbrook Cove. They planned to monitor the metal concentration in the salmon flesh, with the ultimate intention of marketing the salmon on a large scale. In their proposal, the deep open pit would be filled with sea water and used for fish culture. Considering the remarks made by Dr. Ruth Patrick,[15] this would be highly undesirable.

As of July 1972, the mining operation had apparently been closed down. Weir Ditch, which had poured effluents into Weir Cove on the southern side of Cape Rosier, had been another major source of heavy metal contamination. As of July 28, its seaward end had been filled in. Although monitoring of the site should be continued, it is probably not within the capabilities of the Student Summer Ocean Engineering Laboratory to continue the systematic sediment monitoring on a large scale, recognizing the difficulties which were encountered attempting to use analytical techniques and equipment and the great amount of time necessary to sort benthic sediment samples. However, monitoring of metals in worms and clams in the Cove is relatively simpler, and should be continued if AAS equipment is available.

6.6 Detailed Procedure

6.6.1 Sampling Plan

A grid pattern consisting of 24 stations was selected on the basis of previous sampling and analysis done by the FWQA.[6] Basically, a 3 x 8 pattern was laid out in the channel separating Holbrook Island and Cape Rosier. If time allowed, multiple sediment samples would be taken at each station, assuring adequate sampling of the benthos.

6.6.2 Sampling Technique

Samples were taken with a modified Petersen grab sampler at most stations. Some stations were coarse gravel or bare rock, preventing adequate grab sampling. The grab was hand-operated from the deck of the lobster boat.

All samples were sieved as soon as possible after return (usually within 6 hours) through 0.25 mm sieves, preserved with 10% formalin, and buffered to saturation with sodium borate (preventing calcareous shell decomposition). Subsamples for AAS analysis were placed in acid-rinsed containers and preserved with 2-3 ml concentrated HNO_3.

6.6.3 Sample Analysis

Sorting of benthic samples was accomplished under low magnification microscopy. All animals retained by the sieve were transferred to a methyl alcohol preservative. Identification was accomplished using standard available keys.

Analysis of sediment and water samples will be done by atomic absorption spectrometry using Jarrell Ash instrumentation. The method followed will be the standard methods used by the Environment Protection Agency,[16] with minor alteration by the M.I.T. lab. Although metal ion concentrations of some of the Goose Falls Stations probably fall quite low, previous surveys of the area (FWQA)[6] have not found it necessary to use special low detection limit methods of analysis, especially since interferences are more common with these methods.

Interferences known as matrix interferences occur when there are high concentrations of acids or dissolved salts, as would be the case with the samples considered here. These are controlled by dilution or by matching the concentrations of major constituents in samples and standards. When there is no way of matching concentrations, the method of additions[17] is used. For analysis of the samples taken from Holbrook Cove, a rinse to remove sodium interference will be adequate. Several runs will be made to determine statistical confidence intervals.

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7.0 INSTRUMENTATION

7.1 Karman Vortex Trail Current Meter

7.1.1 Objective

The basic goal of this project is the evolution of a compact and reliable current velocity measuring device utilizing the regular velocity-dependent oscillation of vortices behind a blunt object in a moving fluid. Several general design criteria were established: (1) The instrument must be capable of being set and monitored without diver assistance; (2) the output of the instrument must be recordable on magnetic tape; (3) data reduction should be convenient.

7.1.2 Background

Work was carried out during the 1971 M.I.T. Sea Grant Summer Laboratory based on similar objectives (see M.I.T. Sea Grant Report Number 72-3). These attempts were unsuccessful. The experience gained at that time allowed the successful redesign of the instrument during the 1972 Summer Lab. The basis of operation of the instrument is the velocity-dependent vortex shedding of a blunt object moving with respect to a fluid. The wake pattern generated by this object is known as a Karman Vortex Trail. This wake pattern is characterized by periodic shedding of vortices from alternate sides of the blunt object. Each shed vortex moves downstream causing lateral movement of the fluid in the wake of the object. The instrument is based on the detection of this movement. Here the magnitude of movement is not important, but rather the frequency of the change in direction of the fluid behind the blunt object is desired and, thus, the frequency of vortex shedding. This frequency is then empirically related to the velocity of fluid flow, through the calibration of the meter.

7.1.3 Results

The final results, based on a rather short testing period of one day off the dock at Castine and three days at varying locations in Holbrook Cover, were in general successful. The instrument, coupled with a simple oscillator, recorder and timer on the surface, provided data at half-hour intervals over most of the test period. The circuit interfacing the instrument with the recorder, however, was unreliable and created a large amount of unreadable data. Data reduction, while intended to be accomplished electronically, was easily handled aurally, each twenty-four hours worth of collected data requiring approximately forty-five minutes to put into tabular or graphic form. Graphical results of several periods of monitoring are shown in Figures 4.2 and 7.1. The validity of the data is difficult to determine. At present, there is no other tabulated data concerning current flow in the test areas. The results do show fair correlation with times of high and low tide. For example, in Figure 7.1 no current was evident shortly before high tide at 2324 hours and low tide at 0554 hours, the times being appropriate for dockside at Castine. The irregularity of the current profile presented for Holbrook Cove may well represent the apparent current surges which were noted on several occasions by the observers of the current drogues used in this area, as described in Section 3.0 of this report.

7.1.4 Conclusions

Although the test period was too short to allow conclusive evaluation of the instruments reliability, sensitivity and range in open water, the results would indicate that the meter offers a valid substitute for impeller-type current meters, when measuring low velocity currents. The instrument holds up well under rough treatment and requires no diver assistance in mooring.

7.1.5 Recommendations

The success achieved, though limited, would recommend further work on the development of this instrument as a component of a complete system for current monitoring. Most seriously needed would be the perfection of the interfacing electronics. Completion of the digital recording system which was undertaken during the lab would offer considerable advantages and possibilities in the area of data reduction. Concerning the meter itself, one could use pressure transducers as the means of converting the fluid motion to a modulated electric signal, replacing the present arrangement of fin and photocell.

7.1.6 Detailed Procedure

Preliminary design of the instrument took place in the months after the 1971 Summer Lab, and was based on experience

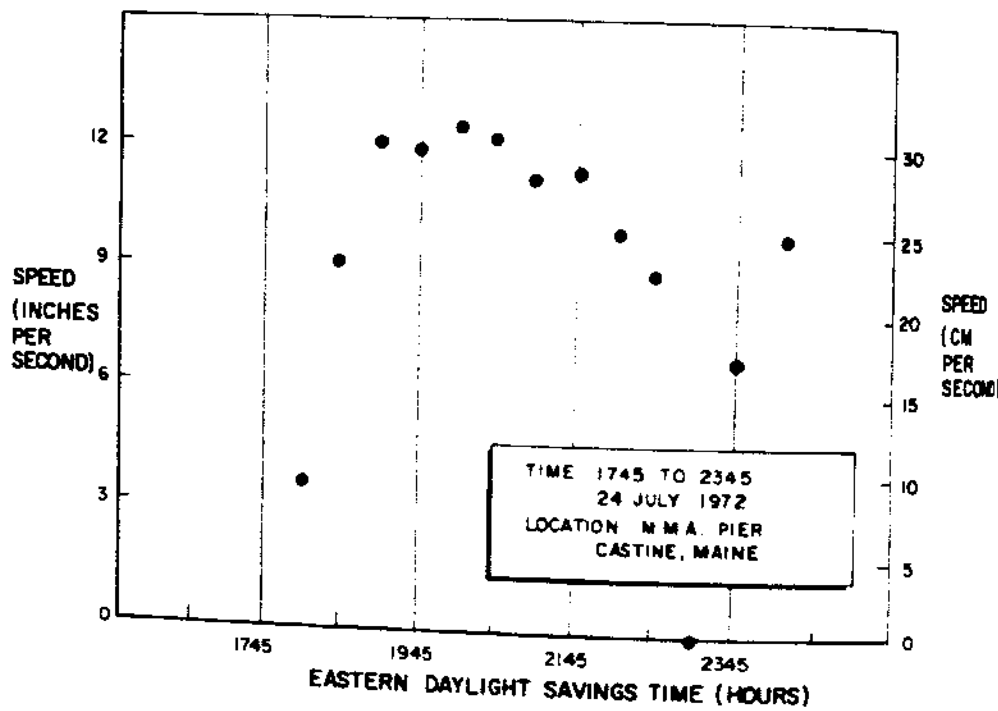


Figure 7.1

Karman Vortex Trail Current Meters
Results at Castine

gained during the lab. An attempt was made to build a current meter using the vortex shedding phenomenon. The attempt involved trying to sense the frequency of vibration of a wire placed in a fluid flow. The presence of the wire caused the development of a Karman Vortex Trail. In simplified terms, the periodic lateral displacement of the fluid caused the wire to vibrate at the frequency of the vortex shedding. The attempt was then made to sense this vibration using electromechanical means. Due to the very small displacements and energy transfers involved, little success was achieved. It was decided to increase the dimensions to afford greater ease in detection of the movement of the fluid. A one-inch cylinder was used to generate the vortex trail. Sensing of the frequency of vortex shedding was done by a fin mounted on needle bearings in the flow behind the cylinder. Electrical pickup was accomplished by placing a magnet on the fin and positioning a reed switch close enough to be activated by the magnet. This version provided linear response from three-tenths of a knot to just below two knots with sensitivity to one-tenth of a knot. The instruments' dimensions were approximately two inches by three and one-half inches by six inches.

The primary shortcoming of the instrument was that its range of operation was too high to be considered for use in tidal current surveys. Several things were done in an attempt to lower the range of response. First, the effective Reynolds number of the instrument was increased by providing a venturi at the intake of the meter, thus increasing the current velocity seen by the instrument over that of the ambient flow. Little improvement was noted. It is believed that the force imparted to the sensing fin by the fluid movement was of the same order as the force exerted by the magnet on the reed switch, so the sensing of the movement of the fin was relegated to a photo cell rather than the proximity switch and magnet. Tests demonstrated an extension in the effective range of instrument down to about three inches per second. It was still apparent that more energy must be imparted to the wake to obtain greater sensitivity. To achieve this end, an ellipse replaced the cylinder. It was oriented with the major axis perpendicular to the flow. It had been observed that the ellipse generates a wake that is wider than its greatest dimension whereas the wake of a cylinder is roughly the same width as its diameter. The meter now showed a response down to one inch per second (1/20 of a knot) under test tank conditions.

7.1.7 Fabrication

The physical layout of the meter is shown in Figure 7.2. The fin in the wake of the cylinder responds to the movement of the fluid. This lateral movement becomes a rotational movement of the wires used to support the fin. The interposer, rigidly attached to the upper supporting wire moves back and forth between the photocell and light source, which modulates the output of the oscillator. The prototype instrument had dimensions of two inches by six inches by twenty inches. The large length was provided in an attempt to reduce turbulence encountered by the ellipse caused by the leading edges of the duct. All electronics, except the photocell and light source, are designed to be on the surface, thus limiting the amount of waterproofing that must be accomplished. The light source and photocell were cast in plexiglass with their individual leads connected to a four-wire hydrophone cable to the surface. These connections were sealed by simply dipping the soldered joints in fiberglass resin. No trouble was encountered in this method of waterproofing. The original system design called for the meter to be connected to an analog-to-digital converter which would feed digital data to a recorder. This equipment was not ready for use, however, so a simpler method of providing recordable signals was used. The photocell, having a change in resistance which was dependent on the change in light to which it was exposed, was used as part of an astable multivibrator. As the resistance changed, the output frequency of the multivibrator changed. All frequencies were in the audio range and were easily recorded. As was mentioned earlier, the data was readily reduced aurally. This configuration results in a signal which is frequency-modulated at the rate with which the ellipse sheds vortices.

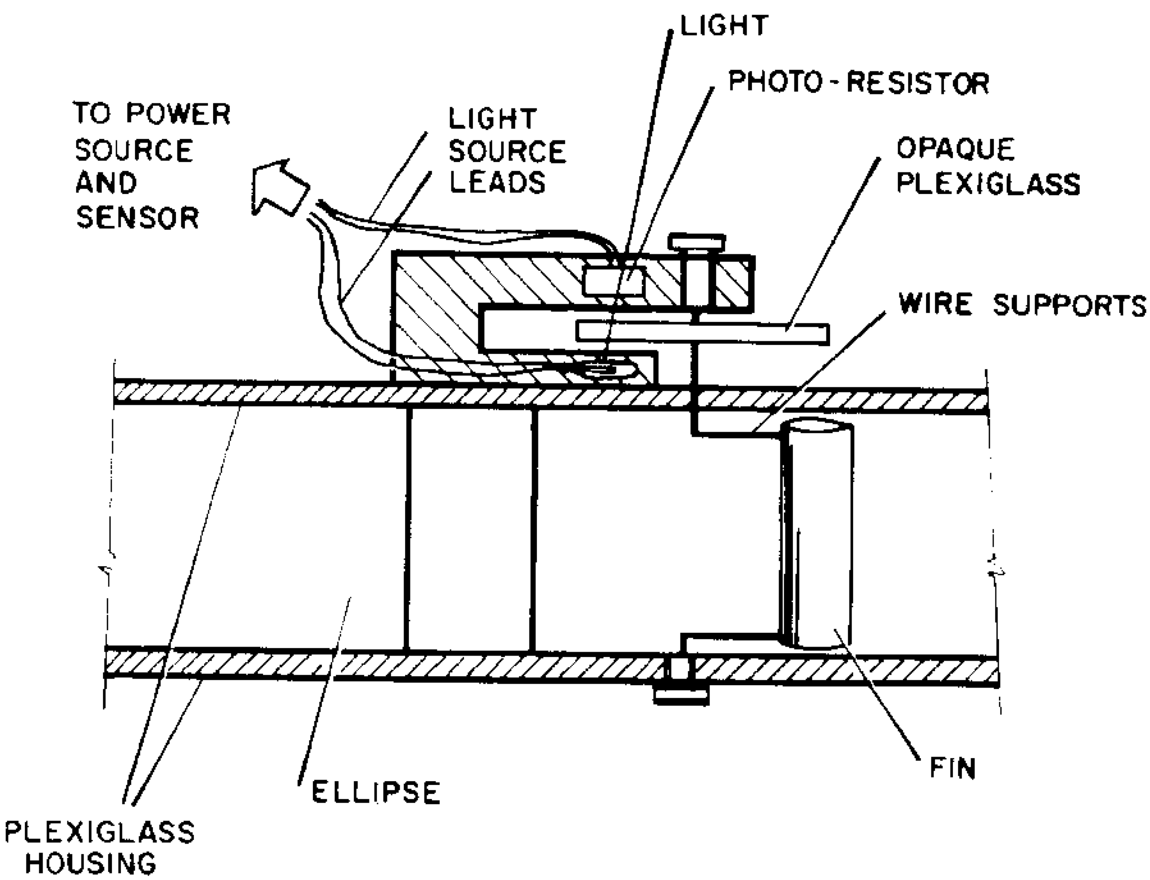


Figure 7.2

Karman Vortex Trail Meter Layout

7.1.8 Calibration

Calibration was carried out, using the instrument towing carriage of the wave tank in the Hydrodynamics Lab at M.I.T. This was used in preference to the ship model towing tank, due to the very low control speeds which could be achieved. Respons of the meter from one inch per second to twelve inches per second was obtained. Calibration data is shown in Figure 7.3 along with a curve showing theoretical response. The theoretical curve is based on the following empirical formula relating frequency of vortex shedding to fluid velocity:

$$n = \frac{SV}{d}$$

where n is frequency, S is the Strouhal number, V is the veloci and d is the characteristic diameter (the major axis of the ellipse, 1-7/16"). The Strouhal number is constant in this regime of Reynolds number (greater than 1000). After the concl sion of operations in Castine, the ship model towing tank was used to determine the angular response of the unit to test the feasibility of using the instrument as a current direction indi cator. It was hoped that the response would be such as to allo two of the instruments to be mounted in a fixed position at right angles to each other to give vectoral information as well as data about the magnitude of the current. Tests showed that the response of the instrument intercepting the current flow at angles of greater than thirty degrees was too poor to allow su a configuration.

7.1.9 Meter Implacement

The mooring of the current meter is designed to be as si ple as possible. To maintain a stationary position a fifty-po weight is used at the bottom. A line runs directly up to the meter at the desired height above the bottom and is fastened rigidly to the housing about eight inches from the leading ed on the underside of the instrument. Leading upward from the same position on the top of the housing is a line to a submer float. This float maintains the vertical position of the mete A short line is attached on the float line and leads to the ta of the instrument to keep it horizontal. The electrical cable

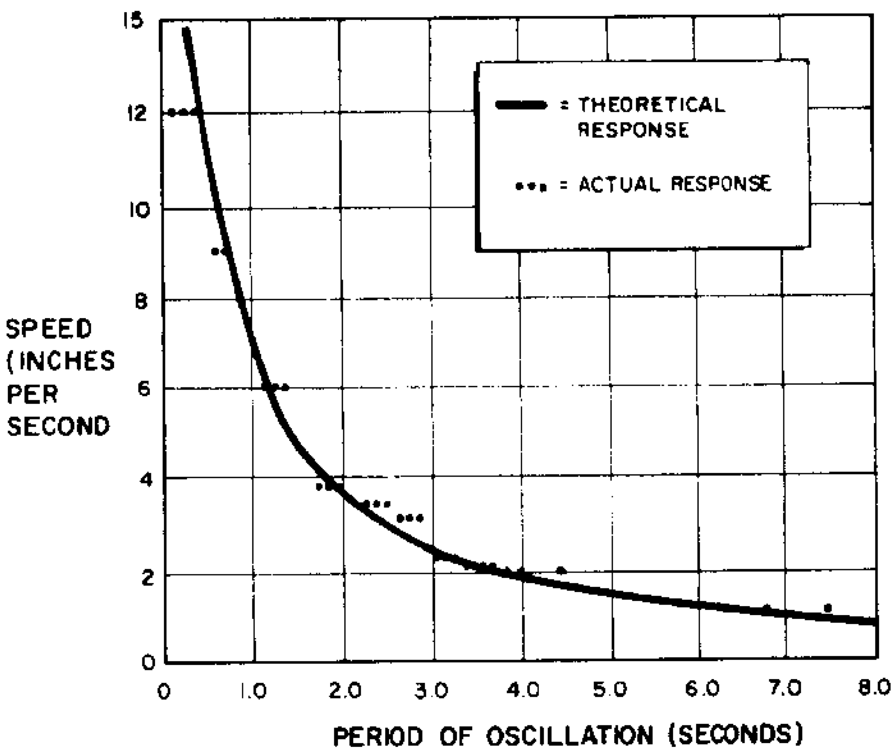


Figure 7.3

Karman Vortex Trail Current Meter
Calibration Curve

(for power and data transmission) is attached at various points to the instrument support cable and is supported at the surface by its own float and a five-quart pressure cooker which provides the watertight housing for the electronics and recorder. A retrieving line is attached to the submerged float and again supported by a surface buoy. No trouble was experienced with this mooring for this instrument. It appeared to allow adequate freedom for the instrument to orient itself with the current flow and showed no sign of drifting off station.

7.2 Impeller-Driven Current Meter

7.2.1 Objective

The objective of this project is the development of a compact and reliable current velocity measuring device utilizing an impeller. Several general design criteria were established: (1) The instrument must be capable of being set and monitored without diver assistance; (2) the output of the instrument must be recordable on magnetic tape; and (3) data reduction must be convenient.

7.2.2 Background

An impeller current velocity measuring device was designed for the 1971 Summer Ocean Engineering Laboratory (see Figure 7.4). This device consisted of a seven-inch-diameter cylindrical housing made of plexiglas tubing, a 24-inch-diameter impeller fashioned from fiberglas, a plexiglas shaft which was driven by the impeller and turned a 5-inch-diameter disc (also fabricated of plexiglas) in which 60 small holes had been drilled at equal intervals on a circumference of four and one-half inches. The disc was used to alternately shadow and expose a photocell to a light source. The unit proved to be cumbersome and unreliable; hence a redesign was undertaken.

The design of the 1972 impeller current velocity meter incorporates many improvements. These include: reduction in size and bulk, an improved impeller, and a better harness (used in securing the meter to the mooring). In the redesign a light source and sensing device (photocell) are sealed in the flanges fore and aft of the impeller hub. The impeller hub has several holes drilled parallel to its axis through which light passes

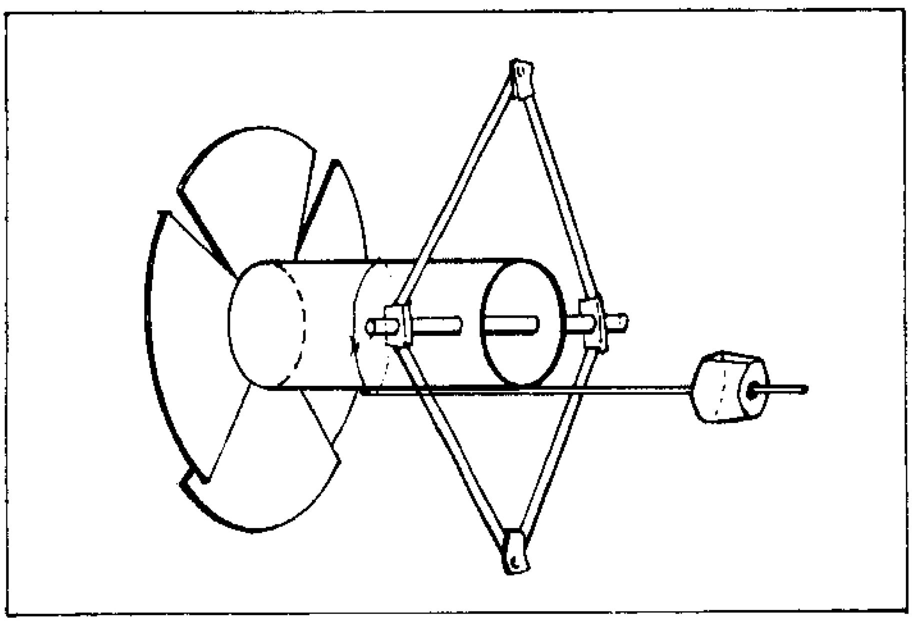


Figure 7.4 Impeller Current Meter
(1971 Version)

when one of the holes is lined up with the light source and the sensing device. In this way several pulses are received from the meter for each revolution of the impeller, permitting accurate readings at low current velocities. The leads from the light source and the sensing device are led into a hydrophone cable, and through the cable to the surface instrument package. The instrumentation package was placed in a pressure cooker which also served as a float. The pressure cooker contained a motorcycle battery, a small amplifier for the signal from the meter, a clock, and a cassette recorder.

7.2.3 Calibration of the Impeller Current Meters

The current meters were calibrated in the M.I.T. towing tank. The major problem which had to be overcome was that the fluorescent lighting in the towing tank interfered with the photocells in the transparent current meters. This was rectified by shutting off the lights in the towing tank during calibration runs. The current meters were painted black before they were shipped to Castine, Maine, to prevent the ambient light from interfering with the operation of the meters when they were moored at the test sites.

The calibration procedure for the three meters constructed in preparation for the 1972 Summer Ocean Engineering Laboratory consisted of towing the meter at speeds of from 0.2 knots to 1.5 knots and employing a frequency counter to ascertain the pulses per second received from the photocells for each speed. It should be noted that the calibration results from all three meters are identical. The empirical correlation between the pulses per second and the speed is:

$$\text{speed (knots)} = 0.25 + 0.53 \text{ (pulses/second)}$$

7.2.4 Mooring

The mooring of the current meter is fairly simple (see Figures 7.5 and 7.6). A 50-pound block is used as an anchor. A line is passed up from the anchor to the meter and then to a float with 25 pounds of buoyancy moored just beneath the surface. Thus there is a 25-pound tension in the line at all times. A slack line attached to the hydrophone cable is led to the instrument package floating on the surface. A buoy is attached to the

