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The logic behind the placement of names on maps is investigated as part of a study, the object of which is the automation of map lettering. After describing the basic principles the author illustrates his solution.

The Logic of Automated Map Lettering

Pinhas Yoeli
Tel-Aviv University, Israel

Introduction

The lettering of maps *i.e.* the addition of names, explanations and numbers to the 'mute' map sheets constitutes an amazing percentage of the overall production time of maps —sometimes up to 50 *per cent* and more. While automated draughting processes have had a strong influence on the editing and drawing time of the 'mute' part of maps, they have had so far, only a limited influence on the production of the name contents of maps. Certain techniques, like light printing and semi-automated lettering, where name lists are printed on film and then projected onto their proper map-place on light sensitive film, take only a little less time than the classical methods of manual attachment of labels to the map.

The main reason for this is, in our opinion, the fact that existing lettering techniques have failed, so far, to relieve the map maker from the two basic tasks of map lettering, namely:

a. The editing process, *i.e.* the determination of the name contents of the map.
b. The actual placement of the names in their proper place.

In order to fully automate map lettering with the help of computers and appropriate output devices, the process has therefore to be split up into the following three, basically independent steps:

1. Editing of name contents for a specific map.
2. Computation of name placements.
3. Hardcopy output.

The computerised execution of the first step requires the existence of a geographical name bank whose contents, scope and form of organisation determines the range of maps whose production it can serve. The automation of the name placements necessitates the formulation of a computer-compatible method of the arrangement of names on the map.

General editing and graphic considerations

The basic considerations for the editing and graphic presentation of the name plate of a map are the following:

a. The choice of the name contents and its classification (settlements, rivers, *etc.*).
b. Determination of type characters and sizes.
c. Placement.

Automated methods can solve the problem of the selection of the names for a specific map only if we have at our disposal a well organised, computer-compatible, name bank. The decisions as to the scope of the name contents and the various letter characters and sizes to be used are a matter for the map editor (or the programmer) and depend, among other considerations, on the output equipment at his disposal. These problems will not be dealt with in this paper which is limited mainly to the problem of automated name placement. It should, however, be pointed out that the result of an automated placement is closely connected with the decisions mentioned above. There is a limit to the number of names which can be placed on a certain area beyond which the wish to convey as much written information as possible on the map, defeats its own purpose. The number of letters of a basic, minimal, size which theoretically can be placed on a map sheet can be expressed by the ratio free map area area of basic letter size. By 'free map area' is meant the area of map which is not occupied by any other linear or point symbol of the same colour as the names. This is based on the assumption that, theoretically, names can be crossed by lines of a different colour and still remain readable (*e.g.* a black name crossed by a road indicated by a red band). The minimal basic letter size is that size of lettering which can still be easily read under normal conditions without magnification. The full exploitation of this theoretically available space for placement of names is limited

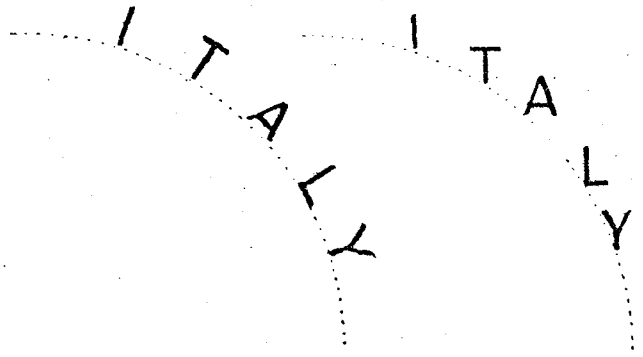


Figure 1. Curved names showing rotation and non-rotation of letters.

by the necessity to have a certain free space around names and that a map, in order to achieve its optimal information value, should not be too overcrowded by names.

For large scale topographical maps (up to 1:100 000) the above considerations are mostly without practical importance as on most of these maps the available lettering space is never fully exploited. This is not so on small scale maps. There the map editor is usually faced with the problem of selecting a smaller number of names than he would like to put on the map. It is for these cases that a precise knowledge of the name carrying capability of a map as a function of scale and purpose of the map in question is required. Only then can the parameters for the editing program of the name contents, based on name banks, be defined.

The specific solution depends, of course, on the output instrument available. In the following the general principles of map name placement are dealt with, while the precise methodology for automated placement is treated later. Provided that the characters, relations of sizes and colours of the various names and name groups on the map have been chosen by the map editor according to optimal cartographic-geographic criteria, the easy legibility and identification of the map's names depends on the following:

a. Precise graphic relation between the name and the relevant item.
b. Minimum of mutually disturbing interference between the names themselves and between the names and the other contents of the map.
c. Application of didactical principles, *i.e.* the placement of the name in such a way as to amplify, if possible, the characteristics of the items named (*e.g.* flowing placement of river names, *etc.*).

The question of the precise graphic relation between names and relevant items necessitates the introduction of the classification of map names into three groups.

1. Names of points or items which cover a small area (*e.g.* spot heights, settlements, *etc.*).
2. Names of lines or bands (*e.g.* rivers, boundaries, *etc.*).
3. Names of areas.

The differentiation between 1 and 3 depends, to a large extent, on the scale of the map. Spot heights, of course, are points in any scale. Settlements can, however, cover a certain area on one map while becoming a point symbol (or a small circle) on a map of smaller scale. As the optimal graphic solution for the placement of point names differs from the placement of area names the conclusion must be drawn, that in order to make a name bank universally suitable for the automation of map lettering in any scale we must supply the necessary parameters according to which the computer should be able to decide if a certain item in a certain scale is to be treated, for name placement's sake, as a point or an area.

It is generally accepted that the best graphic solution for point names is the horizontal position *i.e.* parallel to the upper and lower margin of the map. This principle must, however, be modified for geographical maps of smaller scales on which the names are to be placed parallel to the latitude circles. The same applies, in principle, to area names, as long as there is no obvious need to deflect from the horizontal. Considering the implications of the direction of the name placement for the automated process, the technical possibilities of the available output instruments must be kept in mind. Most of these devices print horizontal lines only. Some, like the 'Lumitype', can print curved names, but without the necessary turning of the individual letters in the direction of the radius of curvature (see *Figure* 1).

