An Experiment in the

COMPUTER GENERALIZATION OF MAPS

Technical Report No. 1

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ABSTRACT

A number of maps drawn by a computer - plotter combination from digitalized coastal outline information are employed to test various rules of map generalization. Tests include redrawing of information compiled from WAC charts and from 1/50000 Topographic map sheets at several reduced scales.

ACKNOWLEDGEMENTS

The preparation of this report has been facilitated by the assistance of several individuals. Mr. A. V. Hershey, of the Naval Weapons Laboratory, and Mr. C. Bristor, of the Meteorological Satellite Laboratory, both made available world outlines stored on magnetic tape. Professor J. C. Sherman of the University of Washington provided digitalized information for the coast of Alaska. Mr. D. Kolberg prepared some of the detailed information for Kodiak Island. Mr. E. Franckowiak assisted on various aspects of the project . Mr. F. Rens, graduate student in the Department of Geography, did virtually all of the computer programming so vital to the project and carried the bulk of the attendant frustrations. Mr. F. Brock of the Meteorology Computation Laboratory graciously permitted the experiments to be performed on the laboratory's graphic plotter and provided the necessary assistance to make this instrument perform. The University of Michigan Computation Center contributed materially in the numerical processing of the data. The University's Office of Research Administration, and the Office of Naval Research, especially Mr. Robert Alexander of the Geography Branch, provided valuable administrative advice and support. Equipment manufactures, from several companies, supplied details of instruments and their operation. The project has also benefited greatly from conversations with Drs. J. D. Nystuen and J. C. Sherman.

INTRODUCTION

The current revolution in data processing procedures is beginning to have an impact in the field of cartography. This is inevitable since map making characteristically requires manipulation of large volumes of information, numerous computations of a fairly complicated nature, and often (particularly in military situations) a sense of urgency. Digital computers initially are applied to the mechanization of operations already being performed but of a routine nature. These include algebraic manipulations in situations for which the mathematical steps are well known (e.g., triangulation adjustment, map projections) and accounting or administrative functions (preparation of alphabetical lists of place names, and so on). The advent of graphic plotters (instruments which will draw lines) extends this process to operations which traditionally are considered non-mathematical. Map generalization is one such operation.

It appears difficult to determine the exact nature of map generalization, in spite of a growing literature on the subject. The entire problem seems to relate to the question of map scale. It is difficult for laymen to appreciate the enormous reduction involved in the preparation of a map. Consider, for example, a toy automobile (a scale model). A typical reduction here is 1/24 (one inch represents two feet). Map scales range from roughly 1/24,000 to 1/40,000,000. The difference here is several orders of magnitude. As the scale decreases it becomes increasingly difficult to represent any features on the map, particularly as the minimum practical size for a mark on a map is on the order of 0.02 inches. This implies that a feature would need to be more than twelve miles across to be shown at all on a map at a scale of 1/40,000,000. This approach to cartography is rather mechanical, somewhat like the lines per inch resolution of imagery received from Tiros weather satellites. The cartographic tradition is more artistic and imaginative; strict adherence to positional accuracy is abandoned in favor of an approach which judiciously over-enlarges certain features. Consider the artisan producing smaller and smaller scale models of an automobile. If he attempts to adhere to a strict scale relation, but must eliminate features of less than a certain size, his model may eventually no longer look like an automobile. His objective is, however, that the model continues to be recognizable as, and to have the attributes of, an automobile. Somehow he must capture the essential characteristics of automobiles, as a class of objects, and preserve these characteristics during the reduction of scale. The objective of cartographic generalization appears to be similar.

A few specific examples provide elaboration of the intricacies of the process. In the preparation of a small scale map of populated places it is necessary to eliminate some places or the map, with the over-enlarged symbols, would not be legible. It is relatively easy to eliminate all towns of less than a certain size. For most of the map this may work well, but a small isolated town may, because it is the only settlement in the area, be more important than its size would indicate. Often it would be represented on the map, in spite of its small size. To program this step for a computer one could specify a set of rules which eliminate all

settlements of less than a certain size, except (for example) if there is no settlement of comparable size within a certain radius. Another solution might be to employ a classification of settlements based on importance, rather than size. Importance requires specification of "importance for what purpose", and so on. The entire logic (and this is what the computer programmer requires) utilized by the cartographer is complicated.

As a further example, consider a once glaciated area containing many lakes. Typically these lakes are small but extremely numerous. Strict size criteria would require deletion of the majority of the lakes. To retain the character of the area, and to distinguish it from areas containing no lakes, a sprinkling of miniscule (but still larger than the scale would indicate) lakes seems appropriate. Perhaps programming a computer to recognize that the density of small lakes in this region is greater than average, with a feedback mechanism to locally modify the initial deletion criteria, can be achieved. Observe how this situation is almost the opposite of the previous example.

Finally, it occurs frequently that a railroad runs along a narrow river bank, with a road adjacent to the railroad, both of these being at the foot of a steep hill. Strict positional accuracy (to scale) hardly leaves room for the contours and the river's edge, to say nothing of the transportation facilities. Typically everything is displaced slightly to provide the plotting space. This causes no serious problem to the map user, and, in fact is more likely to assist in identification (the metrical information is subordinate to the topological). This appears to represent a different class of problems than those previously cited. To require a computer to recognize when two symbols are about to be placed in the same position is not particularly difficult logically, but it does require a fairly large computer memory, especially if simultaneous juggling of several elements is required. Even as simple an operation as not printing two place names on top of each other becomes complicated.

The foregoing situations are only a few selections from the available literature and are not intended as a comprehensive review of the subject. Generalization is a part of the "art" of cartography, and the majority opinion appears to be that this can never be performed by a computer. Such an opinion obscures the fact that the term generalization, as employed in cartography, appears to cover several classes of situations. It is quite probable that many of these are beyond the economic capabilities of current computers. It is possible, however, that some of them are not. Clarification of the several situations covered by the term generalization may assist in this determination. Two situations already discussed here are of the types "include - do not include" and "move - do not move". The cartographer of the future may sit at a desk all day doing no drawing at all but only making such decisions.

A second consideration is that an increase in the number of computer produced maps is almost inevitable. The question really is not whether a computer can generalize maps, but rather how to instruct a computer to generalize maps, or perhaps, what is the current economic level of computer generalization? The existing computers are sterile in the sense that they

are unable to make judgments except when instructed in detail. The instructions presented to the computers, however, are prepared by clever programmers, and there are many advanced programming techniques (decision theory, learning theory, etc.) now being developed. The optimistic point of view is that these programmers will be able to prepare sets of instructions which cover many of the situations encountered in cartographic generalization. In order to evaluate the effectiveness with which this is done there should be some standards of comparison. At present these are only very loosely formulated. One can classify published maps as being either "poorly" generalized or as "effectively" generalized. Such classifications have been published and suggest that some criteria exist, though they may not be sufficiently explicit to produce instructions for a computer. The current existence of "poorly" generalized maps suggests four possibilities: (1) Computer generalized maps, being based on explicit instructions, may provide more consistent maps and may be an improvement (in several interpretations) over current maps; (2) They may, on the average only, be an improvement; (3) They may be only as good as some of the current poorly generalized maps; or (4) They may be even worse than those produced by the novice cartographer. Situations (1) and (2), and marginally (3), could be considered a net benefit given the current demand for maps. The experiment to be described is an attempt to provide answers to some of these questions.

GENERALIZATION OF COASTLINES

A simple example of map generalization occurs in the drawing of coastlines. As the map scale becomes smaller and smaller, less and less detail of the coast can be shown. This situation is discussed in some detail in the available literature. The generalization of coastlines is only a special case of the more general problem, and a simple case at that. It is anticipated that an analysis of this situation will lead to suggestions for the more general case.

The assembled information relevent to the generalization of coastlines consists of sequential lists of latitude and longitude points stored in a form which can be accepted by data processing equipment. In effect such information constitutes a digitalized outline map from which conventional maps can rapidly be prepared. Data of this type have been available for this experiment for the following areas:

(1) World; entire world on one reel of magnetic tape. Approximately 8,200 points along the coastlines of the world at a spacing of circa thirty miles between points. The same tape contains another 10,000 points covering the United States in more detail. The information was collected from various map sources under the direction of A. V. Hershey. The details of this tape and its utilization are given in a published report by Hershey.

(2) World; entire world on one reel of magnetic tape. Approximately 14,000 points along the coastlines. The information was collected under the direction of C. Bristor from 1:5,000,000 Global Navigation Charts and is intended for automatic super-

imposition of coastal outlines on Tiros photographs. The tape was prepared by the Meteorological Satellite Laboratory of the U. S. Weather Bureau and differs from the Naval Weapons Laboratory tape in the density of detail and in the organization of the information on the tape.

(3) United States; 678 sequential latitude and longitude points recorded on punched cards. Information taken from 1:2,500,000 USGS map of the United States.

(4) Seward Peninsula; complete coastal outline appearing on World Aeronautical Chart #76, information collected to the nearest five minutes under the direction of J. C. Sherman and recorded on punched cards.

(5) Kodiak Island; 480 points recorded on punched cards. Information taken from 1:1,000,000 World Aeronautical Chart #136.

(6) Kodiak Island; Northeastern portion of island punched on cards. Information taken from Army Map Service 1:50,000 topographic map sheets. (series Q701, sheets 6336I, 6336III, 6336IV).

The method of recording differs slightly for each of these sets of data. A general classification might be along the following lines.

Space sampling: A pair of coordinates is recorded every time the curve in question crosses an arbitrary coordinate line. This appears practical for large operations since coordinate recording machines are now available which will automatically digitalize a line being followed with a stylus. The interval between points can be very small (0.005 inch for example). The data covering Seward Peninsula (4) and Kodiak Island (5) were recorded in a somewhat similar manner. A pair of coordinates was obtained for every intersection of the coastline with a five minute line of latitude or longitude.

