1978

The 1:100 000 Mapping Programme and Ground Truth

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Abstract

The Division of National Mapping has several years of experience in field completion of the 1:100,000 Topograhic Map Series during which time economical and successful techniques based upon aerial methods have been developed. The emphasis on mapping is now shifting to map revision.

This paper discusses the philosophy of ground truth and how field inspection and accuracy testing is used to verify the quality of our maps. It describes the methods used in the field and in the office and shows how the processes of map completion and map revision are similar but different.

Introduction

The Division of National Mapping, under a Cabinet Directive, commenced, in 1965, a program to map the whole of Australia at a scale of 1:100,000 with 20 metre contours.

The Army was to provide a major contribution with the State mapping authorities assisting to varying degrees.

To produce this series, the Commonwealth of Australia produced a manual, "Specifications for Topographic Map Series, Australia 1:100,000 Scale" with the aim "to provide a national map coverage in as much detail as can be clearly portrayed at the scale".

The accuracy of the printed maps was to be as specified in the National Mapping Council publication "Standards of Map Accuracy".

While these specifications set out the type of detail that would be shown and how it would be drawn, and the map accuracy specifications stated the accuracy with which it would be positioned, any specification as to the completeness of the map appeared to be by implication only.

In other words, it would be possible to produce a map that complied with the map specification in all respects, except that it may not present ground truth in that features might be omitted altogether or wrongly interpreted.

In the era of plane table methods, it was axiomatic that the compilation showed "ground truth" because the data gathering was done on the ground where the map detail was actually seen, identified and plotted by the compiler.

However, with the introduction of aerial photography and photogrammetric plotting methods, data gathering was performed remote from the ground situation and the map compiler no longer actually "eyeballed" the features he was plotting.

Also the date of compilation was not the date the detail was plotted but essentially the date the aerial photography was flown.

It was this situation then that led to the Division setting up a Map Completion Section in 1969 to check by ground and air inspection changes in map detail that had occurred between the date of photography and the date of compilation and to verify the correctness of interpretation. Necessary changes were made to the compilation prior to final drawing and the map dated at the date of field completion.

In applying the "ground truth" criteria to map detail, four basic factors must be considered.

These factors can best be illustrated by the replies that can be given to the following questions:

1. Where is it?
2. What is it?
3. Is it there now?
4. Is it still there?

These questions expanded mean:

1. Where is it? —(a) relatively, in relation to adjoining features and,
   (b) aboslutely, in relation to a National co-ordinate reference system.
2. What is it? — in relation to the specification criteria.
3. Is it there now? — considering the elapsed time between the aerial photography and the compilation dates.
4. Is it still there? — after successive time intervals thus considering the need for cyclic revision.

These factors or questions can be defined in operational or functional terms respectively as:

1. Map accuracy determination.
2. Photo interpretation techniques.
3. Map completion operations.
4. Map revision operations.

Map Accuracy

The modern production of maps is a complex procedure within which we can identify a number of discrete steps, viz control, compilation and production. Each process generates errors which will be reflected in the final printed map.

Aerial photography depends upon the physical characteristics of the camera lens and the stability of the film especially during processing. Diapositives, compensated for lens distortion, refraction and earth curvature still contain inherent small errors.

Control is produced by field survey methods and the quality of the control generally depends upon efficiency and economy requirements. For the 1:100,000 mapping program National Mapping has established a network of horizontal control using E.D.M. traversing techniques, the Aerodist airborne system and doppler satellite fixes to supplement and extend the geodetic network. Similarly a network of spirit levelling has been intensified with A.P.R. and Laser Terrain Profiler (L.T.P.) airborne systems, barometric heighting and Elevation Meter networks for the production of vertical model control. However, most horizontal control is not in a form suitable for compilation and must be further processed to produce model control by control intensification.

Control intensification is the next step in the process whereby the density of survey control is increased to produce the model control required for compilation. National Mapping adopted a systematic approach to this problem by grouping model control into Block Adjustment areas contained within loops of the primary network so that systematic error could be kept to a minimum.

The accuracy of the compilation process has been a very important criterion for the design of plotting equipment,and checking techniques can ensure that the accuracy of plotting is as high as possible. Finally the fair-drawing and printing processes are undertaken so that maximum accuracy is maintained.

