# GUIDELINES IN ESTABLISHING MAPPING SPECIFICATIONS

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## 1. Introduction

Resolution IV/7 adopted at the 1984 Rio Congress reading:

"The Congress,
noting the importance of product specifications in the digital and analogue mapping processes,
recognising that there are large differences in specifications used throughout the world,
recommends that standardisation of mapping specifications be investigated within the realm of ISPRS",

resulted in the formation of a Working Group with the task to fulfil the terms of the resolution and to devise a programme of work which could be tackled up to the Kyoto Congress in 1988.

The aim of re-focusing the attention on this topic was that,

whilst the international surveying and mapping community would agree that ideally a set of mapping specifications should be:

- realistic, in that they represent a clear translation of the users' actual requirements, enabling an acceptable product to be produced both efficiently and economically;
- up-to-date, in that they clearly reflect the more demanding and more sophisticated user requirements in the light of increasing complexity that can be observed in the planning and decision making process; and
- simple, in that they are expressed in clearly understandable terms, both from a user's and a producer's point of view;

until recently, there has been little support for the idea that specifications should also be:

- universally applicable, this not in the sense that the widely varying mapping requirements throughout the world could or ever should lead to a uniform set of specifications being adopted and used, but rather that the terminology used is standardized. This so that their implications are universally understood and misinterpretations between the parties involved, users and producers or clients and contractors, are avoided.

The idea of trying to standardize specifications is neither new nor original. After a series of conferences, the UN produced a standard set of specifications in the early 1960's for the International Map of the World at a scale of 1:1 million. In the field of medium and small scale mapping, the American National Map Accuracy Standards have been widely adopted as guide-

lines. To fill the gap in the field of large scale mapping, the RICS, following an initiative of the British Air Survey Association, presented a model set of specifications for mapping at scales between 1:1000 and 1:10.000 to the 1980 ISP Hamburg Congress.

The ISP failed to accept this challenge, though through Commission I, did set up a working group on aerial photography specifications, which were adopted as "guidelines" at the 1984 Rio Congress. The only response, though this was admittedly promoted more by litigation in the Californian courts, has been the initiative of the ASP Committee for Specifications and Standards to produce and publish a draft accuracy standard for mapping at scales larger than 1:20.000.

The main call for standardization has, however, come from the field of digital mapping, in order to facilitate the handling, storage, merging, retrieval and exchange of digital map data.

## 2. W.G. tasks and scope

The initial thoughts were that the two main tasks of the W.G. should be:
- to provide a forum for the presentation and exchange of views on the general topic of mapping standards and specifications
- specifically to investigate the standardization of mapping specifications and to present the results as guidelines to be used in their formulation;

whilst the scope of its activities should be limited to:
- a concentration on the requirements to be fulfilled by the final product
- a concentration on topographic mapping products (line maps, annotated photomaps and digital data bases), in the scale range 1:500 to 1:100.000.

Comments from the W.G. members on these proposals were:
* it is very ambitious to tackle the whole range of mapping scales from 1:500 to 1:100.000 and line/orthophoto/digital mapping all in one specification. It is unlikely to be comprehensible to map users not specialists in mapping (Mr. Leatherdale, U.K.)
* the range is so great the finalisation of the complete set of specifications will be a herculean task (Dr. Zarzycki, Canada)
* the W.G. might have more than enough to do if it concentrated on the photogrammetric input to mapping alone (Mr. Macdonald, U.K.)
* there are already a number of international and national standards in preparation or in use and it would be more important to make use of these than to produce yet another one (Mr. Leatherdale, U.K.).
* Mapping standards and specifications have been the topic of discussion for several decades. Most countries have developed them to suit their own purposes, related to their own socio-economic needs and cultural backgrounds.

A large degree of uniformity exists at small scales. It is unlikely that uniformity at larger scales will be achieved, or is in fact desirable, since mapping at these scales is determined by the level of economic development and the technological sophistication of the users.