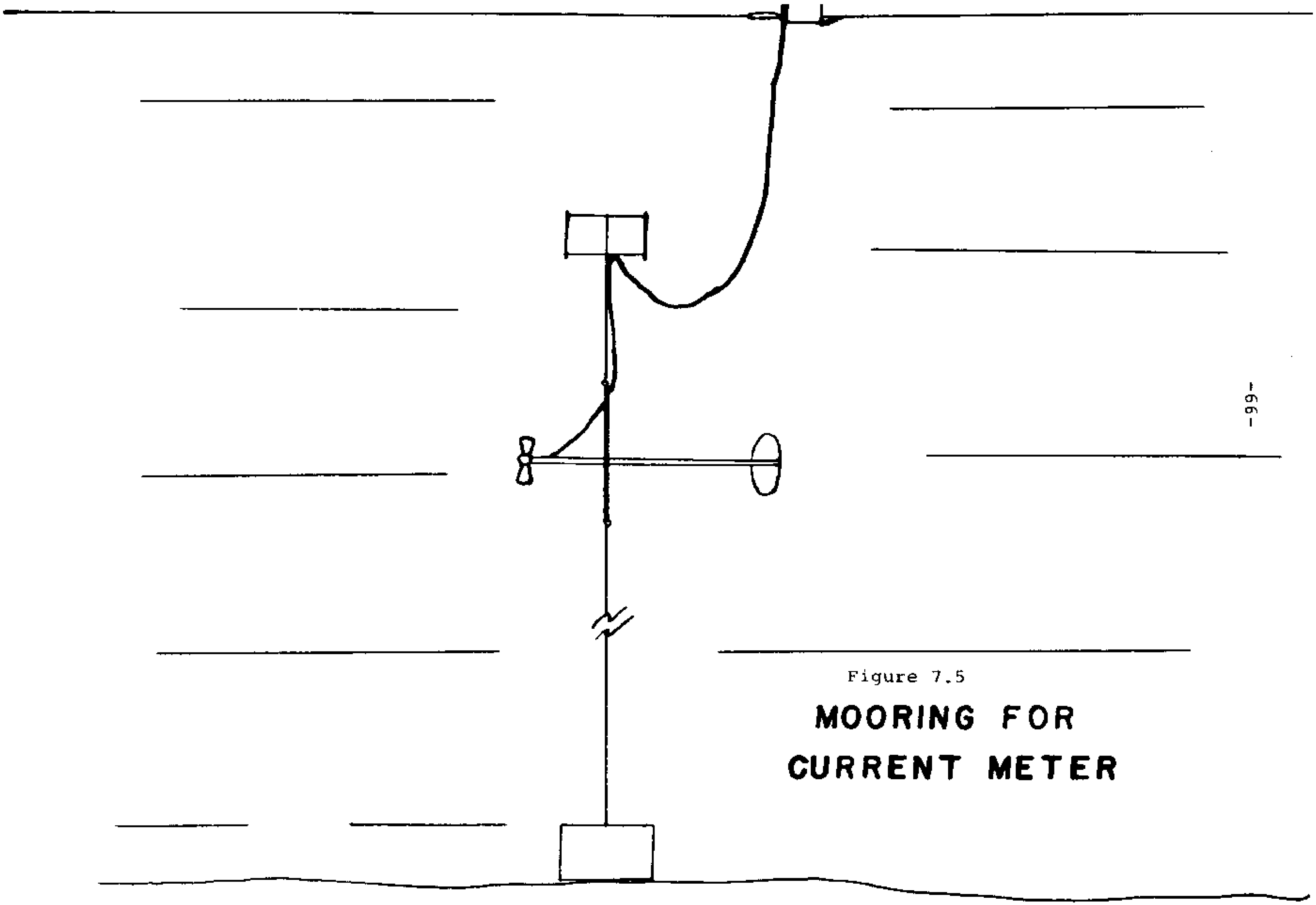


Figure 7.5

MOORING FOR CURRENT METER

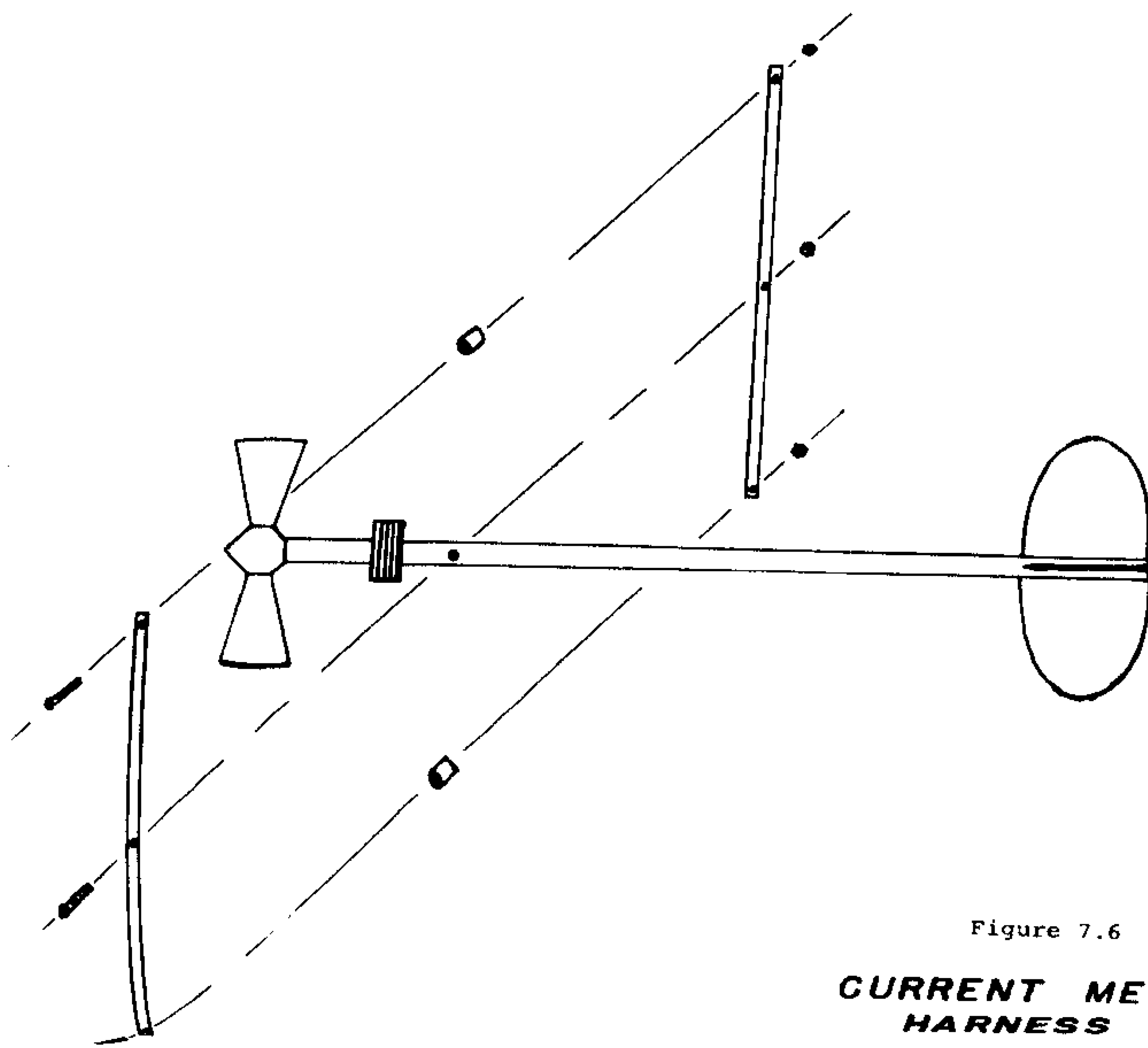


Figure 7.6

CURRENT METER HARNESS

subsurface float to mark the meter. This arrangement permits the cassette to be changed without disturbing the current meter.

7.2.5 Conclusions

The meters performed as designed. The problem with ambient light interfering with the photocells was overcome by making the flanges and impeller hub opaque. A problem developed with mooring harness in that the meter was attached at its center of gravity and when it was raised or lowered it tended to try to rotate until its axis lined up with the mooring line. In one such case the impeller of one meter was broken.

7.2.6 Recommendations

The mooring arrangement should be redesigned to correct the deficiency exhibited when the meter is raised or lowered during implantation or retrieval. A device that will measure current direction should be devised to act as a companion instrument so that both current direction and velocity can be measured at any given instant and recorded.

7.3 Current Direction Indicator

7.3.1 Objective

The major inadequacy of the current metering equipment became apparent during the initial weeks of the project. This inadequacy lay in the inability of the meters to distinguish current direction. It was decided that a companion instrument capable of yielding data on current direction was required. Two basic criteria were established: (1) The instrument should not require diver assistance; and (2) the output should be compatible with the digital recorder which was under development for use with the current meters.

7.3.2 Background

During the 1971 Summer Ocean Engineering Laboratory, construction of a current direction indicator was attempted using a variable capacitor which tuned an oscillator circuit whose output was recorded in analog form (see Sea Grant Report No. MITSG 72-3). The instrument housing and capacitor were moored in a fixed position and a vane (which was allowed to swing with the current) varied the capacitor position. This proved very cumbersome, since it required a three-point moor, a buoying system to maintain the indicator's position vertical, pressurization of the instrument, and considerable diver assistance. The large frictional resistance between the capacitor's shaft and the watertight seals caused problems.

The requirement that the direction indicator be a companion to the current velocity metering devices caused a drastic departure from the concept of the current direction indicator attempted in 1971. The primary changes in design criteria were as follows:

1) Since the housings of current velocity meters rotate to maintain their alignment with the current, then the housing of the current direction indicator must also rotate and the sensing device must maintain a constant orientation (as the sensing device in a gyro or magnetic compass). In the 1971 design the housing maintained a constant orientation and the sensing device oriented itself to align with current.
2) Since the data transmitted from the current velocity metering devices are in digital format, the data transmitted from the current direction indicator must also be in digital format to permit the use of the same recording and data reduction equipment. In the 1971 design the data were transmitted in an analog format.
3) Since the designs of the current velocity meters were based upon a criterion of minimal diver involvement, this criterion must also be invoked in the design of the current direction indicator. As has been previously stated, the 1971 design required extensive diver services.

7.3.3 Results

To meet the design criterion that the housing of the current direction indicator must rotate and the sensing element must maintain a constant orientation, the principle of the magnetic compass card was utilized. It was recognized that four binary bits will permit the transmission of sixteen digital information bits. This characteristic can be utilized to identify digitally sixteen 22-1/2° sectors. It is believed that, for this application, further refinement of current direction would not be sufficiently useful to justify the additional complexity of additional binary bits.

A magnetic compass card was fabricated. Four concentric circles were drawn on the card and interrupted slots were cut on the concentric circles such that rotation of the compass card with respect to the housing would alternately interrupt or pass light from one side of the card to one or more of the four photocells located in a radial line on the opposite side of the card and spaced to coincide with the four concentric circles. The sixteen sectors are identified digitally by determining which of the four photocells are exposed to the light source.

The instrument did not reach the test stage due to the late starting date. The housing is a four-inch i.d. plexiglas tube with end caps three-quarters of an inch thick fitted with O-ring seals. The final version of the compass card uses two permanent alnico magnets and is mounted on needle bearings. The sensing unit's functional resistance to rotation was very small, but it was sufficient to affect the reliability of the orientation of the card with respect to the earth's magnetic field. The light-sensing unit was put together and tested in the housing. No problems were found in sensing the card position using this method. However, it was discovered that a small amount of iron in one of the photocells affected the magnets on the card.

7.3.4 Conclusion and Recommendations

The success of the sensing method makes further attempts at development of this instrument attractive. A compass card with stronger magnetic units and less rotational friction is required. If fabrication proves too difficult, a commercial compass card can be adapted. If photocells which do not affect the compass card cannot be obtained, then perhaps light pipes can be used in the proximity of the card. Completion and testing of the digital recorder and the interfacing circuitry is yet to be accomplished.

7.4 Oxygen and pH Meters

7.4.1 Objective

The ambitious sampling project encompassed by the Holbrook Cove Survey made the automation of the measurement of the environmental factors extremely attractive. The objective of this project is to provide instrumentation that will make the measurement of the oxygen content and pH of water samples a simple, accurate procedure.

7.4.2 Background

During the 1971 Summer Ocean Engineering Laboratory, preliminary measurement of dissolved oxygen concentrations were made using the Winkler iodometric titration method. This proved to be time-consuming and laborious. In planning the biological investigation related to determining the effect of the Callahan mine outfall upon the ecology of Holbrook Cove, it became apparent that it would be necessary to monitor all environmental conditions including the concentrations of dissolved oxygen in and the pH of each water sample. It was therefore decided to obtain a polarographic oxygen electrode and to construct an oxygen meter for use with this electrode. In addition, a simple design for a pH meter was noted in the November 1968 edition of Popular Electronics and it was decided to construct this device for use in the survey.

7.4.3 Results

Both the oxygen and pH meters were constructed. Due to limitations of time, the oxygen meter was not used. The pH meter was constructed, but the proper microammeter was not available and the project's volt-ohm meter was substituted. This substitution proved unsatisfactory due to the high impedance of the volt-ohm meter rendering the meter deflections too small to permit determination of the pH of the water samples to the desired limits of accuracy. The meter was tested in buffer solutions whose pH values were 4.0, 7.0 and 10.0 and the readings appeared to be correct within the limits of accuracy permitted by the volt-ohm meter.

7.4.4 Conclusions

Both meters appear to be operational and require only minor modification (in the case of the pH meter) for increased accuracy, and calibration (in the case of the oxygen meter). They will greatly simplify the measurements of oxygen content and pH.

7.4.5 Detailed Description of the Oxygen Meter and Probe

The polarographic oxygen probe consists of a silver tube whose diameter is one centimeter which acts as an anode and contains a gold cathode at its center. This cathode is maintained at a constant voltage of -0.8 volts with respect to the anode. Both the anode and cathode are coated with either teflon or polyethylene which permits only the gaseous oxygen to diffuse through the coating to the electrodes. This coating prevents the other ions present in sea water from coming in contact with the electrodes. The space between the teflon (or polyethylene) film and the cathode is filled with a fifty percent normal solution of potassium hydroxide.

Conductance between the anode and cathode is produced by the following chemical reaction:

At the gold cathode

4 electons + O_2 -- 4 OH

(Thus, one mole of oxygen produces the flow of four electrons)

At the silver anode

4 Ag + 4 OH -- 2 Ag_2O + 2 H_2O + 4 electrons

(Thus, the conductivity between the anode and cathode is proportional to the oxygen concentration)

The purpose of the oxygen meter is to translate the conductance at the oxygen meter probe to a voltage which can then be read on a standard voltmeter. The operation of the oxygen meter is a follows (see Figure 7.7).

1) A reference voltage is obtained by adding in series a silicon diode and a germanium diode forming a voltage drop of 1.0 volts, which is nearly independent of current flow.

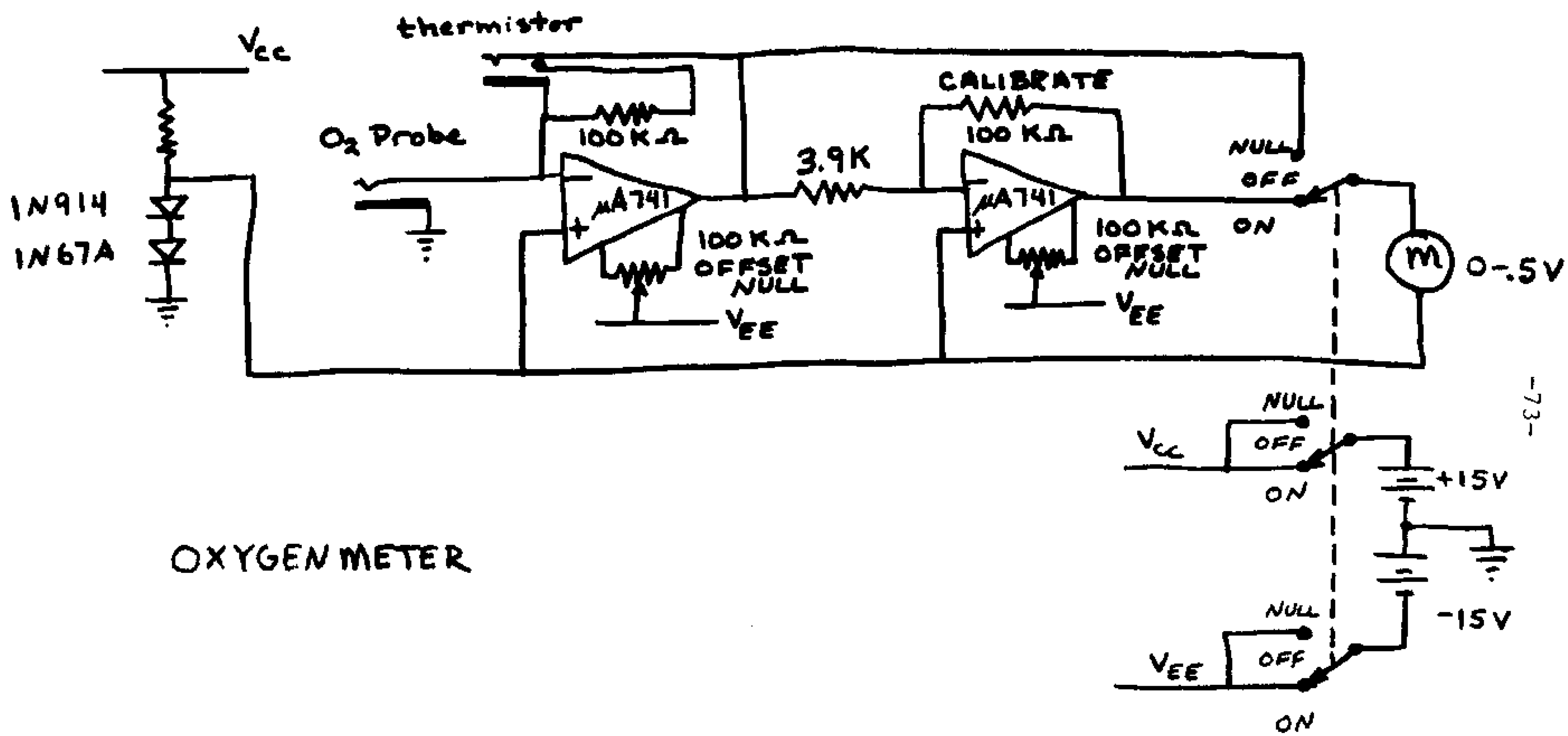


Figure 7.7

Oxygen Meter Circuit Diagram

2) The reference voltage (1.0 volts) is maintained at the inverting input of the first stage of the operational amplifier by virtue of its high gain (200,000) and using negative feedback.
3) An output voltage is developed when the conductance of the probe permits current to flow through the thermistor. The output voltage is directly proportional to the current flow and hence to the oxygen concentration at the probe.

In order to calibrate the oxygen meter, the following procedure is used:

1) Disconnect the oxygen probe from the oxygen meter and check to be sure the voltmeter readout indicates zero voltage. If the voltmeter does not indicate zero voltage, place the oxygen meter switch in the "null" position and adjust the first stage offset-null variable resistance pot until the voltmeter indicates zero volts.
2) Place the oxygen meter switch in the "on" position and adjust the second stage offset-null variable resistance pot until the voltmeter again indicates zero volts.
3) Plug the oxygen probe into the oxygen meter. Check to be sure that the oxygen meter switch is in the "on" position. Place the probe in a solution of known oxygen concentration and adjust the calibration variable resistance pot until the voltmeter indicates a voltage that corresponds to the oxygen concentration of the solution being used for calibration.

7.5 Automated Data Recorder

7.5.1 Objective

The objective of this project is the design and construction of an automated system to: a) convert analog data to digital format; b) record the converted data on magnetic tape; and c) automatically transcribe the recorded data onto IBM cards for data processing. The system is to have the capability of receiving, converting and recording from several sensors during any given time span.

7.5.2 Background

Plans for the Holbrook Cove Survey called for the deployment of current velocity meters at several locations and to leave these instruments in place to measure current data over considerable time spans. It did not appear practicable to expect an operator to man these instruments and record the data manually. In addition, it was anticipated that a great many observations were to be recorded and the time and effort involved in transcribing this information from analog format into machine-readable digital format seemed prohibitive.

7.5.3 Results

The automated data recorder is designed and various of the elements have been constructed and tested. The concept appears attractive and feasible although there are still technical difficulties to be overcome.

The automated system consists of several units. These incl

1) Encoder (one for each sensor)
2) Decoder (one for each automated system)
3) Recorder (one for each automated system)
4) Power Supply (one for each automated system)

The encoder circuit has two major states: analog to digit conversion and data recording. The encoder is designed as a "bus" instrument to allow for general multiplexing of any number of sensors. During the first major state, the time (in seconds) since the initializing pulse which cleared all counters and flip-flops is displayed on the "bus" lines. Each sensor's output has its own counter which keeps a running count of the sensor's impulses until the end of an interval determined by the time signals on the "bus" and a gate. Near the end of MS1 (majo state 1), a tape recorder is turned on to allow the tape to come up to speed. By the beginning of MS2 all analog to digital conversions are complete and the recording on the cassette tape recorder can begin. The method chosen is based on the standard technique involved in low-speed remote computer terminals. The data from each sensor's counter is sampled in turn and converted to the serial form: start bit, 8 data bits (msb first), 2 stop bits. The bits are recorded on the tape by the method of

Frequency Shift Keying (FSK) in which one tone indicates a zero, a second tone indicates a one. This transmission is terminated by a data word of 377octal which serves as an end-of-record mark.

The decoder is in two sections. The first is a standard teletype line receiver similar to the one used by Digital Equipment Corporation in their Logic Handbook. The second part converts the eight bits derived from the first part to two hexidecimal characters in Hollerith format. These characters are sent to the relay drivers which cause the relays to simulate a person punching the keys of an IBM 029 keypunch.

No special requirements are imposed on the magnetic tape recorder by the encoder and decoder. The application of the automated data recording system, however, makes it mandatory that it be compact, reliable, and conserve electrical energy. The speed of the capstan drives should be independent of the power supply voltage.

The power supply is any 12-volt dc electrical source. A motorcycle battery was utilized during the 1972 Summer Ocean Engineering Laboratory.

Since the automated system was not completed, a substitute circuit was designed and utilized (see Figure 7.8). This circuit is a standard astable multivibrator, except that one of the timing resistors is replaced by a photoresistor. In addition, a resistor has been added in series with the photoresistor to prevent the resistance in this path from becoming such a small value that oscillation ceases. Astable multivibrators will not commence oscillation if both transistors are saturated. To prevent this condition from occurring, the timing components were selected to insure that they were extremely asymmetrical. The purpose of this circuit is to convert the electrical pulse (generated when the current velocity meter photocell is exposed to its light source) into a voltage which oscillates in the audio range. This oscillating voltage was then used by the magnetic tape recorder to record the pulse as an audible tone on the magnetic tape.

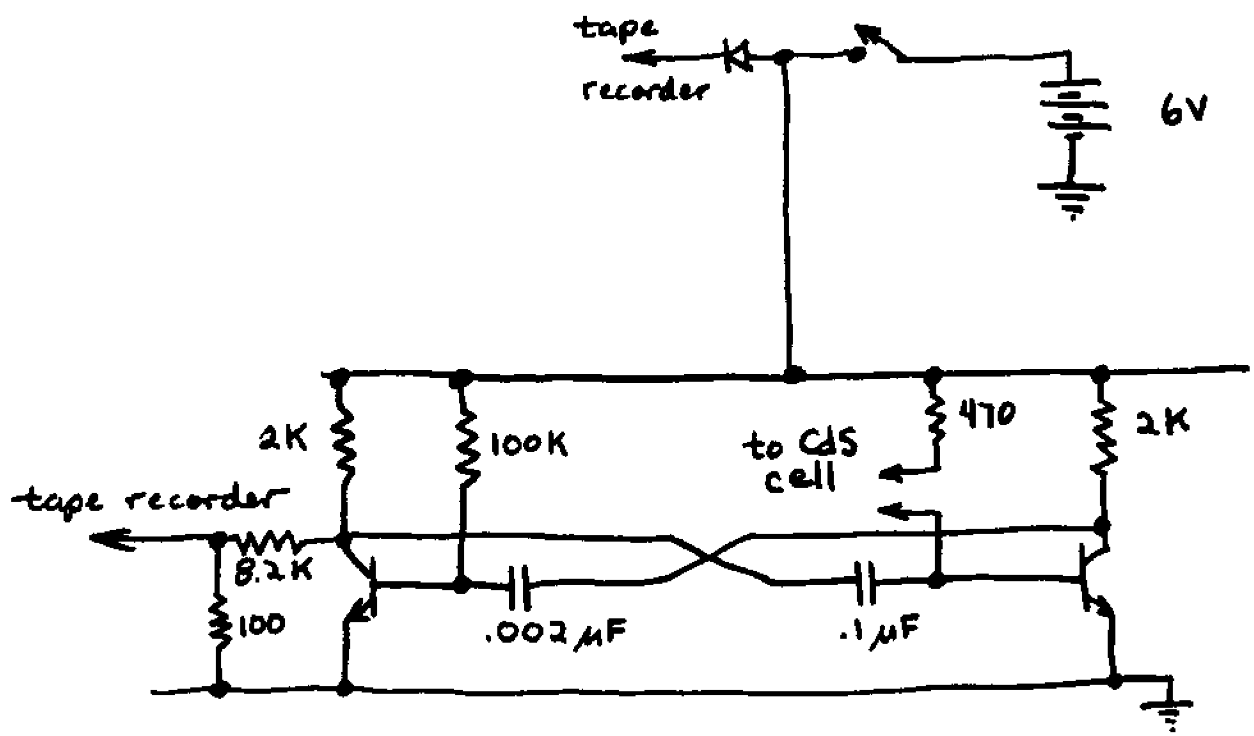


Figure 7.8

Astable Multivibrator Circuit Diagram

7.5.4 Conclusions

The automated data recorder system is technically feasible. The primary problems encountered are fairly mundane. The power consumption must be decreased if the system is to be operated over the time spans envisioned. The timing and recording components must be reduced in physical size.

The FSK transcriber requires additional design work. Its major problem is that a scheme to generate signals to activate the "skip" and "card release" functions on the IBM 029 keypunch must be worked out.

The substitute astable multivibrator circuit worked, but was not problem-free. The primary problems centered about the photoresistor, which was affected by ambient light conditions. This sometimes caused a frequency change in the audible tone and on other conditions it prevented oscillations.

7.5.5 Recommendations

It is believed that perfection of the automated data recording system will make a significant contribution to the oceanographic data-gathering effort. For this reason, it is recommended that this project be continued.

It is recommended that a redesign substituting MOS logic for the existing TTL logic be undertaken to reduce power consumption. This redesign will also make the recorder less sensitive to the power supply voltage.

A review of the frequency and time length of data samples should be made since both affect the power consumption of the data recorder system.

7.6 Tide Gauge

7.6.1 Objective

The objective of this project is to design and construct an instrument which will accurately measure and record the fluctuations in the water height during the tidal cycle. This instrument is to be capable of continuous operation for at least 24 hours and is to be able to operate in all weather conditions.

7.6.2 Background

In conjunction with the measurements of current flows in Holbrook Cove, it was desirable to obtain a measurement of the water height at both the southern and northwestern entrances to the Cove simultaneously. These measurements, which would require the construction of two instruments, would then be used to determine the relative importance of each entrance during the ebbing and flooding tides. After this was determined, it was planned to move one instrument to various sites within the Cove in an effort to further establish the tidal flood and ebb patterns of the Cove.

7.6.3 Results

Due to time limitations, only one instrument was machined in time for field testing. These tests, which occurred during the final days at Maine Maritime Academy, were disappointing because they yielded no accurate data and demonstrated that the machine, as designed and constructed, did not meet the design criteria.

The data obtained from these tests more closely approximated a step function than the expected sine function. A possible explanation for this behavior is that the internal friction of the machine could not be overcome by the small forces generated by the minute tidal changes. Thus, only when the summation of these forces became greater than some critical value, determined by the frictional forces of the apparatus, would the machine begin to scribe, rapidly dissipating the accumulated tidal force.

7.6.4 Conclusions

While the initial results obtained from this machine were unacceptable, the prototype did indicate many specific areas of the design which, if modified, would allow an instrument capable of performing the desired function to be produced. Fundamental to these changes is the consideration of internal friction and the selection of best methods to minimize this force.

7.6.5 Recommendations

The design of this apparatus is best considered as comprised of two components: The first component utilizes a Westclo clock mechanism to power a rotating drum upon which a continuous graph may be scribed; and the second component which reduces (scales) the vertical displacement of the tide and uses the tidal energy to drive a scribe which marks upon the rotating drum. To shield this entire component from the weather, it is entirely encased in a plexiglas case.

The details of the first component, which are found in Figure 7.9, show the rotating drum mounted on a combination thrust and radial bearing and driven by a pulley/belt arrangement by the clock mechanism. A better design would be to utilize a horizontal drum mounted by radial bearings on both ends of the drum. This double mounting will prevent any radial displacement of the drum when subjected to the pressure of the scribe and the consequent binding which occurs when only one bearing is used. Another improvement which suggests itself is the utilization of microchain and sprockets to rotate the drum. This will overcome the slippage inherent in a pulley/belt arrangement at very small angular velocities. A further time check could be provided by a clock-activated scribe, activated at regular time intervals.

The second component, as shown by Figure 7.9, is comprised of a weight and a float suspended from a large sprocket by a chain. The weight and float are designed to travel vertically with the tide, rotating the sprocket wheel, which subsequently drives a small pinion gear against a movable rack which is displaced vertically one-fifteenth the amount of the displacement caused by the tide. Affixed to this rack is a scribe which stays in contact with the drum continuously. If the vertical rotating drum is replaced by a horizontal rotating drum, the rack and pinion assembly can be replaced by an assembly utilizing a screw-activated scribe, which should be an improvement.