Thus each step has a definite error component which when aggregated to the stage of the final printed map must meet an unequivocal accuracy requirement. The National Mapping specifications require detail on our maps to be within 0.5 mm of their true position so that on our 1:100,000 National Topographic Map Series a significant point of detail shown on the map must be within 50 m of its true position on the ground.

There is really no quantitative way of knowing what errors have accumulated at any particular step nor can we estimate what the error of any point will be unless we have some independent objective criteria for the measurement of errors on the final map.

This was the problem that confronted us when we began producing our new 1:100,000 maps. The maps were compiled using techniques that were judged would result in optimum quality maps produced as efficiently and economically as possible. However, there was a need to verify that the quality really was as good as we expected. Consequently we undertook a survey in the Mackay region of Central Queensland in 1970 to evaluate planimetric and altimetric accuracy parameters.

The criterion of signficance is of the utmost importance in the selection of test points and we found that our results confirmed the conclusions reached by Thompson (1971)[1]. A schematic diagram (see fig. 1) shows the distribution of planimetric and altimetric test points over the five map sheets tested and the results of that testing are summarised in Table 1. On the basis of the field testing we were able to conclude that our 1:100,000 maps did in fact meet the accuracy specifications. This proved that our mapping system was sound.

SUMMARY OF ACCURACY TESTING

PLANIMETRIC:	Total No. Test Points	= 52
	No. Successful Tests	= 48 (92%)
	Standard Deviation	= 22.6 m.
ALTIMETRIC:	Total No. Test Points	= 127
	No. Successful Tests	= 121 (95%)
	Standard Deviation	= 5.9 m

TABLE 1

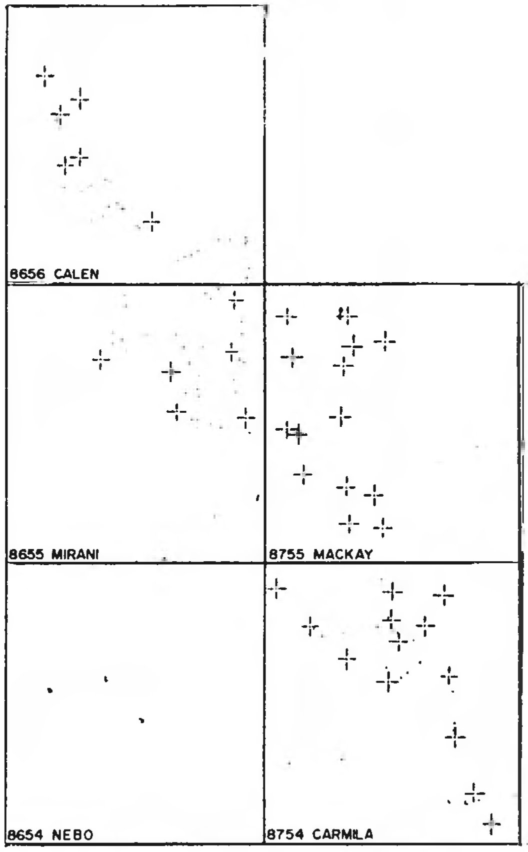

FIGURE I

Diagram showing distribution of Horizontal and Vertical Test Points

Legend : —|— Horizontal
· Vertical

With advances in mapping technology since 1970, we have been changing our techniques, for example the L.T.P. is now used exclusively for producing vertical control, so that there is always a need to maintain quality control checks. This ensures that the map product remains at the correct standards of accuracy.

Modern testing methods are used such as the JMR and the L.T.P. The L.T.P. has been used to produce profiles for comparison with digitally produced contours and the JMR doppler satellite receiver has also been used.

In a typical test in the Australian Capital Territory in 1973 the comparison between the L.T.P. profile and map contours along that profile produced a standard deviation of 2.8 m while in another test in the Emerald area of Queensland we observed differences with a standard deviation of 2.6 m between L.T.P. points and those obtained by digital processes associated with the production of orthophotomaps.