It is, of course, theoretically possible to construct automated output devices which could place curved names in precisely the same manner as when being done manually. The curving of names, where absolutely necessary, could then also be programmed as part of the general placement program. We wonder, however, if the necessary expense and effort involved, would be justified economically. Counting the number of curved names on representative maps at various scales has shown that they constitute only 5 to 10 *per cent* of map names, and in only a small proportion of these is curving cartographically absolutely necessary. We therefore suggest, that automated name placement should be limited to horizontal names only, and that the problem of curved names should be solved, as in the past, by a final manual touch-up of the automated output. This covers also the question of oblique names, as far as they still occur on maps. From the graphic-cartographic point of view oblique names should, anyway, never be left in a straight line, but should be put on a—preferably circular—curve.

Very useful directions for the optimal placement of point names have been put forward by Imhof[1] and others. The main objective of the recommendations in these publications is didactical. The names, according to these, should be placed not only according to optimal graphic-considerations, but also to amplify the geographical information contents of the map. If, for example, a town is situated on the left bank of a river, the name should also be put on the left side, or if the river bisects the town let the name be bisected by the river, or if a certain point item lies near a border line, care should be taken that the name should, if possible, be placed inside that border, *etc.* Name placements which take considerations like these into account result, of course, in maps of higher quality. However, the question arises if automated processes should go into such degrees of sophistication. There is, in principle, no obstacle in programming these deliberations, but again, it is doubtful if this would be economically sound and if the increase in map quality achieved would justify the effort involved. It may be that we shall have to put up with the fact that automation of certain processes might bring with it a certain reduction of quality. The gain of speed and expediency may well compensate for the, certainly regrettable, loss of sophistication. A certain amount of manual touch-up will have to be applied, anyway, to the final

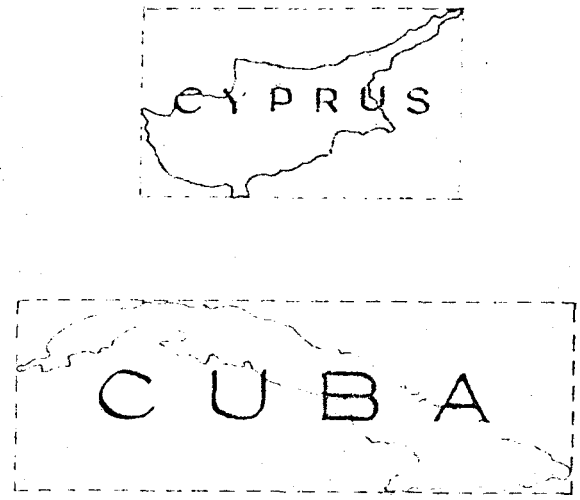


Figure 2.

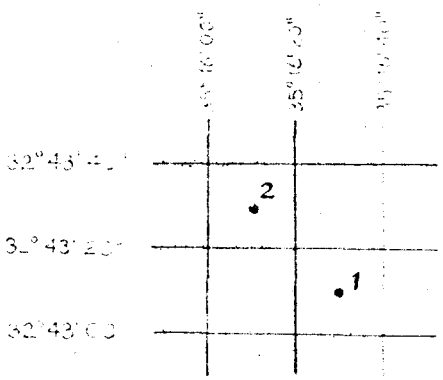


Figure 3.

automated map product and we suggest leaving the execution of such improvements to that stage.

The naming of lines on maps like rivers, roads, railways, shipping lines, air traffic lines, *etc.*, also gives rise to the question as to the best direction in which the names are to be placed. For rivers the names are mostly placed along parts of the river, following its natural flow. Names of straight or regular lines are usually placed parallel to the line. The same considerations as for curved names are valid here. While, in principle, it is of course possible to program such placement, the actual execution would be most complicated, and would, among other things, require a highly versatile output instrument, the construction of which, just for the sake of this kind of placement, is economically questionable. We, therefore, recommend again, that the placement of names of this category be left to manual or semi-automated execution.

Areas on maps include many widely varying features. The placement of their names depends mainly on the size and the configuration of the area. The first question in regard to the automation of their placement is how to define the area in the name bank. We have to keep in mind that, contrary to a digitised map in general, where all the lines surrounding areas have to be digitised in order to enable the redrawing of the map, the main aim of the name bank is the computation of the placement of the names. If we would consider an automation of all cartographically possible placement alternatives of area names, a complete digitisation of the border lines of the areas would be essential for the name bank. This would, however, necessitate such a huge accumulation of data that it would make the establishment of a universally usable name data bank practically illusory. But even if it would be feasible, the computation of the placement of curved area names so as to satisfy every possible area configuration would be an unnecessary complication of automated name placement methodology. Therefore, only the computation of horizontally placed area names is considered. To achieve this it is sufficient to include in the name bank the extreme west, east, north and south coordinates of the area only, *i.e.* to assume that every area is, for name-placement's sake, a rectangle. According to the size of this rectangle as a function of the map's scale the name is to be placed either inside or outside this rectangle. The principles of the placement of the name of small areas *i.e.* areas too small to accommodate the name inside them, are basically the same as for point name placements with small methodological differences only.

Names inside an area should cross the centre of gravity of the area and should be evenly spread across the rectangle without coming too near to the border line. Precise relations will be defined later. The positioning of the sides of the circumscribing rectangles according to the extreme west, east, north and south points of the area may result in a placement where a part or parts of the name will fall outside the area as illustrated in *Figure* 2.

To prevent this, care should be taken by the editor of the basic name bank that for every area such a, maximum area, rectangle should be defined which will ensure the placement of all the letters inside the area.

Cartographers, when lettering maps, usually place area names first in order to position and spread, where necessary, the name without the disturbing presence of the smaller names of point symbols. The only care they have to take at this stage is not to cover the point symbols themselves. The same consideration exists for automated placement.