As was previously indicated, the primary obstacle to the machine functioning properly is that insufficient energy is generated by small tidal displacements to cause the machine to scribe continuously. As shown in Figure 7.9, the weight and float are both suspended within tubes for the purpose of damping out any local surface disturbances on the water surface. As shown, a float is placed in a tube open to the sea, while a counterweight is placed in a tube sealed to the sea. This arrangement allows the float to rise and fall with the water admitted to its tube. It is apparent that the top and bottom positions of the float during slack tide define the conditions critical to the proper functioning of the tide gauge. These

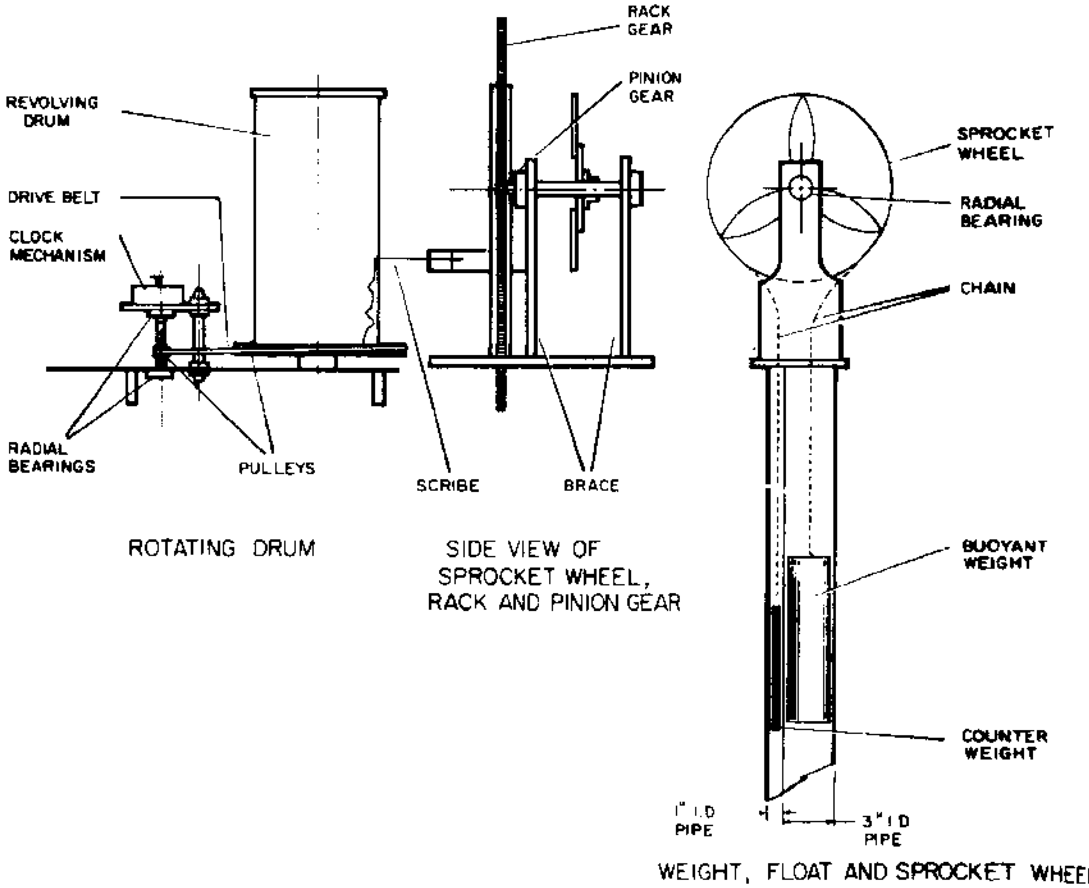


Figure 7.9

Tide Gauge Construction

critical conditions are summarized in Figure 7.10. The results of the tests during the Summer Ocean Engineering Laboratory and careful examination of Figure 7.10 lead to the conclusion that both the float and the weight must be increased in size if the gauge is to function as designed. An obvious method of accomplishing this is to utilize a large doughnut-shaped float circumscribing a large sealed tube in which a counterweight is suspended. This improvement would tend to minimize the nonlinearity of the system indicated by the equations in Figure 7.12. The nonlinearity can also be eliminated by properly calibrating the tide gauge.

7.7 Detailed Bottom Topography of Holbrook Cove

7.7.1 Objective

The objective of this project is to obtain the data required to build a detailed topographical model of the bottom configuration in Holbrook Cove. As a first step it is necessary to define the water height above mean lower low water as a function of time.

7.7.2 Background

It has been noted that some of the prominent bottom features such as rocks and shoals are not indicated on the charts of Holbrook Cove. In order to rectify this deficiency, a careful and systematic program of taking and recording soundings, using a small boat and lead line, is planned.

7.7.3 Results

During the 1972 Summer Ocean Engineering Laboratory there was time to complete only the first step, i.e., prepare a nomogram (see Figure 7.11) that will permit the prediction of water height above mean lower low water as a function of time. During the process of checking this nomogram against observed tide heights at the dock of the Maine Maritime Academy, it was discovered that the scope of the tide was about 12 inches greater than would be predicted using the Coast and Geodetic Survey Tide Tables. An example of the use of Figure 7.11 is in Appendix C.

7.7.4 Conclusions

The tide height observations at the dock at the Maine Maritime Academy agreed with the predictions calculated using

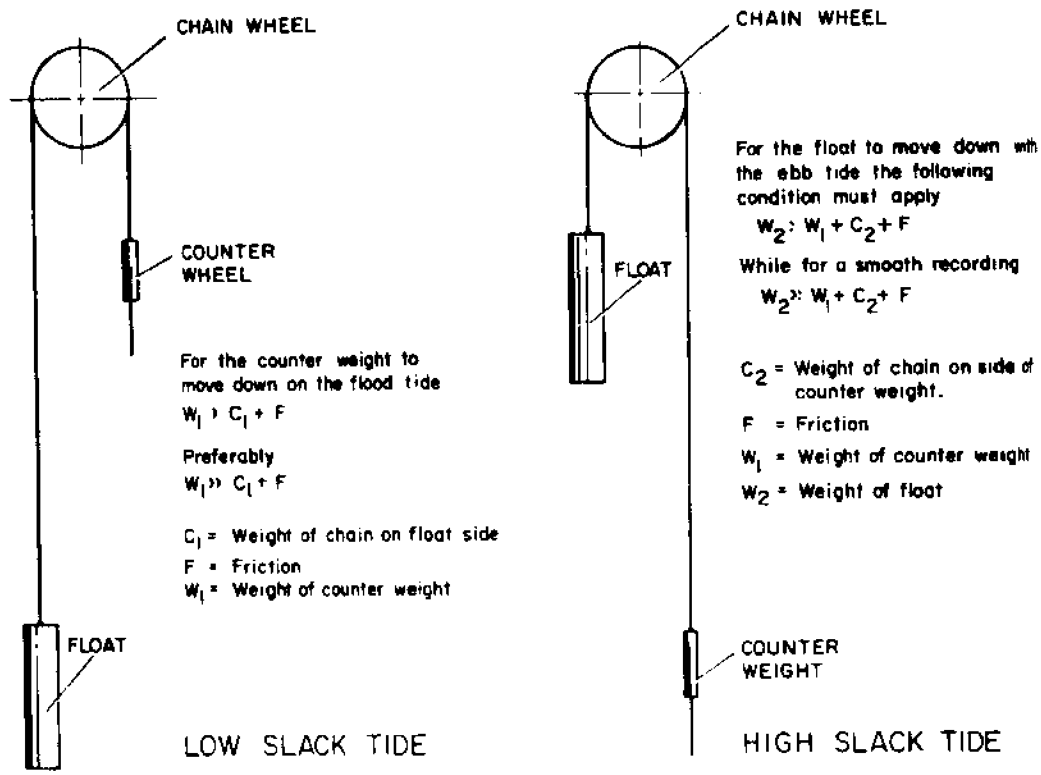


Figure 7.10

Tide Gauge Critical Conditions

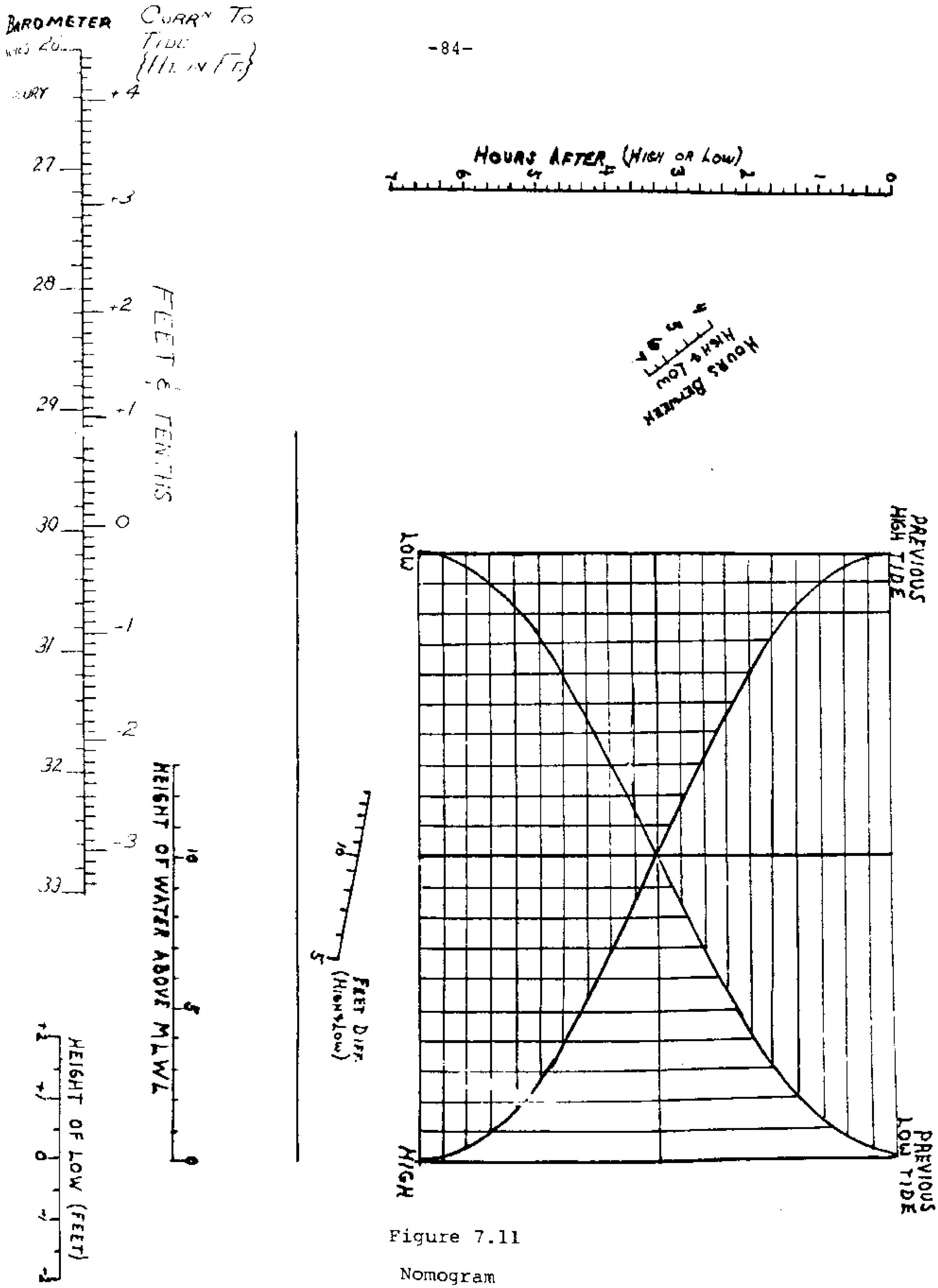


Figure 7.11

Nomogram

the nomogram. Based upon the observations, it appears that the corrections to tide height for Castine, Maine (as indicated in the Coast and Geodetic Survey Tide Tables), are in error. The correction for High water should read +1.7 vice +0.7.

7.7.5 Recommendations

The first step in the process of building the topographical model of the bottom configuration of Holbrook Cove is completed with the preparation of the nomogram. It is recommended that the nomogram be used to correct soundings taken in the subsequent phases of the project to obtain water heights corresponding to mean lower low water depths.

7.8 Bottom Sample Corer

7.8.1 Objective

The purpose of this project is to design, build, and test a corer to obtain bottom mud samples. The corer should be inexpensive and easy to operate.

7.8.2 Background

There were two reasons for choosing this project. One was to obtain experience in designing and building a piece of oceanographic equipment; the second was to produce a corer that would be available for use in the ocean engineering program at Maine Maritime Academy.

7.8.3 Results

In the actual test in Holbrook Cove, the unit was lowered into the water to check the balance. It was then lowered until the messenger hit bottom, allowing the corer to fall. When the corer was released, it was observed that the line holding the tripping device, corer and messenger became taut and then went slack. When the unit was retrieved, it was discovered that the line attaching the corer to the tripping device had been severed. The boat used for this test had not been moored and the test site was not buoyed. All attempts to locate the corer failed.

7.8.4 Conclusions

Judging from the observations of the line holding the tripping device, corer and messenger, the corer penetrated the bottom and would have permitted the retrieval of a core if it had not been lost. The design of the corer should be modified to provide for a steel wire leader for attachment of the corer to the tripping device.

7.8.5 Recommendations

Future tests of this device should be conducted only after the boat has been moored and the site suitably marked so that, in the case of severed lines, the lost units may be located and retrieved. The basic design appears sound, although it is not possible to state whether or not the samples retrieved using the corer would be sufficiently undisturbed to permit an accurate reconstruction of the boundaries and depths of the sedimentary layers.

7.8.6 Detailed Procedure

The corer consists of a body composed of an internal pipe and an external pipe. On the ends of these pipes are two fittings called the head and tail. These fittings are threaded to fit on the ends of both pipes. They are designed in such a manner that the outer pipe will take the stress and the internal pipe will retrieve the sample. Once obtained, the sample is removed by pushing the sediment out with a push rod which consists of a wooden tip the same diameter as the internal pipe and a rod longer than the pipe.

On one end of the tripping device is a messenger and on the other side, the corer. The tripping mechanism and arm are all designed so that the whole device, with corer and messenger, will balance in the water. When the device is lowered, the messenger, which has 35 feet of line extended ahead of the corer, touches the bottom and allows the tripping arm to rotate and the corer to fall to the bottom a distance equal to the messenger line length plus four feet (the length of the corer). Once the corer hits the bottom, the whole unit is raised and the sample removed.

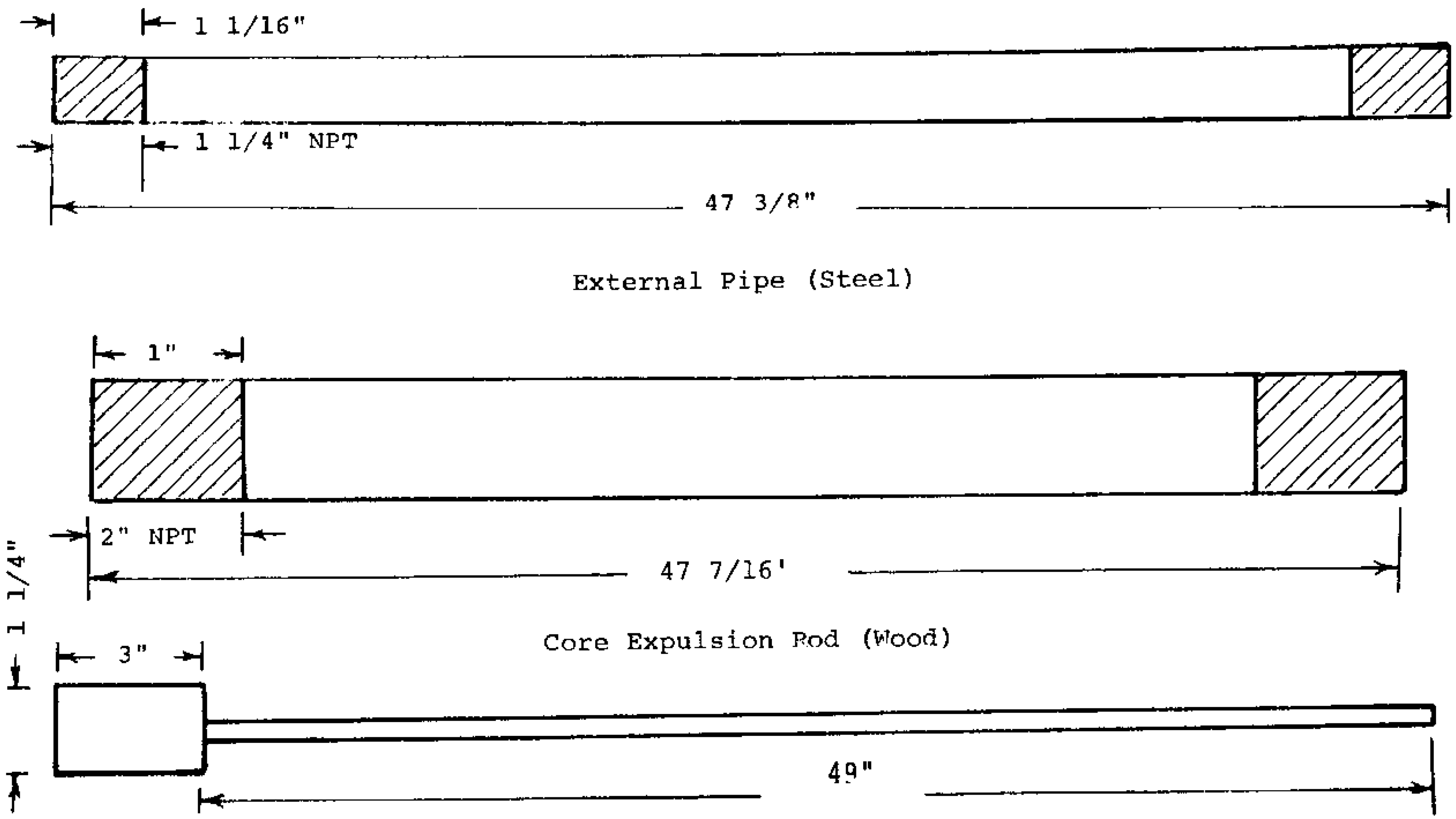
Figure 7.12 Corer

BODY

Internal Pipe (Steel)

External Pipe (Steel)

Core Expulsion Rod (Wood)



Not to Scale

Figure 7.13 Corer

Tripping Mechanism

2-Triangular 10.2# Plates

4-1/2" Holes

4-6" Bolts

(Not to Scale)

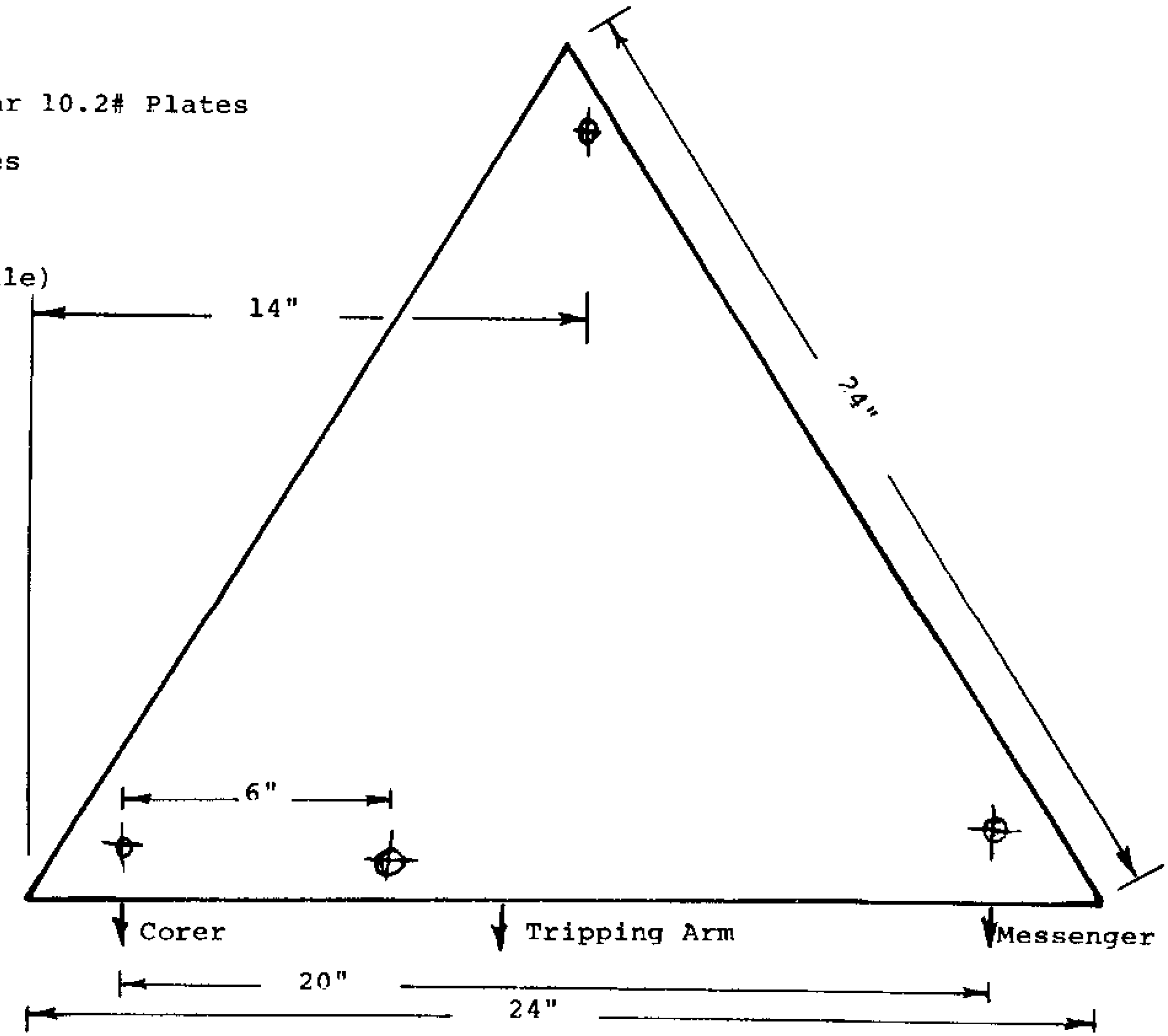
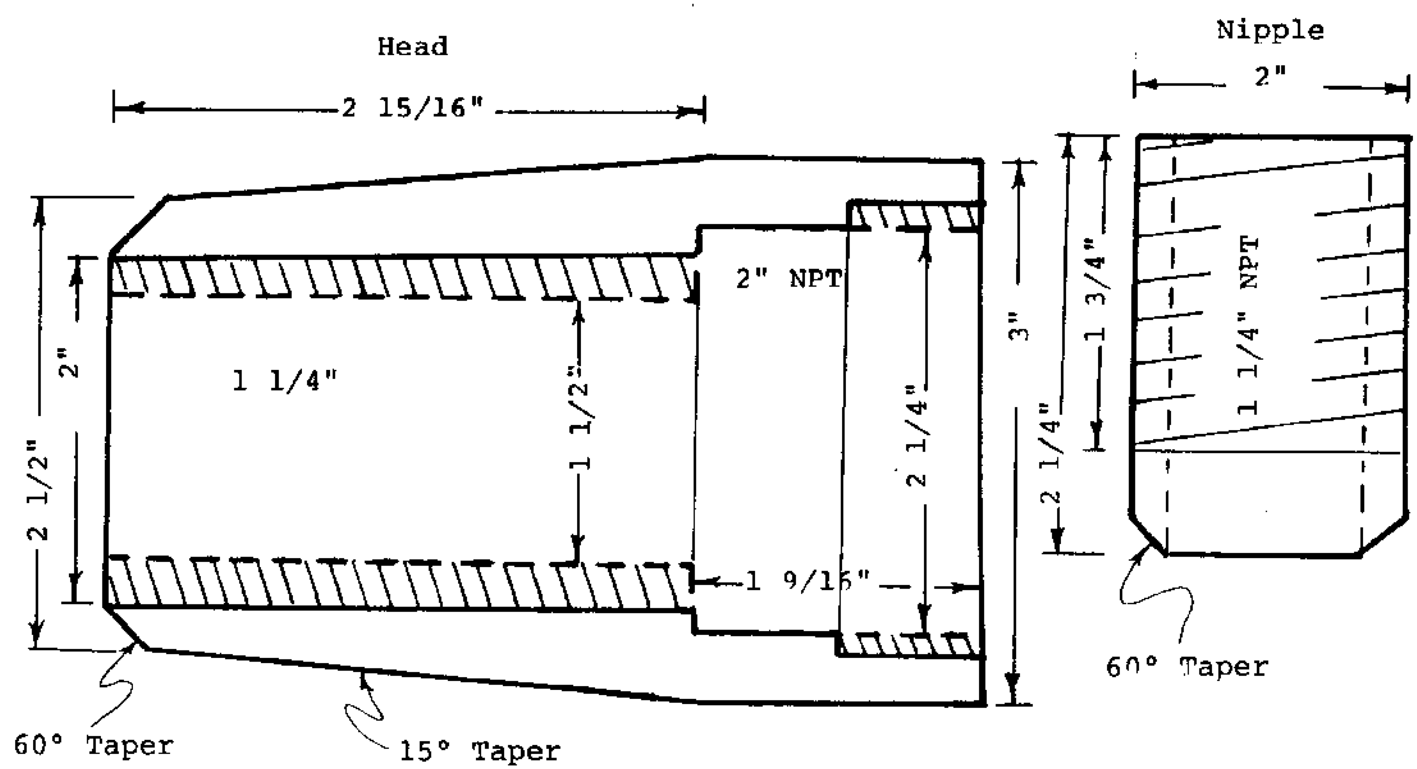


Figure 7.14

Head and Nipple Insert



Note: Nipple fits in front of head and is replacable in the event cutting edge is damaged on a rock.

APPENDIX A

DROGUE BODY COMPUTER PROGRAMS

APPENDIX A

The first computer program is modified solely by input data. There is no need for a modification of the source program.

One of the first data cards is a parameter decision card specifying which options the user of the program wishes to utilize. This is stated in the program listing. The flow chart points out the various combinations of options possible. Comment cards are permitted at certain points to keep track of special data.

One possible option is the use of data-smoothing subroutines. The preferred smoothing subroutine is spline fit. Spline fit approximates an idealized drafting spline curve through the data positions. If the number of equations (positions) is too small to permit the use of a spline, a least-squares fit subroutine is used.

Another important option is the IAXIS parameter which rotates the axis such that the X coordinates can be plotted and calculated as a function of the Y coordinates.

The spline and least-squares subroutines compute the Y coordinates as a function of the X coordinates. A reversal in buoy velocity will cause infinite looping in the spline and least-squares subroutines since they will yield two or more values of Y for one value of X. If a buoy reverses direction, the program will terminate the buoy path and restart it in the opposite direction. In cases of vorticity (in the Holbrook Cove Survey), many restarted paths resulted. In those cases, it was specified on the decision card that no interpolated values were desired and that all broken segments should be connected. Because the spline fit subroutine allows the user to specify the placement of the constraints on the equations, the user sometimes supplied cards listing the position of constraints and/or position of output points desired. If the user wished to place the constraint or position of output points, he specified a positive number of constraints and output points, with the positions given in X coordinates. If the user wished the program to pick the positions, a negative number was specified. If a buoy back-tracked, the program itself decided on a number of constraints and output points, and the placement of each.

In order to graphically represent velocities in addition to pathlines, two subroutines placed either a tickmark for times or a line through two or more buoy paths, depending on user specification (e.g., if the distance between ten-minute tickmarks decreased, the buoy was traveling slower. If the distance increased, the buoy was traveling faster).