Time sampling: A pair of coordinates is recorded at a fixed time interval (e.g. 0.1 second) as a stylus is made to follow the curve. This has the advantage that easily followed (and presumably less intricate) lines result in fewer coordinates. Data recorded in this manner have not been available for the experiment.

Amplitude sampling: A pair of coordinates is recorded whenever the curve departs from a straight line by more than some predetermined amount. The distance between points is then a function of the curvature of the curve. The Kodiak Island information obtained from 1/50,000 topographic maps was collected in this manner. In practice this required a straight line of a specified width drawn on a sheet of transparent plastic. This is superimposed on the coastline with one end on the previous coordinate point, and is then rotated until the first emergence of the coastline from under the inked straight line is as far as possible from the initial data point. This point of first emergence becomes the next data point. The process is then repeated with this new initial data point. In this instance the line width was approximately 0.026 inches (a No. 2 leroy pen).

Visual sampling: A coordinate point is recorded at intervals which seem appropriate to the individual performing the recording. Data sets 1, 2, and 3 were obtained in this manner. The net effect appears to be a form of amplitude sampling, perhaps with a conscious or unconscious bias toward inclusion of geographically important features. A detailed comparison of a portion of the data for Seward Peninsula from data sets 1 and 2 indicates general agreement but individual differences. The source maps for these data were not identical which may explain some of the differences. A general difficulty throughout is the definition of "Coastline", particularly in areas of marsh or offshore sand bars, spits, and so on.

Equidistant spacing: A coordinate point is recorded at approximately equidistant spacings, as determined on a map with the aid of a compass or a circle of predetermined radius drawn on transparent plastic.

Priority assignment: Any of the above methods of data recording might be employed but with different points assigned a rating as to importance. Generalization might then be by classes of like (or greater) rating. This has the advantage of allowing insertion of a subjective element into the data recording process. Recording of priorities, however, obviously complicates and retards the data collection procedure. Priority assignment might be especially necessary for the relational aspects of coastal information with other types of information, for example, a point where a river intersects a coast, if both categories are to be generalized together.

A detailed examination of the information contained on the two magnetic tapes (supra) has indicated that, while undoubtedly satisfactory for the purposes intended, this information is not well suited to the research objectives of the current contract. The complexity of the outline of Kodiak Island, for example, makes it an excellent choice for the study of problems of coastline generalization. On the Naval Weapons Laboratory tape, however, Kodiak Island is represented by only twelve points. The entire island is omitted by the Meteorologiaal Satellite Laboratory tape.

Given a set of coastline information as sequential list of coordinate points, it is possible to begin to formulate rules for generalization. One wonders immediately to what extent the success of generalization depends on the method employed to record the coastline information. Three distinct methods of recording coastal information have been employed in this experiment. On a priori grounds it also appears that it is possible to distinguish between a cognitive generalization and a statistical generalization. In terms of coastlines, a cognitive generalization would, on the basis of topical information, designate certain categories of points as being essential - not to be eliminated - with deletion of other points being optional, whereas, the simplest statistical generalization might randomly eliminate points while maintaining certain statistical properties of the parent population.

In terms of specific computer rules for coastline generalization one might:

(1) Plot all points, which amounts to no generalization.

(2) Eliminate every nth point, where n is a function of the reduction in scale from the original compilation scale.

(3) Randomly eliminate 1/nth of the points, where n is again a function of the reduction in scale from the original compilation scale.

(4) As above except that points of priority n (or greater) are retained.

(5) Eliminate points if the absolute value of the angle between the legs meeting at the point in question lies within some predetermined interval.

(6) Eliminate points if, after conversion to scaled map projection coordinates, their distance apart is less than some function of the line width produced by the drawing instrument. This is the approach employed with considerable success by Hershey. It takes advantage of rapid computational facilities and requires that the sometimes complicated projection transformations be applied to each point before it is decided whether or not to include the point. Hershey's maps also raise the question of whether an extrapolation procedure might not be desirable if the points are too far apart.

Each of these rules is relatively easy to program for a computer and only procedure (4) requires more than coordinates of the coastal points.

An additional method of generalization, based on the work of Polish mathematicians, has recently been discussed by Maling. Here the curve in question is replaced by the envelope of circles of a predetermined radius centered on the curve. The net effect is replacement of the curve by a somewhat smoother curve. The amount of generalization depends on the radius of the system of circles, which of course can be quite small (on the order of the line drawn by the plotting instrument). Programming of this procedure is somewhat more intricate but could be effected, one disadvantage being that two different generalizations are possible, since there is an interior and an exterior envelope.

No matter which generalization procedure is employed some type of evaluation must be applied. It is not at all clear how this can be done. If the problem were the generalization of contours, one might randomly sample a large number of points and compare the average elevation and its variance before and after generalization. The approach adopted here is to visually compare the computer - plotter produced maps with reference tracings taken from published maps.

Equipment and Programming Considerations

A computer program was employed to convert the latitude and longitude values into map projection coordinates (Lambert Conformal Conic) at the requisite scale and, more critically, incorporated a set of rules which performed the actual generalization of the information to be mapped. Generalization rules (1), (2), and (3) from the above list were employed. This procedure required approximately one second per thirty points (IBM 7090), including storing of the results on magnetic tape. Data from this tape were then plotted by a Calcomp digital incremental plotter under the

control of a CDC-160A computer. Drawing of the individual maps took between five and fifteen minutes. Details of the programs and computers are relatively unimportant, but characteristics of the specific plotter are of considerable relevance. The instrument draws straight lines between coordinate points in eight cardinal directions. In any other direction a straight line is approximated by steps, 0.01 inch in length, in one of the eight cardinal directions. The result is that some lines appear slightly jagged. This is not of serious consequence for the experiment. Plotters drawing smoother lines are commercially available and can be employed for final map drawing. The Calcomp plotter, however, automatically rejects all points which are less than 0.01 inch from the previous points. In effect, then, the plotter automatically adds generalization rule (6). The consequences of this equipment characteristic are difficult to evaluate. The drawing pens used in the experiment consisted of an ink pen (circa 0.45 mm line width) and a ball point pen (circa 0.2 mm).

Disscussion of Results

Examination of the machine maps is revealing. Data recording errors are blatently obvious. These are of no consequence for this experiment, and have been ignored, but would cause difficulty in actual practice. The data in this case were recorded by hand and the errors constitute only a small, but readily noticed, percentage of all the data points. Comparison of the Maps of Seward Peninsula and of the Great Lakes region, compiled by somewhat different methods, do not display any detectable differences which could be attributed to differences in compilation. These maps also illustrate the large reductions from compilation scale which appear feasible without any generalization beyond that introduced by the Calcomp plotter. These maps appear somewhat better than comparable photoreductions, though the comparison is not quite appropriate. A machine drawn map of Kodiak Island at the original compilation scale indicates the crudity of the map at this size. The map does not begin to appear comparable to hand drawn maps until the data points are less than 0.1 inch apart. Further reduction, with no generalization other than that introduced by the plotter, leads to illegible maps with no reduction in pen size. For Kodiak Island, a relatively complex shape and therefore well suited to the study, this occurs at a tenfold reduction over the compilation scale. Changing to a smaller pen size naturally permits further reduction.

Comparison of the maps, at all scales, with deletion of every other point, every fifth point, a random half of the points, and a random fifth of the points, suggest that these methods of generalization are not appreciably better than drawings including all points except those deleted by the plotting instrument. This argues for the

effectiveness of this relatively simple method of generalization (rule #6). Random deletion of coastal points yields the least appealing map generalization of all the methods attempted.

The generalization illustrated for the detail from the northwestern portion of Kodiak Island includes a reasonable approximation at a reduction factor of 100. This suggests that it is entirely feasible to compile coastal data from topographic sheets onto magnetic tape and then produce drawings for maps at scales as small as 1/5,000,000. Any such effort, however, would need to consider the use of data reduction equipment (coordinate recorders). In this event it is likely that the coordinate points would be much closer together than is the case with manual recording and the data would be obtained in map projection coordinates rather than latitude and longitude.