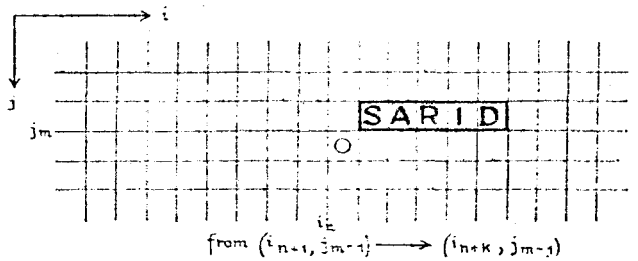


Figure 4. Priority 1.

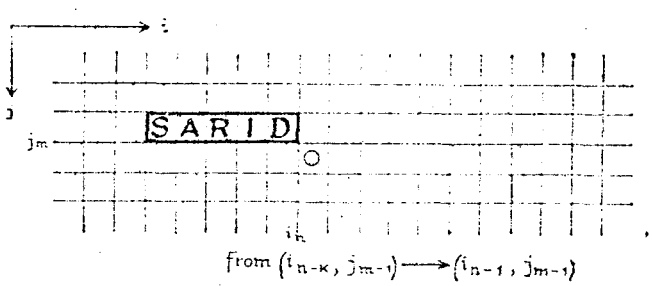


Figure 5. Priority 2.

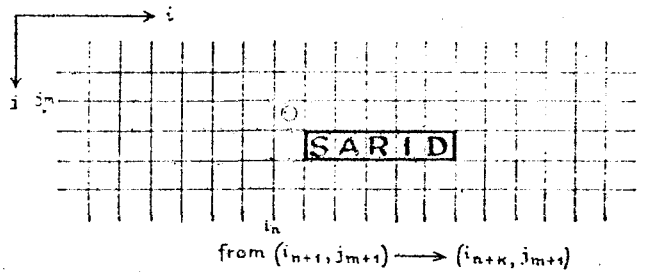


Figure 6. Priority 3.

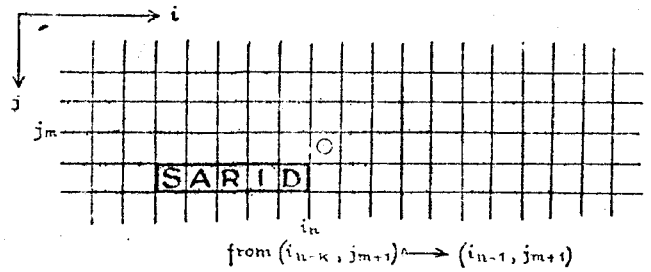


Figure 7. Priority 4.

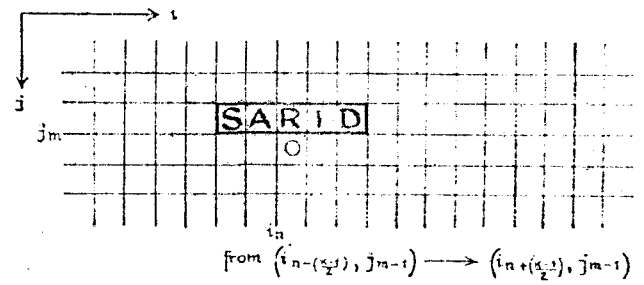


Figure 8. Priority 5.

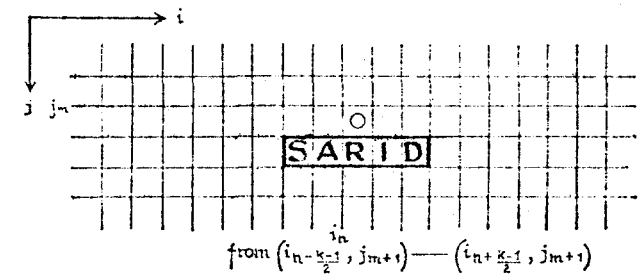


Figure 9. Priority 6.

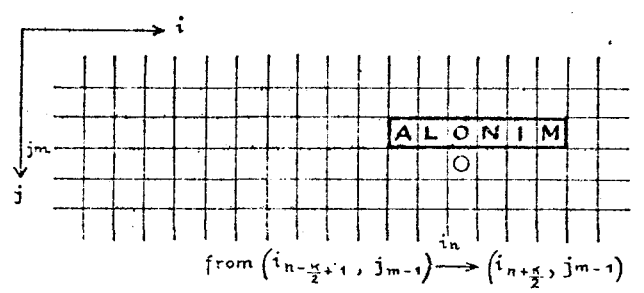


Figure 10. Priority 7.

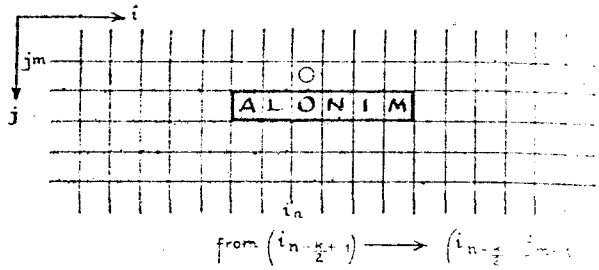


Figure 11. Priority 8.

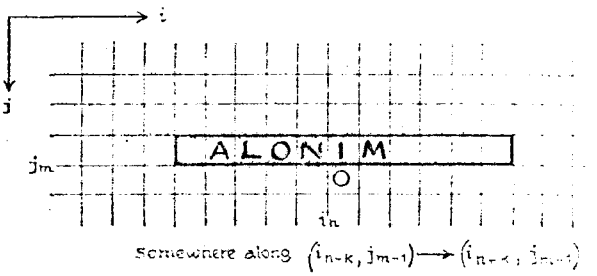


Figure 12. Priority 9.

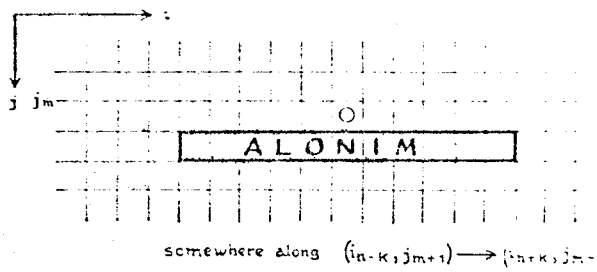


Figure 13. Priority 10.