In the numerical printout part of the program, two types of velocities were computed: a backwards difference velocity and a centered difference velocity. The backwards difference velocity is computed by dividing the distance between the position under consideration and the position at the previous observation by the difference between the time of the observation of the position under consideration and the time of the previous observation. The centered difference velocity is computed by dividing the sum of the distances between the position under consideration and the positions of the previous observation and the next subsequent observation by the sum of the differences between the times of observation of the position under consideration and the times of the previous and next subsequent observations. The subroutine STOREC could be further modified to allow a least-squares or other velocity approximation if the user wished to modify the source.

All sorts, with the exception of TSORT, are interchange sorts, as the number of sorted items cannot exceed 99. The limit on the number of buoys' segments is explained by the fact that the program considers each buoy segment caused by backtracking to be a separate and equal segment (e.g., in the case of vorticity, a buoy input with 99 points may be composed of 20 or more segments, etc.). TSORT takes an already sorted list and puts them in ascending order, in the event that they were originally in descending order.

There are a few limits and constraints that are intrinsic in the source program, and to be changed require the source to be modified. Numerical limits are listed. Other major limits not listed follow. The IWARN array is a controlling factor in the dumping of input constraints and output positions for the interpolation routines and timelines. If a buoy backtracks, IWARN for that particular buoy is activated. This means that all input constraints are dumped and replaced and that timelines are not allowed on any of the segments (tickmarks are).

Spline is used in all cases except where the number of points is too close to the number of equations. Then, and only then, is least squares used.