In both these tests we were satisfied that the L.T.P. could be satisfactorily used for evaluation purposes and that the results indicated that the map quality was consistent with our standards (see fig. 2).

We have recently used the JMR equipment for map accuracy testing because it has the advantage of being totally independent of mapping systems. We carried out the survey on the Colac 1:250,000 map sheet with the JMR as part of the map completion phase of the six constituent 1:100,000 sheets. Four points were carefully selected to be photogrammetrically significant and were added to

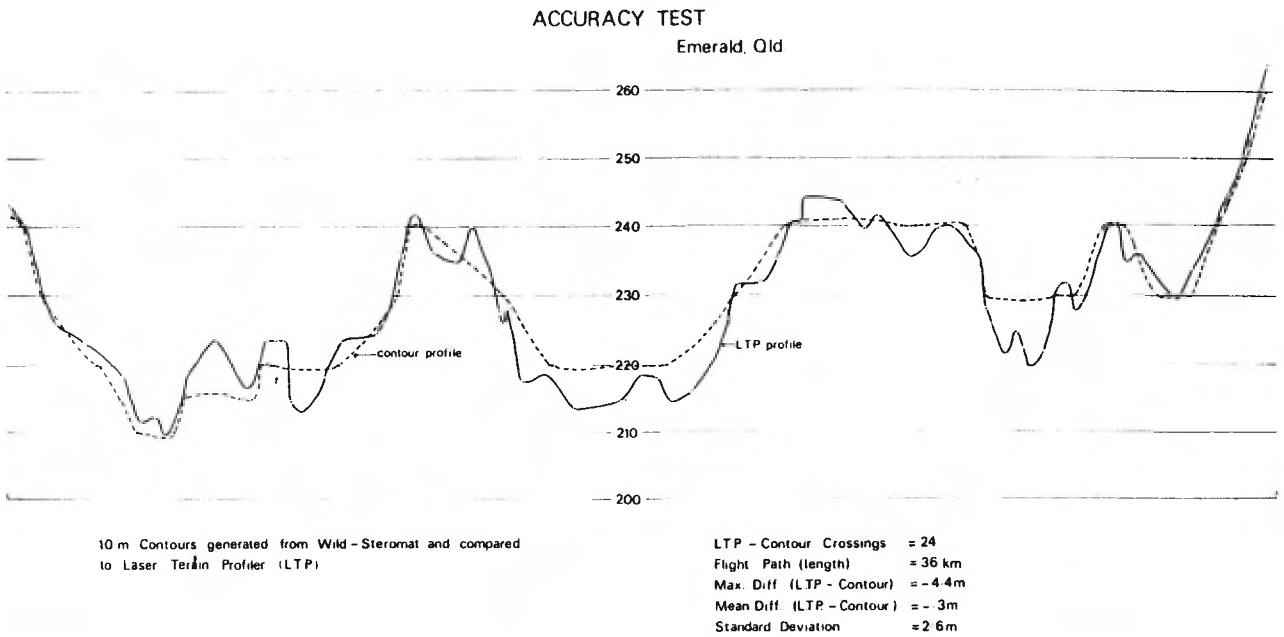

FIGURE 2

the maps. The maximum error was 20 m, mean error 13.5 m and standard deviation 7.2 m so that the quality of the compilations were judged to be of a high order. Now these four points were added using map completion techniques so that the results refer to the accuracy of the map after map completiion. Because detail on the manuscripts was used as control for plotting these points it is reasonable to conclude that the compilation is more accurate than these figures indicate. However, it is certain from this that the map completion process does maintain the quality of the map.

In addition to these direct comparisons we have used large scale mapping from other agencies to make comparisons with our maps; however, meaningful conclusions have not been possible.

This question of significance is a limiting factor for the selection of test points on large scale maps. It mainly shows up because linear features are subject to increasing generalisation of form as the scale becomes smaller, for example a power line crossing a creek would normally produce a good test point but at different scales the generalisation tends to make an identification difficult. Based on our experiments with this type of tests we have tended to abandon this approach to accuracy testing.

Correctness and Interpretation

The essence of ground truth testing is that the map is compared with the ground and visually verified to agree. National Mapping has a well justified bias towards aerial techniques and we have developed an aerial inspection technique for map completion which is efficient and economical. We must husband our resources so that we are well satisfied with the result we are getting for the effort we expend.