Consequently, although the provision of a forum for presenting and exchanging views on standards and specifications would be useful, the work involved in trying to develop universal 'guidelines' does not appear to be worthwhile. If the communication between interested parties can be improved (and sustained), the most applicable standards and specifications will be adopted (Dr. Zarzycki, Canada).

* photography and mapping tasks which are well understood present no difficulties but the design of a data base which is more innovative cannot be precisely specified in advance but most evolve with the project even though this is not liked by the contractors (Prof. Konecny, F.R. Germany).
* the standards and specifications for digital data should be determined by the uses of the data for purposes other than the production of graphics. In this context the specifications appear to be cartographically weighted: that is to say the digital data component exists simply to provide a graphic. Is this intended? If so then the specifications are inadequate for digital data bases, since these data bases have much wider applications (Dr. Zarzycki, Canada).

From these and other comments received, it became clear that a modified programme would have to be devised, the two overriding considerations being:
- that the programme is practical i.e. it can be realised in the time available up to the Kyoto Congress
- that the programme is useful i.e. instead of developing yet another set of specifications, collect hints that could be of use when specifications have to be drawn up.

A modified proposal that appeared to satisfy these two requirements was accepted at the 1986 Commission IV Symposium held in Edinburgh. The modifications introduced were:

- a simplification of the 'guidelines' in the sense of producing an 'aide-mémoire' instead, outlining essential aspects that must be included, optional aspects that may be considered and pitfalls to be avoided in drawing up the various sets of specifications. The detail required will of course vary with the item under consideration.
- simplification of the scope such as grouping the otherwise wide scale range of 1:500 to 1:100.000 into 3 main classes (large/medium/small); preparing 'base guidelines' for topographic line mapping and supplementing these with changes for other applications (cadastral/engineering surveys, etc.) and for other products (photomaps/digital databases).

## 3. Basic guidelines for topographic line mapping

These guidelines refer, in principle, to topographic mapping at large scales. Where necessary, they will be supplemented with changes required for medium and small scale mapping. Changes for other products, such as photomaps and digital data bases, and for other applications, such as cadastral and engineering surveys, are given in the next section.

Furthermore, since many of the items which have to be included in mapping specifications do not lead to misinterpretations between user and producer, these guidelines will concentrate on the more problematical items in a set of specifications. In addition, it must be realised that there are a number of general pitfalls that are common to most of these problematical items, namely:
- specifications that are simply copied from previous sets, without considering the needs to be fulfilled by the current set being established.
- specifications that are based on achievable product performances rather than on product requirements
- inconsistencies between clauses in a single set of specifications.

The problematic items in line mapping specifications are:

a) mapping purpose: unquestionably the most important item, in view of the fact that it is highly correlated with other important items such as type of product, map scale, map content and map accuracy.

In general, a change in mentality is required. Mapping agencies must become aware of the fact that they are in the information business and not in the mapping business. Furthermore they must recognize that nothing they do or produce is an end in itself. It only has value to the extent that it genuinely meets a user need.

With regard to the identification of these needs, mapping agencies make the mistake of looking to the map products users might request to satisfy their needs, instead of concentrating on the information needs themselves. Furthermore, mapping agencies are generally too passive. They wait for users to come up with their demands, instead of going out and studying what users are doing and thereby establish what the users true information needs are.

This establishment of mapping purpose presents no problem when a single-purpose product is required. With multi-purpose products, a main purpose has to be established for each individual scale within the map series.

b) type of product: although this might be considered irrelevant in the context of line mapping, it is included in this discussion in order to emphasise the role that intermediate products might play in the mapping project, i.e. before going to the design phase, it will have to be clearly established whether or not any of the intermediate products such as the aerial photography, the results of the ground control surveys, the aerial triangulation results, etc. are also needed for other purposes as well. If this is the case, then these intermediate products assume the role of an end-product and their additional requirements (for those other purposes) must be included in the specifications.

c) map scale: in principle, the two main considerations governing the choice of map scale are the map purpose (the desired accuracy of scaling off information from the map) and the map readability (in relation to the density and type of information to be represented).