DROGUE BODY COORDINATE
AND VELOCITY CALCULATION
COMPUTER PROGRAM

```
      COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,   MAIN0001
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINO(99),     MAIN0002
     2YINO(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IADICH,XINT,  MAIN0003
     3YINT,INCRCT,JUSIN,IMLINE                                            MAIN0004
      COMMON /AREA1/ IHELP                                                MAIN0005
      COMMON /AREA2/ XMAX,XMIN,YMAX,YMIN                                  MAIN0006
      COMMON /AREA7/ TCHAR,MWSTAR                                         MAIN0007
      REAL*8 CHAR1,CHAR2,CHAR3,CHAR4,CHAR5,TCHAR,CHAR21,CHAR22,CHAR23,    MAIN0008
     1CHAR24,CHAR25                                                       MAIN0009
      LOGICAL*1 MIWSAR(9),IFLT(9)                                         MAIN0010
C     CHARACTER VARIABLES                                                 MAIN0011
C                                                                         MAIN0012
C                                                                         MAIN0013
C     COMMON/AREA1/  EMERGENCY ESCAPE CLAUSE                              MAIN0014
C     COMMON/AREA2/  MAXIMUM DIMENSION SIZES                              MAIN0015
C     COMMON/AREA7/  HIGH OR LOW TIDE CHARACTERS AND TIME                 MAIN0016
C                                                                         MAIN0017
C     SUBROUTINES AND FUNCTION LIST                                       MAIN0018
C     TIMELS  CALCULATES CURVES THAT INTERSECT POSITIONS AT GIVEN TIMES   MAIN0019
C     TIMEMK CALCULATES TICKMARKS ON THE POSITIONS FOR GIVEN TIMES        MAIN0020
C     DUCK A SPLINE FIT CURVE                                             MAIN0021
C     GLSQ SOLVES EQUATIONS GIVEN TO IT BY DUCK IN A LEAST SQUARES WAY    MAIN0022
C     AUTOD PLACES THE POSITION OF THE CONSTRAINTS FOR CURVES BY DUCK     MAIN0023
C     DUCKT EXAMINES THE POSITIONS OF THE CONSTRAINTS  WILL VOID THEM     MAIN0024
C     PRITOK WILL PRINT OUT THE POSITIONS OF THE CONSTRAINTS              MAIN0025
C     INTERP PREPARES EQUATIONS AND SOLVES FOR A LEAST SQUARES FIT        MAIN0026
C     GLSQXZ  M.I.T. COMPUTER MATHLIB  LEAST SQUARES FIT                  MAIN0027
C     SIMEQ IBM SSP FOR THE SOLUTIONS OF SIMULTANEOUS EQUATIONS           MAIN0028
C     COEF PRINTS OF THE EQUATION COEFFICIENTS USED IN SPLINE AND LEAST   MAIN0029
C     SQUARES                                                             MAIN0030
C     XOUTER CALCULATES AT REGULAR INTERVALS THE OUTPUT POSITIONS         MAIN0031
C     TSORT SPECIAL SORT PLACES INPUT POINTS IN ASCENDING ORDER IF THEY   MAIN0032
C     ARE INPUTTED IN DESCENDING ORDER                                    MAIN0033
C     SORT  A STANDARD INTERCHANGE SORT                                   MAIN0034
C     RSORT INTERCHANGE SORT WITH A TAG-A-LONG ARRAY                      MAIN0035
C     PRAPN PUNCHES AND/OR PRINTS INPUT POINTS                            MAIN0036
```

```
C       CUTER PUNCHES OR PRINTS OUTPUT POINTS
C       DEGREE OUTPUTS A DEGREE.MINUTE NUMBER FROM INPUT DEGREES  OUTPUT +
C       STOREC CALCULATES CENTERED VELOCITIES AND FUTHER IMPROVEMENTS
C
C       LIMITATIONS
C       FINAL NO. OF BUOY SEGMENTS <= 40
C       MAX. NO. INPUT POINTS  99
C       CONSTRAINTS CN SPLINE  MUST BE <= INPUT POINTS -4
C       MAX. OF CONSTRAINTS  20
C       MAX. NO.  OUTPUT POINTS  500
C       POSITICNS OF CONSTRAINTS MUST BE INPUTTED IF  +CONSTRAINTS INPUT
C       POSITION OF OUTPUT MUST BE INPUT IF +OUTPUT POINTS INPUTTED
C       IF OUTPUT OR CONSTRAINTS NEGATIVE PROGRAM CALCULATES ABS() NC.
C       POSITIONS MUST BE INPUTTED IN TERMS OF X AND Y COORDINATES
C       ORIGIN IS STATION OF FIRST ANGLES +X IS IN DIRECTICN OF NEXT STAT.
C       UNITS ARE:
C                DEGREES.MINUTES
C       IF TRANSITS USED 0-9C-0 SCALES THEN INPUT 2 DEGREES.MINUTES FOR
C       ANGLES GREATER THAN 9C BUT READING LESS THAN 90
C                METERS.METER
C                HOURHOURMINUTEMINUTESECONDSECOND
C
C
C       INITIALIZATION OF VALUES
C
        F=.0001
        XMAX=0.0
        XMIN=0.0
        YMAX=0.0
        YMIN=0.0
        IHELP=0
        KIN=5
        KOT=6
        KPUT=7
        IFIRST=1
        NORMAL=2
```

```
      ILAST1=3
      JOBNUM=0
      ILOOP=0
      XSIGNI=1.0
      DO 7777 IMESS=1,40
C
C     IWARN IS TO SAVE THE MEMORY OF WHICH JOBS HAD BROKEN BUOY PATHS
C     THIS INFO  IS USED FOR DESTROYING CONSTRAINT AND OUTPUT DATA AND
C     AND FOR STOPPING TIMELINES ON THE REASON THAT IT WILL BACKTRACK
C     TO FAR TO ALLOW A FUNCTION(X) TO EXIST  PREVENTS A BLOW-UP
      IWARN(IMESS)=0
 7777 CONTINUE
C
C     FIRST CARD IS A CHARACTER COMMENT CARD  ANY COMMENT ON IT WILL
C     PRINTED AND/OR PUNCHED IN THE OUTPUT
      READ(KIN,1795)CHAR1,CHAR2,CHAR3,CHAR4,CHAR5,CHAR21,CHAR22,CHAR23,
     1CHAR24,CHAR25
C
C     PARAMETER INPUT CHOICES
C     IPUN=1 PUNCHING
C     INOROT=1  PUNCH OUTPUT ONLY
C     JUSIN=1  DONOT CALCULATE INTERPOLATION OUTPUT POINTS
C     ICONET=1  CONNECT BROKEN SEGMENTS CAUSED BY BUCY BACKTRACKING
C     IAXIS=1  X AXIS=-Y AXIS    Y AXIS= X AXIS
C     ITMARK=1 CALCULATE TIME TICKMARKS
C     IMLINE=1 CALCULATE A SMOOTH TIMELINE BY USING SPLINE OR LEAST SQU.
C     ISTRLN=1  SEGMENTED TIMELINE NO SPLINE OR LSFIT CALCULATIONS
C
      READ(KIN,1000)IPUN,INOROT,JUSIN,ICONET,IAXIS,ITMARK,IMLINE,ISTRLN
C
      WRITE(KOT,1022)
      WRITE(KOT, 1101)
      WRITE(KOT,1796)CHAR1,CHAR2,CHAR3,CHAR4,CHAR5,CHAR21,CHAR22,CHAR23,
     1CHAR24,CHAR25
      IF(IPUN.NE.0)WRITE(KPCT,1101)
      IF(IPUN.NE.0)WRITE(KPCT,1796)CHAR1,CHAR2,CHAR3,CHAR4,CHAR5 ,CHAR21
```

```
      1,CHAR22,CHAR23,CHAR24,CHAR25                                     MAIN0109
       WRITE(KOT ,1050)IPUN,INOROT,JUSIN,ICONET,IAXIS,ITMARK,IMLINE,    MAIN0110
      1ISTRLN                                                           MAIN0111
       IF(IPUN.NE.0)                                                    MAIN0112
      1WRITE(KPCT,1050)IPUN,INOROT,JUSIN,ICONET,IAXIS,ITMARK,IMLINE,    MAIN0113
      2ISTRLN                                                           MAIN0114
       IF(IAXIS.EQ.1)XSIGNI=-1.0                                        MAIN0115
C                                                                       MAIN0116
C      INPUT NUMBER OF BUOY GROUPS                                      MAIN0117
C      INPUT DEGREES.MINUTES THAT THE BASELINE FROM ORIGIN IS OFF TRUE N MAIN0118
C      INPUT LENGHT OF BASELINE IN METERS.METER                         MAIN0119
C      INPUT  "HIGHTIDE"  OR  " LOWTIDE"                                MAIN0120
C      INPUT TIME OF HIGH OR LOW TIDE                                   MAIN0121
C      OPTIONAL INPUT OF ANGLES FOR MAX DIMENSICN IN Y DIRECTION        MAIN0122
C      OPTIONAL IS NON-CONSTRAINING ON REST OF INPUT                    MAIN0123
       READ(KIN,1100)NOJOBS                                             MAIN0124
       READ(KIN,1200)DEGTN,BASLN,TCHAR,MWHOUR,MWMIN,MWSEC,NSECA,ANGA,NSEC MAIN0125
      1B,ANGB                                                           MAIN0126
C                                                                       MAIN0127
C      CHECK ON CORRECT INPUT FOR MAX DIMENSIONS                        MAIN0128
       IF((ANGA+ANGB).LT.1.0) GOTO 1911                                 MAIN0129
       IF(NSECA.EQ.2)ANGA=180.00-ANGA                                   MAIN0130
       IF(NSECB.EQ.2)ANGB=180.00-ANGB                                   MAIN0131
       IANGA=ANGA                                                       MAIN0132
       IANGB=ANGB                                                       MAIN0133
       XTEMP=(IANGA+ (ANGA-IANGA)*1.66666)*.0174533                     MAIN0134
       YTEMP=(IANGB+ (ANGB-IANGB)*1.66666)*.0174533                     MAIN0135
       IF((XTEMP+YTEMP).GE.3.14159)WRITE(KOT,1301)JOBNUM,ILOOP,ANGA,ANGB MAIN0136
       IF((XTEMP+YTEMP).GE.3.14159)GOTO 1911                            MAIN0137
       YMAX=(BASLN*SIN(XTEMP)*SIN(YTEMP))/SIN(XTEMP+YTEMP)              MAIN0138
       IF(IAXIS.EQ.1)YMAX=(YMAX*COS(XTEMP))/SIN(XTEMP)                  MAIN0139
C                                                                       MAIN0140
C      CONVERSION OF TRUE NORTH DEGREES.MINUTES TO RADIANS              MAIN0141
 1911  NDEGTN=DEGTN+E                                                   MAIN0142
       NMINT=(DEGTN-NDEGTN+E)*100.                                      MAIN0143
       NADDD=NMINT/60                                                   MAIN0144
```

```
      NDEGTN=NDEGTN+NADDD                                               MAIN0145
      NDEGTN=NDEGTN-(NDEGTN/360)*360                                    MAIN0146
      NMINT=NMINT-NADDD*60                                              MAIN0147
      DEGTN=(NDEGTN+NMINT/60.)*.0174533                                 MAIN0148
C                                                                       MAIN0149
      WRITE(KOT,1001)NDEGTN,NMINT,BASLN ,TCHAR,MWHOUR,MWMIN,MWSEC,YMAX  MAIN0150
      NOJOBA=IABS(NOJOBS)                                               MAIN0151
      JOBNUM=1                                                          MAIN0152
 6000 IB1=1                                                             MAIN0153
      WRITE(KOT, 1888)JOBNUM                                            MAIN0154
      ISTIME=0                                                          MAIN0155
C                                                                       MAIN0156
C     INPUT NO. OF SIGHTINGS FOR BUOY AND A MESSAGE                     MAIN0157
      READ(KIN,1300)NIN,CHAR1,CHAR2,CHAR3,CHAR4,CHAR5,CHAR21,CHAR22,    MAIN0158
     1CHAR23                                                            MAIN0159
C                                                                       MAIN0160
      WRITE(KOT,1598)CHAR1 ,CHAR2,CHAR3 ,CHAR4,CHAR5,CHAR21,CHAR22,CHAR23 MAIN0161
C                                                                       MAIN0162
      WRITE(KOT,1201)TCHAR                                              MAIN0163
      NINA=IABS(NIN)                                                    MAIN0164
      ICHECK=0                                                          MAIN0165
 7000 IB=IB1                                                            MAIN0166
      KOUNT=0                                                           MAIN0167
      NINAD=NINA                                                        MAIN0168
      DO 5000 ILOOP=IB,NINAD                                            MAIN0169
      IADICH=0                                                          MAIN0170
      ICHECK=ICHECK+1                                                   MAIN0171
C                                                                       MAIN0172
C     SECTOR FOR TRANSIT ANGLE ONE                                      MAIN0173
C     TRANSIT ANGLE ONE                                                 MAIN0174
C     SECTOR FOR TRANSIT ANGLE TWO                                      MAIN0175
C     TRANSIT ANGLE TWO                                                 MAIN0176
C     TIME OF SIGHTING HOURS                                            MAIN0177
C     TIME OF SIGHTING MINUTES                                          MAIN0178
C     TIME OF SIGHTING SECONDS                                          MAIN0179
C     SECTOR IS BLANK IF INPUTTING  FROM FULL 360 DEGREES               MAIN0180
```

```
      READ(KIN,1400)NSEC1,ANG1,NSEC2,ANG2,IHOUR,MINUT,NSEC
C
      NSUBT=(IHOUR*3600 + MINUT*60 + NSEC) - (MWHOUR*3600 + MWMIN*60 +
     1MWSEC)
      CALL TIMEPH(NSUBT,MIWSAR)
      IF(NSEC1.EQ.2)ANG1=180.00-ANG1
      IF(NSEC2.EQ.2)ANG2=180.00-ANG2
      IANG1=ANG1
      IANG2=ANG2
C
C     DEGREES--> RADIANS
      XTEMP=(IANG1+ (ANG1-IANG1)*1.66666)*.0174533
      YTEMP=(IANG2+ (ANG2-IANG2)*1.66666)*.0174533
C
C     CHECK FOR BLANK CARDS  ANGLES =0 OR > 180
      IF(((ABS(XTEMP+YTEMP)).LT.3.14159).AND.(XTEMP.NE.0.0).AND.(YTEMP
     1.NE.0.0))GOTO 5500
      KOUNT=KOUNT+1
      ILOKI=ILOOP-KOUNT
      IF(ILOOP.NE.NINAD)GOTO 5679
      J=ILOOP-1
C
C     CLEAN OUT STOREC
      CALL STOREC(ILAST1,J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,MIWSAR,
     1ILAP,IELT,DIST,VEL,VELOC,DIRCT)
      WRITE(KOT,1601)J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(L),
     1L=1,9),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT
 5679 WRITE(KOT,1301) JOBNUM,ILOOP,ANG1,ANG2
      IF(ILOOP.NE.NINAD)WRITE(KOT,1201)TCHAR
      GOTO 5000
 5500 ILOKI=ILOOP-KOUNT
      IETIM=IHOUR*3600+MINUT*60+NSEC
      YINT=(BASLN*SIN(XTEMP)*SIN(YTEMP))/SIN(XTEMP+YTEMP)
      XINT=(YINT*COS(XTEMP))/SIN(XTEMP)
C
C     CHANGE OF AXIS
```

```
      IF(IAXIS.NE.1)GOTO 1912                                           MAIN0217
      STORAG=YINT                                                       MAIN0218
      YINT=XINT                                                         MAIN0219
      XINT=-STORAG                                                      MAIN0220
C                                                                       MAIN0221
 1912 IF(ILOKI.LE.1)GOTO 5505                                           MAIN0222
C                                                                       MAIN0223
C     CHECK FOR IDENTICAL POINTS                                        MAIN0224
      IF(XINT.NE.XIN(JOBNUM,(ILOKI-1)))GOTO 5505                        MAIN0225
      KOUNT=KOUNT + 1                                                   MAIN0226
      ILOKI=ILOOP-KOUNT                                                 MAIN0227
      IF(ILOOP.NE.NINAD)GOTO 5976                                       MAIN0228
      J=ILOOP-1                                                         MAIN0229
C                                                                       MAIN0230
C     CLEAN OUT STOREC                                                  MAIN0231
      CALL STOREC(ILAST1,J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,MIWSAR, MAIN0232
     1ILAP,IELT,DIST,VEL,VELOC,DIRCT)                                   MAIN0233
      WRITE(KOT,1601)J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(L), MAIN0234
     1L=1,3),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT                       MAIN0235
 5976 WRITE(KOT,4344)ANG1,ANG2,XINT,YINT,JOBNUM,ILOOP                   MAIN0236
      IF(ILOOP.NE.NINAD)WRITE(KOT,1201)TCHAR                            MAIN0237
      GOTO 5000                                                         MAIN0238
C                                                                       MAIN0239
 5505 IF(ILOKI.LT.3)GOTO 5600                                           MAIN0240
C                                                                       MAIN0241
C                                                                       MAIN0242
C     CHECK ON POSSIBLE CHANGE OF DIRECTION  BACKWARDS                  MAIN0243
C     IF TRUE THEN CUT OFF OLD SEGMENT AND BEGIN NEW                    MAIN0244
      IF(((XINT.GE.XINO(ILOKI-1)).AND.(XINO(ILOKI-1).GE.XINO(ILOKI-2))) MAIN0245
     1.OR.((XINT.LE.XINO(ILOKI-1)).AND.(XINO(ILOKI-1).LE.XINO(ILOKI-2)))MAIN0246
     2)GOTO 5600                                                        MAIN0247
      J=0                                                               MAIN0248
      ILAP=IETIM-IETIMO                                                 MAIN0249
      DIST=SQRT(((XIN(JOBNUM,(ILOKI-1))-XINT)**2)+ ((YIN(JOBNUM,        MAIN0250
     1(ILOKI-1))-YINT)**2))                                             MAIN0251
      XNUMER=(YIN(JOBNUM,(ILOKI-1)) - YINT)*(-1.)                       MAIN0252
```

```
      XDENOM=-(XIN(JOBNUM,(ILOKI-1))-XINT)*XSIGNI                       MAIN0253
      IF(IAXIS.EQ.0)DIRCT=(-ATAN2(XNUMER,XDENOM) + DEGTN)/.0174533      MAIN0254
      IF(IAXIS.EQ.1)DIRCT=(-ATAN2(XDENCM,XNUMER) + DEGTN)/.0174533      MAIN0255
      CALL TIMEPH(ILAP,IELT)                                            MAIN0256
      VELOC=0.00                                                        MAIN0257
      VEL=0.00                                                          MAIN0258
      IF(ILAP.NE.0)VEL=DIST/FLOAT(ILAP) *100.0                          MAIN0259
      NDIRC=DIRCT                                                       MAIN0260
      TMINN=( DIRCT-NDIRC)*.6                                           MAIN0261
      DIRCT=NDIRC                                                       MAIN0262
      CIRCT=DIRCT + TMINN                                               MAIN0263
      CIRCT=DEGREE(DIRCT)                                               MAIN0264
      CALL STOREC(NORMAL,J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,MIWSAR, MAIN0265
     1ILAP,IELT,DIST,VEL,VELCC,DIRCT)                                   MAIN0266
      WRITE(KOT,1601)J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(L),L MAIN0267
     1=1,9),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT                        MAIN0268
C                                                                       MAIN0269
C     CLEAN OUT STCREC                                                  MAIN0270
      CALL STOREC(ILAST1,J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,MIWSAR  MAIN0271
     1,ILAP,IELT,DIST,VEL,VELOC,DIRCT)                                  MAIN0272
      WRITE(KOT,1601)J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(L),L MAIN0273
     1=1,9),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT                        MAIN0274
      WRITE(KOT,1401)JOBNUM,ILOOP                                       MAIN0275
      IWARN(JOBNUM)=1                                                   MAIN0276
C                                                                       MAIN0277
C     CHECK ON INTERPOLATICN  POINTS                                    MAIN0278
      IF(JUSIN.EQ.1)WRITE(KCT,1201)                                     MAIN0279
      IF(JUSIN.EQ.1)GOTO 5600                                           MAIN0280
C                                                                       MAIN0281
C                                                                       MAIN0282
      LEN(JOBNUM)=ILOKI-1                                               MAIN0283
      WRITE(KOT,1518)                                                   MAIN0284
C                                                                       MAIN0285
C     AVERAGE CIRECTION ANC VELCOITY                                    MAIN0286
      ADIST=SQRT(((XIN(JOBNUM,LEN(JOBNUM))-XIN(JOBNUM,1))**2)+          MAIN0287
     1((YIN(JOBNUM,LEN(JOBNUM))-YIN(JOBNUM,1))**2))                     MAIN0288
```

```
      IATIME=ITIME(JOBNUM,LEN(JOBNUM))-ITIME(JCBNUM,1)
      IF(IATIME.EQ.0)AVEL=C.00
      IF(IATIME.NE.0)AVEL=ADIST/FLOAT(IATIME) *100.0
      ADIRCT=0.00
      IF(ADIST.NE.C.0)ADIRCT=(-ATAN2((YIN(JOBNUM,LEN(JOBNUM))-YIN(JOBNUM
     1,1)),(XIN(JCBNUM,LEN(JCBNUM))-XIN(JOBNUM,1)))+CEGTN)/.0174533
      IF(IAXIS.EQ.C)GOTO 7372
      IF(ADIST.NE..0)ADIRCT=(-ATAN2((-XIN(JOBNUM,LEN(JOBNUM))+XIN(JOBNUM
     1,1)),(YIN(JOBNUM,LEN(JCBNUM))-YIN(JOBNUM,1)))+CEGTN)/.0174533
 7372 CALL TIMEPH(IATIME,IELT)
      NDIRC=ADIRCT
      TMINN=(ADIRCT-NDIRC)*.6
      ADIRCT=NDIRC
      ADIRCT=ADIRCT+TMINN
      ADIRCT=DEGREE(ADIRCT)
      WRITE(KOT,1517)ADIST,(IELT(IZ),IZ=1,9),AVEL,ADIRCT
      NDK=(ILOKI-1)/3
      IF(NDK.GT.6)NDK=6
      NDKA=NDK
      NOUT=(ILOKI-1)*3
      IF(ICCNET.EQ.1)IADICH=1
      IF((IPUN.NE.C).AND.(INCRCT.EQ.0)) CALL PRAPN
      IF((IPUN.EQ.C).OR.(INCROT.NE.0))CALL PRINTO
      IF(JLSIN.NE.0)GOTO 5050
C
      IF(LEN(JCBNUM).GT.1)GCTO 5501
C
      WRITE(KOT,1333)JOBNUM,LEN(JOBNUM)
      IF(IPUN.NE.0)WRITE(KPCT,1333)JOBNUM,LEN(JCBNUM)
      GOTO 5050
 5501 CALL XOUTER
C
C     DECISION ON WHICH INTERPOLATION TO USE
      IF(LEN(JCBNUM).GT.4)GOTO 5502
      IARITY=1
      CALL INTERP(LEN(JOBNUM),IARITY,NOUT)
```

```
      GOTO 5503
 5502 CALL AUTOD
C
C     ESCAPE CLAUSE CAUSED IN CALCULATING THE POSITIONS OF CONSTRAINTS
      IF(IHELP.EQ.1)GOTO 9587
      IARITY=1
      CALL DUCK(LEN(JOBNUM),XINO,YINO,NDK,XDK,NOUT,XOUT,YOUT,IARITY)
 5503 IF(IPUN.NE.0)CALL OUTER
      IF(IPUN.EQ.0)CALL PRCT
 5050 JOBNUM=JOBNUM+1
      NOJOBA=NOJOBA+1
      IWARN(JOBNUM)=1
      VELOC=0.00
      VEL=0.00
      DIRCT=0.00
      DIST=0.00
      ILAP=0
      CALL TIMEPH(ILAP,IELT)
      ITIME(JOBNUM,1)=IETIM
      XIN(JOBNUM,1)=XINT
      YIN(JOBNUM,1)=YINT
      XINO(1)=XINT
      YINO(1)=YINT
      IB1=2
      NINA=NINAD-ILOOP+1
      J=1
      WRITE(KOT, 1888)JOBNUM
      WRITE(KOT,1201)TCHAR
      CALL STOREC(IFIRST,J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,MIWSAR,
     1ILAP,IELT,DIST,VEL,VELOC,DIRCT)
      IETIMO=IETIM
C     IF MORE POINTS IN THIS GROUP RESTART BROKEN SEGMENT
      IF(ICHECK.LT.IABS(NINA))GOTO 7000
      LEN(JOBNUM)=1
      WRITE(KOT,1601)J,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(L),L
     1=1,9),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT
```

```
      GOTO 5423
C
C     PREVIOUS BLOCK       FOR BACKTRACKING BUOYS AND ALL MEASURES FOR
C     RESTARTING THE NEXT SEGMENT
C
C
C     STORAGE OF TIMES FOR USE IN TIMELINES OR TIME MARKS
 5600 ITIME(JOBNUM,ILOKI)=IETIM
      XINC(ILOKI)=XINT
      YINC(ILOKI)=YINT
      XIN(JOBNUM,ILOKI)=XINT
      YIN(JOBNUM,ILOKI)=YINT
      IF(ILOKI.GT.1)GOTO 5800
      ILAP=0
      DIST=0.00
      VEL=0.00
      VELCC=0.00
      ISTORE=1
      DIRCT=0.00
      GOTO 5900
 5800 IL=ILOKI-1
      ILAP=IETIM-IETIMO
      DIST=SQRT(ABS((XINT-XINC(IL))**2+(YINT-YINC(IL))**2))
      VEL=0.00
      IF(ILAP.NE.0)VEL=DIST/FLOAT(ILAP)*100.0
      DIRCT=0.00
      IF(DIST.NE.0)DIRCT=(-ATAN2((YINT-YINC(IL)),(XINT-XINC(IL)))+DEGTN)
     1/.0174533
      IF(IAXIS.EQ.0)GOTO 8389
      IF(DIST.NE.0)DIRC=(-ATAN2((-XINT+XINC(IL)),(YINT-YINC(IL)))+DEGTN)
     1/.0174533
      DIRCT=DIRC
 8389 NDIRC=DIRCT
      TMINN=(DIRCT-NDIRC)*.6
      DIRCT=NDIRC
      DIRCT=DIRCT+TMINN
```

```fortran
      DIRCT=DEGREE(DIRCT)
      ISTORE=2
 5500 CALL TIMEPH(ILAP,IELT)
      N=3
      ILUUP=ILOOP
      CALL STOREC(ISTORE,ILUUP,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,
     1MIWSAR,ILAP,IELT,DIST,VEL,VELOC,DIRCT)
      IF(ILOKI.GT.1)
     1WRITE(KOT,1601)ILUUP,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(
     1L),L=1,9),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT
C
C     CLEAN OUT STOREC
      IF(ILOOP.EQ.NINAD)CALL STOREC(N,ILUUP,ANG1,ANG2,XINT,YINT,IHOUR,
     1MINUT,NSEC,MIWSAR,ILAP,IELT,DIST,VEL,VELOC,DIRCT    )
      IF(ILOOP.EQ.NINAD)
     1WRITE(KOT,1601)ILUUP,ANG1,ANG2,XINT,YINT,IHOUR,MINUT,NSEC,(MIWSAR(
     1L),L=1,9),(IELT(L),L=1,9),DIST,VEL,VELOC,DIRCT
      IETIMO=IETIM
 5000 CONTINUE
      LEN(JOBNUM)=ILOKI
      WRITE(KOT,1518)
C
C     CALCULATION OF TOTAL DISTANCE  AND AVERAGED VELOCITY AND TIME
C     BY USING FIRST AND LAST POINTS
      ADIST=SQRT(((XIN(JOBNUM,LEN(JOBNUM))-XIN(JOBNUM,1))**2)+
     1((YIN(JOBNUM,LEN(JOBNUM))-YIN(JOBNUM,1))**2))
      IATIME=ITIME(JOBNUM,LEN(JOBNUM))-ITIME(JOBNUM,1)
      IF(IATIME.EQ.0)AVEL=0.00
      IF(IATIME.NE.0)AVEL=ADIST/FLOAT(IATIME) *100.0
      ADIRCT=0.00
      IF(ADIST.NE.0.0)ADIRCT=(-ATAN2((YIN(JOBNUM,LEN(JOBNUM))-YIN(JOBNUM
     1,1)),(XIN(JOBNUM,LEN(JOBNUM))-XIN(JOBNUM,1)))+DEGTN)/.0174533
      IF(IAXIS.EQ.0)GOTO 9369
      IF(ADIST.NE..0)ADIRCT=(-ATAN2((-XIN(JOBNUM,LEN(JOBNUM))+XIN(JOBNUM
     1,1)),(YIN(JOBNUM,LEN(JOBNUM))-YIN(JOBNUM,1)))+DEGTN)/.0174533
 9369 CALL TIMEPH(IATIME,IELT)
```

```
      NDIRC=ADIRCT
      TMINN=(ADIRCT-NDIRC)*.6
      ADIRCT=NDIRC
      ADIRCT=ADIRCT+TMINN
      ADIRCT=DEGREE(ADIRCT)
      WRITE(KOT,1517)ADIST,(IELT(IZ),IZ=1,9),AVEL,ADIRCT
C
 5423 IF((IPUN.NE.0).AND.(INDRCT.EQ.0)) CALL PRAPN
      IF((IPUN.EQ.0).OR.(INDRCT.NE.0))CALL PRINTO
      IF(JUSIN.NE.0)GOTO 4000
C
C     IF ANY BUOY GROUP HAD TO BE DIVIDED BECAUSE OF BACKTRACKING BUOYS
C     THEN THE PROGRAM WILL DESTROY ALL INPUT FOR CONSTRAINTS AND OUTPUT
C     IT WILL THEN REPLACE THEM
      IF(IWARN(JOBNUM).EQ.0)GOTO 5950
      READ(KIN,1300)NDK
      NDKA=IABS(NDK)
      IF(NDKA.GE.(LEN(JOBNUM)-3))NDKA=(LEN(JOBNUM))/3
      ND1=(NDK+7)/8
C
C     DUMP INPUT POINTS
      IF(NDK.GT.0)READ(KIN,1700)(DUMP,I=1,ND1)
      IF((-NDK).GE.(LEN(JOBNUM)-3))NDK=-LEN(JOBNUM)/3
      IF((NDK.LE.0).AND.(IABS(NDK).GT.6))NDK=-6
      IF(NDKA.GT.6)NDKA=6
      NDKA=IABS(NDK)
      READ(KIN,1300)NOUT
      NOUTA=IABS(NOUT)
      NOUT1=(NOUT+7)/8
C
C     DUMP INPUT POINTS
      IF(NOUT.GT.0)READ(KIN,1700)(DUMP,I=1,NOUT1)
      IF(NOUT.EQ.0)NOUT=-LEN(JOBNUM)*3
      NOUTA=IABS(NOUT)
C
      IF(LEN(JOBNUM).GT.1)GOTO 5601
```

```
C
      WRITE(KOT,1333)JOBNUM,LEN(JOBNUM)                                MAIN0469
      IF(IPUN.NE.0)WRITE(KPCT,1333)JOBNUM,LEN(JCBNUM)                  MAIN0470
      GOTC 4000                                                        MAIN0471
 5601 CALL XOUTER                                                      MAIN0472
      IF(LEN(JCBNUM).GT.4)GCTO 5602                                    MAIN0473
      IARITY=1                                                         MAIN0474
      CALL INTERP(LEN(JOBNUM),IARITY,NCUTA)                            MAIN0475
      GOTO 5603                                                        MAIN0476
 5602 CALL AUTOD                                                       MAIN0477
      IF(IHELP.EQ.1)GOTO 9987                                          MAIN0478
      IARITY=1                                                         MAIN0479
      CALL DUCK(LEN(JOBNUM),XINO,YINO,NDKA,XDK,NOUTA,XCUT,YOUT,IARITY) MAIN0480
 5603 IF(IPUN.NE.0)CALL CUTER                                          MAIN0481
      IF(IPUN.EQ.0)CALL PRCT                                           MAIN0482
      GOTO 4000                                                        MAIN0483
 5950 READ(KIN,1300)NDK                                                MAIN0484
      IF(NDK.EQ.0)NDK=LEN(JCBNUM)/3                                    MAIN0485
      IF((-NDK).LT.(LEN(JOBNUM)-3))GOTC 6969                           MAIN0486
      NDK=-LEN(JOBNUM)/3                                               MAIN0487
      IF((NDK.LE.0).AND.(IABS(NDK).GT.6))NDK=-6                        MAIN0488
 6969 NDKA=IABS(NDK)                                                   MAIN0489
      IF(NDK.GT.0)READ(KIN,1500)(XDK(I),I=1,NDK)                       MAIN0490
      IF(LEN(JOBNUM).LT.5)GCTO 5957                                    MAIN0491
      IF(NDK.LT.0)CALL AUTCE                                           MAIN0492
      IF(IHELP.EQ.1)GOTO 9987                                          MAIN0493
      IF(NCKA.LT.(LEN(JOBNUM)-3    ))GOTO 5701                         MAIN0494
      NDK= LEN(JOBNUM)/3                                               MAIN0495
      IF(NCK.GT.6)NDK=6                                                MAIN0496
      NDKA=NDK                                                         MAIN0497
      CALL AUTOD                                                       MAIN0498
      IF(IHELP.EQ.1)GOTO 9987                                          MAIN0499
 5701 IF(NDK.GT.0)CALL DUCKT                                           MAIN0500
 5957 READ(KIN,1300)NOUT                                               MAIN0501
      IF(NCUT.EQ.0)NOUT=-LEN(JCBNUM)*3                                 MAIN0502
      NOUTA=IABS(NOUT)                                                 MAIN0503
                                                                       MAIN0504
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```
      IF(NCUT.LT.0)CALL XCUTER                                          MAIN0505
      NOUTA=IABS(NCUT)                                                  MAIN0506
      IF(NCUT.GT.0)READ(KIN,1500)(XOUT(I),I=1,NOUT)                     MAIN0507
C                                                                       MAIN0508
      IF(LEN(JOBNUM).GT.1)GOTO 5702                                     MAIN0509
C                                                                       MAIN0510
      WRITE(KOT,1333)JOBNUM,LEN(JOBNUM)                                 MAIN0511
      IF(IPUN.NE.0)WRITE(KPCT,1333)JOBNUM,LEN(JOBNUM)                   MAIN0512
      GOTO 4000                                                         MAIN0513
 5702 IF(NCUT.GT.0)CALL SORT(XCUT,NCUT)                                 MAIN0514
      IF(LEN(JOBNUM).GT.4)GOTO 5703                                     MAIN0515
      IARITY=1                                                          MAIN0516
      CALL INTERP(LEN(JOBNUM),IARITY,NCUTA)                             MAIN0517
      GOTO 5704                                                         MAIN0518
 5703 IARITY=1                                                          MAIN0519
      CALL DUCK(LEN(JOBNUM),XINO,YINO,NOKA,XOK,NOUTA,XCUT,YOUT,IARITY)  MAIN0520
 5704 IF(IPUN.EQ.0)CALL PRCT                                            MAIN0521
      IF(IPUN.NE.0)CALL CUTER                                           MAIN0522
 4000 JOBNUM=JOBNUM+1                                                   MAIN0523
C                                                                       MAIN0524
C     IF NO. OF BUOY SEGMENTS LESS THAN INPUT DO MORE                   MAIN0525
      IF(JOBNUM.LE.NCJOBA)GOTO 6000                                     MAIN0526
C                                                                       MAIN0527
C                                                                       MAIN0528
      IF((IMLINE.EQ.0).AND.(ITMARK.EQ.0))GOTO 9998                      MAIN0529
C                                                                       MAIN0530
C                                                                       MAIN0531
C                                                                       MAIN0532
C     ISTART MUST BE LESS THAN IFIN. THEREFORE IF THE BOUYS ARE TIMED   MAIN0533
C     FOR A PERIOD OVER 24 HOURS OR IF THEY ARE TIMED THROUGH A NEW DAY MAIN0534
C     IE.  START AT 230000 TO 000100 THEN  TIME MUST BE ADJUSTED        MAIN0535
C                                                                       MAIN0536
C     TIME OF STARTING HOURS                                            MAIN0537
C     TIME OF STARTING MINUTES                                          MAIN0538
C     TIME OF STARTING SECONDS                                          MAIN0539
C     TIME OF FINISH HOURS                                              MAIN0540
```

```
C       TIME OF FINISH MINUTES
C       TIME OF FINISH SECONDS
C       CT OF TIME HOURS
C       CT OF TIME MINUTES
C       CT OF TIME SECONDS
        READ(KIN,1600)NSHOUR,NSMIN,NSSEC,NFHOUR,NFMIN,NFSEC,IHDT,IMDT,ISDT
C
C
        IDT=IHDT*3600+IMDT*60+ISDT
        MWSTAR=MWHOUR*3600+MWMIN*60+MWSEC
        ISTART=NSHOUR*3600+NSMIN*60+NSSEC
        IFIN=NFHOUR*3600+NFMIN*60+NFSEC
        IF((((IMLINE.NE.0).AND.(IABS(NOJOBS).GT.1)).OR.(ISTRLN.NE.0))CALL
       1TIMELS
        IF(((IMLINE.EQ.0).AND.(ITMARK.NE.0).AND.(ISTRLN.EQ.0))CALL TIMEMK
  9998  NOJOBS=((JOBNUM-1)*NOJOBS)/IABS(NOJOBS)
        WRITE(KOT,1112)XMAX,XMIN,YMAX,YMIN
C
C       OUTPUT NUMBER OF SEGMENTS
        IF(IPUN.NE.0)WRITE(KPCT,1115)XMAX,XMIN,YMAX,YMIN
C       OUTPUT MAXIMUM DIMENSIONS
        WRITE(KOT,1801)NOJOBS
        IF(IPUN.NE.0)WRITE(KPCT,1901)NOJOBS
C
        GOTO 9999
C       ESCAPE CLAUSE
  9987  WRITE(KOT,1784)JOBNUM
        IF(IPUN.NE.0)WRITE(KPCT,1784)JOBNUM
  9999  STOP
  1795  FORMAT(10A8)
  1112  FORMAT('-',        XMAX=',F10.3,'       XMIN=',F10.3,'       YMAX=',
       1F10.3,'       YMIN=',F10.3///)
  1115  FORMAT(' REMOVE THIS CARD. PUT THE NEXT CARD RIGHT AFTER PARAMETER
       1 CHECK CARD.'/'        XMAX=',F10.3,'       XMIN=',F10.3,'       YMAX=',
       2F10.3,'       YMIN=',F10.3)
  1796  FORMAT(10A8)
```