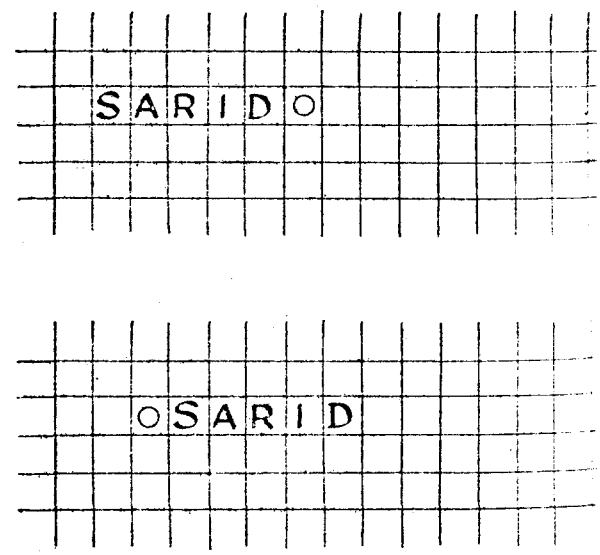


Figure 14.

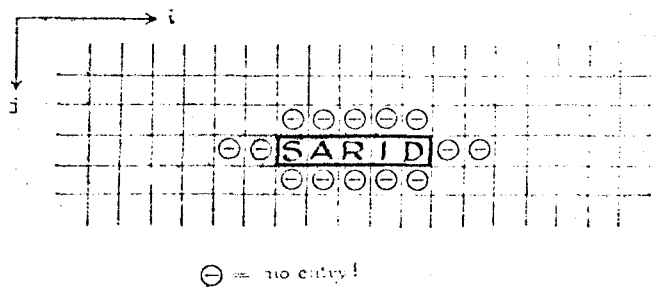
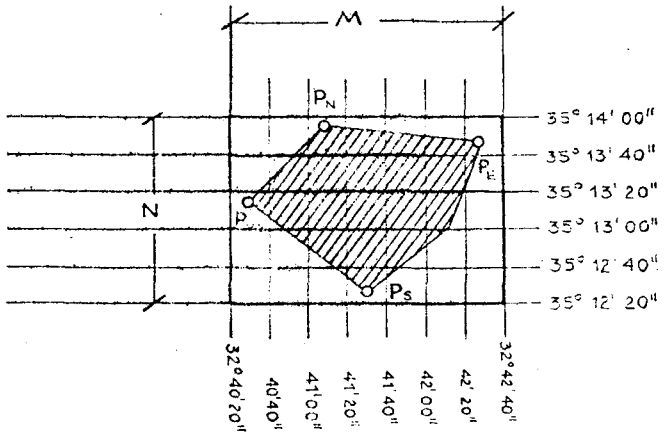


Figure 15. The 'free zone'.



	λ_E	λ_W	φ_N	φ_S
P_E	32°42'27"			
P_W		32°40'12"		
P_N			35°13'51"	
P_S				35°12'31"

Figure 16.

Area names should be positioned first and the space occupied by them has to be put in the computer memory to arrange in a second step, the point names around and, if graphically possible, between the area name letters. This might require a repeated run of the outprint medium through the output instrument, depending on the characteristics of the output instrument used.

The method of placement

For the purpose of the computation of the name placement, the map area is considered to be covered with a rectangular grid of small area elements. The size of this basic area unit depends on the graphic output device. The smaller the basic unit, the more flexible becomes the placement process. In the practical demonstrations for this paper, and for lack of any other output device, we made use of what is probably the most unsuited output instrument for map-names placement *i.e.* the line printer. The basic area unit in this instrument is of the size of one letter *i.e.* 4mm × 5mm. The graphic output results attached to this paper are therefore to be regarded as an improvisation only, whose sole purpose is to prove the feasibility of the method. The principles used in the placement method with the line printer are easily applicable to any other output instrument, if the possible refinements available by the use of smaller basic area units are then taken into account.

Name grid and geographic coordinates

The coordinates used in the name bank must be brought into relation with the rectangular grid of the area units into which the map is supposed to be resolved. This gives rise to the question as to what kind of coordinates should be used in the name bank. The simplest relation occurs, of course, if these are plane rectangular coordinates like the area-units grid of the output medium. These coordinates can be collected from maps drawn on a normal cylindrical projection or from maps covered with a local plane rectangular coordinate system. This would, however, be detrimental to the creation of a world-wide universally usable geographical name bank. To achieve this goal spherical geographical coordinates only are suited. The problem, which then arises, is how to achieve placement of names parallel to the circles of latitude for maps of any projection. For large scale maps this problem is theoretical only. There the differences between the geographical grid even if it is drawn on a non-normal cylindrical projection, and the rectangular grid used for the positioning of the names, is usually so small, that their effect on the name

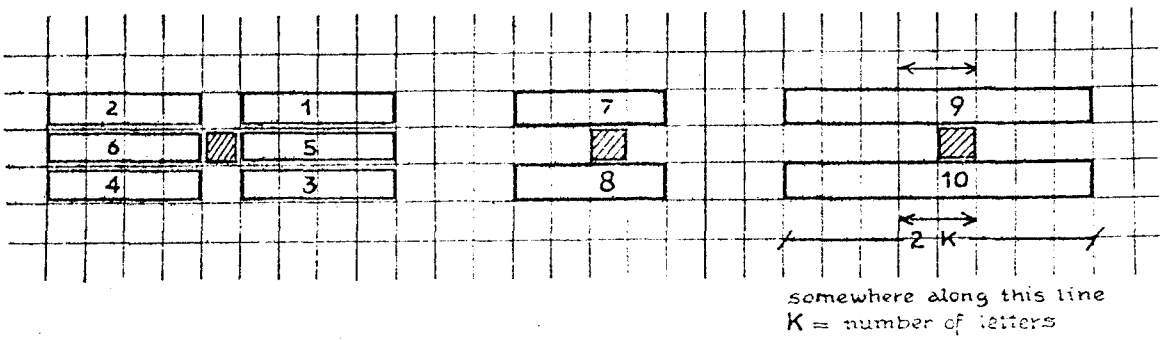


Figure 17. Priorities for name placement (hatched rectangle equals one basic unit).