Given that the number of map sheets to be produced increases explosively with increasing map scale, the all important question to be answered, particularly with regard to the design of urban or national mapping programmes, is that of the largest scale of topo mapping that is appropriate to the various parts of the city or the country. Hereby, it must be borne in mind that the decision to produce a particular scale in a certain area introduces an even greater obligation to keep these map sheets up-to-date.

In this regard, it is probably true that the terrain characteristics of the project area is often neglected as a factor influencing the choice of the map scale, since one would otherwise not be confronted with the stipulation of total coverage of a city or country at standard map scales - a stipulation that is admittedly largely compensated in practice by the allocation of mapping priorities to those areas where the development is taking place.

d) map content: considerable attention needs to be paid to map content as it is the major cost generating item in map production. Map content is obviously highly correlated with the map purpose and again presents few problems in single-purpose products. In multi-purpose products, however, the map content should satisfy the requirements of as many users as possible.

There are obviously economic trade-offs in these decisions on map content between the cost of data collection and the benefit to the multi-purpose product. Furthermore, it should also be borne in mind that the needs of all potential users will never be known completely and therefore the main challenge will be to ensure that neither insufficient nor redundant information is collected.

In defining map content, particular attention has to be paid to the "special information requirements" users might have in particular situations. In large scale mapping programmes of urban areas, these special requirements relate, in particular, to the "street furniture" i.e. the obligation to map features such as lamp posts, manhole covers, public phone booths, etc. which are normally not identifiable on the aerial photography unless special precautions have been taken in advance, such as signalisation, timing of photography such that lamps posts identifiable by their shadows cast, etc.

In medium and small scale mapping programmes, these special information requirements concern features of importance to a particular area and which therefore have to be collected, even though they would normally not appear on a topo map at that scale.

e) relief representation: of importance is the decision on what is the main source of height information - spot heights (or a DTM) supplemented with interpolated contours or contours, supplemented with spot heights at salient features, to improve the terrain representation? It might seem obvious that spot heights are only appropriate in flat terrain, but it is important, from the accuracy point of view, that the main source does not change from contours to spot heights within a single mapping programme or project.

The decision on the spot heights or DTM density needed in a particular area is simply a question of economics, since the cost is linearly proportional to the density. This is not the case with regard to the contour interval, however, whose choice is governed by the purpose of the map and the steepness of the terrain. The latter aspect is correlated with the attainable height accuracy and therefore the general tendency of stipulating standard contour intervals for particular map scales is questionable.

This will be illustrated with the example of the height accuracy specifications for a 1:50.000 map with a 10 m contour interval. With the allowance for a slope correction, the standard deviation of heights checked should be within $\sqrt{(3.0)^2 + (15 \tan \alpha)^2}$ metres, where $\alpha$ is the angle of slope. In the table below, the tolerances for the standard deviation in height and the minimum contour intervals are given for different terrain slopes.

| Slope | Std. dev. | c.i. |
|---|---|---|
| 0° | 3.0 m | 10 m |
| 15° | 5.4 m | 20 m |
| 30° | 9.5 m | 30 m |
| 45° | 15.3 m | 50 m |
| 60° | 30.2 m | 100 m |

It is clear that a contour interval of 25 m or even 50 m would be more appropriate in sheets of the more mountainous regions.

Finally, contour specifications should be clear on the situation that applies when contours are drawn in heavily vegetated areas i.e. are they annotated differently to indicate that they do not meet the specifications?; do other tolerances apply?; etc.

f) map accuracy: more confusion and diversity can be found in map accuracy specifications than in any other item and it would appear that this results from many accuracy specifications being based on what is achievable, rather than what is needed?

Typical mistakes found in accuracy specifications are the abuse of statistical concepts i.e. both confidence limits and absolute tolerances are defined, and these are often contradictory, e.g. "90% of heights checked shall be within half the contour interval and no height error shall exceed the contour interval". Notable exceptions in this regard are the recent specifications issued by both the RICS and the ASPRS.

Another typical mistake found is the incorrect application of the slope correction i.e. the allowed reduction of the apparent height error for a horizontal displacement of the contour within the permissable horizontal error for the map. Since this is a question of error propagation, the formula should read $\sqrt{A^2 + (B \tan \alpha)^2}$ and not $(A + B \tan \alpha)$.