```
      GOTO 800
  666 DXNCR=(XINO(INCO)-XINO(1))/(FLOAT(INCO)+1.)
      DXNCR=(DXNCR*(FLOAT(INCO)+1.))/100.
      J=100
      NPTS=100
      XOUT(1)=XINO(1)
      DO 802 M=2,99
      XOUT(M)=XOUT(M-1)+DXNCR
  802 CONTINUE
      WRITE(KOT,888)
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      IF(INCO.GT.4)GOTO 808
C
C     TYPE OF CURVE  LEAST SQUARES
C
      NDEGX=INCO
      IARITY=0
      CALL INTERP(NDEGX,IARITY,NPTS)
      GOTO 805
C
  808 INCA=INCO-4
C
C     TYPE OF CURVE  SPLINE
C
      XDK(1)=XINO(1)+DXNCR
      DO 801 M=2,INCA
      XDK(M)=XDK(M-1)+DXNCR
  801 CONTINUE
      IARITY=0
      CALL DUCK(INCO,XINO,YINO,INCA,XDK,100,XOUT,YOUT,IARITY)
  805 IF(IPUN.EQ.0)GOTO 803
      WRITE(KPOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      WRITE(KPOT,854)
      WRITE(KPOT,860)(YOUT(L),L=1,100)
      WRITE(KPOT,870)
      WRITE(KPOT,860)(XOUT(L),L=1,100)
```

```
      MBAK=MBAK + 1
      WRITE(KOT,877)
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      WRITE(KOT,877)
      WRITE(KOT,855)
      DO 704 L=1,J
      WRITE(KOT,865) YOUT(L),XOUT(L)
  704 CONTINUE
      IF(IPUN.EQ.0)GOTO 800
      WRITE(KPOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      WRITE(KPOT,854)
      WRITE(KPOT,860)(YOUT(L),L=1,J)
      WRITE(KPOT,870)
      WRITE(KPOT,860)(XOUT(L),L=1,J)
      GOTO 800
C
C
  647 MBAK=MBAK+1
      CALL RSORT(XINO,YINO,INCO)
C
C     SEGMENTED TIMELINE OR NOT
      IF(((ISTRLN.EQ.0).OR.(IMLINE.EQ.1)).AND.(INCO.GT.2))GOTO 666
C
      J=INCO
      WRITE(KOT,877)
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      IF(IPUN.EQ.0)GOTO 777
      WRITE(KPOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      WRITE(KPOT,854)
      WRITE(KPOT,860)          (YINO(L),L=1,INCO)
      WRITE(KPOT,870)
      WRITE(KPOT,860)      (XINO(L),L=1,INCO)
  777 WRITE(KOT,855)
```

```
1633 FORMAT('1',' *********** JOBNUMBER  ',I4,'  START **************')     MAIN0577
1000 FORMAT(8I2)                                                              MAIN0578
1C50 FORMAT(' PARMS IPUN=',I1,'INCRCT=',I1,'JUSIN=',I1,'ICONET=',I1,'IA      MAIN0579
    1XIS=',I1,'ITMARK=',I1,'IMLINE=',I1,'ISTRLN=',I1)                        MAIN0580
4344 FORMAT('-','CUPLICATE POINTS FOR ANGLES ',2F7.2/' POSITICNS IS (',      MAIN0581
    1F10.2,',',F1C.2,')'/' IN JOBNUMBER ',I3,'  ILCCP EQUALS  ',I3///)       MAIN0582
1100 FORMAT(I2)                                                               MAIN0583
1200 FORMAT(2F10.C,A8,2X,3I2,4X,I1,F9.0,I1,F9.0)                              MAIN0584
1C01 FORMAT(//' DEGREES THAT THE BASELINE IS CFF TRUE NORTH ',I4,'  MIN      MAIN0585
    1UTES',I3//' THE LENGHT OF THE BASELINE IS ',F10.2,'  METERS'//          MAIN0586
    2' ',A8,'  TIME =  ',1X,I3,':',I2,':',I2,' HH:MM:SS'//' Y MAXIMUM        MAIN0587
    3INPUTTED AS  ',F10.2,' METERS'///)                                      MAIN0588
1300 FORMAT(I10,8A8)                                                          MAIN0589
1598 FORMAT(/8A8//)                                                           MAIN0590
1518 FORMAT(//' AVERAGES FOR GROUP:     TOTAL DISTANCE    TOTAL TIME          MAIN0591
    1   AVEG. VEL.     AVERG. DIRCT.'/'                                      MAIN0592
    3 METERS          HH:MM:SS          CM/SEC            DEG.MIN')          MAIN0593
1517 FORMAT(23X,F10.2,6X,3I1,5X,F10.2,8X,F1C.2)                               MAIN0594
1500 FORMAT(8F10.C)                                                           MAIN0595
1101 FORMAT(' *********************** MAIN JCB START ***************')        MAIN0596
1600 FORMAT(3I2,4X,3I2,4X,3I2)                                                MAIN0597
1401 FORMAT('-',' ***** BACKTRACKING BUOY ***** JCBNUMBER ',I2,' POSITI       MAIN0598
    1CN ',I4,///)                                                            MAIN0599
1301 FORMAT('-',' ANGLE > PI CR =0.0      JOBNUMBER',I5,'  ILCOP POSITI       MAIN0600
    1CN ',I5,'  ANGLE 1 IS ',F6.2,'  ANGLE 2 IS  ',F6.2///)                  MAIN0601
1691 FORMAT(1X,I1C,2F10.2,2F10.1,I4,':',I2,':',I2,5X,9A1,2X,9A1,1F11.2,       MAIN0602
    12F11.1,F11.2)                                                           MAIN0603
1201 FORMAT('-','  POSIT.NC','   ANGLE 1','   ANGLE 2','   X CCORD',          MAIN0604
    1'   Y COCRD','  START TM',6X,A8          ,'   TIM ELPT','   DISTANCE     MAIN0605
    2','  BACK.VEL.','  CENT.VEL.','  DIRCT(N).'/                            MAIN0606
    3              1X,13X,'CEG.MIN    DEG.MIN    METERS    METERS  HH',      MAIN0607
    3':MM:SS      HH:MM:SS   HH:MM:SS     METERS     CM/SEC     CM/SEC       MAIN0608
    4','   DEG.MIN')                                                         MAIN0609
1784 FORMAT(' ************* WARNING THIS JOB, NUMBER ',I4,' HAS SLIPPED       MAIN0610
    1BY ALL'   /' PROTECTICNS SO IT WAS CANCELLED IN AUTOC ***********'/     MAIN0611
    2' EXAMINE WHATEVER DATA IS PRINTED OUT CR PUNCHED CUT BEFORE USING      MAIN0612
```

```
    3 IT'                       /' ********* MAIN JOB END ***************')   MAIN0613
1400 FORMAT(I1,F9.0,I1,F9.C,3I2)                                              MAIN0614
1700 FORMAT(F10.0)                                                            MAIN0615
1801 FORMAT('                    TCTAL NUMBER CF JCBS ECLALS',I3,'             MAIN0616
    1         '////' ***************** MAIN JOB END ***************')         MAIN0617
1333 FORMAT(  '0000 JCB NUMBER ',20X,I2,' NCT DONE INSUFFICIENT INPUT P        MAIN0618
    1CINTS =',I3)                                                             MAIN0619
1C22 FORMAT('1')                                                              MAIN0620
1501 FCRMAT(' REMCVE THIS CARD. PUT THE NEXT CARD RIGHT AFTER X AND Y M        MAIN0621
    1IN AND MAX CARD '/' TCTAL NUMBER OF JOBS DONE =  ',I3/' **********        MAIN0622
    2************** MAIN JCB END **********************************')          MAIN0623
     END                                                                      MAIN0624
```

```
C       TIMELINES SUBROUTINE ***********************
C       CALCULATES A SMOOTH  OR SEGMENTED TIMELINE
        SUBROUTINE TIMELS
        COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),ICT,
       1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XIND(99),
       2YIND(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IADICH,XINT,
       3YINT,INCROT,JUSIN,IMLINE
        COMMON /AREA2/ XMAX,XMIN,YMAX,YMIN
        COMMON /AREA7/ TCHAR,MWSTAR
        LOGICAL*1 MTIME(9),NTIME(9),MISTAR(9),MIFIN(9),MIDT(9),MMWSTA(9)
        REAL*8 TCHAR
        RANGE=(YMAX-YMIN)/40.
        XRANGE=RANGE/4.
        MBAK=0
        WRITE(KOT,888)
        WRITE(KOT,890)
        IF(IPUN.NE.0)WRITE(KPOT,890)
        CALL TIMEPH(ISTART,MISTAR)
        CALL TIMEPH(IFIN,MIFIN)
        CALL TIMEPH(IDT,MIDT)
        CALL TIMEPH(MWSTAR,MMWSTA)
        WRITE(KOT,895)(MISTAR(L),L=1,9),(MIFIN(L),L=1,9),(MIDT(L),L=1,9)
       1,(MMWSTA(L),L=1,9)
        IF(IPUN.NE.0)WRITE(KPOT,895)(MISTAR(L),L=1,9),(MIFIN(L),L=1,9),
       1(MIDT(L),L=1,9),(MMWSTA(L),L=1,9)
        NIDTS=(IFIN-ISTART)/IDT +1
        DO 800 N=1,NIDTS
        I=ISTART+IDT*(N-1)
        CALL TIMEPH(I,NTIME)
        IZ=ISTART-MWSTAR+ IDT*(N-1)
        CALL TIMEPH(IZ,MTIME)
        NDEGX=0
        INCO=0
        JOBNNN=JOBNUM-1
C
C       CALCULATES POSITION OF A TIMEMARK BY SEARCHING ALL ARRAYS FOR
```

```
C       ALL TIMES     DOES A LINEAR INTERPOLATION IF TIME IN THE MIDDLE
C       OF INPUTTED TIMES
        DO 810 JOB=1,JOBNNN
        IF((IWARN(JOB).NE.0).AND.(ISTRLN.NE.1))GOTO 810
        LENJ1=LEN(JOB)-1
        IF(LENJ1.LT.1)GOTO 810
        DO 820 K=1,LENJ1
        IF(I.EQ.ITIME(JOB,K))GOTO 830
        IF(((I.GT.ITIME(JOB,K)).AND.(I.LT.ITIME(JOB,K+1))).OR.(((I.LT.
       1ITIME(JOB,K)).AND.(I.GT.ITIME(JOB,K+1))))GOTO 840
  820  CONTINUE
        GOTO 810
  830  INCC=INCC+1
        XINC(INCC)=YIN(JOB,K)
        YINO(INCC)=XIN(JOB,K)
        GOTO 810
  840  INCO=INCO+1
        IDENOM=ITIME(JOB,K+1)-ITIME(JOB,K)
        NUMER=I-ITIME(JOB,K)
        RATIO=FLOAT(NUMER)/FLOAT(IDENOM)
        XINC(INCC)=YIN(JOB,K) + (YIN (JOB,K+1)-YIN (JOB,K))*RATIO
        YINC(INCC)=XIN(JOB,K) + (XIN (JOB,K+1)-XIN (JOB,K))*RATIO
  810  CONTINUE
C
        IF(INCO.GT.1)GOTO 847
C
C       CHECK ON WHETHER A TIMEMARK IS TO BE DONE IF INSUFFICIENT POINTS
C       CALCULATIONS BELOW
        IF((INCC.LT.1).OR.(ITMARK.NE.1))GOTO 800
        XOUT(1)=XINC(1)-RANGE
        YOUT(1)=YINO(1)
        DO 10 I9=2,5
        XOUT(I9)=XOUT(I9-1) + XRANGE
        YOUT(I9)=YINC(1)
   10  CONTINUE
        J=5
```

```
      MBAK=MBAK + 1                                                     TIML0073
      WRITE(KOT,877)                                                    TIML0074
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK      TIML0075
      WRITE(KOT,377)                                                    TIML0076
      WRITE(KOT,855)                                                    TIML0077
      DO 704 L=1,J                                                      TIML0078
      WRITE(KOT,865) YOUT(L),XOUT(L)                                    TIML0079
  704 CONTINUE                                                          TIML0080
      IF(IPUN.EQ.0)GOTO 800                                             TIML0081
      WRITE(KPOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK     TIML0082
      WRITE(KPOT,854)                                                   TIML0083
      WRITE(KPOT,860)(YOUT(L),L=1,J)                                    TIML0084
      WRITE(KPOT,870)                                                   TIML0085
      WRITE(KPOT,860)(XOUT(L),L=1,J)                                    TIML0086
      GOTO 800                                                          TIML0087
C                                                                       TIML0088
C                                                                       TIML0089
  647 MBAK=MBAK+1                                                       TIML0090
      CALL RSORT(XIND,YIND,INCO)                                        TIML0091
C                                                                       TIML0092
C     SEGMENTED TIMELINE OR NOT                                         TIML0093
      IF(((ISTRLN.EQ.0).OR.(IMLINE.EQ.1)).AND.(INCO.GT.2))GOTO 666      TIML0094
C                                                                       TIML0095
      J=INCO                                                            TIML0096
      WRITE(KOT,877)                                                    TIML0097
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK      TIML0098
      IF(IPUN.EQ.0)GOTO 777                                             TIML0099
      WRITE(KPOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK     TIML0100
      WRITE(KPOT,854)                                                   TIML0101
      WRITE(KPOT,860)         (YIND(L),L=1,INCO)                        TIML0102
      WRITE(KPOT,970)                                                   TIML0103
      WRITE(KPOT,860)      (XIND(L),L=1,INCO)                           TIML0104
  777 WRITE(KOT,855)                                                    TIML0105
      DO 555 L=1,INCO                                                   TIML0106
      WRITE(KOT,865) YIND(L),XIND(L)                                    TIML0107
  555 CONTINUE                                                          TIML0108
```

```
      GOTO 800                                                         TIML0109
  666 DXNCR=(XINO(INCO)-XINO(1))/(FLOAT(INCO)+1.)                      TIML0110
      DXNCR=(DXNCR*(FLOAT(INCO)+1.))/100.                              TIML0111
      J=100                                                            TIML0112
      NPTS=100                                                         TIML0113
      XOUT(1)=XINO(1)                                                  TIML0114
      DO 802 M=2,99                                                    TIML0115
      XOUT(M)=XOUT(M-1)+DXNCR                                          TIML0116
  802 CONTINUE                                                         TIML0117
      WRITE(KOT,888)                                                   TIML0118
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK     TIML0119
      IF(INCO.GT.4)GOTO 808                                            TIML0120
C                                                                      TIML0121
C     TYPE OF CURVE  LEAST SQUARES                                     TIML0122
C                                                                      TIML0123
      NDEGX=INCO                                                       TIML0124
      IARITY=0                                                         TIML0125
      CALL INTERP(NDEGX,IARITY,NPTS)                                   TIML0126
      GOTO 805                                                         TIML0127
C                                                                      TIML0128
  808 INCA=INCO-4                                                      TIML0129
C                                                                      TIML0130
C     TYPE OF CURVE  SPLINE                                            TIML0131
C                                                                      TIML0132
      XDK(1)=XINO(1)+DXNCR                                             TIML0133
      DO 801 M=2,INCA                                                  TIML0134
      XDK(M)=XDK(M-1)+DXNCR                                            TIML0135
  801 CONTINUE                                                         TIML0136
      IARITY=0                                                         TIML0137
      CALL DUCK(INCO,XINO,YINO,INCA,XDK,100,XOUT,YOUT,IARITY)          TIML0138
  805 IF(IPUN.EQ.0)GOTO 803                                            TIML0139
      WRITE(KPOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK    TIML0140
      WRITE(KPOT,854)                                                  TIML0141
      WRITE(KPOT,860)(YOUT(L),L=1,100)                                 TIML0142
      WRITE(KPOT,870)                                                  TIML0143
      WRITE(KPOT,860)(XOUT(L),L=1,100)                                 TIML0144
```

```
 803 WRITE(KOT,855)                                                    TIML0145
     DO 804 L=1,100                                                    TIML0146
     WRITE(KOT,865) YOUT(L),XOUT(L)                                    TIML0147
 804 CONTINUE                                                          TIML0148
 800 CONTINUE                                                          TIML0149
     IF(IPUN.NE.0)WRITE(KPCT,885)MBAK                                  TIML0150
     IF(IPUN.NE.0)WRITE(KPCT,880)                                      TIML0151
     WRITE(KOT,885)MBAK                                                TIML0152
     WRITE(KOT, 880)                                                   TIML0153
     RETURN                                                            TIML0154
 895 FORMAT(' STARTING TIME= ' ,9A1, '  FINISHING TIME= ' ,9A1/ '  DT  TIML0155
    1OF TIME=  ',9A1,'  WATER OR MOONTIME =  ',9A1)                    TIML0156
 888 FORMAT('1')                                                       TIML0157
 890 FORMAT(' ****************TIMELINES START ***********************') TIML0158
 950 FORMAT(' TIMELINES NORMAL TIME=  ',9A1,'   TIME AFTER ',A8,'=',9A1 TIML0159
    1/'  OUTPUT POINTS=  ',I4,'   TIMELINES NO.=  ',I4)                TIML0160
 854 FORMAT(' XOUTS IBM 1130 *****************************************') TIML0161
 860 FORMAT(8F10.3)                                                    TIML0162
 870 FORMAT(' YOUTS IBM 1130 *****************************************') TIML0163
 865 FORMAT(F10.3,5X,F10.3)                                            TIML0164
 880 FORMAT(' ************************ TIMELINES END *****************') TIML0165
 855 FORMAT(' IBM XOUTS',5X,' IBM YOUTS')                              TIML0166
 885 FORMAT(' NO. OF TIMELINES ',I3,'   PUT THIS CARD JUST AFTER TIMELI TIML0167
    1NES START')                                                       TIML0168
 877 FORMAT('-')                                                       TIML0169
     END                                                               TIML0170
```

```
C      TIMEMARK SUBROUTINE ************************
C      SUBROUTINE TC CALCULATE TIMEMARKS(TICKLIKE)ONLY
       SUBROUTINE TIMEMK
       COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPCT,KOT,KIN,XIN(40,99),IDT,
      1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XIND(99),
      2YINC(99),XOUT(500),YCUT(500),NIN,ITMARK,ICONET,ISTRLN,IACICH,XINT,
      3YINT,INDRCT,JUSIN,IMLINE
       COMMON /AREA2/ XMAX,XMIN,YMAX,YMIN
       COMMON /AREA7/ TCHAR,MWSTAR
       LOGICAL*1 MTIME(9),NTIME(9),MISTAR(9),MIFIN(9),MIDT(9),MMWSTA(9)
       REAL*8 TCHAR
       JOBNNN=JOBNUM-1
       INCC=1
       MBAK=0
       J=5
       RANGE=(YMAX-YMIN)/40.
       XRANGE=RANGE/5.
       WRITE(KOT,666)
       WRITE(KOT,890)
       IF(IPUN.NE.0)WRITE(KPCT,890)
       CALL TIMEPH(ISTART,MISTAR)
       CALL TIMEPH(IFIN,MIFIN)
       CALL TIMEPH(IDT,MIDT)
       CALL TIMEPH(MWSTAR,MMWSTA)
       WRITE(KOT,895)(MISTAR(L),L=1,9),(MIFIN(L),L=1,9),(MIDT(L),L=1,9)
      1,(MMWSTA(L),L=1,9)
       IF(IPUN.NE.0)WRITE(KPCT,895)(MISTAR(L),L=1,9),(MIFIN(L),L=1,9),
      1(MIDT(L),L=1,9),(MMWSTA(L),L=1,9)
       NIDTS=(IFIN-ISTART)/IDT +1
C
C      CALCULATIONS OF TIMEMARKS  DOES A LINEAR  APPROX.  IF INBETWEEN
       DO 800 N=1,NIDTS
       I=ISTART+IDT*(N-1)
       CALL TIMEPH(I,NTIME)
       IZ=ISTART-MWSTAR+ IDT*(N-1)
       CALL TIMEPH(IZ,MTIME)
```

```
      DO 810 JOB=1,JOBNNN
      LENJ1=LEN(JOB)-1
      IF(LENJ1.LT.1)GOTO 810
      DO 820 K=1,LENJ1
      IF(I.EQ.ITIME(JOB,K))GOTO 830
      IF(((I.GT.ITIME(JOB,K)).AND.(I.LT.ITIME(JOB,K+1))).OR.(((I.LT.
     1ITIME(JOB,K)).AND.(I.GT.ITIME(JOB,K+1))))GOTO 840
  820 CONTINUE
      GOTO 810
  830 XINO(INCO)=YIN(JOB,K)
      YINO(INCO)=XIN(JOB,K)
      GOTO 815
  840 IDENOM=ITIME(JOB,K+1)-ITIME(JOB,K)
      NUMER=I-ITIME(JOB,K)
      RATIO=FLOAT(NUMER)/FLOAT(IDENOM)
      XINO(INCO)=YIN(JOB,K) + (YIN (JOB,K+1)-YIN (JOB,K))*RATIO
      YINO(INCO)=XIN(JOB,K) + (XIN (JOB,K+1)-XIN (JOB,K))*RATIO
  815 XOUT(1)=XINO(1)-RANGE
      YOUT(1)=YINO(1)
      DO 816 I9=2,J
      XOUT(I9)=XOUT(I9-1) + XRANGE*(I9-1)
      YOUT(I9)=YINO(1)
  816 CONTINUE
      MBAK=MBAK + 1
      WRITE(KOT,888)
      WRITE(KOT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      WRITE(KOT,877)
      WRITE(KOT,855)
      DO 804 L=1,J
      WRITE(KOT,865) YOUT(L),XOUT(L)
  804 CONTINUE
      IF(IPUN.EQ.0)GOTO 810
      WRITE(KPCT,850)(NTIME(L),L=1,9),TCHAR,(MTIME(L),L=1,9),J,MBAK
      WRITE(KPCT,854)
      WRITE(KPCT,860)(YOUT(L),L=1,J)
      WRITE(KPCT,870)
```

```
      WRITE(KPCT,860)(XOUT(L),L=1,J)                                    TIMK0073
  810 CONTINUE                                                          TIMK0074
  800 CONTINUE                                                          TIMK0075
C                                                                       TIMK0076
      IF(IPUN.NE.0)WRITE(KPCT,885)MBAK                                  TIMK0077
      IF(IPUN.NE.0)WRITE(KPCT,880)                                      TIMK0078
      WRITE(KOT,885)MBAK                                                TIMK0079
      WRITE(KOT, 880)                                                   TIMK0080
      RETURN                                                            TIMK0081
  666 FORMAT('1')                                                       TIMK0082
  895 FORMAT(' STARTING TIME= ' ,9A1,  '  FINISHING TIME= ' ,9A1/ '  DT TIMK0083
     1CF TIME=  ',9A1,'  WATER OR MOONTIME =   ',9A1)                   TIMK0084
  888 FORMAT('-')                                                       TIMK0085
  890 FORMAT(' *****************TIMEMARKS START ***********************')TIMK0086
  850 FORMAT(' TIMEMARKS NORMAL TIME=  ',9A1,'   TIME AFTER ',A8,'=',9A1TIMK0087
     1/'  OUTPUT POINTS=  ',I4,'   TIMEMARKS NO.=  ',I4)                TIMK0088
  854 FORMAT(' XOUTS IBM 1130 *******************************************')TIMK0089
  860 FORMAT(8F10.3)                                                    TIMK0090
  870 FORMAT(' YOUTS IBM 1130 *******************************************')TIMK0091
  865 FORMAT(F10.3,5X,F10.3)                                            TIMK0092
  880 FORMAT(' *********************** TIMEMARKS END *****************')TIMK0093
  855 FORMAT(' IBM XOUTS',5X,' IBM YOUTS')                              TIMK0094
  885 FORMAT(' NO. OF TIMEMARKS ',I3,'   PUT THIS CARD JUST AFTER TIMEMATIMK0095
     1RKS START')                                                       TIMK0096
  877 FORMAT(/)                                                         TIMK0097
      END                                                               TIMK0098
```

```
C     DUCK SUBROUTINE ****************************                      DUCK0001
C     SPLINE CURVE SUBROUTINE                                           DUCK0002
      SUBROUTINE DUCK(NIN,XIN,YIN,NDK,XDK,NOUT,XOUT,YOUT,IARITY)        DUCK0003
      DIMENSION XIN(1),YIN(1),XOUT(1),YOUT(1),XDK(1),XN(105),XD(25)     DUCK0004
     1 ,H(105,25),C(27),EXTRA(105)                                      DUCK0005
      COMMON /AREA2/ XMAX,XMIN,YMAX,YMIN                                DUCK0006
      DR(XX,SS)=(1.-XX)*((1.-SS**2)-(1.-XX)**2)/(2.*SS*(1.-SS)**2)      DUCK0007
      DL(XX,SS)=XX*(SS*(2.-SS)-XX**2)/(2.*SS**2*(1.-SS))                DUCK0008
      NEQ=NDK+2                                                         DUCK0009
      DEL=XIN(NIN)-XIN(1)                                               DUCK0010
      DO 3 N=1,NIN                                                      DUCK0011
    3 XN(N)=(XIN(N)-XIN(1))/DEL                                         DUCK0012
      DO 7 N=1,NDK                                                      DUCK0013
    7 XD(N)=(XDK(N)-XIN(1))/DEL                                         DUCK0014
      DO 1 M=1,NIN                                                      DUCK0015
      H(M,NDK+1)=1.0                                                    DUCK0016
      H(M,NDK+2)=XN(M)                                                  DUCK0017
      H(M,NDK+3)=YIN(M)                                                 DUCK0018
      DO 1 N=1,NDK                                                      DUCK0019
      IF(XN(M).GT.XD(N)) GO TO 2                                        DUCK0020
      H(M,N)=DL(XN(M),XD(N))                                            DUCK0021
      GO TO 1                                                           DUCK0022
    2 H(M,N)=DR(XN(M),XD(N))                                            DUCK0023
    1 CONTINUE                                                          DUCK0024
      CALL GLSQ(H,C,EXTRA,NIN,NEQ,BUG,0.00001,0.00001)                  DUCK0025
      ITIPE=1                                                           DUCK0026
C     PRINT COEFFICIENTS OF SPLINE FIT                                  DUCK0027
      CALL COEF(C   ,NDK,ITIPE)                                         DUCK0028
      DO 4 M=1,NOUT                                                     DUCK0029
      XQ=(XOUT(M)-XIN(1))/DEL                                           DUCK0030
      YOUT(M)=C(NDK+1)+C(NDK+2)*XQ                                      DUCK0031
      DO 4 N=1,NDK                                                      DUCK0032
      IF(XQ.GT.XD(N)) GO TO 5                                           DUCK0033
      YOUT(M)=YOUT(M)+C(N)*DL(XQ,XD(N))                                 DUCK0034
      GO TO 4                                                           DUCK0035
    5 YOUT(M)=YOUT(M)+C(N)*DR(XQ,XD(N))                                 DUCK0036
```

```
 4    CONTINUE                                                          DUCK0037
C                                                                       DUCK0038
C     DO DIMENSION SCAN  IARITY CHECKS ON FROM WHERE THE DIMENSIONS CAME DUCK0039
C     TIMELINES INVOLVES A ROTATION OF AXIS                             DUCK0040
      DO 17 M=1,NCUT                                                    DUCK0041
      IF(IARITY.EQ.0)GOTO 100                                           DUCK0042
      IF(XCUT(M).GT.XMAX)XMAX=XOUT(M)                                   DUCK0043
      IF(XCUT(M).LT.XMIN)XMIN=XOUT(M)                                   DUCK0044
      IF(YCUT(M).GT.YMAX)YMAX=YOUT(M)                                   DUCK0045
      IF(YCUT(M).LT.YMIN)YMIN=YOUT(M)                                   DUCK0046
      GOTO 17                                                           DUCK0047
  100 IF(YCUT(M).GT.XMAX)XMAX=YOUT(M)                                   DUCK0048
      IF(YCUT(M).LT.XMIN)XMIN=YOUT(M)                                   DUCK0049
   17 CONTINUE                                                          DUCK0050
      RETURN                                                            DUCK0051
      END                                                               DUCK0052
```

```
C     GLSQ SUBROUTINE ****************************         GLSQ0001
C     AUGMENTED MATRIX TO SCLVE SIMULTANEOUS ECUATICNS      GLSQ0002
      SUBROUTINE GLSQ(A,X,IL,N,M,ALPHA,E1,E2)               GLSQ0003
      DIMENSION A(105,25),X(1),IL(1)                        GLSQ0004
      MM=M+1                                                GLSQ0005
      LL=1                                                  GLSQ0006
      DO 60 J=1,MM                                          GLSQ0007
60    IL(J)=0                                               GLSQ0008
      I=1                                                   GLSQ0009
      DO 3 K=1,MM                                           GLSQ0010
      II=I+1                                                GLSQ0011
      DO 4 J=II,N                                           GLSQ0012
      IF(ABS(A(J,K))-E1)4,4,6                               GLSQ0013
6     T1=SQRT((A(J,K))**2+(A(I,K))**2)                      GLSQ0014
      S=A(J,K)/T1                                           GLSQ0015
      C=A(I,K)/T1                                           GLSQ0016
      DO 5 L=K,MM                                           GLSQ0017
      T2=C*A(I,L)+S*A(J,L)                                  GLSQ0018
      A(J,L)=-S*A(I,L)+C*A(J,L)                             GLSQ0019
5     A(I,L)=T2                                             GLSQ0020
      LL=LL+1                                               GLSQ0021
4     CONTINUE                                              GLSQ0022
      IF(ABS(A(I,K))-E2)3,3,8                               GLSQ0023
8     IL(K)=I                                               GLSQ0024
      I=I+1                                                 GLSQ0025
3     CONTINUE                                              GLSQ0026
      X(MM)=-1.0                                            GLSQ0027
      II=M                                                  GLSQ0028
      DO 35 I=1,M                                           GLSQ0029
35    X(I)=0.0                                              GLSQ0030
      DO 30 J=1,M                                           GLSQ0031
      IF(IL(II))30,30,31                                    GLSQ0032
31    S=0.0                                                 GLSQ0033
      LL=II+1                                               GLSQ0034
      I=IL(II)                                              GLSQ0035
      DO 32 K=LL,MM                                         GLSQ0036
```

```
 32   S=S+A(I,K)*X(K)                                                GLSQ0037
      X(II)=-S/A(I,II)                                               GLSQ0038
 30   II=II-1                                                        GLSQ0039
      IF(IL(MM))50,51,50                                             GLSQ0040
 51   ALPHA=0.0                                                      GLSQ0041
      GO TO 52                                                       GLSQ0042
 50   I=IL(MM)                                                       GLSQ0043
      ALPHA=A(I,MM)                                                  GLSQ0044
 52   RETURN                                                         GLSQ0045
      END                                                            GLSQ0046
```

```
C     AUTOC SUBROUTINE ****************************
C     SUBROUTINE TC PLACE PCSITIONS OF CONSTRAINTS IF  -CONSTRAINTS      AUDK0001
C     INPUTTED.                                                          AUDK0002
C     PLACES CONSTRAINTS AT AREAS OF GREATEST CURVATURE   IE 2ND DERIVAT AUDK0003
      SUBROUTINE ALTOC                                                   AUDK0004
      COMMON IPUN,JCBNUM,IWRN(40),LEN(40),KPOT,KJT,KIN,XIN(40,99),IDT,   AUDK0005
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINC(99),    AUDK0006
     2YINC(99),XOUT(500),YCUT(500),NIN,ITMARK,ICONET,ISTRLN,IACICH,XINT, AUDK0007
     3YINT,INDROT,JLSIN,IMLINE                                           AUDK0008
      COMMON /AREA1/ IHELP                                               AUDK0009
      DIMENSION ACURS(97)                                                AUDK0010
      NXNDK=IABS(NDKA)                                                   AUDK0011
C                                                                        AUDK0012
C     ESCAPE CLAUSE                                                      AUDK0013
      IF(NXNDK.GE.(LEN(JOBNUM)-3   ))GOTO 298                            AUDK0014
      NIN2=LEN(JCBNUM)-2                                                 AUDK0015
      SUMAC=0.                                                           AUDK0016
      DO 200 I=1,NIN2                                                    AUDK0017
C                                                                        AUDK0018
C     CALCULATION OF SECOND  DERIVATIVE                                  AUDK0019
      ACURS(I)=((((YIN (JCBNUM,I)-YIN (JOBNUM,I+1)) / (XIN (JOBNUM,I)-   AUDK0020
     1XIN (JOBNUM,I+1))) -((YIN (JCBNUM,I+1)-YIN (JCBNUM,I+2)) / (XIN    AUDK0021
     2(JOBNUM,I+1)-XIN (JOBNUM,I+2)))) / ((XIN (JOBNUM,I)-XIN (JOBNUM,   AUDK0022
     3I+2))/ 2.))                                                        AUDK0023
      SUMAC=SUMAC+ABS(ACURS(I))                                          AUDK0024
  200 CONTINUE                                                           AUDK0025
      NOLD=0                                                             AUDK0026
      TEMP=0.                                                            AUDK0027
      CURPC=SUMAC/FLOAT(NXNDK)                                           AUDK0028
      INDEX1=1                                                           AUDK0029
  225 DO 210 K=INDEX1,NIN2                                               AUDK0030
      XNDK=ABS((ABS(ACURS(K))+TEMP) / CURPD)                             AUDK0031
      NNDK=XNDK+.501                                                     AUDK0032
      DIF=(XNDK-FLOAT(NNDK))+.002                                        AUDK0033
      IF(NNDK.LT.1)GOTO 220                                              AUDK0034
      JKL=K                                                              AUDK0035
                                                                         AUDK0036
```

```
      XNDK=NNDK
      TEMP=DIF*CURPD
      XNCR=(XIN (JOBNUM,K+2)  -XIN (JOBNUM,K))/(XNDK+1.)
      TXINC=0.
      DO 230 I=1,NNDK
      NOLD=NOLD+1
      TXINC=TXINC+XNCR
      IF(NOLD.GT.NXNDK)GOTO 240
      XDK(NOLD)=XIN (JOBNUM,K)+TXINC
  230 CONTINUE
      GOTO 210