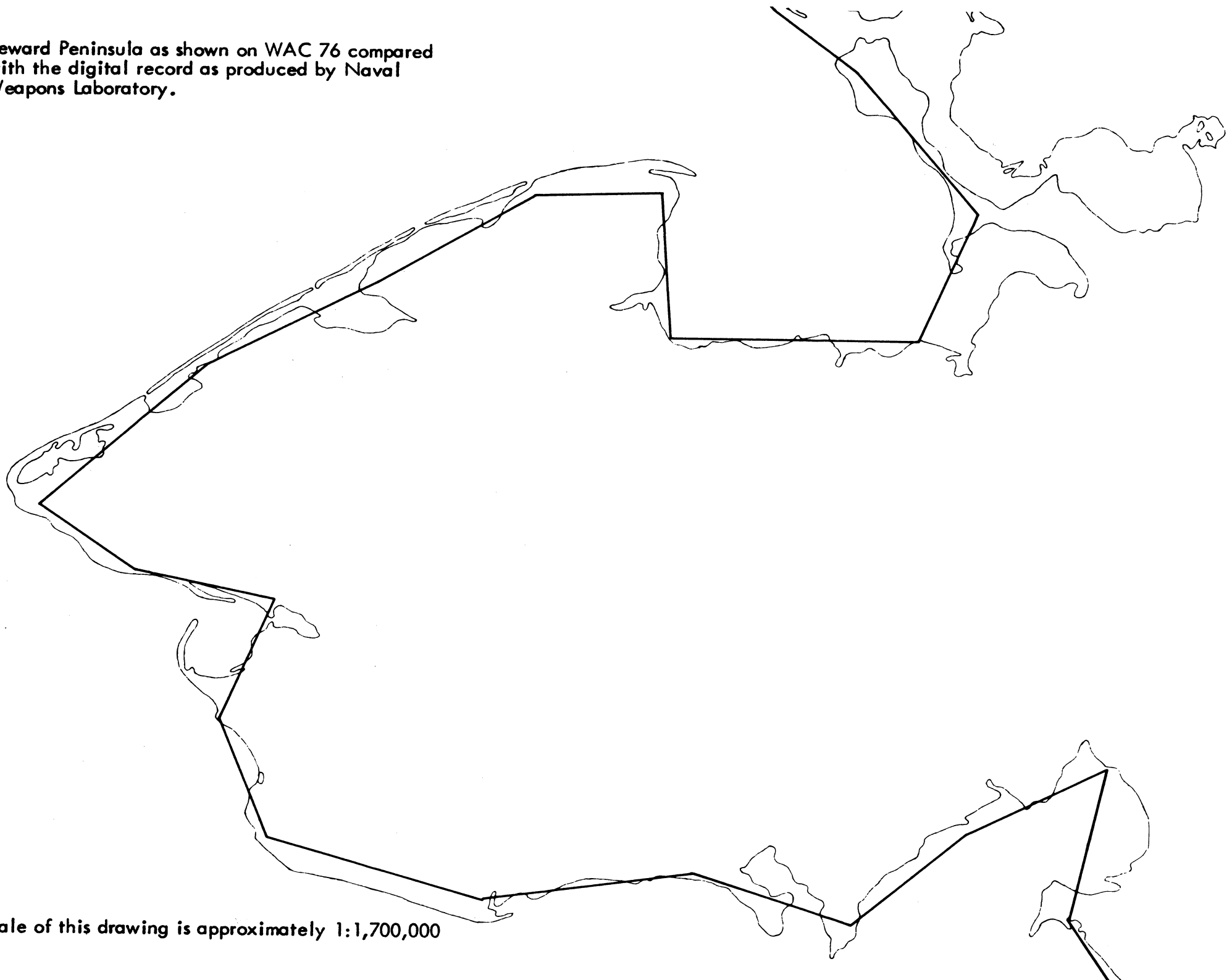
The method of generalization given by rule (6) is such that adjacent, or at least sequential, points are compared. This is a local rule for generalization and does not consider the consequences of points which are spatially close but widely separated in terms of position in a sequential list. Such points will occur at U-shaped inlets or when islands are close to the mainland. The difficulties of generalization occur at these places. It is not known to what extent these situations can be anticipated during the data collection phases of computerized cartography or by more complicated rules of computer generalization.

One of the advantages of storing map information on computer tapes is that the map projection can be changed. For certain situations the speed of scale change may be important, but in every day operations reasonable solutions to this problem can be obtained by conventional procedures. Map projection transformations are more time consuming and costly. In changing from one projection to another it can occur (because of the local projection distortion) that points which initially appeared close together will appear too far apart on the new projection. In an attempt to remedy this situation a computer interpolation of latitude and longitude points between the initially recorded coastal points was attempted. This consisted of converting all of the given points for Kodiak Island into coordinates on a local gnomonic map projection, followed by linear interpolation in the gnomonic plane, with subsequent reconversion of the interpolated (and given) points into latitude and longitude. This yields interpolated points which lie on the great circle connecting the two given points. Two maps were then plotted on a Mercator projection with an equatorial scale of 1/2,000,000. The local scale in the vicinity of Kodiak Island is therfore approximately 1/1,000,000. One map consisted of the original data and the other of the original data plus the interpolated points. This appears to have been an insufficiently drastic example since the two maps are almost indistinguishable. The length of the lines (five minutes) connecting the data points was sufficiently small so that the great circles are

are virtually straight lines on both the Lambert Conformal Conic projection (from which the data were compiled) and the Mercator projection. A more severe test of the interpolation procedure might have been the plotting of Kodiak Island on an oblique azimuthal equidistant projection centered near South Africa. Examination of the tabulated interpolated points, however, did indicate a satisfactory insertion of supplementary data points approximately halfway between the given points. This procedure therefore can be employed for interpolation when required.

As a final conclusion, it is clear from the examples presented that a great deal of map generalization is feasible using computer techniques. It is also clear that a great deal of additional work needs to be performed. It is hoped that the short comings of the materials presented here will stimulate others to improve upon these experiments.

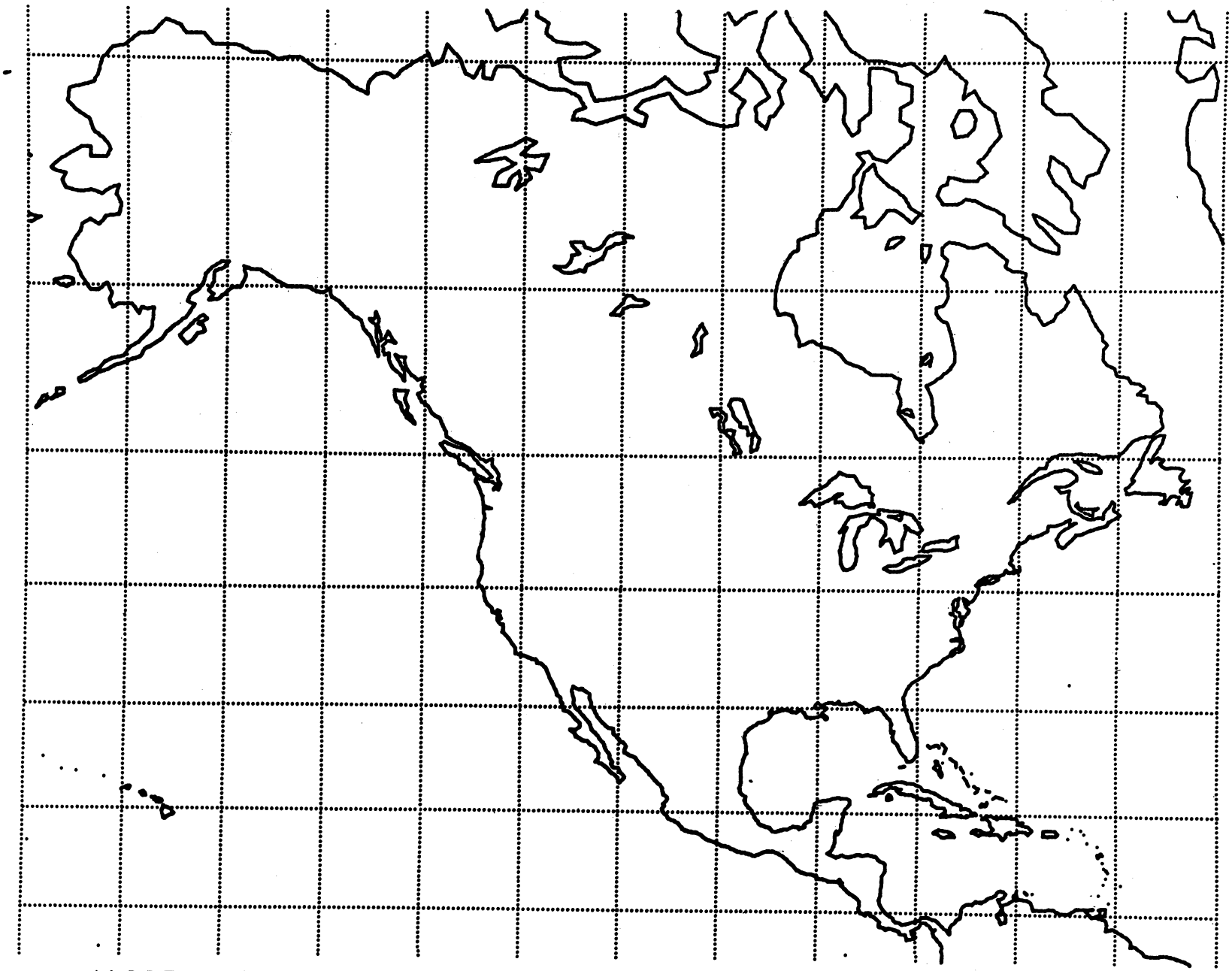
Seward Peninsula as shown on WAC 76 compared with the digital record as produced by Naval Weapons Laboratory.



Scale of this drawing is approximately 1:1,700,000

Seward Peninsula as shown on WAC 76 compared with the digital record as produced by Meteorological Satellite Laboratory.