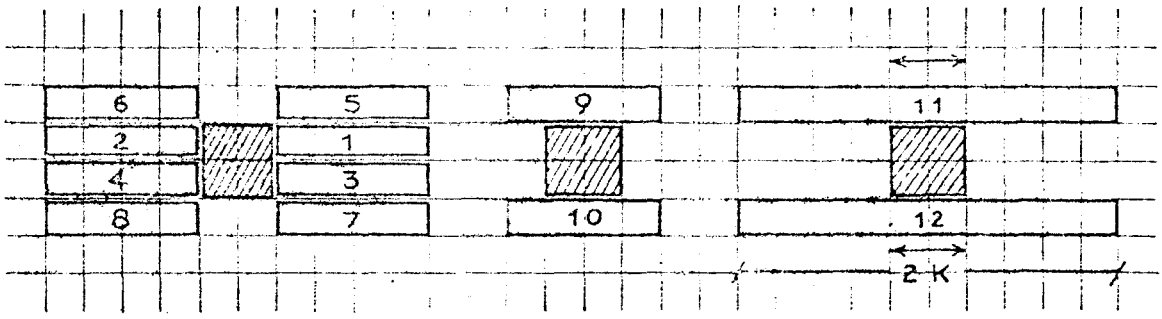


Figure 18. Priorities for name placement (hatched rectangle equals an even number of basic units).

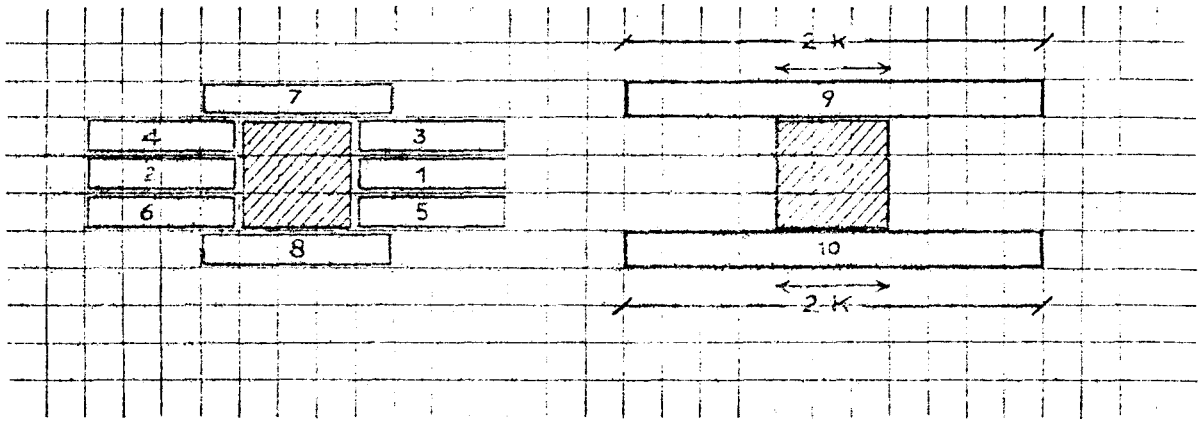


Figure 19. Priorities for name placement (hatched rectangle equals an uneven number of basic units).

placement can be neglected. The problem becomes more difficult for small scale atlas maps drawn on projections which result in very pronounced curvatures of the geographical grid. If a versatile output instrument is used, which can position names in any direction and even curve them, the computer program will have to take care, that the names should always be written parallel to the latitude curves.

For more rigid output devices which can print in one direction only, the solution is found through the breaking up of the map into several sections each bordered by two meridians and two parallels. For each section the mean meridian is placed parallel to the direction of the ordinates of the name grid. After each section is named separately, they are assembled to form the final map. For names which should be placed at right angles to the north south direction, the height of the letter equals the latitude difference $\triangle\varphi$ and the width of the letter equals the longitude difference $\triangle\lambda$. The absolute magnitude of $\triangle\varphi$ and $\triangle\lambda$ depends on the scale and the projection of the map. Care should be taken, that for small scale maps the computer program has to provide for the fact that the relation between the measurements of the letter and $\triangle\varphi$ and $\triangle\lambda$ are not constant but a function of φ and λ. This holds true for all projections (except for the normal cylindrical 'square projection') and not only for non-equal area projections as one might presume. The ratio between the height and width of the letters remains constant while the ratio between the relevant $\triangle\varphi$ and $\triangle\lambda$ varies according to the properties of the projections used.

Priorities in placing point names

In the experimental map (*Figure* 23) a line printer was used in which the smallest basic area unit is the size of the one letter *i.e.* a rectangle of 4 × 5mm. There should be no difficulty in applying the same principles to output devices with smaller basic units. The point to which the name refers is considered to lie in the centre of that basic area unit whose north-west corner is defined by the geographical coordinates nearest to those of the point. In *Figure* 3, for example, the two points in a letter grid system

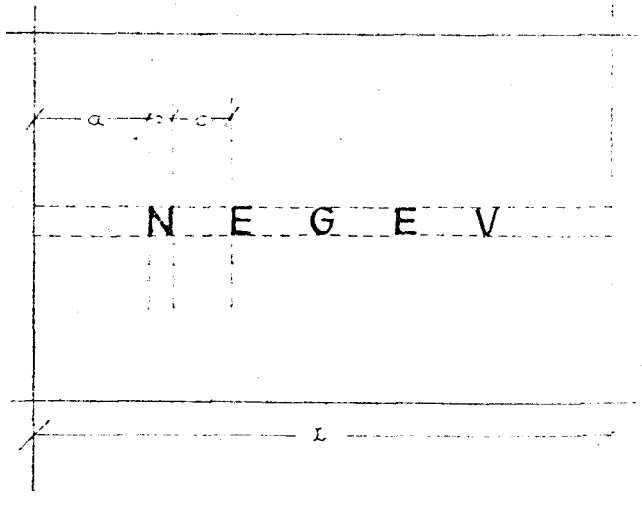


Figure 20. Letter spacing.
L length of circumscribed rectangle
n number of letters
b mean width of letters
c (L-n. b) (3-n)
a 2c

whose smallest grid line value is 20″ would be considered to lie in the following squares:

Point	*Longitude*	*Latitude*
1	35° 16′ 12″	32° 43′ 24″
2	35° 16′ 08″	32° 43′ 45″

Figures 4 to 14 illustrate priorities in name placement in order of decreasing desirability for a point located in square $i_n j_m$. The name is K letters in length.