  220 TEMP=TEMP+DIF*CURPD
  210 CONTINUE
      IF(NOLD.GE.NXNDK)GOTO 240
      IF((JKL+1).LT.NIN2)INDEX1=JKL+1
      IF((JKL+1).GE.NIN2)INDEX1=1
      CURPD=CURPD/2.0
      GOTO 225
  240 DO 235 MNK=1,NXNDK
      DO 238 MNM=1,NXNDK
      IF(MNK.EQ.MNM)GOTO 238
      IF(ABS(XDK(MNK)-XDK(MNM)).GE.(XNCR*.66))GOTO 238
      XDK(MNM)=(XIN(JOBNUM,(LEN(JOBNUM)))-XDK(MNM))/3.0   +XDK(MNM)
      GOTO 240
  238 CONTINUE
  235 CONTINUE
C
C     CALLING A TEST OF ITS VALUES
      CALL DUCKT
      GOTO 299
  298 IHELP=1
  299 RETURN
```

```
C     DUCKT SUBROUTINE ***************************
C     CHECKS ON POSITIONS OF CONSTRAINTS
C     WILL VOID THEM IF POSITIONED TO CLOSE TO END
      SUBROUTINE DUCKT
      COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINC(99),
     2YINO(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IADICH,XINT,
     3YINT,INORCT,JLSIN,IMLINE
      CALL SORT(XDK,NDKA)
      J1=0
      NINA=LEN(JOBNUM)
  989 DO 990 I=1,NDKA
      J1=J1 + 1
      XLOW=XDK(I)-XINO(1)
      HIGH=XINO(NINA)-XDK(I)
      IF((XLOW.GT.3.).OR.(HIGH.LT.3.))GOTO 990
      IF(XLOW.GT.3.)GOTO 991
      ADD=(XINO(2)-XINO(1))/2. +XINO(1)
      WRITE(KOT,981)I,XDK(I),ADD
      XDK(I)=ADD
C
C     TEST TO PREVENT INFINITE LOOP
      IF(J1.GT.2)GOTO 95
      GOTO 989
  991 SUB=(XINO(NINA)-XINO(NINA-1))/2. +XINO(NINA-1)
      WRITE(KOT,981)I,XDK(I),SUB
      XDK(I)=SUB
C
C     TEST TO PREVENT INFINITE LOOP
      IF(J1.GT.2)GOTO 95
      GOTO 989
  990 CONTINUE
   95 XDK(I)=(XINO(NINA)-XINO(1))/2.
      CALL PRITDK
      RETURN
  981 FORMAT('-','DUCK NUMBER  ',I3,' PRESENT VALUE ',F10.3,'  HAS NOW
```

```
1BEEN SUBSTITLED WITH THE VALUE ',F10.3///)                                    DUKT0037
 END                                                                           DUKT0038
```

```
C     PRITCK SUBROUTINE *************************
C     PRINTS OUT POSITIONS OF CONSTRAINTS ON SPLINE CURVE                PRDK0001
      SUBROUTINE PRITDK                                                  PRDK0002
      COMMON IPUN,JCBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,  PRDK0003
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XIND(99),    PRDK0004
     2YIND(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IACICH,XINT, PRDK0005
     3YINT,INORCT,JUSIN,INLINE                                           PRDK0006
      WRITE(KOT,250)NDKA,JCBNUM                                          PRDK0007
      NXNDK=IABS(NDKA)                                                   PRDK0008
      DO 245 I=1,NXNDK                                                   PRDK0009
      WRITE(KOT,260)XDK(I)                                               PRDK0010
  245 CONTINUE                                                           PRDK0011
      RETURN                                                             PRDK0012
  250 FORMAT('-',I4,' IS THE NUMBER OF DUCKS USED FOR JOB NUMBER ',I4/   PRDK0013
     1//' XDK COORDINATES')                                              PRDK0014
  260 FORMAT(F10.3)                                                      PRDK0015
      END                                                                PRDK0016
                                                                         PRDK0017
```

```
C       INTERP SLBRCLTINE **************************                        INTP0001
C       SUBRCUTINE THAT PREPARES ARGUEMENTS FOR GLSQXZ                      INTP0002
C       ALSC OUTPUTS PCINTS LSING GLSQXZ'S COEFFICIENTS                     INTP0003
        SUBROUTINE INTERP(NDEGX,IARITY,NPTS)                                INTP0004
        COMMCN IPUN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,   INTP0005
       1ISTART,IFIN,YIN(40,99),ITIME(40,99),NCKA,NOUT,XDK(20),XINO(99),     INTP0006
       2YINO(99),XOUT(500),YCLT(500),NIN,ITMARK,ICONET,ISTRLN,IALICH,XINT,  INTP0007
       3YINT,INORCT,JUSIN,IMLINE                                            INTP0008
        COMMCN /AREA2/ XMAX,XMIN,YMAX,YMIN                                  INTP0009
        CIMENSION PARAM(4)                                                  INTP0010
        IF(NCEGX.GE.3)NCDX=3                                                INTP0011
        IF(NCEGX.EQ.2)NODX=2                                                INTP0012
        CALL GLSQXZ(NDCX,PARAM,NDEGX)                                       INTP0013
        CO 99 K=1,NPTS                                                      INTP0014
        YOUT(K)=0.0                                                         INTP0015
        CO 111 I=1,NCDX                                                     INTP0016
        NPOWER=I-1                                                          INTP0017
        YOUT(K)=YOUT(K) + PARAM(I)*XOUT(K)**NPOWER                          INTP0018
  111   CONTINUE                                                            INTP0019
C                                                                           INTP0020
C       CIMENSION CHECK  ON FRCM WHERE VALUES CAME FRCM  TIMELINES RCT.AXS  INTP0021
        IF(IARITY.EQ.0)GOTO 1C0                                             INTP0022
        IF(XOUT(K).GT.XMAX)XMAX=XOUT(K)                                     INTP0023
        IF(XCUT(K).LT.XMIN)XMIN=XOUT(K)                                     INTP0024
        IF(YCUT(K).GT.YMAX)YMAX=YOUT(K)                                     INTP0025
        IF(YCUT(K).LT.YMIN)YMIN=YOUT(K)                                     INTP0026
        GOTC 99                                                             INTP0027
  100   IF(YOUT(K).GT.XMAX)XMAX=YOUT(K)                                     INTP0028
        IF(YCUT(K).LT.XMIN)XMIN=YOUT(K)                                     INTP0029
   99   CONTINUE                                                            INTP0030
        WRITE(KOT,25C)                                                      INTP0031
        ITIPE=0                                                             INTP0032
        C                                                                   INTP0033
C       WRITE CUEFFICIENTS FCR LEAST SQUARES FIT                            INTP0034
        CALL CCEF(PARAM,NCCX,ITIPE)                                         INTP0035
        RETURN                                                              INTP0036
```

```
250 FORMAT(//' LISTING OF COEFFICIENTS OF LEAST SQUARES METHOD'/)         INTP0037
    END                                                                    INTP0038
```

```
C     GLSQXZ SUBROUTINE **************************                     GLXZ0001
C     LEAST SQUARES ROUTINE  M.I.T.  COMPUTER MATHLIB.                 GLXZ0002
      SUBROUTINE GLSQXZ(NPARAM,PARAM,NPTS)                             GLXZ0003
C                                                                      GLXZ0004
C     NPARAM IS THE NUMBER OF COEFFICIENTS YOU WANT RETURNED           GLXZ0005
C     PARAM IS A VECTOR CONTAINING THE COEFFICIENTS                    GLXZ0006
C                                                                      GLXZ0007
      COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPCT,KOT,KIN,XIN(40,99),IDT,GLXZ0008
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINO(99),  GLXZ0009
     2YINO(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IACICH,XINT,GLXZ0010
     3YINT,INOROT,JUSIN,IMLINE                                         GLXZ0011
      DIMENSION A(100),PARAM(1),XPOWER(6)                              GLXZ0012
C  ZERO ARRAYS BEFORE SUMMING.                                         GLXZ0013
   10 DO 20 I = 1, NPARAM                                              GLXZ0014
   20    PARAM(I) = 0.0E0                                              GLXZ0015
C                                                                      GLXZ0016
      IXPMAX=2*(NPARAM-1)                                              GLXZ0017
      DO 30 I = 1, IXPMAX                                              GLXZ0018
   30    XPOWER(I) = 0.0E0                                             GLXZ0019
C                                                                      GLXZ0020
C  COMPUTE SUMS OF POWERS OF X AND OF POWERS OF X TIMES Y.             GLXZ0021
      DO 50 K = 1, NPTS                                                GLXZ0022
         XP = 1.0E0                                                    GLXZ0023
      XK=XINO(K)                                                       GLXZ0024
      YK=YINO(K)                                                       GLXZ0025
         DO 40 I = 1, IXPMAX                                           GLXZ0026
            IF (I .LE. NPARAM) PARAM(I) = PARAM(I) + XP * YK           GLXZ0027
            XP = XP * XK                                               GLXZ0028
            XPOWER(I) = XPOWER(I) + XP                                 GLXZ0029
   40    CONTINUE                                                      GLXZ0030
   50 CONTINUE                                                         GLXZ0031
C                                                                      GLXZ0032
C  COMPUTE COEFFICIENTS OF NORMAL EQUATIONS.  THE COEFFICIENT MATRIX   GLXZ0033
C  HAS A BANDED STRUCTURE.                                             GLXZ0034
      A(1) = NPTS                                                      GLXZ0035
      IF (NPARAM .EQ. 1) GO TO 90                                      GLXZ0036
```

```
C
      DO 80 I = 2, NPARAM
         XP = XPOWER(I - 1)
         DO 60 K = 1, I
C
C
            A(K, I + 1 - K) = XP
            A(K + NPARAM * (I - K)) = XP
   60    CONTINUE
C
         XP = XPOWER(NPARAM + I - 2)
         DO 70 K = I, NPARAM
C
C
            A(NPARAM + I - K, K) = XP
            A(I + (NPARAM - 1) * K) = XP
   70    CONTINUE
   80 CONTINUE
C
C  SOLVE NORMAL EQUATIONS.
   90 CALL SIMEQ(A,PARAM,NPARAM,IERR)
      IF (IERR .NE. 0) WRITE (6, 1002)
      RETURN
C
 1002 FORMAT(39H LSFIT:  NORMAL EQUATIONS ARE SINGULAR.)
      END
```

```
C     SIMEQ SUBROUTINE ***************************
C     IBM  SSP SUBROUTINE TO SOLVE SIMULTANEOUS EQUATIONS FOR LSFIT
      SUBROUTINE SIMEQ(A,B,N,KS)
C
C        DESCRIPTION OF PARAMETERS
C           A - MATRIX OF COEFFICIENTS STORED COLUMNWISE.  THESE ARE
C               DESTROYED IN THE COMPUTATION.  THE SIZE OF MATRIX A IS
C               N BY N.
C           B - VECTOR OF ORIGINAL CONSTANTS (LENGTH N). THESE ARE
C               REPLACED BY FINAL SOLUTION VALUES, VECTOR X.
C           N - NUMBER OF EQUATIONS AND VARIABLES. N MUST BE .GT. ONE.
C           KS - OUTPUT DIGIT
C                0 FOR A NORMAL SOLUTION
C                1 FOR A SINGULAR SET OF EQUATIONS
C
      DIMENSION A(1),B(1)
C
C        FORWARD SOLUTION
C
      TOL=0.001
      KS=0
      JJ=-N
      DO 65 J=1,N
      JY=J+1
      JJ=JJ+N+1
      BIGA=0
      IT=JJ-J
      DO 30 I=J,N
C
C        SEARCH FOR MAXIMUM COEFFICIENT IN COLUMN
C
      IJ=IT+I
      IF(ABS(BIGA)-ABS(A(IJ))) 20,30,30
   20 BIGA=A(IJ)
      IMAX=I
   30 CONTINUE
```

```
C
C        TEST FOR PIVOT LESS THAN TOLERANCE (SINGULAR MATRIX)             SIMQ0037
C                                                                          SIMQ0038
      IF(ABS(BIGA)-TOL) 35,35,40                                           SIMQ0039
   35 KS=1                                                                 SIMQ0040
      RETURN                                                               SIMQ0041
C                                                                          SIMQ0042
C        INTERCHANGE ROWS IF NECESSARY                                     SIMQ0043
C                                                                          SIMQ0044
   40 I1=J+N*(J-2)                                                         SIMQ0045
      IT=IMAX-J                                                            SIMQ0046
      DO 50 K=J,N                                                          SIMQ0047
      I1=I1+N                                                              SIMQ0048
      I2=I1+IT                                                             SIMQ0049
      SAVE=A(I1)                                                           SIMQ0050
      A(I1)=A(I2)                                                          SIMQ0051
      A(I2)=SAVE                                                           SIMQ0052
C                                                                          SIMQ0053
C        DIVIDE EQUATION BY LEADING COEFFICIENT                            SIMQ0054
C                                                                          SIMQ0055
   50 A(I1)=A(I1)/BIGA                                                     SIMQ0056
      SAVE=B(IMAX)                                                         SIMQ0057
      B(IMAX)=B(J)                                                         SIMQ0058
      B(J)=SAVE/BIGA                                                       SIMQ0059
C                                                                          SIMQ0060
C        ELIMINATE NEXT VARIABLE                                           SIMQ0061
      IF(J-N) 55,70,55                                                     SIMQ0062
   55 IQS=N*(J-1)                                                          SIMQ0063
      DO 65 IX=JY,N                                                        SIMQ0064
      IXJ=IQS+IX                                                           SIMQ0065
      IT=J-IX                                                              SIMQ0066
      DO 60 JX=JY,N                                                        SIMQ0067
      IXJX=N*(JX-1)+IX                                                     SIMQ0068
      JJX=IXJX+IT                                                          SIMQ0069
   60 A(IXJX)=A(IXJX)-(A(IXJ)*A(JJX))                                      SIMQ0070
   65 B(IX)=B(IX)-(B(J)*A(IXJ))                                            SIMQ0071
                                                                           SIMQ0072
```

```
C                                                                       SIMQ0073
C        BACK SCLUTICN                                                  SIMQ0074
C                                                                       SIMQ0075
   70 NY=N-1                                                            SIMQ0076
      IT=N*N                                                            SIMQ0077
      CO 8C J=1,NY                                                      SIMQ0078
      IA=IT-J                                                           SIMQ0079
      IB=N-J                                                            SIMQ0080
      IC=N                                                              SIMQ0081
      CO 80 K=1,J                                                       SIMQ0082
      B(IB)=B(IB)-A(IA)*B(IC)                                           SIMQ0083
      IA=IA-N                                                           SIMQ0084
   80 IC=IC-1                                                           SIMQ0085
      RETURN                                                            SIMQ0086
      END                                                               SIMQ0087
```

```
C     COEF SUBROUTINE ****************************
C     OUTPUT COEFFICIENTS FOR BOTH SPLINE AND LEAST SQUARES FIT
      SUBROUTINE COEF(ZIN,NCK,ITIPE)
      DIMENSION ZIN(1)
C
C     THIS INSTALLATION REQUIRES LOGICAL UNIT 6 AS THE PRINTER
C
      KOT=6
C
C
      IF(ITIPE.EQ.0)GOTO 750
      WRITE(KOT,500)
  750 DO 766 I=1,NCK
      WRITE(KOT,600)ZIN(I)
  766 CONTINUE
      WRITE(KOT,800)
      RETURN
  500 FORMAT(  //' LISTING OF COEFFICIENTS USED IN SUBROUTINE DUCK'/)
  600 FORMAT(F13.3)
  800 FORMAT( / )
      END
```

```
C     XOUTER SUBROUTINE *************************               XOUT0001
C     ROUTINE TO PLACE OUTPUT POINTS IF NOUT INPUTTED AS <=0     XOUT0002
      SUBROUTINE XOUTER                                          XOUT0003
      COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPCT,KOT,KIN,XIN(40,99),IDT,  XOUT0004
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINC(99),    XOUT0005
     2YINC(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IACICH,XINT, XOUT0006
     3YINT,INORCT,JUSIN,IPLINE                                   XOUT0007
      NOUTA=IABS(NOUT)                                           XOUT0008
      XNCR=(XIN (JOBNUM,LEN(JOBNUM)) -XIN (JOBNUM,1))/FLOAT(NOUTA)   XOUT0009
      XOUT(1)=XIN (JOBNUM,1)                                     XOUT0010
      XOUT(NOUTA)=XIN (JOBNUM,LEN(JOBNUM))                       XOUT0011
      NOUTA1=NOUTA-1                                             XOUT0012
C                                                                XOUT0013
C     PLACES THEM AT REGULAR INTERVAL                            XOUT0014
      DO 300 I=2,NOUTA1                                          XOUT0015
      XOUT(I)=XOUT(I-1) +XNCR                                    XOUT0016
  300 CONTINUE                                                   XOUT0017
      RETURN                                                     XOUT0018
      END                                                        XOUT0019
```

```
C     OUTER SUBROUTINE WITH OPTIONAL ENTRY PROT ************
C     PUNCHED AND/OR PRINTED OUTPUT POINTS
      SUBROUTINE OUTER
      COMMON IPUN,JCHNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINO(99),
     2YINO(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONET,ISTRLN,IADICH,XINT,
     3YINT,INDRCT,JUSIN,INLINE
      COMMON/ONE/IANS
C
C     ICONET ADDITIONAL POINTS
      LX=NOUT + IADICH
      WRITE(KPOT,450)LX , JCHNUM
      NOUTA=IABS(NOUT)
      WRITE(KPOT,455)
      IF(IADICH.NE.1)
     1WRITE(KPOT,460)(XOUT(I),I=1,NOUTA)
C
C     DECISION ON POSITION OF ICONET POINT
      IF((IADICH.EQ.1).AND.(IANS.NE.1))WRITE(KPOT,460)(XOUT(I),I=1,NOUTA
     1),XINT
      IF((IADICH.EQ.1).AND.(IANS.EQ.1))WRITE(KPOT,460)XINT,(XOUT(I),I=1,
     1NOUTA)
      WRITE(KPOT,470)
      IF(IADICH.NE.1)
     1WRITE(KPOT,460)(YOUT(I),I=1,NOUTA)
      IF((IADICH.EQ.1).AND.(IANS.NE.1))WRITE(KPOT,460)(YOUT(I),I=1,NOUTA
     1),YINT
      IF((IADICH.EQ.1).AND.(IANS.EQ.1))WRITE(KPOT,460)YINT,(YOUT(I),I=1,
     1NOUTA)
      ENTRY PROT
C
C     PRINTED ONLY
C
C     ICONET ADDITIONAL POINT
      LX=NOUT + IADICH
      WRITE(KOT,450)LX,JCHNUM
```

```
      NOUTA=IABS(NCUT)
      WRITE(KOT,475)
      IF((IADICH.EQ.1).AND.(IANS.EQ.1))WRITE(KOT,465)XINT,YINT
      DO 400 I=1,NCUTA
      WRITE(KOT,465) XOUT(I),YOUT(I)
  400 CONTINUE
      IF((IADICH.EQ.1).AND.(IANS.NE.1))WRITE(KOT,465)XINT,YINT
      WRITE(KOT,480)JOBNUM
      WRITE(KOT,490)
  490 FORMAT('1')
  450 FORMAT(I4,'  OUTPUT POINTS FOR JOB NUMBER  ',I2)
  460 FORMAT(8F10.3)
  455 FORMAT(' XOUTS FOLLOW ********************************************')
  470 FORMAT(' YOUTS FOLLOW ********************************************')
  480 FORMAT('-',' ************ END OF JOBNUMBER ',I4,'***************')
  465 FORMAT(3X,F10.3,5X,F10.3)
  475 FORMAT('-',' XOUTS COORD    YOUTS COORD')
      RETURN
      END
```

```
C     PRAPN SUBROUTINE WITH OPTIONAL ENTRY PRINTO **********
C     PUNCHED AND/OR PRINTED INPUT POINTS
      SUBROUTINE PRAPN
      COMMON IPUN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,
     1ISTART,IFIN,YIN(40,99),ITIME(40,99),NDKA,NOUT,XDK(20),XINO(99),
     2YINO(99),XOUT(500),YOUT(500),NIN,ITMAPK,ICONET,ISTRLN,IADICH,XINT,
     3YINT,INOROT,JUSIN,IMLINE
      COMMON /AREA2/ XMAX,XMIN,YMAX,YMIN
      COMMON/ONE/IANS
C     COMMON/ONE/  FOR ICONET POSITION IF A TSORT HAS BEEN DONE
C
C
C     SORT INPUT POINTS IN SPECIAL SORT
      CALL TSORT
C     ICONET ADDITIONAL POINT
      LX=LEN(JOBNUM) + IADICH
      WRITE(KPOT,150) LX,JOBNUM
      LENT=LEN(JOBNUM)
      WRITE(KPOT,155)
      IF(IADICH.NE.1)
     1WRITE(KPOT,160)(XIN (JOBNUM,I),I=1,LENT)
C
C     DECISION OF WHERE CONNECTION POINT GOES
      IF((IADICH.EQ.1).AND.(IANS.NE.1))WRITE(KPOT,160)(XIN(JOBNUM,I),I=1
     1,LENT),XINT
      IF((IADICH.EQ.1).AND.(IANS.EQ.1))WRITE(KPOT,160)XINT,(XIN(JOBNUM,I
     1),I=1,LENT)
      WRITE(KPOT,170)
      IF(IADICH.NE.1)
     1WRITE(KPOT,160)(YIN (JOBNUM,I),I=1,LENT)
      IF((IADICH.EQ.1).AND.(IANS.NE.1))WRITE(KPOT,160)(YIN(JOBNUM,I),I=1
     1,LENT),YINT
      IF((IADICH.EQ.1).AND.(IANS.EQ.1))WRITE(KPOT,160)YINT,(YIN(JOBNUM,I
     1),I=1,LENT)
      ENTRY PRINTO
C
```

```
C       PRINTED ONLY                                                    PRAP0037
        IF((IPUN.NE.1).OR.(INCROT.EQ.1))CALL TSORT                      PRAP0038
        LX=LEN(JOBNUM) + IADICH                                         PRAP0039
        IF(LEN(JOBNUM).EQ.1)LX= LEN(JOBNUM)                             PRAP0040
        WRITE(KOT,150)LX,JOBNUM                                         PRAP0041
        LENT=LEN(JOBNUM)                                                PRAP0042
        WRITE(KOT,175)                                                  PRAP0043
        IF(LEN(JOBNUM).EQ.1)GOTO 600                                    PRAP0044
        IF((IADICH.EQ.1).AND.(IANS.EQ.1))WRITE(KOT,165)XINT,YINT        PRAP0045
  600   DO 100 I=1,LENT                                                 PRAP0046
        WRITE(KOT,165)XIN (JOBNUM,I),YIN (JOBNUM,I)                     PRAP0047
C                                                                       PRAP0048
C       MAX DIMENSION CHECK                                             PRAP0049
        IF(XMAX.LT.XIN(JOBNUM,I))XMAX=XIN(JOBNUM,I)                     PRAP0050
        IF(XMIN.GT.XIN(JOBNUM,I))XMIN=XIN(JOBNUM,I)                     PRAP0051
        IF(YMAX.LT.YIN(JOBNUM,I))YMAX=YIN(JOBNUM,I)                     PRAP0052
        IF(YMIN.GT.YIN(JOBNUM,I))YMIN=YIN(JOBNUM,I)                     PRAP0053
  100   CONTINUE                                                        PRAP0054
        IF(LEN(JOBNUM).EQ.1)GOTO 700                                    PRAP0055
        IF((IADICH.EQ.1).AND.(IANS.NE.1))WRITE(KOT,165)XINT,YINT        PRAP0056
  700   RETURN                                                          PRAP0057
  150   FORMAT(I3,' POINTS IN FOR JOB NUMBER ',I2)                      PRAP0058
  155   FORMAT(' XIN POINTS FOLLOW ****************************************')  PRAP0059
  160   FORMAT(8F10.3)                                                  PRAP0060
  165   FORMAT(2X,F10.3,5X,F10.3)                                       PRAP0061
  170   FORMAT(' YIN POINTS FOLLOW ****************************************')  PRAP0062
  175   FORMAT('-',' XINS COORD ','     YINS COORD')                    PRAP0063
        END                                                             PRAP0064
```

```
C      TSORT SUBROUTINE *************************                       TSRT0001
C      SPECIAL SORT PUTS THE LEAST MEMBER FIRST IN CASE POINTS          TSRT0002
C      INPUTTED IN DESCENDING  ORDER                                    TSRT0003
       SUBROUTINE TSORT                                                 TSRT0004
       COMMON IPLN,JOBNUM,IWARN(40),LEN(40),KPOT,KOT,KIN,XIN(40,99),IDT,TSRT0005
      1ISTART,IFIN,YIN(40,99),ITIME(40,99),NOKA,NOUT,XOK(20),XINO(99),  TSRT0006
      2YINO(99),XOUT(500),YOUT(500),NIN,ITMARK,ICONFT,ISTRLN,IAEICH,XINT,TSRT0007
      3YINT,INORCT,JUSIN,IMLINE                                         TSRT0008
       COMMON/ONE/IANS                                                  TSRT0009
       IANS=0                                                           TSRT0010
       IF(XIN (JOBNUM,1).LE.XIN (JOBNUM,LEN(JOBNUM)))GOTO 640           TSRT0011
       IANS=1                                                           TSRT0012
       MEND=LEN(JOBNUM)/2                                               TSRT0013
       DO 600 I=1,MEND                                                  TSRT0014
       TEMPX=XIN (JOBNUM,I)                                             TSRT0015
       TEMPY=YIN (JOBNUM,I)                                             TSRT0016
       ITEMP=ITIME(JOBNUM,I)                                            TSRT0017
       NUM=LEN(JOBNUM)+1-I                                              TSRT0018
       XIN (JOBNUM,I)=XIN (JOBNUM,NUM)                                  TSRT0019
       YIN (JOBNUM,I)=YIN (JOBNUM,NUM)                                  TSRT0020
       ITIME(JOBNUM,I)=ITIME(JOBNUM,NUM)                                TSRT0021
       XIN (JOBNUM,NUM)=TEMPX                                           TSRT0022
       YIN (JOBNUM,NUM)=TEMPY                                           TSRT0023
       ITIME(JOBNUM,NUM)=ITEMP                                          TSRT0024
  600  CONTINUE                                                         TSRT0025
  640  RETURN                                                           TSRT0026
       END                                                              TSRT0027
```

```
C     SORT SUBROUTINE ****************************             SORT0001
C     INTERCHANGE  SORT                                            SORT0002
      SUBROUTINE SORT(ARRAY,NUM)                                   SORT0003
      DIMENSION ARRAY(1)                                           SORT0004
      DO 700 I=1,NUM                                               SORT0005
      HOLD=-2.**32                                                 SORT0006
      IHOLD=-2**32                                                 SORT0007
      NUM2=NUM-I +1                                                SORT0008
      DO 710 J=1,NUM2                                              SORT0009
      IF(HOLD.GT.ARRAY(J))GOTO 710                                 SORT0010
      HOLD=ARRAY(J)                                                SORT0011
      IHOLD=J                                                      SORT0012
  710 CONTINUE                                                     SORT0013
      ARRAY(IHOLD)=ARRAY(NUM2)                                     SORT0014
      ARRAY(NUM2)=HOLD                                             SORT0015
  700 CONTINUE                                                     SORT0016
      RETURN                                                       SORT0017
      END                                                          SORT0018
```

```
C     RSORT SUBROUTINE ***************************               RSRT0001
C     INTERCHANGE SORT WITH TAG-A-LONG ARRAY                     RSRT0002
      SUBROUTINE RSORT(XISC,YISC,INC)                            RSRT0003
      DIMENSION XISO(1),YISC(1)                                  RSRT0004
      DO 900 I=1,INC                                             RSRT0005
      HOLD=-2.**32                                               RSRT0006
      IHOLD=-2**32                                               RSRT0007
      NUM2=INC-I +1                                              RSRT0008
      DO 910 J=1,NUM2                                            RSRT0009
      IF(HOLD.GT.XISC(J))GOTO 910                                RSRT0010
      HOLD=XISO(J)                                               RSRT0011
      IHOLD=J                                                    RSRT0012
      YOLD=YISC(J)                                               RSRT0013
  910 CONTINUE                                                   RSRT0014
      XISC(IHOLD)=XISC(NUM2)                                     RSRT0015
      YISC(IHOLD)=YISC(NUM2)                                     RSRT0016
      XISC(NUM2)=HOLD                                            RSRT0017
      YISC(NUM2)=YOLD                                            RSRT0018
  900 CONTINUE                                                   RSRT0019
      RETURN                                                     RSRT0020
      END                                                        RSRT0021
```

```
C      STOREC SUBROUTINE   ************************
C      CALCULATES VALUES FOR CENTERED VELOCITY AND FOR FUTHER IMPROVEMENT
       SUBROUTINE STOREC(ICEC,ICOUNT,ANG1,ANG2,XCORC,YCORC,IHOUR,MINUT,
      1NSEC,MIWSAR,ILAP,IELT,DIST,VEL,VELOC,DIRCT)
       LOGICAL*1 IIELT(9),ICELT(9),IELT(9),NIWSAR(9),MIWSAR(9),KIWSAR(9)
       GO TO (900,100,200), ICEC
  100  DXEMP=FLOAT(ILAP) + FLOAT(IOLAP)
       CVELOC=DVEL*FLOAT(IOLAP)/DXEMP + VEL*FLOAT(ILAP)/DXEMP
       IF(ICOUNT.EQ.2)CVELOC=0.00
       GOTO 800
C
C      TRANSFER STATION
  200  CVELOC=OVEL
  800  IXCOUN=ICCOUN
       XANG1=OANG1
       XANG2=CANG2
       XXCORD=CXCORC
       XYCORD=OYCORC
       IXHOUR=IIHOUR
       IXMIN=IMINUT
       IXNSEC=INSEC
       IXLAP=IOLAP
       DO 905 JB=1,9
       IIELT(JB)=ICELT(JB)
  905  NIWSAR(JB)=KIWSAR(JB)
       XDIST=ODIST
       XVEL=OVEL
       XVELOC=OVELOC
       XDIRCT=OCIRCT
  900  IOCOUN=ICOUNT
       CANG1=ANG1
       CANG2=ANG2
       CXCORD=XCORD
       CYCORD=YCORC
       IIHOUR=IHOUR
       IMINUT=MINUT
```

```
      INSEC=NSEC
      IDLAP=ILAP
      DO 910 JB=1,9
      KIWSAR(JB)=MIWSAR(JB)
  910 IDELT(JB)=IELT(JB)
      CDIST=DIST
      CVEL=VEL
      CVELOC=VELOC
      CDIRCT=DIRCT
      IF(IDEC.EQ.1)RETURN
      ICOUNT=IXCOUN
      ANG1=XANG1
      ANG2=XANG2
      XCORD=XXCORD
      YCORD=XYCORD
      IHOUR=IXHOUR
      MINUT=IXMIN
      ILAP=IXLAP
      NSEC=IXNSEC
      DO 920 JB=1,9
      MIWSAR(JB)=NIWSAR(JB)
  920 IELT(JB)=IIELT(JB)
      DIST=XDIST
      VEL=XVEL
      VELOC=XVELOC
      DIRCT=XDIRCT
C
      RETURN
      END
```

```
      FUNCTION DEGREE(ANGLEZ)                                               DEGR0001
C     FUNCTION TO CHANGE DEGREES TO POSITIVE DEGREES.MINUTES FOR OUTPUT     DEGR0002
      NANGLE=IFIX(ANGLEZ)                                                   DEGR0003
      MANGLE=IFIX(ANGLEZ-FLCAT(NANGLE))                                     DEGR0004
      MAD=MANGLE/6C                                                         DEGR0005
      NANGLE=NANGLE+MAD                                                     DEGR0006
      MANGLE=MANGLE-MAD*60                                                  DEGR0007
      NANGLE=NANGLE-(NANGLE/360)*360                                        DEGR0008
C                                                                           DEGR0009
C     NEGATIVE ANGLE FIX                                                    DEGR0010
      IF(NANGLE.GE.0)GOTO 1C0                                               DEGR0011
      ISUB=0                                                                DEGR0012
      IF(MANGLE.NE.0)ISUB=-1                                                DEGR0013
      IF(MANGLE.NE.0)MANGLE=60 + MANGLE                                     DEGR0014
      NANGLE=360 + ISUB +NANGLE                                             DEGR0015
C                                                                           DEGR0016
  100 CEGREF=FLCAT(NANGLE) +FLCAT(MANGLE)/10C                               DEGR0017
      RETURN                                                                DEGR0018
      END                                                                   DEGR0019
```

```
      SUBROUTINE TIMEPH(NSECS,FIELD)
C     OUTPUTS A HH:MM:SS CHARACTER(ARRAY) FROM INPUT TIME IN SECONDS
      LOGICAL*1 FIELD(1),DIGITS(13)
      DATA DIGITS/'0','1','2','3','4','5','6','7','8','9','-',':',' '/
C
C     COMPARISON OF BYTES
      IF(NSECS.LT.0)FIELD(1)=DIGITS(11)
      IF(NSECS.GE.0)FIELD(1)=DIGITS(13)
      FIELD(4)=DIGITS(12)
      FIELD(7)=DIGITS(12)
      IHOUR=NSECS/3600
      IMINUT=(NSECS-IHOUR*3600)/60
      ISEC=NSECS-IHOUR*3600-IMINUT*60
      I        =IABS(IHOUR/10)
      FIELD(2)=DIGITS(I+1)
      I        =IABS(IHOUR-(IHOUR/10)*10)
      FIELD(3)=DIGITS(I+1)
      I=IABS(IMINUT/10)
      FIELD(5)=DIGITS(I+1)
      I        =IABS(IMINUT-(IMINUT/10)*10)
      FIELD(6)=DIGITS(I+1)
      I        =IABS(ISEC/10)
      FIELD(8)=DIGITS(I+1)
      I        =IABS(ISEC-(ISEC/10)*10)
      FIELD(9)=DIGITS(I+1)
C
      RETURN
      END
```