Scale of this drawing is approximately 1:1,700,000



NORTH AMERICA Drawn by cathode ray tube After Hershey

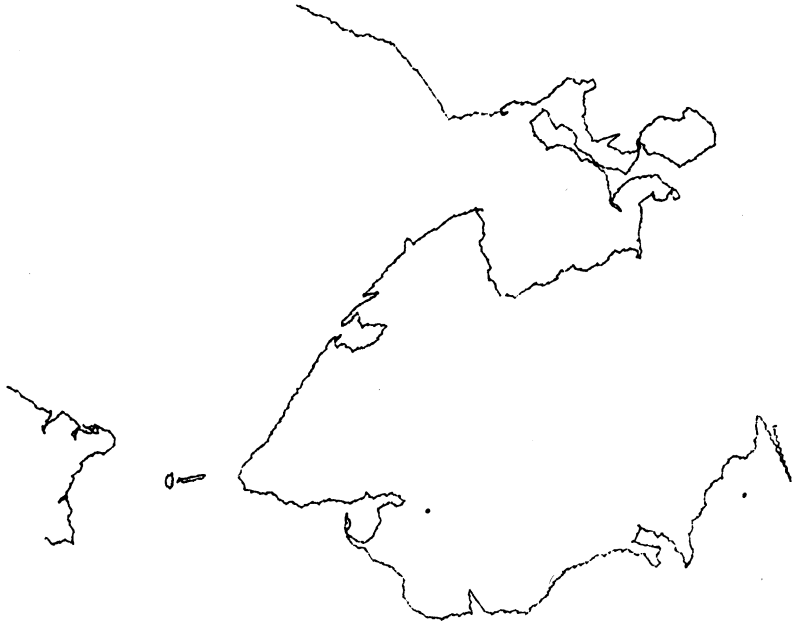
SEWARD PENINSULA

Machine drawn, all points included

1/2,000,000

SEWARD PENINSULA

Machine drawn, all points included



1/10,000,000

1/25,000,000

1/50,000,000

GREAT LAKES

Machine drawn, all points included

1/10,000,000

1/50,000,000

1/100,000,000

KODIAK ISLAND

1/1,000,000

Tracing from

World Aeronautical Chart number 76

KODIAK ISLAND

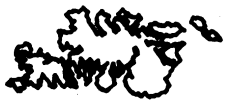
1/1,000,000

Machine drawn,

all points included

1/20,000,000

1/10,000,000

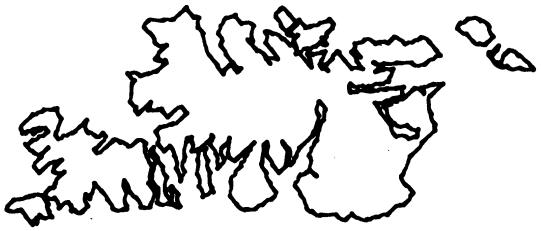


KODIAK ISLAND

Machine drawn with ink pen, all points included

1/5,000,000

1/4,000,000



1/3,000,000

1/2,000,000

1/1,500,000

KODIAK ISLAND 1/2,000,000

KODIAK ISLAND

Machine drawn in ink and ball point pen

1/10,000,000

all points

random half of points

every other point

random fifth of points

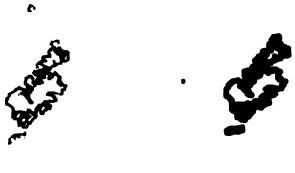
every fifth point

1/20,000,000

random fifth

random half

every other



all points

KODIAK ISLAND 1/5,000,000

Machine drawn in ink and ball point pen

all points

Tracing

random half of points

every other point

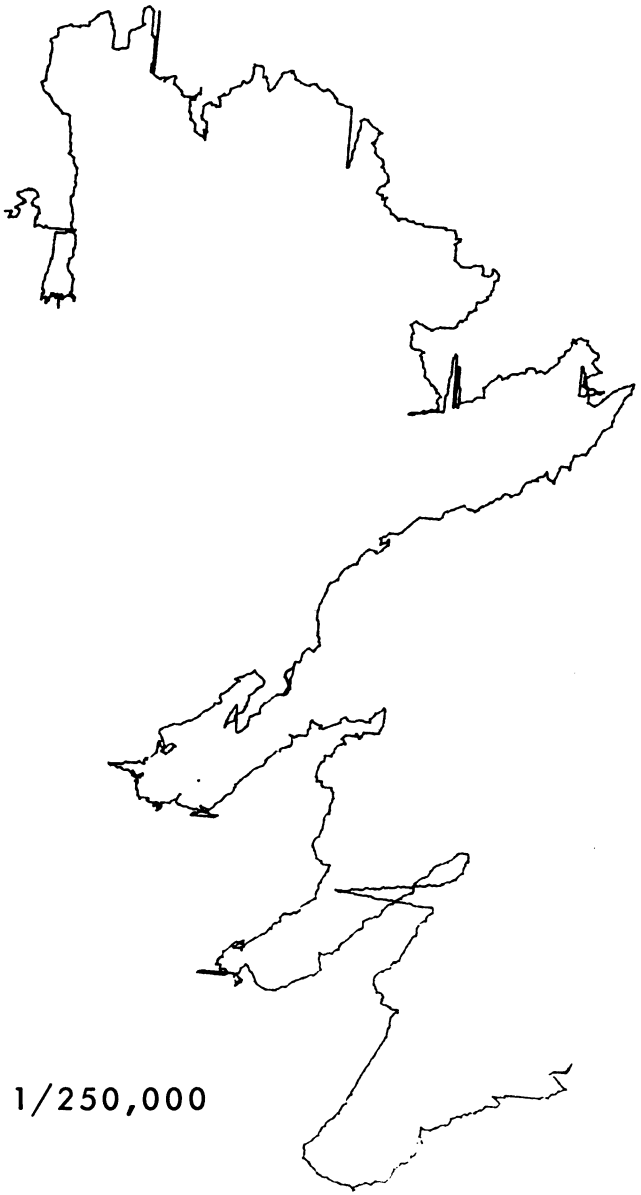
random fifth of points

every fifth point

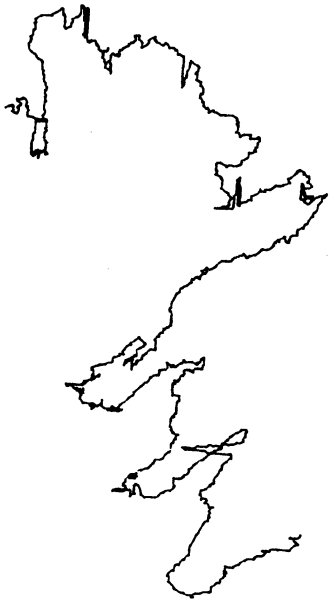
DETAIL OF KODIAK ISLAND

Machine drawn from data compiled at 1/50,000

all points



1/250,000



1/500,000

1/1,000,000

1/5,000,000

Tracing from 1/5,000,000

Jet Navigation Chart

showing area involved

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APPENDIX I

COORDINATES OF KODIAK ISLAND GROUP
COMPILED FROM WAC CHART

LATITUDE AND LONGITUDE IN DECIMAL DEGREES (14X,8F7.3)

DECK NO.,	ISLAND,	SEQUENCE NO.,	4*(LAT,LON)				REMARKS
2	1	1	+ 58000-153267+	57950-153250+	57917-153183+	57900-153167	KODIAK IS
2	1	2	+ 57850-153083+	57833-153067+	57817-153083+	57833-153100	WAC
2	1	3	+ 57867-153167+	57833-153200+	57750-153200+	57750-153217	
2	1	4	+ 57783-153250+	57800-153333+	57833-153433+	57783-153417	
2	1	5	+ 57750-153333+	57700-153333+	57750-153400+	57767-153417	
2	1	6	+ 57750-153500+	57733-153500+	57700-153500+	57683-153500	
2	1	7	+ 57633-153500+	57667-153517+	57750-153567+	57833-153583	
2	1	8	+ 57883-153667+	57883-153750+	57867-153833+	57833-153900	
2	1	9	+ 57800-153917+	57750-153933+	57717-153917+	57700-153833	
2	1	10	+ 57683-153750+	57667-153667+	57600-153583+	57583-153583	
2	1	11	+ 57633-153667+	57650-153750+	57650-153833+	57600-153833	
2	1	12	+ 57550-153750+	57533-153667+	57533-153750+	57583-153833	
2	1	13	+ 57583-153850+	57550-153833+	57500-153817+	57417-153817	
2	1	14	+ 57333-153750+	57300-153667+	57283-153667+	57300-153750	
2	1	15	+ 57333-153800+	57383-153833+	57417-153867+	57500-153917	
2	1	16	+ 57533-154000+	57533-154083+	57550-154000+	57583-153967	
2	1	17	+ 57633-154000+	57650-154083+	57667-154200+	57650-154250	
2	1	18	+ 57633-154333+	57583-154417+	57567-154500+	57533-154500	
2	1	19	+ 57533-154500+	57500-154633+	57467-154667+	57417-154717	
2	1	20	+ 57350-154750+	57333-154767+	57283-154750+	57267-154750	
2	1	21	+ 57267-154667+	57250-154583+	57167-154533+	57083-154517	
2	1	22	+ 57000-154517+	56983-154500+	56967-154417+	56917-154300	
2	1	23	+ 56833-154300+	56867-154250+	56917-154200+	56933-154250	
2	1	24	+ 56950-154167+	57000-154150+	57083-154100+	57100-154083	
2	1	25	+ 57117-154167+	57117-154250+	57083-154333+	57050-154417	
2	1	26	+ 57083-154450+	57117-154417+	57150-154333+	57133-154250	
2	1	27	+ 57133-154167+	57117-154083+	57117-154000+	57083-154067	
2	1	28	+ 57000-154133+	56967-154083+	57000-154050+	57033-154000	
2	1	29	+ 57083-153933+	57133-153833+	57167-153800+	57133-153750	
2	1	30	+ 57100-153833+	57083-153883+	57050-153167+	57000-153967	
2	1	31	+ 56950-153917+	57000-153520+	57016-153833+	57000-153833	
2	1	32	+ 56983-153833+	57000-153767+	56967-153833+	56917-153917	
2	1	33	+ 56867-154000+	56833-154083+	56750-154133+	56750-154083	
2	1	34	+ 56750-154000+	56767-153917+	56833-153850+	56850-153750	
2	1	35	+ 56867-153750+	56883-153750+	56917-153700+	56933-153667	
2	1	36	+ 56950-153583+	57000-153550+	57017-153583+	57017-153667	
2	1	37	+ 57033-153583+	57050-153667+	57050-153750+	57083-153667	
2	1	38	+ 57083-153583+	57067-153500+	57083-153483+	57117-153500	
2	1	39	+ 57150-153500+	57167-153483+	57167-153550+	57183-153500	
2	1	40	+ 57167-153467+	57117-153417+	57167-153367+	57183-153333	
2	1	41	+ 57217-153417+	57217-153167+	57217-153083+	57233-153000	
2	1	42	+ 57250-152950+	57283-153000+	57283-153083+	57300-153167	
2	1	43	+ 57333-153100+	57333-153150+	57317-153083+	57333-153000	
2	1	44	+ 57333-152917+	57333-152883+	57317-152917+	57267-152833	
2	1	45	+ 57300-152750+	57283-152667+	57333-152633+	57400-152667	
2	1	46	+ 57417-152733+	57433-152750+	57450-152833+	57450-152917	
2	1	47	+ 57433-153000+	57467-153000+	57467-152917+	57500-152917	
2	1	48	+ 57517-152917+	57500-152833+	57500-152750+	57450-152583	
2	1	49	+ 57450-152500+	57417-152467+	57433-152417+	57417-152333	
2	1	50	+ 57500-152317+	57533-152250+	57583-152167+	57617-152167	
2	1	51	+ 57617-152250+	57633-152333+	57600-152417+	57667-152417	