It is important that we know as much about an area as possible before we commence the aerial survey so that we obtain as much reference material as we can. To do this we draw on the extensive resources of our own reference and record repositories and write to or visit state and local authorities. We use this reference material to verify such items as the following: vegetation types and boundaries, land uses, recreational and nature conservation areas and boundaries, transportation and communication systems, public utilities, industries, etc., etc.

We carry out a preliminary edit of the compilation and mark-up the field sheets, which are copies of the compilation. These copies are generally in the form of dyelines, often two colour types, but we have also used the Cromalin colour proof process. These sheets are prepared especially for use by the aircrew.

Two inspectors, seated one on each side of an aircraft, are a typical aircrew for aerial inspection surveys. The aircraft, a high-wing single-engined Cessna type, flies on a predetermined grid pattern at a height of about 1500 m above the terrain along flight lines separated by about 7000 metres. Each inspector thus views each alternate corridor twice—that is, he sees it from each edge. We have found that during an aerial sortie we can inspect two map sheets during a period of about five hours after which concentration tends to fall off. The density of the changed or new detail affects these averages for obvious reasons. For example, in sparsely settled country there are few details and not much change: but in closely settled and urban areas there is an enormous quantity of detail so that the aircraft speed must be reduced and the flight lines brought closer together.

The aerial inspection provides a very rapid and economical visual inspection and experienced observers can cope easily. Not every feature, however, can be positively identified from the air so that we sometimes find it necessary to visit specific features on the ground before we can finally resolve their identity. In addition to resolving specific problems we also carry out random sampling to ensure that we are maintaining our standards.

The quality of the aerial inspection is a direct function of the ability of the observers to identify detail from the air, and it is worth recording that the most common response from people experiencing aerial inspection for the first time is that they express surprise that they can identify so much detail.

We have had an opportunity to quantify the value of our map completion techniques. To do this we carried out an exhaustive re-inspection of Mount

Stuart (2153) sheet and were able to conclude that 5% of significant detail had not been detected, that is it had been omitted from the map. However, we also concluded that in order to detect these features we would have to increase our aerial inspection by 75% in terms of hours flown with a similar increase in supplementary photography.

We decided that the consequent increase in allocated resources to meet this standard and also maintain our production capacity was not warranted and that the quality of the maps being produced by the present technique was satisfactory.

Our current output of field completed maps has been raised to about 120 per annum and with revision included will be raised to 195 in 1977/78, 250 in 1978/79 and 400 in 1979/80.

The first objective of the field inspection process is to verify that all detail shown on the map is correct and that the interpretation of detail from the aerial photography is correct. The second objective is to ensure that the detail existing at the date of the inspection is the same as that existing at the date of the mapping photography. The most usual changes observed are new cultual features resulting from development, from large reservoirs to minor road deviations.

Changes are of major importance and the number is usually a function of the elapsed time since the mapping photography. We have drawn some samples which show that development affecting maps is occurring throughout the whole of Australia and not just concentrated in the more populated regions.

Table 2 shows the results of a sample drawn from map sheets which may have been map completed already. One sheet has been drawn from each of the three categories shown in Annex E of the Map Specifications.[1]

Completion and Compilation

Having determined the deficiencies of the manuscript compilation the problem becomes one of correction, where the new and changed detail must now be added to the manuscript. Up to this stage we have taken great care to identify interpretation errors and determine necessary corrections and we have always been aware of the necessity not to degrade the map.

The original detail was compiled photogrammetrically so that it is logical that additional detail should also be compiled photogrammetrically. We have always followed up our aerial inspection with supplementary photography, which is flown with either a 70 mm format or our RC9 camera and the choice depends on whether there is a little or a lot of new detail.

In most cases the RC9 camera is preferred and we fly at about 4600 m so that the photography is at a scale of about 1:50,000. We feelthat this provides us with pictutes with good resolution for identifying detail and yet gives good coverage economically. The photographic runs are flown east-west whenever possible to keep the photography compatible with the mapping photography: but because it is flown for special purposes it is not held to the full standards of our systematic general purpose photography, however, the economics are more favourable. It has 60% overlap and we accept some cloud and a sun angle down to about 15°. The quality is satisfactory for revision but would probably be unsatisfactory for some photogrammetric purposes.