In case none of the first four priorities is possible because of occupied units (see later) a differentiation between an even and uneven number of letters must be made (*Figures* 5 to 8). If none of the above placements is possible the name should be placed somewhere along the line of units above or below the point.

None of the priorities above provides for the placement of the name along the line on which the point lies because the point symbol might interfere visually with the name and be regarded as one of the letters (*Figure* 14).

Free zones

To prevent names from touching or even overlying each other, a 'free zone' must be laid around the name after it has been placed (*Figure* 15). Touching points at the upper and lower corner of the first and last letters of the names are admissible.

If a name of K letters is placed on row j_f and occupies the squares i_g to $i_{g+(K-1)}$ the following squares surrounding the name must be permanently 'shut' for further use:

1. the square containing the point.
2. in row j_{f-1}: from i_g to $i_{g+(K-1)}$.
   in row j_f: squares i_{g-1}, i_{g-2}, i_{g+K} and i_{g+K+1}.
   in row j_{f+1}: from i_g to $i_{g+(K-1)}$.

Names of small areas

'Small areas' are those areas on a map which are too small for their names to be placed inside their boundaries or for which it is undesirable to place the name inside the

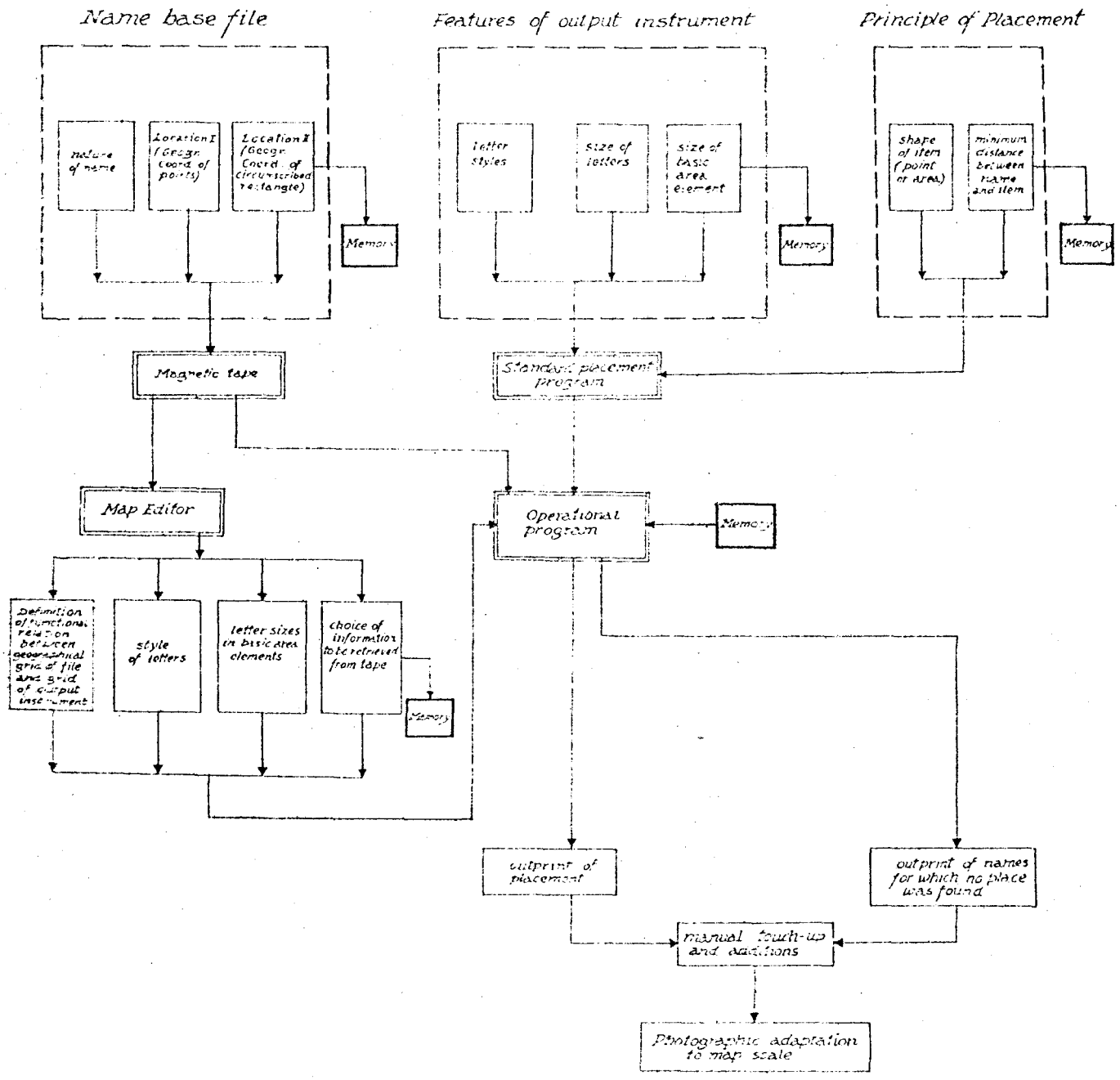


Figure 21. Flow chart of automated map lettering system.

area (*i.e.* town areas on which the name would destroy the street pattern). They are consequently placed outside but without being spread.

Let λ_E, λ_W be the longitude and φ_N, φ_S the latitude of the extreme points P_E, P_W, P_N and P_S of the area. These geographic coordinates, which are considered to define a rectangle circumscribing the area, are rounded off to the value of the nearest letter grid line value falling outside the area (*Figure* 16).