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2  1  52     + 57683-152417+ 57667-152450+ 57650-152500+ 57667-152500
2  1  53     + 57717-152500+ 57750-152467+ 57783-152417+ 57817-152333
2  1  54     + 57817-152417+ 57833-152417+ 57900-152500+ 57900-152583
2  1  55     + 57917-152583+ 57917-152633+ 57833-152633+ 57867-152667
2  1  56     + 57833-152717+ 57817-152750+ 57833-152767+ 57833-152833
2  1  57     + 57750-152850+ 57440-152833+ 57750-152917+ 57833-152900
2  1  58     + 57883-152833+ 57917-152833+ 57950-152917+ 57950-153000
2  1  59     + 57917-153000+ 57933-153083+ 57967-153167+ 58000-153267
                + 95000
2  2   1     + 58467-152667+ 58417-152683+ 58417-152717+ 58433-152750AFOGNAK
2  2   2     + 58417-152783+ 58400-152833+ 58367-152833+ 58333-152750ISLAND
2  2   3     + 58333-152800+ 58267-152750+ 58283-152500+ 58283-152917WAC 136
2  2   4     + 58300-153000+ 58267-153083+ 58250-153100+ 58233-153083
2  2   5     + 58200-153000+ 58167-152917+ 58183-153000+ 58183-153083
2  2   6     + 58200-153167+ 58167-153233+ 58100-153167+ 58100-153083
2  2   7     + 58083-153083+ 58033-153000+ 58000-152867+ 57983-152833
2  2   8     + 58000-152767+ 58050-152750+ 58067-152667+ 58083-152617
2  2   9     + 58167-152583+ 58167-152550+ 58083-152550+ 58083-152517
2  2  10     + 58117-152500+ 58133-152417+ 58100-152333+ 58167-152333
2  2  11     + 58250-152267+ 58250-152233+ 58167-152167+ 58150-152083
2  2  12     + 58167-152067+ 58200-152000+ 58250-151967+ 58333-151967
2  2  13     + 58350-152000+ 58333-152017+ 58267-152083+ 58317-152083
2  2  14     + 58250-152117+ 58250-152150+ 58333-152117+ 58367-152083
2  2  15     + 58367-152167+ 58350-152250+ 58300-152250+ 58417-152267
2  2  16     + 58417-152333+ 58333-152367+ 58300-152417+ 58333-152400
2  2  17     + 58367-152417+ 58333-152500+ 58400-152500+ 58417-152517
2  2  18     + 58433-152500+ 58467-152500+ 58450-152583+ 58467-152667
                + 95000
2  3   1     + 57967-153500+ 57917-153533+ 57900-153500+ 57867-153417UGANIK
2  3   2     + 57833-153333+ 57800-153250+ 57833-153200+ 57867-153250ISLAND
2  3   3     + 57917-153333+ 57950-153417+ 57967-153500+ 95000        WAC  136
2  4   1     + 59417-153433+ 59383-153500+ 59333-153583+ 59317-153583AUGUSTINE
2  4   2     + 59300-153500+ 59317-153417+ 59333-153367+ 59367-153333ISLAND
2  4   3     + 59417-153383+ 59417-153433+ 95000                      WAC 136
2  5   1     + 55917-155583+ 55867-155667+ 55833-155750+ 55817-155750CHIRIKOF
2  5   2     + 55783-155667+ 55767-155583+ 55833-155567+ 55917-155567ISLAND
2  5   3     + 55917-155583+ 95000                                    WAC 136
2  6   1     + 56600-154500+ 56583-154567+ 56567-154583+ 56533-154667TUGIDAK
2  6   2     + 56500-154733+ 56483-154750+ 56417-154767+ 56400-154750ISLAND
2  6   3     + 56417-154717+ 56450-154667+ 56500-154583+ 56517-154500WAC 136
2  6   4     + 56533-154500+ 56583-154533+ 56600-154500+ 56583-154433
2  6   5     + 56533-154417+ 56583-154400+ 56600-154417+ 56600-154500
                + 95000
2  7   1     + 56617-154083+ 56600-154167+ 56600-154250+ 56583-154300SITKINAK
2  7   2     + 56567-154333+ 56517-154333+ 56500-154250+ 56517-154167ISLAND
2  7   3     + 56550-154083+ 56583-154067+ 56617-154083+ 95000        WAC 136
2  8   1     + 57217-153250+ 57167-153300+ 57133-153333+ 57100-153333SITKALIDAK
2  8   2     + 57083-153383+ 57083-153333+ 57083-153317+ 57067-153333ISLAND
2  8   3     + 57050-153333+ 57017-153333+ 57000-153317+ 57000-153267WAC 136
2  8   4     + 57083-153183+ 57100-153167+ 57100-153083+ 57117-153083
2  8   5     + 57117-153000+ 57117-152917+ 57167-152917+ 57183-153000
2  8   6     + 57167-153083+ 57100-153083+ 57167-153067+ 57183-153083
2  8   7     + 57167-153117+ 57150-153167+ 57183-153167+ 57217-153250
                + 95000
2  9   1     + 58100-153333+ 58083-153367+ 58067-153417+ 58033-153333RASPBERRY
2  9   2     + 58033-153250+ 58050-153250+ 58083-153333+ 58067-153250ISLAND
2  9   3     + 58017-153167+ 58000-153083+ 57983-153000+ 57967-152917WAC 136
2  9   4     + 58000-152917+ 58017-153000+ 58083-153083+ 58083-153167
2  9   5     + 58133-153250+ 58100-153333+ 95000
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2 10    1      + 58600-152583+ 58567-152583+ 58583-152617+ 58550-152583SHUYAK
2 10    2      + 58517-152667+ 58500-152617+ 58483-152583+ 58467-152500ISLAND
2 10    3      + 58500-152433+ 58517-152417+ 58583-152333+ 58633-152333WAC 136
2 10    4      + 58600-152417+ 58583-152433+ 58600-152500+ 58600-152550
2 10    5      + 58600-152583+ 98000
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APPENDIX II

COORDINATES OF SEWARD PENINSULA
COMPILED FROM WAC CHART NO. 76

LATITUDE AND LONGITUDE IN DECIMAL DEGREES (14X,8F7.3)

DECK NO.,ISLAND,SEQUENCE NO., 4*(LAT,LON) REMARKS

3	1	1	+ 68000-165250+	67967-165167+	67950-165083+	67917-165033	SEWARD
3	1	2	+ 67900-165000+	67883-164917+	67850-164833+	67867-164833	PENINSULA
3	1	3	+ 67833-164800+	67817-164750+	67783-164667+	67750-164583	WAC 76
3	1	4	+ 67750-164567+	67717-164500+	67700-164417+	67683-164333	
3	1	5	+ 67667-164283+	67650-164250+	67633-164167+	67600-164083	
3	1	6	+ 67583-164050+	67550-164000+	67500-163950+	67467-163917	
3	1	7	+ 67417-163867+	67383-163833+	67333-163800+	67250-163750	
3	1	8	+ 67167-163717+	67100-163667+	67100-163583+	67083-163500	
3	1	9	+ 67083-163450+	67083-163417+	67067-163333+	67067-163250	
3	1	10	+ 67050-163167+	67033-163083+	67033-163000+	67017-162917	
3	1	11	+ 67000-162833+	67017-162833+	67017-162917+	67050-162917	
3	1	12	+ 67050-162833+	67050-162750+	67050-162667+	67033-162667	
3	1	13	+ 67017-162583+	67017-162500+	67000-162467+	66983-162417	
3	1	14	+ 67000-162333+	67000-162250+	67000-162217+	67017-162167	
3	1	15	+ 67033-162083+	67033-162000+	67050-161917+	67050-161833	
3	1	16	+ 67033-161750+	67000-161717+	67017-161667+	67000-161617	
3	1	17	+ 66983-161583+	66983-161500+	66950-161500+	66950-161583	
3	1	18	+ 66950-161667+	66917-161733+	66900-161750+	66833-161800	
3	1	19	+ 66817-161833+	66750-161867+	66683-161833+	66667-161783	
3	1	20	+ 66650-161450+	66617-161667+	66583-161583+	66550-161500	
3	1	21	+ 66533-161417+	66533-161333+	66550-161250+	66583-161217	
3	1	22	+ 66617-161167+	66633-161083+	66633-161000+	66650-160917	
3	1	23	+ 66650-160833+	66633-160750+	66600-160667+	66583-160583	
3	1	24	+ 66583-160500+	66617-160500+	66633-160417+	66600-160333	
3	1	25	+ 66583-160300+	66550-160250+	66500-160200+	66417-160217	
3	1	26	+ 66383-160250+	66383-160333+	66383-160417+	66367-160500	
3	1	27	+ 66367-160583+	66367-160667+	66367-160750+	66367-160833	
3	1	28	+ 66400-160917+	66417-160933+	66450-161000+	66483-161083	
3	1	29	+ 66500-161167+	66550-161167+	66583-161250+	66500-161317	
3	1	30	+ 66483-161333+	66467-161417+	66450-161500+	66450-161583	
3	1	31	+ 66483-161667+	66500-161750+	66533-161833+	66567-161917	
3	1	32	+ 66583-161933+	66633-162000+	66667-162067+	66700-162083	
3	1	33	+ 66750-162033+	66800-162083+	66833-162167+	66833-162250	
3	1	34	+ 66917-162283+	66950-162333+	66933-162333+	66933-162417	
3	1	35	+ 66917-162500+	66900-162583+	66833-162583+	66833-162567	
3	1	36	+ 66783-162500+	66750-162483+	66733-162500+	66733-162417	
3	1	37	+ 66733-162333+	66717-162250+	66683-162167+	66667-162133	
3	1	38	+ 66600-162083+	66583-162000+	66550-161917+	66500-161867	
3	1	39	+ 66417-161867+	66350-161917+	66333-161933+	66317-161917	
3	1	40	+ 66267-161833+	66283-161833+	66333-161917+	66367-161833	
3	1	41	+ 66383-161750+	66400-161667+	66400-161583+	66400-161500	
3	1	42	+ 66383-161417+	66383-161333+	66367-161250+	66350-161167	
3	1	43	+ 66333-161133+	66300-161083+	66250-161000+	66200-161000	
3	1	44	+ 66200-161083+	66250-161083+	66217-161167+	66233-161250	
3	1	45	+ 66250-161317+	66267-161333+	66283-161333+	66283-161417	
3	1	46	+ 66267-161500+	66250-161550+	66217-161583+	66167-161633	
3	1	47	+ 66133-161667+	66083-161750+	66083-161767+	66067-161750	
3	1	48	+ 66000-161817+	65983-161833+	66000-161867+	66033-161833	
3	1	49	+ 66050-161917+	66067-162000+	66067-162083+	66083-162133	
3	1	50	+ 66067-162167+	66050-162250+	66033-162333+	66050-162417	
3	1	51	+ 66050-162500+	66050-162583+	66067-162667+	66083-162733	