The new and changed detail is identified on the supplementary photography under stereoscopic inspection and then transferred to the map by photogrammetric techniques. In most cases relief distortions are not a problem so that we can use simplified plotters. We make extensive use of the Bausch and Lomb Zoom Transfer Scope (ATS) which is a plotter designed specifically for map revision. Orientation and scaling of a single photo is controlled by detail previously plotted on the manuscript. By this process new detail is plotted accurately and rapidly.

Where existing detail is scarce or where unacceptable relief distortions are encountered the original mapping photography with model control is returned to a Wild B8 plotter. Before the plotting is commenced any new detail is transferred from the supplementary photography by differential stereoscope to the mapping photography. This process requires two discrete steps and takes much more time than the direct process of the ZTS but sometimes it must be done.

The most important precaution that must be taken is that no new interpetation errors are to be

MAP SHEET		AREA CATEGORY (ANNEX E)	QUANTITY OF MAP DETAIL		
			BEFORE COMPLETION	ADDED BY COMPLETION	
NAME	NO.		(NO.)	(NO.)	(%)
Penola	7023	Closely Settled	5784	2632	46
Bobadah	8233	Moderately Settled	1602	291	18
Zanthus	3635	Sparsely Settled	14	15	107
OVERALL			7400	2938	40

TABLE 2

introduced otherwise the field inspection effort will be wasted. The philosophy of the process is that ground truth has been established by the field survey and that the subsequent photogrammetric operations have only been used to plot detail. However, conflicts do occur and we place great weight on the final checking of the map which is always undertaken by experienced personnel. We have found that those people who have extensive experience in photo interpretation and map compilation plus extensive experience in field inspection are consistently more reliable than those who specialise in only one area.

As we have stated elsewhere in this paper we have been able to evaluate the results of the map completion process and we are satisfied that the quality of our maps is up to the standards we have been aiming at.

Map Revision

The National Mapping Council resolved at the 1977 meeting (Resolution 372) ". . . that in the National Topographic Map Series at 1:100,000 scale, the revision of existing maps at intervals of not more than ten years should, as a principle, take precedence over the production of new maps".

This resolution recognises the importance of constant systematic revision to the extent of delaying, if necessary, the production of new maps.

The distinction between the "map completion" function and the "map revision" function must be recognised. The former is a 'once only' operation which fills the information gap between the date of the source data, usually aerial photography, and the compilation date. The latter is a repetitive operation which fills the information gap between the date of the existing published map and a new revised map publication date.

The length of the revision cycle for a map series is a matter of some complexity. There are a number of parameters which must be considered and attempts are being made to formulate these into a mathematical model which can be processed by a computer to provide a map revision priority list and hence determine a series revision program.

The techniques of map revision obviously must be very similar to those used for map completion. However it must be realised that, in the case of revision, not all of the existing published maps were compiled through the normal sequence of photogrammetric plotting followed by the map completion processes.

In some cases numbers of larger scale maps, each with their own accuracy and their own compilation dates, were used as the source data.

The revision processes will have the effect of up-dating the total map to a common point in time but the accuracy checking aspect will be complicated by the non-homogeneous nature of the source material and will therefore require careful thought and planning.

In the case of completion work the base is the preliminary compilation sheet, and for revision the base would usually be made up from the fair drawn reproduction material.

As with completion work, it is most important that the revision data is plotted using techniques that will not degrade the original plotting accuracies.

The schematic diagram (fig. 3) presents the functional steps in map production with the distinction between the first edition and subsequent revised editions shown.

Nomenclature

The nomenclature on our maps has become of increasing importance and we have been seeking reliable sources throughout Australia. We have found that the various states adopt different approaches to this aspect and of course National Mapping has no statutory function like the State Authorities.

However, it has become clear that there are two levels of status of names—official and non-official. The official status is conferred by the states nomenclature boards and is applied to natural features such as rivers, creeks, mountains etc, as well as to cultural features with historical or other significance. The latter include such features as government bores especially on stock routes and so on.