The height N of the rectangle in side lengths of the basic area units is $\frac{\varphi N - \varphi S}{\triangle \varphi} = N$, where $\triangle\varphi$ is the constant increment in geographical latitude of the letter grid and φN, φS the rounded off values.

The length M of the rectangle in side lengths of the basic area units is $\frac{\lambda W - \lambda E}{\triangle \lambda} = M$ where $\triangle\lambda$ is the constant increment of the letter grid in geographical longitude and λW, λE again the rounded off values.

The order of priorities in the various placements of the name in relation to this rectangle depends on the number of basic area units of which the height of the rectangle is comprised (*Figures* 17 to 19).

Area names

Names of areas are placed so as to cross the centre point of the circumscribing rectangle. Their spreading is a function of the mean width b of the letters chosen by the map editor. The distance a of the extreme letters from the border of the rectangle is proposed to be twice the spreading distance c. *Figure* 20 illustrates their placement.

Although the width of the letters is not constant we have chosen to spread them at constant intervals. This may sometimes create the visual impression of uneven spreading. If more sophisticated placement is required, the computer program will have to take into consideration the various width of the letters of the alphabet and the appropriate spreading distances be computed accordingly.

The operation of the system is illustrated by the flow chart in *Figure* 21 and the component parts are described below.

Name base file

The name base file is organised according to three aspects.

a. The nature of the name (or number).
   This refers to the character of the relevant item: settlements, seas and lakes, mountains, spot heights, *etc.*
b. Location I:
   Geographical coordinates of a point item (spot heights, *etc.*). It should be remembered that this refers to items which are points in maps of any scale.
c. Location II:
   Geographical coordinates of the sides of the circumscribing rectangle of area items. The computer will have to decide, according to the map editor's decision on the map scale if these names are to be treated according to the logic of the point or area name placement.

Features of output instrument

The system has to be adapted to the features of the available output instrument. The three basic considerations which have to be taken into account for the formulation of a standard program for any specific instrument are:

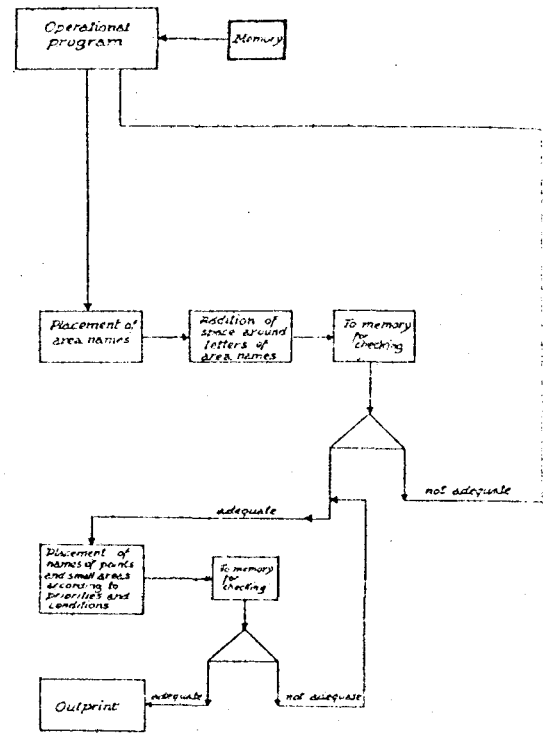


Figure 22. Operational program of name placement.

a. The assortment of letter styles available.
b. The size of letters.
c. The size of the basic area element *i.e.* the smallest possible displacement.

Principles of placement

Here the logic of the placement has to be formulated. As this is different for points, small areas and large areas the program has to provide for the decision by the computer as to which of the placement principles to apply according to the size of the item in the scale of the specific map. In addition to this the minimum distance in basic area elements between the names and surrounding items (points, circumscribing rectangle and adjacent names) which has to be kept, has to be programmed.

The name base file is put on magnetic tape while both the 'Features of the output instrument' and the 'Principles of placement' are put in the computer memory. According to this basic group of parameters the standard placement program usable for every kind of map is formulated.

Map editor

The map editor of any specific map has to decide the following:

a. Mathematical formulation of the functional relation between the geographical grid of the name file, the projection grid of his map and the grid of the area units in the output instrument.
b. Decision on what kind of items have to be selected by the computer from the name base file and for which part of the earth's surface (in geographical coordinates).
c. Style of lettering for the various groups of names he chooses to include in his map.
d. Sizes of these letters.

These decisions combined with the standard placement program lead to the operational program of which a separate flow chart is shown (*Figure* 22).