SAMPLE OUTPUT

FOR DROGUE BODY COORDINATE

AND VELOCITY CALCULATION

COMPUTER PROGRAM

```
********************** MAIN JOB START ****************
GIB  LOWTIDE    7/24/72  MAIN-DECK        WING GD
PARMS IPUN=0IN IRCT=0JUSIN=0ICONT=1IAXIS=1ITMARK=1IMLINE=0ISTRLN=0

DEGREES THAT THE BASELINE IS OFF TRUE NORTH  -71  MINUTES-39

THE LENGHT OF THE BASELINE IS      366.20  METERS

 LOWTIDE  TIME =     5:54: 0 HH:MM:SS

Y MAXIMUM  INPUTTED AS         0.0  METERS
```

*********** JOBNUMBER 1 START ***********

C18 LOWTIDE

POSIT.NO	ANGLE 1 DEG.MIN	ANGLE 2 DEG.MIN	X COORD METERS	Y COORD METERS	START TM HH:MM:SS	LOWTIDE HH:MM:SS	TIM ELPT HH:MM:SS	DISTANCE METERS	BACK.VEL. CM/SEC	CENT.VEL. CM/SEC	DIRCT(N). DEG.MIN
1	53.50	99.45	-500.7	365.0	5:36: 0	-00:18:00	00:00:00	0 0	0.0	0.0	0.0
2	52.00	90.00	-471.3	368.2	5:43:40	-00:10:20	00:07:40	29.51	6.4	4.9	14.00
3	51.30	90.15	-465.4	370.2	5:48:10	-00:05:50	00:04:30	6.17	2.3	2.3	0.0
4	51.00	91.15	-467.3	378.4	5:54: 0	00:00:00	00:05:50	9.37	2.4	2.4	276.00

***** BACKTRACKING BUOY ***** JOBNUMBER 1 POSITION 4

AVERAGES FOR GROUP:

TOTAL DISTANCE METERS	TOTAL TIME HH:MM:SS	AVEG. VEL. CM/SEC	AVERG. DIRCT. DEG.MIN
35.52	00:12:10	4.87	11.00

4 POINTS IN FOR JOB NUMBER 1

XINS COORD	YINS COORD
-500.707	365.019
-471.274	368.199
-465.442	370.229
-467.279	378.395

LISTING OF COEFFICIENTS OF LEAST SQUARES METHOD

-432.961
-3.499
-0.004

10 OUTPUT POINTS FOR JOB NUMBER 1

XOUTS COORD	YOUTS COORD
-500.707	365.940
-496.788	366.577
-492.870	367.401
-488.951	368.010
-485.033	368.505
-481.114	368.996
-477.196	369.152
-473.277	369.307
-469.442	369.265
-467.279	379.395

*********** END OF JOBNUMBER 1 ***********

POSIT.NO	ANGLE 1 DEG.MIN	ANGLE 2 DEG.MIN	X COORD METERS	Y COORD METERS	START TM HH:MM:SS	LENTIDE HH:MM:SS	TIM ELPT HH:MM:SS	DISTANCE METERS	BACK.VEL. CM/SEC	CENT.VEL. CM/SEC	DIRCT(N). DEG.MIN
1	51.00	91.15	-407.3	378.4	5:56: 0	00:00:00	00:00:00	0.0	0.0	0.0	0.0
2	47.30	91.00	-409.6	375.3	6:13:55	00:19:55	00:19:55	57.74	4.8	5.2	21.00
3	46.30	91.15	-397.1	376.9	6:16:40	00:22:40	00:02:45	12.58	7.6	8.1	11.00
4	45.00	90.15	-369.8	369.8	6:22:20	00:28:20	00:05:40	28.21	8.3	8.6	32.00
5	44.15	90.00	-358.7	368.2	6:24:20	00:30:20	00:02:00	11 25	9.4	10.9	26.00
6	39.45	97.45	-296.5	356.5	6:33:45	00:39:45	00:09:25	63.23	11.2	11.7	28.00
7	38.15	97.00	-278.7	353.6	6:35:55	00:41:55	00:02:10	18 03	13.9	15.5	27.00
8	34.15	93.00	-231.4	339.8	6:41: 0	00:47:00	00:05:05	49 36	16.2	16.7	34.00
9	30.00	79.45	-192.5	333.4	6:44:45	00:50:45	00:03:45	39.40	17.5	17.1	27.00
10	27.15	78.15	-171.3	332.6	6:46:55	00:52:55	00:02:10	21 21	16.3	15.0	20.00
11	20.00	73.00	-120.6	331.3	6:52:45	00:58:45	00:05:50	50.71	14.5	16.0	19.00
12	13.00	57.45	-74.2	321.4	6:57:10	01:03:10	00:04:25	47 45	17.9	16.8	30.00
13	2.30	16.00	-14.0	319.5	7: 3:25	01:09:25	00:06:15	60 27	16.1	15.7	20.00
14	-6.45	-34.30	37.2	314.1	7: 9: 0	01:15:00	00:05:35	51.42	15.3	14.2	24.00
15	-13.30	-49.00	73.1	304.6	7:13:50	01:19:50	00:04:50	37 19	12.8	12.5	33.00
16	-17.30	-54.45	94.9	301.1	7:16:55	01:22:55	00:03:05	22 09	11.9	12.2	27.00
17	-22.05	-58.00	119.2	293.7	7:20:20	01:26:20	00:03:25	25.33	12.4	9.8	35.00
18	-26.15	-60.15	141.7	287.2	7:25:10	01:31:10	00:04:50	23 40	8.1	6.1	34.00
19	-27.15	-60.00	146.2	283.8	7:28:15	01:34:15	00:03:05	5 67	3.1	3.1	55.00

AVERAGES FOR GROUP:	TOTAL DISTANCE METERS	TOTAL TIME HH:MM:SS	AVEG. VEL. CM/SEC	AVERG. DIRCT. DEG.MIN
	620.70	01:34:15	10.98	27.00

19 POINTS IN FOR JOB NUMBER 2

XINS COORD	YINS COORD
-407.279	378.395
-409.622	375.349
-397.132	376.864
-369.813	369.812
-358.684	368.199
-296.538	356.549
-278.749	353.591
-231.397	339.793
-192.485	333.393
-171.286	332.572
-120.574	331.330
-74.197	321.395
-13.992	319.544
37.177	314.106
73.134	304.626
94.938	301.104
119.173	293.732
141.651	287.240
146.171	283.809

4 IS THE NUMBER OF DUCKS USED FOR JOB NUMBER 2

XDR COORDINATES
-369.717
-263.948

-18.510
306.725

LISTING OF COEFFICIENTS USED IN SUBROUTINE DUCK

65.829
-156.311
-26.712
-168.205

-20 OUTPUT POINTS FOR JOB NUMBER 2

XOUTS COORD	YOUTS COORD
-467.279	378.201
-436.607	377.606
-405.934	375.960
-375.261	372.947
-344.589	366.393
-313.916	359.292
-283.244	351.944
-252.571	345.303
-221.899	339.959
-191.226	335.433
-160.554	331.922
-129.881	328.796
-99.209	325.110
-68.536	323.573
-37.864	320.953
-7.191	318.027
23.481	314.469
54.154	309.905
84.826	303.553
146.171	294.399

*********** END OF JOBNUMBER 2***************

STARTING TIME= 05:35:00 FINISHING TIME= 07:25:00
OF OF TIME= 00:10:00 WATER OR MOONTIME = 05:54:00

TIMEMARKS NORMAL TIME= 05:45:00 TIME AFTER LOWTIDE=-00:09:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 1

IBM XOUTS	IBM YOUTS
-469.540	359.341
-469.540	361.232
-469.540	365.016
-469.540	370.692
-469.540	378.260

TIMEMARKS NORMAL TIME= 05:55:00 TIME AFTER LOWTIDE= 00:01:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 2

IBM XOUTS	IBM YOUTS
-464.384	368.782
-464.384	370.674
-464.384	374.458
-464.384	380.133
-464.384	397.701

TIMEMARKS NORMAL TIME= 06:05:00 TIME AFTER LOWTIDE= 00:11:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 3

IBM XOUTS	IBM YOUTS
-435.435	367.252
-435.435	369.144
-435.435	372.928
-435.435	378.604
-435.435	386.172

TIMEMARKS NORMAL TIME= 06:15:00 TIME AFTER LOWTIDE= 00:21:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 4

IBM XOUTS	IBM YOUTS
-404.701	366.486
-404.701	368.378
-404.701	372.162
-404.701	377.837
-404.701	385.405

TIMEMARKS NORMAL TIME= 06:25:00 TIME AFTER LOWTIDE= 00:31:00

OUTPUT POINTS= 5 TIMEMARKS NO.= 5

IBM XOUTS	IBM YOUTS
-354.284	357.914
-354.284	359.806
-354.284	363.590
-354.284	369.266
-354.284	376.833

TIMEMARKS NORMAL TIME= 06:35:00 TIME AFTER LOWTIDE= 00:41:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 6

IBM XOUTS	IBM YOUTS
-286.275	345.382
-286.275	347.274
-286.275	351.058
-286.275	356.734
-286.275	364.302

TIMEMARKS NORMAL TIME= 06:45:00 TIME AFTER LOWTIDE= 00:51:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 7

IBM XOUTS	IBM YOUTS
-190.039	323.839
-190.039	325.730
-190.039	329.514
-190.039	335.190
-190.039	342.758

TIMEMARKS NORMAL TIME= 06:55:00 TIME AFTER LOWTIDE= 01:01:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 8

IBM XOUTS	IBM YOUTS
-96.958	316.903
-96.958	318.[illegible]
-96.958	322.479
-96.958	329.155
-96.958	335.723

TIMEMARKS NORMAL TIME= 07:05:00 TIME AFTER LOWTIDE= 01:11:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 9

IBM XOUTS	IBM YOUTS
0.548	308.542
0.548	310.434
0.548	314.218
0.548	327.462

```
0.543          327.462

TIMEMARKS NORMAL TIME=   07:15:00   TIME AFTER  LOWTIDE= 01:21:00
 OUTPUT POINTS=     5   TIMEMARKS NO.=    10

IBM XOUTS      IBM YOUTS
   81.384        293.833
   81.384        295.725
   81.384        299.505
   81.384        305.195
   81.384        312.752

TIMEMARKS NORMAL TIME=   07:25:00   TIME AFTER  LOWTIDE= 01:31:00
 OUTPUT POINTS=     5   TIMEMARKS NO.=    11

IBM XOUTS      IBM YOUTS
  140.576        278.003
  140.576        279.895
  140.576        283.675
  140.576        289.355
  140.576        296.923
NO. OF TIMEMARKS  11   PUT THIS CARD JUST AFTER TIMEMARKS START
******************* TIMEMARKS END *****************

     XMAX=   146.171     XMIN=  -500.707     YMAX=   378.395     YMIN=     0.0

             TOTAL NUMBER OF JOBS EQUALS  2

****************** MAIN JOB END ***************
```

OUTPUT POINTS= 5 TIMEMARKS NO.= 5

IBM XOUTS	IBM YOUTS
-354.284	357.914
-354.284	359.806
-354.284	363.590
-354.284	369.266
-354.284	376.833

TIMEMARKS NORMAL TIME= 06:35:00 TIME AFTER LOWTIDE= 00:41:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 6

IBM XOUTS	IBM YOUTS
-286.275	345.382
-286.275	347.274
-286.275	351.058
-286.275	356.734
-286.275	364.302

TIMEMARKS NORMAL TIME= 06:45:00 TIME AFTER LOWTIDE= 00:51:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 7

IBM XOUTS	IBM YOUTS
-190.039	323.838
-190.039	325.730
-190.039	329.514
-190.039	335.190
-190.039	342.758

TIMEMARKS NORMAL TIME= 06:55:00 TIME AFTER LOWTIDE= 01:01:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 8

IBM XOUTS	IBM YOUTS
-96.558	316.903
-96.558	319.[illegible]
-96.558	322.479
-96.558	329.155
-96.558	335.723

TIMEMARKS NORMAL TIME= 07:05:00 TIME AFTER LOWTIDE= 01:11:00
OUTPUT POINTS= 5 TIMEMARKS NO.= 9

IBM XOUTS	IBM YOUTS
0.548	308.542
0.548	310.434
0.548	314.218
0.548	327.462

```
TIMEMARKS NORMAL TIME=   07:15:00   TIME AFTER  LOWTIDE= 01:21:00
OUTPUT POINTS=     5   TIMEMARKS NO.=    10

IBM XOUTS       IBM YOUTS
   81.384         293.833
   81.384         295.725
   81.384         299.505
   81.384         305.195
   81.384         312.752


TIMEMARKS NORMAL TIME=   07:25:00   TIME AFTER  LOWTIDE= 01:31:00
OUTPUT POINTS=     5   TIMEMARKS NO.=    11

IBM XOUTS       IBM YOUTS
  140.676         278.003
  140.676         279.895
  140.676         283.675
  140.676         289.355
  140.676         296.923
NO. OF TIMEMARKS  11   PUT THIS CARD JUST AFTER TIMEMARKS START
*********************** TIMEMARKS END ***********************

     XMAX=   146.171     XMIN=  -500.707     YMAX=   378.395     YMIN=     0.0


               TOTAL NUMBER OF JOBS EQUALS  2


******************** MAIN JOB END ***************
```

DROGUE BUOY PLOTTING

COMPUTER PROGRAM LISTING

```
C
C     PROGRAM: TAKES FIXED DATA PUNCHED DECK AND THEN PLOTS IT.
C     IN THE DATA DECK ITSELF ARE THE INSTRUCTIONS.  NOTHING NORMALLY
C     HAS TO BE CHANGED BY THE PROGRAM USER .
C
      DIMENSION X(100),Y(100 ),XSCL(4),XLAB(20),TEMP1(20)
C
C       X    Y     COORDINATES OF POINTS.
C     XSCL    SCALING FOR MAX AND  MIN    POINTS
C     XLAB    MESSAGE FOR IDENTIFICATION OF POINTS.
C     TEMP1    PRINTING STORAGE FOR INFORMATION(ALPHA FORM) ON  INPUT .
C
C
C     I/O  LOGICAL DEVICE NUMBERS. PRINTER=5,PLOTTER=7,CARD=8
C     CONSOLE OUT=1,CONSOLE IN=6.
      KIN=9
      KEYO=1
      KEYI=6
C
C     PAUSE FOR TURNING DATA SWITCHES AND HARD COPY ON SCOPE.
      PAUSE 16
C
C     WIPES PREVIOUS SCOPE COPY
      CALL ERASE
C
C     IF DATA SWITCH  0  DOWN  PLOTS ON SCOPE ONLY.
      CALL DATSW(0,MODE)
      IF(MODE.EQ.2)CALL LOOK
C
C     IF DATA SWITCH 15  UP OUTPUT COMES OUT ON PRINTER. ELSE ON CONSOL
      CALL DATSW (15,KOT)
      KOT = KOT - ((KOT/2)*2)
      KOT = (KOT*4) + 1
C
      READ(KIN,500)WASTE
      READ(KIN,510)XLAB
```

```
C                                                                       PLOT0037
C     PARAMETERS FROM  MAIN PROGRAM.                                    PLOT0038
      READ (KIN,520)IPUN,INORD,JUSIN,ICONE,IAXIS,ITMAR,IMLIN,ISTRL      PLOT0039
C                                                                       PLOT0040
      WRITE(KOT,525)IPUN,INORD,JUSIN,ICONE,IAXIS,ITMAR,IMLIN,ISTRL      PLOT0041
C                                                                       PLOT0042
C     XMAX,XMIN,YMAX,YMIN                                               PLOT0043
      READ(KIN,530)XSCL(2),XSCL(1),XSCL(4),XSCL(3)                      PLOT0044
C                                                                       PLOT0045
C                                                                       PLOT0046
C     IJOBS=NUMBER OF JOBS IN THIS CALLUP OF PROGRAM.                   PLOT0047
      READ(KIN,540)(TEMP1(K),K=1,7),IJOBS                               PLOT0048
C                                                                       PLOT0049
      WRITE(KOT,700)                                                    PLOT0050
      WRITE(KOT,540)(TEMP1(K),K=1,7),IJOBS                              PLOT0051
C                                                                       PLOT0052
C     INITIALIZATION OF SCOPE AND PLOTTER SCALES AND COORDINATES.       PLOT0053
C     SYMBOLS PUT AT   (0,0)  (XMIN,0)  (XMAX,0)  (0,YMIN)   (0,YMAX)   PLOT0054
      CALL SCALE(1.,1.,0.,0.,0.0)                                       PLOT0055
      CALL FPLOT (1,12.0,-11.0)                                         PLOT0056
      CALL FPLOT (1,0.0,-10.0)                                          PLOT0057
      CALL BEAM(-3.5,-2.5)                                              PLOT0058
C                                                                       PLOT0059
C     .005308  IS TO SCALE METERS TO  .01 INCHES IN A  1:7422  CHART.   PLOT0060
      CALL SCALE(.005308,.005308,XSCL(1),XSCL(3))                       PLOT0061
C                                                                       PLOT0062
      CALL FPLOT(-2,0.0,0.0)                                            PLOT0063
      CALL POINT(-6)                                                    PLOT0064
      CALL FPLOT(-2,0.0,XSCL(3))                                        PLOT0065
      CALL POINT(-5)                                                    PLOT0066
      CALL FPLOT(-2,XSCL(1),0.0)                                        PLOT0067
      CALL POINT(-1)                                                    PLOT0068
      CALL FPLOT(-2,0.0,XSCL(4))                                        PLOT0069
      CALL POINT(-2)                                                    PLOT0070
      CALL FPLOT(-2,XSCL(2),0.0)                                        PLOT0071
      CALL POINT(-1)                                                    PLOT0072
```

```
C                                                                        PLOT0073
      DO 1100 I=1,IJOBS                                                  PLOT0074
C                                                                        PLOT0075
C     INPRINT CHECK FROM PARAM. LIST.                                    PLOT0076
      IF(INPRD .NE.0)GOTO 1200                                           PLOT0077
C                                                                        PLOT0078
C                                                                        PLOT0079
C     NPTS=NUMBER OF POINTS.                                             PLOT0080
      READ(KIN,560)NPTS,(TEMP1(K),K=1,9)                                 PLOT0081
C                                                                        PLOT0082
      WRITE(KOT,700)                                                     PLOT0083
C                                                                        PLOT0084
C     IF DATA SWITCH 15  UP OUTPUT COMES OUT ON PRINTER. ELSE ON CONSOL  PLOT0085
      CALL DATSW (15,KOT)                                                PLOT0086
      KOT = KOT - ((KOT/2)*2)                                            PLOT0087
      KOT = (KOT*4) + 1                                                  PLOT0088
C                                                                        PLOT0089
      WRITE(KOT,560)NPTS,(TEMP1(K),K=1,9)                                PLOT0090
      READ(KIN,500)WASTE                                                 PLOT0091
      READ(KIN,570)(X(K),K=1,NPTS)                                       PLOT0092
      READ(KIN,500)WASTE                                                 PLOT0093
      READ(KIN,570)(Y(K),K=1,NPTS)                                       PLOT0094
C                                                                        PLOT0095
C     IF DATA SWITCH 1  DOWN SKIPS INPUT POINTS.                         PLOT0096
      CALL DATSW(1,IB)                                                   PLOT0097
      IF(IB.EQ.2)GOTO 1200                                               PLOT0098
C                                                                        PLOT0099
                   CALL FGRAF(X,Y,NPTS,+1,-1)                            PLOT0100
C                                                                        PLOT0101
C     JUSTN CHECK FROM PARAM LIST                                        PLOT0102
 1200 IF(JUSTN.NE.0)GOTO 1100                                            PLOT0103
C                                                                        PLOT0104
      READ(KIN,580)NPTS,(TEMP1(K),K=1,9)                                 PLOT0105
      WRITE(KOT,700)                                                     PLOT0106
      WRITE(KOT,580)NPTS,(TEMP1(K),K=1,9)                                PLOT0107
      IF(NPTS.EQ.0)GOTO 1100                                             PLOT0108
```

```
      NPTS=IABS(NPTS)
      READ(KIN,500)WASTE
      READ(KIN,570)(X(K),K=1,NPTS)
      READ(KIN,500)WASTE
C
C     NPTS=NUMBER OF POINTS.
      READ(KIN,570)(Y(K),K=1,NPTS)
C
C
C     IF DATA SWITCH 2  DOWN SKIPS OUTPUT POINTS.
      CALL DATSW(2,I7)
      IF(I7.EQ.2)GOTO 1100
C
                  CALL SGRAF(X,Y,NPTS,+1,-1)
 1100 CONTINUE
C
C     CHECK TO SEE IF A TIME PROGRAM MAY HAVE BEEN USED.
      IF((IMLIN.EQ.0).AND.(ITMAR.EQ.0).AND.(ISTPL.EQ.0))GOTO 9999
C
      READ(KIN,500)WASTE
C
C     ITNUM=NUMBER OF TIME MARKS AND LINES FOR BATCH.
      READ(KIN,590)(TEMP1(K),K=1,4),ITNUM
C
      WRITE(KOT,700)
      WRITE(KOT,590)(TEMP1(K),K=1,4),ITNUM
      IF(ITNUM.EQ.0)GOTO 9998
      WRITE(KOT,700)
      READ(KIN,510)(TEMP1(K),K=1,20)
      WRITE(KOT,510)(TEMP1(K),K=1,20)
      READ(KIN,510)(TEMP1(K),K=1,20)
      WRITE(KOT,510)(TEMP1(K),K=1,20)
      DO 2000 I=1,ITNUM
      WRITE(KOT,700)
      READ(KIN,510)(TEMP1(K),K=1,20)
      WRITE(KOT,510)(TEMP1(K),K=1,20)
```

```
C                                                                        PLOT0145
C     NPT=NUMBER OF POINTS.                                              PLOT0146
      READ (KIN,505)(TEMP1(K),K=1,4),NPT,TEMP1(5),TEMP1(6),TEMP1(7),     PLOT0147
     1TEMP1(8),TEMP1(9),TEMP1(10),TEMP1(11),TEMP1(12),TEMP1(13),         PLOT0148
     2TEMP1(14),TEMP1(15),TEMP1(16),TEMP1(17),TEMP1(18)                  PLOT0149
C                                                                        PLOT0150
      WRITE(KOUT,505)(TEMP1(K),K=1,4),NPT,TEMP1(5),TEMP1(6),TEMP1(7),    PLOT0151
     1TEMP1(8),TEMP1(9),TEMP1(10),TEMP1(11),TEMP1(12),TEMP1(13),         PLOT0152
     2TEMP1(14),TEMP1(15),TEMP1(16),TEMP1(17),TEMP1(18)                  PLOT0153
      READ(KIN,500)WASTE                                                 PLOT0154
      READ(KIN,570)(X(K),K=1,NPT )                                       PLOT0155
      READ(KIN,500)WASTE                                                 PLOT0156
      READ(KIN,570)(Y(K),K=1,NPT )                                       PLOT0157
C                                                                        PLOT0158
C     IF DATA SWITCH 3 DOWN SKIPS TIMELINES AND TIMEMARKS.               PLOT0159
      CALL DATSW(3,I6)                                                   PLOT0160
      IF(I6.EQ.2)GO TO 2000                                              PLOT0161
C                                                                        PLOT0162
                  CALL FGRAF(X,Y,NPT ,+1,-1)                             PLOT0163
 2000 CONTINUE                                                           PLOT0164
 9998 READ(KIN,500)WASTE                                                 PLOT0165
 9999 READ(KIN,500)WASTE                                                 PLOT0166
C                                                                        PLOT0167
C     MESSAGE WRITING PART.                                              PLOT0168
C     POSITIONING OF MESSAGE TO APPEAR ON CHART.                         PLOT0169
      XEMP=XSCL(1)-80.0                                                  PLOT0170
      YEMP=XSCL(3)-150.0                                                 PLOT0171
                  CALL FCHAR(XEMP,YEMP    ,.10,.10,0.0)                  PLOT0172
C                                                                        PLOT0173
                  WRITE(7,599)(XLAB(I),I=1,20)                           PLOT0174
C                                                                        PLOT0175
C                                                                        PLOT0176
      CALL EXIT                                                          PLOT0177
C                                                                        PLOT0178
C                                                                        PLOT0179
C                                                                        PLOT0180
```

```
500  FORMAT(A4)                                                              PLOT0181
510  FORMAT(20A4)                                                            PLOT0182
520  FORMAT(12X,I1,7X,I1,6X,I1,7X,I1,6X,I1,7X,I1,7X,I1,7X,I1)              PLOT0183
525  FORMAT(12X,I1,7X,I1,6X,I1,7X,I1,6X,I1,7X,I1,7X,I1,7X,I1)              PLOT0184
530  FORMAT(10X,F10.0,10X,F10.0,10X,F10.0,10X,F10.0)                        PLOT0185
540  FORMAT(7A4,3X,I2)                                                       PLOT0186
560  FORMAT(I3,9A4,40X,I1)                                                   PLOT0187
570  FORMAT(8F10.0)                                                          PLOT0188
580  FORMAT(I4,9A4,32X,I1)                                                   PLOT0189
590  FORMAT(4A4,2X,I3)                                                       PLOT0190
700  FORMAT('0')                                                             PLOT0191
505  FORMAT(4A4,3X,I5,14A4)                                                  PLOT0192
509  FORMAT(10A4)                                                            PLOT0193
     END                                                                     PLOT0194
```

APPENDIX B

TIDES AT CASTINE, MAINE

JULY 4, 1972 THROUGH JULY 28, 1972

NOTE:

	Castine
L.44	24' N
68	48' W
H.W.	-4 Min on Portland
L.W.	-1 Min on Portland
H.W.	+0.7 FT
L.W.	+0.0 FT

Ranges
MEAN 9.7 FT
SPRING 11.1 FT

MEAN TIDE LEVEL 4.8 FT

ALL HOURS EASTERN DAYLIGHT SAVINGS TIME

	TIDES	
	TIME	HT
July 4, 1972	0503	9.4
	1115	0.1
	1732	10.2
	2356	0.1
July 5	0605	9.2
	1212	0.3
	1834	10.4
July 6	0103	-0.1
	0710	9.1
	1314	0.4
	1932	10.6
July 7	0210	-0.4
	0820	9.1
	1417	0.4
	2035	10.9
July 8	0312	-0.7
	0922	9.3
	1518	0.2
	2137	11.2
July 9	0413	1.0
	1019	9.5
	1616	0.1
	2232	11.4

TIDES

	TIME	HT
July 10	0510	-1.3
	1116	9.0
	1714	-0.1
	2328	10.8
July 11	0601	1.4
	1209	9.8
	1808	-0.2
July 12	0019	11.4
	0651	-1.3
	1258	9.9
	1759	-0.1
July 13	0110	11.1
	0738	-1.1
	1346	9.9
	1950	0.0
July 14	0159	10.7
	0823	-0.7
	1434	9.8
	2039	0.2
July 15	0247	10.1
	0910	-0.2
	1520	9.3
	2130	0.5
July 16	0335	9.5
	0953	0.3
	1606	9.4
	2223	0.8
July 17	0427	8.3
	1041	0.8
	1655	9.2
	2315	1.0
July 18	0520	8.4
	1130	1.2
	1746	9.1
July 19	0013	1.2
	0619	8.1
	1221	1.6
	1839	9.0

TIDES

	TIME	HT
July 20	0109	1.2
	0718	7.9
	1316	1.7
	1935	9.0
July 21	0210	1.1
	0814	7.8
	1411	1.8
	2027	9.1
July 22	0305	0.9
	0909	8.0
	1502	1.7
	2118	9.3
July 23	0354	0.7
	0958	8.2
	1550	1.5
	2204	9.3
July 24	0437	0.4
	1041	8.4
	1635	1.2
	2245	9.9
July 25	0517	0.1
	1122	8.7
	1716	0.9
	2324	10.7
July 26	0554	-0.2
	1158	9.0
	1752	0.6
July 27	0003	10.4
	0630	-0.4
	1236	9.4
	1835	0.3
July 28	0041	10.5
	0707	-0.6
	1313	9.7
	1916	0.0