Unofficial names include most internal property names which are liable to change or which at any rate are of no interest to nomenclature boards. Nevetheless they are important to map users.

Production for 1:100,000 Maps

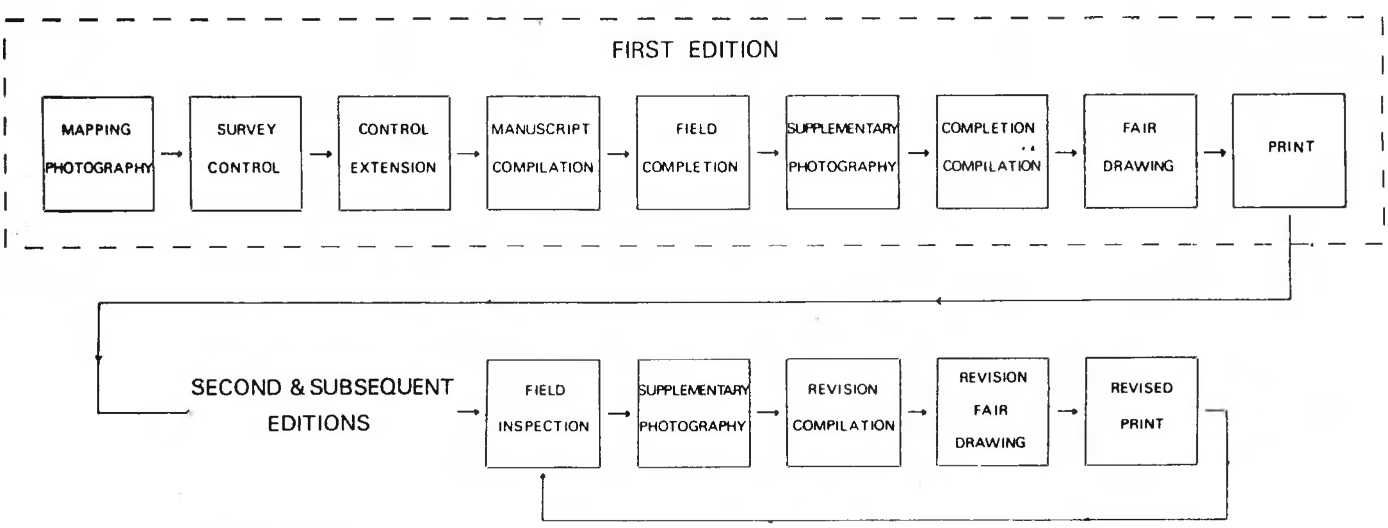

FIGURE 3

The official names are included on our maps after vetting by the State Authorities, but we have experienced some problems in sorting out the unofficial names in some circumstances. We try to use only those names which have local standing so that we tend to include only those which are verified in the records of local authorities. At the present time we do not have the manpower resources to undertake extensive property visitations on the ground.

Conclusion

This paper has attempted to show that map completion and revision techniques can be undertaken within the financial and operational restraints of most mapping authorities. Where necessary the resources of the private sector can be utilised, i.e. aircraft charter, stereoplotting, etc.

The consequences of not undertaking systematic revision of a map series are far more serious than may appear at first glance. They could well include:

1. Eventual necessity to embark on a major re-mapping program.
2. Misplaced user confidence with a resultant effect of wrong decisions based on wrong map information.
3. Subsequent loss of user confidence and ultimate loss of revenue from map sales.

In any case mapping is generally regarded as a function of government and any failure to provide adequate maps may well have political repercussions.

It is encouraging to see the rapid introduction of modern computer-based mapping systems by mapping organisations in Australia. An important part of these systems will be the inclusion of revision facilities so that the constant up-dating task can be achieved economically and quickly.

To the extent that this can be done, the maintenance of the "ground truth" objective for the Australian Topographic Mapping Series may be achieved more efficiently than has been previously thought possible.

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2. "On Map Accuracy Specifications" by Morris M. Thompson and George H. Rosenfield, *Surveying and Mapping (March, 1971).*
3. National Mapping Council, *"Standards of Map Accuracy".*