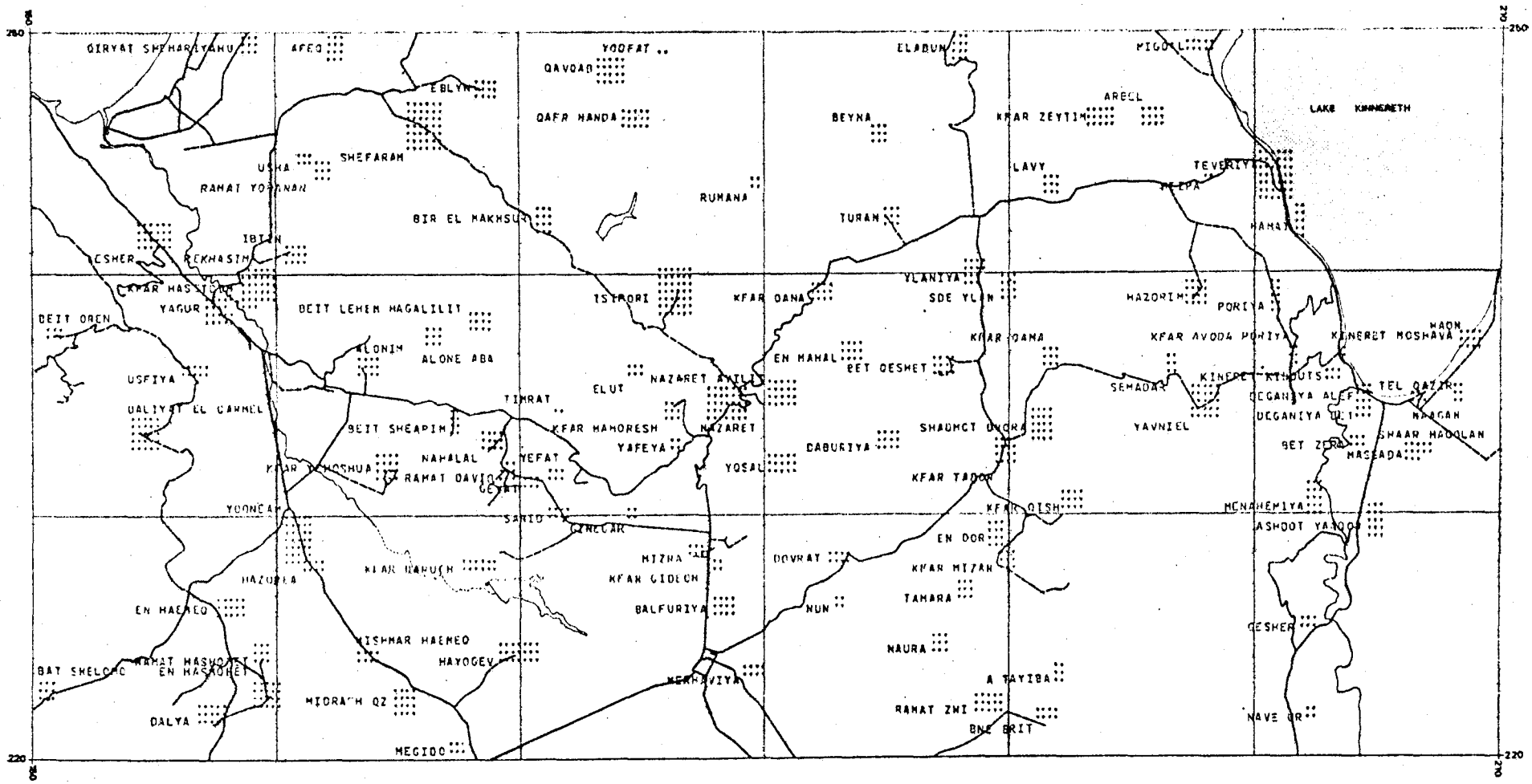


Figure 23. An example of automated name placement.

After the placement has been computed it is printed out according to the facilities of the output instrument. If the map editor's preliminary estimate as to the name carrying ability of his map was too optimistic, there will be names for which the computer could not find any place. These names (or numbers) are to be printed separately so as to enable the map editor to add these manually if possible. If this proves impossible, the editor will have to revise decisions and either reduce the group of items included in his map or change his decisions concerning size of letters. As the computer programs for this system are relatively simple, repeated trials will, hopefully, prove not to be too expensive.

As the scale of the output is usually not the same as the map scale, final scaling can be done photographically.

The operational program (*Figure* 22)

In a first approximation the placement of names of large areas is computed. These are usually spread-out names. After a first attempt the computer checks if none of the letters has fallen on spots or small area items, whose positions are registered in the memory. If this has occurred changes of placement of either the whole name or minor displacements of individual letters are carried-out according to steps of priorities. After the check indicates that the placement is adequate the position of these spread-out letters is put in the memory together with the minimal clearance distance around every letter.

In the second stage the placement of names referring to small areas and spot items is computed and, as before, every placement is checked. If no place can be found after trying all possible variations the name is printed out in a separate list.

Figure 23 is the print-out of the name placement of an area of 3 × 6km of the lower Galilee in Israel bordered by the following rectangular coordinates of the Palestine coordinate system.

West 150 000
East 210 000
South 220 000
North 250 000

The names were chosen from a base file of approximately 3000 names which were collected from nine sheets of the series of 1:50 000 maps of Israel. Either two or four geographical coordinates were registered for every name (two for point items—four for area items). The names were classified according to the following groups:

1. Kibbutz (communal settlements)
2. Moshavs (collective settlements)
3. Villages
4. Townships
5. Ruins
6. Tells
7. Various areas (valleys, mountains, *etc.*)
8. Isolated buildings and institutions schools, police stations, pumping stations)
9. Wells
10. Caves
11. Triangulation points.
12. Spot heights.

To the first four groups, which refer to settlements the following parameters were added in the file.

a. Number of inhabitants.
b. Religious affiliation (Jews, Christians, Moslems, Druses).
c. Year of foundation before 1900 and after.

As the only print-out device at our disposal was a line printer there was no possibility to vary the size of the letters in the printing process. The printout was photographically reduced to the scale of approximately 1:200 000.

For demonstration and checking purposes the areas of the circumscribed rectangles of the items were printed with stars. A manually drawn background of the grid lines, main roads and coastline was photographically combined with the line printer output.

Conclusions and recommendations

The choice of the names, numbers and explanations on a map, their printing type and size and their graphical arrangement on the map are the results of logical decisions by the map editor and the cartographic draughtsman. The process of map lettering can therefore be fully automated, beginning from the choice of the name content (which would be the equivalent of the conventional preparation of the name sheet manuscript) and ending with the actual placement of the names in their proper place on the map.

To facilitate this automation the following is needed:

a. A comprehensive geographical name bank including all those parameters which will allow for computer editing of the name contents for any specific map.
b. A definition of the logic of name placement on maps in computer compatible form.
c. A computer controlled printing device for the hardcopy output of the final map name sheet.

The aim of our work was to formulate the basic concepts of the logic of a computer compatible placement system, based upon a universally usable geographical name bank.

We wish to point out, that the system proposed is unrelated to any already existing maps or map series, the idea being that the geographical name bank should not, in principle, be the registration of the name contents of specific maps. Of course, the names for the bank must be collected from, among other sources, existing maps, but the decisions as to the contents of the name bank should be, as far as possible, independent from scale considerations. It will be a 'universal' bank only if it can be used for a large array of maps of different scales and purposes.

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