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3  1  52    + 66100-162750+ 66083-162833+ 66100-162917+ 66083-162967
3  1  53    + 66067-163000+ 66067-163083+ 66067-163167+ 66067-163250
3  1  54    + 66083-163317+ 66083-163333+ 66083-163417+ 66083-163500
3  1  55    + 66067-163583+ 66067-163667+ 66083-163750+ 66100-163833
3  1  56    + 66167-163867+ 66200-163917+ 66217-163917+ 66250-163883
3  1  57    + 66267-163833+ 66300-163833+ 66333-163867+ 66417-163850
3  1  58    + 66417-163833+ 66450-163750+ 66500-163717+ 66567-163750
3  1  59    + 66583-163750+ 66567-163667+ 66583-163667+ 66600-163750
3  1  60    + 66600-163833+ 66600-163917+ 66600-164000+ 66600-164083
3  1  61    + 66600-164167+ 66583-164250+ 66583-164333+ 66583-164417
3  1  62    + 66567-164500+ 66567-164583+ 66550-164667+ 66533-164750
3  1  63    + 66583-164833+ 66517-164917+ 66500-165000+ 66483-165083
3  1  64    + 66467-165167+ 66450-165250+ 66433-165333+ 66417-165417
3  1  65    + 66400-165500+ 66383-165583+ 66367-165667+ 66350-165450
3  1  66    + 66333-165783+ 66317-165833+ 66300-165917+ 66283-166000
3  1  67    + 66267-166083+ 66250-166100+ 66250-166083+ 66267-166000
3  1  68    + 66283-165917+ 66300-165833+ 66267-165833+ 66250-165867
3  1  69    + 66217-165833+ 66217-165750+ 66200-165667+ 66183-165583
3  1  70    + 66167-165500+ 66133-165583+ 66117-165667+ 66117-165750
3  1  71    + 66117-165833+ 66117-165917+ 66117-166000+ 66117-166083
3  1  72    + 66167-166167+ 66167-166250+ 66200-166250+ 66217-166167
3  1  73    + 66217-166250+ 66200-166333+ 66167-166417+ 66150-166500
3  1  74    + 66117-166583+ 66100-166667+ 66083-166700+ 66067-166750
3  1  75    + 66050-166833+ 66017-166917+ 66017-166983+ 66000-167000
3  1  76    + 65967-167083+ 65933-167167+ 65917-167233+ 65900-167250
3  1  77    + 65883-167333+ 65850-167417+ 65833-167500+ 65800-167583
3  1  78    + 65800-167667+ 65783-167750+ 65767-167833+ 65750-167867
3  1  79    + 65733-167917+ 65717-168000+ 65683-168083+ 65667-168117
3  1  80    + 65600-168083+ 65583-168067+ 65567-168000+ 65550-167917
3  1  81    + 65533-167833+ 65517-167750+ 65500-167700+ 65483-167667
3  1  82    + 65450-167583+ 65433-167500+ 65417-167467+ 65400-167417
3  1  83    + 65400-167333+ 65400-167250+ 65383-167167+ 65383-167083
3  1  84    + 65383-167000+ 65367-166917+ 65350-166833+ 65333-166750
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3  1  86    + 65317-166417+ 65317-166333+ 65300-166250+ 65300-166167
3  1  87    + 65283-166083+ 65250-166033+ 65233-166083+ 65250-166167
3  1  88    + 65267-166250+ 65267-166333+ 65250-166400+ 65233-166417
3  1  89    + 65167-166467+ 65150-166500+ 65117-166583+ 65117-166667
3  1  90    + 65117-166750+ 65133-166833+ 65167-166917+ 65200-166917
3  1  91    + 65250-166850+ 65283-166833+ 65250-166883+ 65217-166917
3  1  92    + 65167-166950+ 65133-166917+ 65083-166833+ 65067-166750
3  1  93    + 65000-166700+ 64983-166667+ 64967-166583+ 64933-166500
3  1  94    + 64917-166467+ 64883-166417+ 64833-166383+ 64800-166417
3  1  95    + 64750-166467+ 64683-166417+ 64667-166400+ 64633-166333
3  1  96    + 64600-166250+ 64583-166167+ 64567-166083+ 64567-166000
3  1  97    + 64567-165917+ 64550-165833+ 64550-165750+ 64533-165667
3  1  98    + 64667-165583+ 64517-165500+ 64500-165417+ 64500-165367
3  1  99    + 64500-165333+ 64483-165250+ 64467-165167+ 64450-165083
3  1 100    + 64433-165000+ 64450-164917+ 64450-164833+ 64467-164750
3  1 101    + 64483-164667+ 64500-164633+ 64517-164583+ 64533-164500
3  1 102    + 64550-164417+ 64567-164333+ 64567-164250+ 64567-164167
3  1 103    + 64567-164083+ 64567-164000+ 64567-163917+ 64583-163833
3  1 104    + 64567-163750+ 64567-163667+ 64567-163583+ 64550-163500
3  1 105    + 64533-163417+ 64500-163333+ 64483-163250+ 64417-163200
3  1 106    + 64400-163167+ 64417-163100+ 64450-163083+ 64467-163083
3  1 107    + 64500-163033+ 64517-163083+ 64533-163167+ 64550-163250
3  1 108    + 64583-163333+ 64617-163250+ 64650-163167+ 64600-163083
3  1 109    + 64583-163017+ 64550-163000+ 64550-162917+ 64500-162833
3  1 110    + 64483-162833+ 64450-162833+ 64417-162800+ 64333-162783
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3   1 111      + 64350-162750+ 64383-162667+ 64417-162617+ 64500-162583
3   1 112      + 64550-162500+ 64567-162417+ 64583-162367+ 64600-162333
3   1 113      + 64617-162250+ 64667-162200+ 64683-162167+ 64700-162083
3   1 114      + 64700-162000+ 64700-161917+ 64750-161867+ 64767-161833
3   1 115      + 64783-161750+ 64783-161667+ 64767-161583+ 64750-161533
3   1 116      + 64750-161517+ 64767-161500+ 64767-161417+ 64817-161333
3   1 117      + 64833-161317+ 64867-161250+ 64917-161183+ 64933-161167
3   1 118      + 64917-161133+ 64530-161083+ 64850-161000+ 64833-160967
                + 95000
3   2   1      + 65667-170933+ 65667-170917+ 65617-170833+ 65617-170750USSR
3   2   2      + 65617-170667+ 65600-170583+ 65667-170517+ 65750-170533WAC 76
3   2   3      + 65783-170500+ 65850-170500+ 65850-170583+ 65833-170617
3   2   4      + 65833-170633+ 65850-170583+ 65883-170500+ 65917-170417
3   2   5      + 65950-170333+ 65967-170250+ 66000-170183+ 66017-170167
3   2   6      + 66033-170083+ 66033-170000+ 66033-169917+ 66017-169833
3   2   7      + 66050-169667+ 66083-169633+ 66133-169667+ 66150-169750
3   2   8      + 66167-169800+ 66183-169833+ 66183-169917+ 66200-170000
3   2   9      + 66183-170000+ 66167-169917+ 66167-169833+ 66133-169833
3   2  10      + 66150-169917+ 66167-170000+ 66167-170050+ 66183-170083
3   2  11      + 66167-170117+ 66133-170167+ 66167-170200+ 66183-170167
3   2  12      + 66200-170083+ 66217-170083+ 66250-170150+ 66267-170167
3   2  13      + 66300-170250+ 66283-170333+ 66283-170417+ 66250-170500
3   2  14      + 66217-170583+ 66250-170583+ 66250-170533+ 66283-170500
3   2  15      + 66317-170417+ 66333-170417+ 66333-170467+ 66350-170500
3   2  16      + 66367-170583+ 66417-170667+ 66450-170750+ 66483-170833
3   2  17      + 66500-170883+ 66517-170917+ 66550-180000+ 95000
3   3   1      + 65733-169083+ 65750-169050+ 65783-169000+ 65800-169000BIGDIOMEDE
3   3   2      + 65800-169050+ 65750-169117+ 65733-169083+ 95000        ISWAC 76
3   4   1      + 65750-168950+ 65733-168550+ 65750-168883+ 65767-168917LITDIOMEDE
3   4   2      + 65750-168950+ 98000                                    ISWAC 76
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APPENDIX III