Finally, many specifications sets employ a fixed ratio of 2 between the confidence limits for contours and spot heights i.e. "90% of contours and spot heights within respectively ½ and ¼ of the contour interval". This is based on the assumption that spot heighting is twice as accurate as contouring in the plotting phase, but it neglects common errors to both spot heighting and contouring in the ground control and aerial triangulation phases i.e. such a fixed ratio is only valid in projects with full, error free ground control in each model.

Finally, it is recommended that in accuracy specifications reference be made to whether the accuracy implies a relative or an absolute accuracy.

g. aerial photography (as an intermediate product): aerial photography specifications present another example of specifications often being drawn up without due consideration of the realistic requirements nor of the conditions under which the aerial photography is to be acquired.

Typical mistakes encountered in these specifications include:
- specifying both maximum and minimum tolerances for parameters such as photo scale, forward overlap and side overlap in areas of substantial

terrain relief differences, even though it is only necessary to plan the flights so as to achieve the minimum tolerances.
- the inclusion of image quality and metric quality clauses such as "the photography shall be completely free from cloud, dense shadow and smoke" or "the original negatives or contact diapositives produced from them shall not contain residual y-parallaxes after relative orientation in excess of 20 micrometres anywhere in the model", which if not met, need not necessarily impair the intended use of the photography, but which nevertheless can lead to its rejection on the grounds of not fulfilling the specifications.

h) ground control (as an intermediate product): the ground control requirements of mapping projects would appear to be often copied from the specifications for establishing geodetic networks, simply because the requirements are unnecessarily high. The most striking example in this respect was reported by P.G. Mott to a Conference of Commonwealth Surveyors. Here the ground control specifications for 1:50.000 mapping of an area of 40.000 sq. kms. of rugged terrain, covered in dense virgin forest and varying in height from below sea level to above 16.000 feet, were are follows:
"... 2 astro fixes with m.s.e. of 0.3" in latitude and azimuth and 0.03" in longitude. Two base lines each 8 kms long with m.s.e. not less than 1:100.000. Thirty 1st order triangulation points equally distributed over the whole mapping area with m.s.e. for triangle closure in position of 2" and in height of 0.2 m 500 1st order levelling points along longitudinal and transversal roads totalling 1500 kms in length. The m.s.e. computed from the difference in two ways levelling not to exceed 4 mm".

Not surprisingly, none of the contractors asked to tender for this project were prepared to accept these specifications.

## 4. Guideline changes for other products and other applications

a) Digital data bases
* More flexibility allowed in the definition of the data base content and in the detailed classification of each item, since changes can be readily incorporated into the system.
* The level of sophistication in the data structure and thereby in the data exchange standards needed to transfer data grows with an increase in the complexity of the relationships established between entities and entity attributes, simply because, in order to be effective, these relationships are explicitly represented in the data structure and hierarchy.
* Instead of fulfilling pre-determined accuracy standards, all entities in a digital data base are tagged with a quality code, indicating the accuracy, resolution, completeness and temporal validity of that element. In accessing the data, users must then decide whether or not it meets their requirements.

b) Photo maps
* Additional requirements imposed upon the aerial photography in terms of density and density range of the original negatives and the density range of the orthophoto or rectified photo image, and for the printing phase, on the density of screen to be used and the percentage dot pattern to be achieved in the highlight and darkest portions.

c) Engineering and cadastral applications

* Primarily a confrontation with very high accuracy requirements for the ground control networks; very small contour intervals; etc, etc. which must be examined carefully in consultation with the user to see if they are realistic or not.

## 5. Final remarks

Specifications can never be final nor complete, since users requirements are changing continuously and thus specifications must change accordingly, since the end product only has value to the extent that it meets user needs.

The assistance received from the Working Group members in the preparation of this report is gratefully acknowledged and it is sincerely hoped that the ISPRS will continue to provide an international forum for the presentation and exchange of views on mapping standards and specifications.