COORDINATES OF DETAIL OF KODIAK ISLAND
COMPILED FROM 1/50,000 TOPOGRAPHIC SHEETS

LATITUDE AND LONGITUDE IN DEGREES ,MINUTES, AND SECONDS
(15X,3(F3.0,F2.0,F2.0,F4.0,F2.0,F2.0))

DECK NO.	ISLAND	SEQUENCE NO.	3*(LAT,LON)	REMARKS
4	1		+573753-1522000 +573740-1522012 +573738-1522037	
4	2		+573725-1522009 +573715-1522036 +573715-1522042	
4	3		+573713-1522054 +573713-1522158 +573710-1522158	
4	4		+573710-1522220 +573705-1522206 +573700-1522215	
4	5		+573700-1522232 +573657-1522240 +573655-1522251	
4	6		+573652-1522250 +573649-1522317 +573645-1522337	
4	7		+573639-1522344 +573635-1522402 +573633-1522409	
4	8		+573634-1522430 +573624-1522435 +573624-1522431	
4	9		+573624-1522426 +573619-1522424 +573620-1522427	
4	10		+573619-1522434 +573615-1522432 +573605-1522442	
4	11		+573557-1522454 +573557-1522500 +573551-1522514	
4	12		+573539-1522524 +573537-1522530 +573535-1522553	
4	13		+573533-1522555 +573535-1522602 +573529-1522625	
4	14		+573525-1522628 +573526-1522622 +573530-1522634	
4	15		+573533-1522656 +573542-1522736 +573556-1522800	
4	16		+573606-1522804 +573610-1522800 +573620-1522740	
4	17		+573631-1522727 +573644-1522702 +573654-1522651	
4	18		+573705-1522644 +573807-1522544 +573816-1522539	
4	19		+573819-1522541 +573821-1522539 +573826-1522539	
4	20		+573833-1522528 +573835-1522527 +573836-1522542	
4	21		+573842-1522556 +573845-1522557 +573848-1522554	
4	22		+573852-1522601 +573852-1522609 +573900-1522618	
4	23		+573908-1522613 +573914-1522601 +573918-1522544	
4	24		+573924-1522537 +573926-1522530 +573952-1522504	
4	25		+574002-1522459 +574008-1522447 +574018-1522433	
4	26		+574024-1522437 +574036-1522737 +574048-1522418	
4	27		+574054-1522355 +574100-1522342 +574113-1522334	
4	28		+574120-1522340 +574119-1522357 +574111-1522412	
4	29		+574102-1522439 +574101-1522445 +574053-1522455	
4	30		+574046-1522510 +574036-1522516 +574031-1522534	
4	31		+574024-1522552 +574016-1522610 +574011-1522618	
4	32		+574003-1522641 +573956-1522646 +573948-1522706	
4	33		+573937-1522724 +573933-1522725 +573929-1522735	
4	34		+573928-1522746 +573930-1522801 +573912-1522752	
4	35		+573906-1522806 +573857-1522844 +573851-1522858	
4	36		+573848-1522918 +573850-1522941 +573855-1522954	
4	37		+573913-1523016 +573909-1523022 +573902-1523029	
4	38		+573856-1523019 +573853-1523026 +573853-1523021	
4	39		+573850-1523031 +573902-1523039 +573900-1523143	
4	40		+573902-1523047 +573902-1523051 +573906-1523054	
4	41		+573907-1523100 +573910-1523059 +573910-1523107	
4	42		+573913-1523107 +573913-1523104 +573918-1523056	
4	43		+573919-1523059 +573920-1523056 +573924-1523056	
4	44		+573934-1523033 +573936-1523020 +573932-1523023	
4	45		+573928-1523040 +573930-1523021 +573927-1523023	
4	46		+573931-1523019 +573941-1522959 +573950-1522930	
4	47		+573956-1522924 +573958-1522917 +574003-1522915	
4	48		+574008-1522909 +574012-1522841 +574022-1522825	
4	49		+574026-1522815 +574042-1522805 +574053-1522754	
4	50		+574100-1522749 +574103-1522810 +574105-1522808	

4	51	+574107-1522816	+574118-1522827	+574128-1522817
4	52	+574138-1522808	+574147-1522807	+574154-1522800
4	53	+574158-1522800	+574210-1522753	+574213-1522756
4	54	+574216-1522755	+574218-1522757	+574221-1522757
4	55	+574223-1522818	+574226-1522819	+574227-1522825
4	56	+574230-1522828	+574247-1522817	+574248-1522813
4	57	+574253-1522813	+574253-1522801	+574256-1522801
4	58	+574257-1522756	+574305-1522747	+574308-1522737
4	59	+574311-1522744	+574315-1522738	+574316-1522716
4	60	+574317-1522718	+574313-1522710	+574316-1522707
4	61	+574319-1522701	+574320-1522637	+574327-1522627
4	62	+574345-1522630	+574339-1522644	+574333-1522654
4	63	+574330-1522656	+574329-1522702	+574332-1522711
4	64	+574331-1522723	+574332-1522736	+574334-1522742
4	65	+574332-1522747	+574329-1522750	+574320-1522819
4	66	+574321-1522829	+574323-1522827	+574323-1522822
4	67	+574324-1522822	+574328-1522844	+574326-1522847
4	68	+574321-1522847	+574318-1522849	+574313-1522856
4	69	+574312-1522906	+574311-1522908	+574311-1522915
4	70	+574312-1522920	+574310-1522918	+574301-1522920
4	71	+574257-1522938	+574255-1522938	+574255-1522946
4	72	+574244-1523004	+574235-1523017	+574222-1523046
4	73	+574217-1523055	+574213-1523058	+574149-1523143
4	74	+574153-1523158	+574147-1523148	+574144-1523215
4	75	+574145-1523124	+574153-1523236	+574153-1523241
4	76	+574156-1523243	+574203-1523238	+574205-1523241
4	77	+574154-1523256	+574154-1523309	+574149-1523310
4	78	+574146-1523317	+574148-1523313	+574152-1523313
4	79	+574154-1523317	+574149-1523320	+574154-1523322
4	80	+574151-1523328	+574154-1523324	+574157-1523337
4	81	+574157-1523334	+574158-1523335	+574156-1523352
4	82	+574159-1523354	+574200-1523356	+574206-1523402
4	83	+574212-1523400	+574215-1523404	+574213-1523358
4	84	+574222-1523408	+574222-1523404	+574220-1523404
4	85	+574219-1523352	+574223-1523349	+574222-1523357
4	86	+574222-1523406	+574225-1523406	+574220-1523357
4	87	+574220-1523347	+574232-1523454	+574235-1523356
4	88	+574233-1523349	+574234-1523345	+574236-1523347
4	89	+574236-1523349	+574238-1523349	+574237-1523344
4	90	+574240-1523345	+574238-1523340	+574240-1523340
4	91	+574246-1523325	+574251-1523324	+574252-1523325
4	92	+574257-1523321	+574251-1523313	+574247-1523316
4	93	+574246-1523309	+574254-1523252	+574256-1523257
4	94	+574251-1523309	+574253-1523313	+574305-1523324
4	95	+574310-1523322	+574316-1523257	+574318-1523238
4	96	+574326-1523210	+574333-1523159	+574339-1523144
4	97	+574341-1523143	+574343-1523131	+574346-1523135
4	98	+574351-1523131	+574404-1523102	+574406-1523106
4	99	+574417-1523033	+574406-1523013	+574351-1523040
4	100	+574337-1523049	+574316-1523126	+574339-1523101
4	101	+574311-1523057	+574319-1523039	+574321-1523039
4	102	+574329-1523034	+574334-1523020	+574343-1523012
4	103	+574345-1523004	+574353-1522947	+574354-1522936
4	104	+574359-1522930	+574412-1522939	+574423-1522925
4	105	+574426-1522920	+574429-1522918	+574428-1522913
4	106	+574431-1522906	+574439-1522904	+574443-1522855
4	107	+574441-1522848	+574442-1522843	+574443-1522844
4	108	+574447-1522838	+574451-1522841	+574455-1522839
4	109	+574456-1522845	+574500-1522845	+574505-1522843

4	110	+574509-1522842	+574514-1522847	+574523-1522843
4	111	+574552-1522822	+574557-1522812	+574605-1522802
4	112	+574608-1522754	+574610-1522750	+574615-1522735
4	113	+574623-1522730	+574625-1522724	+574628-1522717
4	114	+574627-1522706	+574625-1522705	+574635-1522643
4	115	+574640-1522640	+574637-1522648	+574635-1522656
4	116	+574640-1522700	+574646-1522642	+574647-1522636
4	117	+574646-1522627	+574704-1522545	+574707-1522505
4	118	+574713-1522457	+574720-1522425	+574716-1522418
4	119	+574714-1522408	+574716-1522359	+574717-1522359
4	120	+574721-1522349	+574734-1522312	+574733-1522300
4	121	+574739-1522239	+574749-1522228	+574749-1522225
4	122	+574751-1522220	+574750-1522214	+574753-1522218
4	123	+574759-1522159	+574800-1522157	+574759-1522158
4	124	+574749-1522142	+574806-1522129	+574805-1522114
4	125	+574818-1522107	+574821-1522054	+574820-1522048
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4	128	+574916-1521944	+574926-1521932	+574931-1521926
4	129	+574935-1521929	+574928-1522000	+574917-1522021
4	130	+574910-1522039	+574913-1522051	+574951-1522107
4	131	+574920-1522110	+574927-1522023	+574931-1522101
4	132	+574941-1522052	+574947-1522029	+574955-1522046
4	133	+575000-1522040	+575002-1522037	+575006-1522041
4	134	+575007-1522049	+575009-1522051	+575013-1522059
4	135	+575017-1522100	+575019-1522110	+575016-1522122
4	136	+575015-1522120	+575018-1522125	+575015-1522129
4	137	+575011-1522130	+574958-1522151	+574953-1522148
4	138	+574942-1522215	+574943-1522222	+574942-1522228
4	139	+574945-1522238	+574944-1522248	+574942-1522247
4	140	+574939-1522253	+574938-1522305	+574937-1522317
4	141	+574933-1522322	+574931-1522332	+574935-1522339
4	142	+574922-1522406	+574918-1522403	+574912-1522404
4	143	+574910-1522420	+574908-1522427	+574908-1522433
4	144	+574902-1522451	+574900-1522450	+574942-1522456
4	145	+574859-1522500	+574956-1522501	+574952-1522508
4	146	+574854-1522521	+574851-1522622	+574858-1522529
4	147	+574904-1522530	+574911-1522522	+574915-1522530
4	148	+574919-1522536	+574923-1522542	+574932-1522559
4	149	+574952-1522608	+574955-1522602	+574958-1522608
4	150	+575000-1522623	+575003-1522629	+575008-1522623
4	151	+575009-1522623	+575011-1522627	+575015-1522625
4	152	+575022-1522630	+575027-1522620	+575018-1522548
4	153	+575023-1522534	+575023-1522525	+575025-1522501
4	154	+575030-1522454	+575033-1522447	+575040-1522438
4	155	+575043-1522429	+575051-1522425	+575054-1522407
4	156	+575056-1522409	+575058-1522403	+575102-1522402
4	157	+575104-1522359	+575112-1522358	+575115-1522351
4	158	+575122-1522356	+575125-1522403	+575121-1522403
4	159	+575118-1522410	+575120-1522422	+575127-1522424
4	160	+575128-1522435	+575126-1522446	+575126-1522504
4	161	+575132-1522517	+575138-1522514	+575149-1522518
4	162	+575152-1522509	+575154-1522508	+575155-1522515
4	163	+575159-1522516	+575200-1522520	+575202-1522519
4	164	+575204-1522536	+575206-1522537	+575205-1522605
4	165	+575207-1522620	+575212-1522652	+575211-1522706
4	166	+575217-1522716	+575217-1522721	+575224-1522732
4	167	+575232-1522728	+575231-1522736	+575234-1522738
4	168	+575238-1522746	+575246-1522738	+575249-1522730

4	169	+575252-1522728	+575304-1522742	+575305-1522740
4	170	+575309-1522743	+575311-1522742	+575318-1522800
4	171	+575328-1522804	+575329-1522759	+575331-1522758
4	172	+575332-1522754	+575338-1522747	+575339-1522752
4	173	+575340-1522752	+575343-1522759	+575352-1522817
4	174	+575350-1522829	+575300-1522849	+575403-1522850
4	175	+575407-1522903	+575408-1522913	+575413-1522918
4	176	+575414-1522923	+575420-1522932	+575419-1522941
4	177	+575425-1522958	+575423-1523009	+575430-1523036
4	178	+575435-1523044	+575438-1523039	+575434-1523100
4	179	+575415-1523123	+575417-1523126	+575429-1523132
4	180	+575431-1523138	+575440-1523140	+575442-1523153
4	181	+575438-1523156	+575435-1523152	+575430-1523158
4	182	+575427-1523157	+575423-1523203	+575425-1523210
4	183	+575422-1523217	+575418-1523218	+575414-1523237
4	184	+575409-1523243	+575409-1523248	+575406-1523253
4	185	+575404-1523250	+575402-1523253	+575356-1523253
4	186	+575355-1523259	+575358-1523258	+575357-1523308
4	187	+575359-1523312	+575356-1523323	+575345-1523327
4	188	+575342-1523323	+575340-1523316	+575333-1523315
4	189	+575330-1523313	+575332-1523318	+575328-1523317
4	190	+575321-1523317	+575326-1523323	+575330-1523336
4	191	+575338-1523337	+575342-1523345	+575348-1523345
4	192	+575350-1523350	+575356-1523347	+575358-1523349
4	193	+575402-1523345	+575403-1523338	+575408-1523328
4	194	+575414-1523329	+575408-1523331	+575404-1523340
4	195	+575406-1523404	+575410-1523408	+575417-1523419
4	196	+575422-1523417	+575426-1523421	+575420-1523440
4	197	+575424-1523432	+575422-1523446	+575426-1523457
4	198	+575531-1523457	+575436-1523507	+575252-1523505
4	199	+575504-1523503	+575507-1523507	+575532-1523509
4	200	+575535-1523517	+575534-1523522	+575531-1523522
4	201	+575530-1523527	+575517-1523526	+575513-1523530
4	202	+575507-1523550	+575458-1523553	+575451-1523556
4	203	+575448-1523608	+575450-1523620	+575502-1523620
4	204	+575515-1523627	+575528-1523632	+575521-1523652
4	205	+575515-1523706	+575512-1523708	+575510-1523723
4	206	+575512-1523740	+575506-1523803	+575457-1523808
4	207	+575455-1523813	+575454-1523814	+575452-1523810
4	208	+575441-1523812	+575440-1523816	+575426-1523820
4	209	+575422-1523818	+575413-1523820	+575411-1523828
4	210	+575407-1523826	+575340-1523743	+575337-1523730
4	211	+575318-1523724	+575316-1523727	+575309-1523722
4	212	+575300-1523724	+575258-1523726	+575254-1523715
4	213	+575243-1523710	+575236-1523713	+575228-1523709
4	214	+575223-1523714	+575215-1523713	+575213-1523717
4	215	+575156-1523711	+575147-1523715	+575134-1523703
4	216	+575119-1523708	+575114-1523704	+575109-1523712
4	217	+575103-1523713	+575052-1523705	+575049-1523659
4	218	+575048-1523702	+575035-1523706	+575029-1523658
4	219	+575025-1523658	+575025-1523702	+575029-1523702
4	220	+575032-1523708	+575029-1523720	+575031-1523722
4	221	+575032-1523726	+575030-1523728	+575017-1523726
4	222	+575018-1523726	+575031-1523731	+575032-1523735
4	223	+575028-1523731	+575029-1523735	+575033-1523737
4	224	+575033-1523743	+575030-1523740	+575029-1523746
4	225	+575027-1523742	+575024-1523746	+575022-1523749
4	226	+575027-1523749	+575026-1523757	+575032-1523753
4	227	+575036-1523759	+575110-1523742	+575135-1523739

4	228	+575139-1523704	+575143-1523800	+575141-1523806
4	229	+575142-1523811	+575141-1523818	+575150-1523820
4	230	+575149-1523817	+575154-1523810	+575157-1523817
4	231	+575201-1523821	+575203-1523826	+575205-1523829
4	232	+575211-1523820	+575219-1523832	+575218-1523836
4	233	+575219-1523839	+575217-1523843	+575214-1523856
4	234	+575212-1523856	+575206-1523840	+575207-1523845
4	235	+575204-1523848	+575159-1523857	+575157-1523852
4	236	+575148-1523858	+575149-1523911	+575151-1523908
4	237	+575154-1523906	+575155-1523916	+575158-1523912
4	238	+575202-1523916	+575203-1523920	+575201-1523935
4	239	+575206-1523948	+575206-1524000	+990000-1522400

APPENDIX IV

```
            R GNOMONIC PROJECTION AND INVERSE
$ COMPILE MAD
             EXTERNAL FUNCTION (LT,LG,LAT,LON,X,Y,IN)
            R FOR GNOMONIC PROJECTION SET IN=+1
            RFOR INVERSE SET IN =-1
            RALL VALUES IN RADIANS
             INTEGER IN
             V'S PI=31415926536E-10
             V'S TPI=62831853072E-10
             ENTRY TO GNOMOM.
             W'R (LT.NE.PHI).OR.(LG.NE.LAM)
            RCOMPUTE CONSTANTS
             SLT=SIN.(LT)
             CLT=COS.(LT)
             SLG=SIN.(LG)
             CLG=COS.(LG)
             E'L
              W'R IN.G.0
            R GNOMONIC COORDINATES
             DELON=LON-LG
             SDEL=SIN.(DELON)
             CDEL=COS.(DELON)
             SLAT=SIN.(LAT)
             CLAT=COS.(LAT)
             NUM=SLT*SLAT+CLT*CLAT*CDEL
             W'R(.ABS.NUM).L.1E-10
             F'N
             E'L
             X=CLAT*SDEL/NUM
             Y=(CLT*SLAT-SLT*CLAT*CDEL)/NUM
             O'E
            R INVERSE COMPUTATION
             LAT=ARCSIN.((SLT+Y*CLT)/SQRT.(1.+X.P.2+Y.P.2))
             DEN=CLT*SLG+X*CLG-Y*SLT*SLG
             NUM=CLT*CLG-X*SLG-Y*SLT*CLG
             LON=ATN1.(DEN,NUM)
             W'R LON.G.PI,LON=LON-TPI
             E'L
             PHI=LT
             LAM=LG
             F'N
             E'N
```

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