Land Survey Methods and Training in
Participatory Land Use Planning and Land Allocation
Lao-Swedish Forestry Program

SUMMARY

On request of the Lao-Swedish Forestry Program the current situation on practised land survey methods in the Land Use Planning Sub-program have been investigated. Training in land survey methods and mapping has furthermore been conducted with staff from central, provincial and district level of the Department of Forestry. The findings and recommendations given in this report are based on experiences gained by field visits, discussions with staff concerned and the training exercises.

Participatory land use planning and land allocation in rural areas is undertaken within the Sub-program, involving provincial and district staff in the process. The aim of the activities is to develop models suitable for the process.

Implementation of the land use planning and land allocation is carried out in a village over a short period of time. Consequently there is no time for comprehensive land surveying and mapping activities, once the activities have started in the village. The features and requirements for the land survey methods are hence characterised by simplicity and fastness. The survey shall result in a reasonably accurate map that will be useful for the future. The methods used should be fast, simple and efficient and the survey instruments should be uncomplicated, cheap and easy to carry to the field.

The land survey methods practised in the Sub-program are found suitable to some extent, although not entirely.

The current methodology for survey of the individual land parcels is considered sufficiently accurate and detailed. The shape and area of the land parcels are measured with an accuracy to metres. As the configuration of the land parcel coincides with the picture on the large scale map of the land certificate, the methods are estimated to suit the land allocation process well.

The methodology for production of the village base map is on the other hand not considered suitable to fulfil the requirements of the process. The accuracy is too low for enlargement, the map contents are not enough and the details and names on the map are not always correct. The present method of enlarging topographical maps should be abolished. Enlarged aerial photos should be used instead, thus gaining information, accuracy and speed.

The village base map contains information on village boundaries, ground features, various land uses and the position and shape of the individual land parcels. Particularly the last information is very important in the context that the map might have significance as a cadastral map. It is concluded that the participatory land use planning and land allocation process in fact results in a simple cadastre, comprising its basic components, a map displaying the land parcels and a textual register with information on the land and its users. The concept for the future work must consequently be to adopt methods and standards that can be used in a country-wide and complete cadastre.

It is essential that any information collected in the process should be of use in the future. Time, effort and money spent on land allocation and mapping must not be wasted. The process must lead to legal security and stability of land issues.

Even if applied methods to a large extent are found suitable, the staff skill for implementation has to be improved. A lack of thorough understanding of land survey and mapping practices has been noticed. Comprehensive training is needed, on the job and in training centres.

The information in the land registers established in the on-going process should coincide with the contents of the official land registers as decided by the Department of Lands and Housing Management. Coordination of the two registers seems essential.
The field measurements are suggested to be split into two parts, the first part being preparation of an accurate and suitable village base map and the second part being field measurements and positioning of the land parcels. A special land survey and mapping team should be established for the first part, to have the overall responsibility for production of village base maps.

It is further suggested that the results of the land use planning and land allocation activities should be stored in a computerised system. The maps should be digitised and the textual register should be stored in a database. Development of these procedures should be supported by a consultant with experience from this field.

Finally is suggested that new technique will be tested in the land allocation process by trial with a GPS base station. The trials should be assisted by an expert.

General rules and advise on land survey practises and notes on the training activities are included as appendices in the report.

As a final statement can be noted that the current land survey and mapping methods in the Land Use Planning Sub-program seem well suited for their purpose and that they can be improved by small means.

1.0 INTRODUCTION

This report is the result of a short-term consultancy mission carried out on behalf of the Lao-Swedish Forestry Program from January 12 to February 13, 1997. In this period the current situation on practised land survey methods in the Land Use Planning Sub-program were investigated. Further, a four days training course in land survey methods was conducted at central level, followed up by seven days field training in mapping and field measurement with central, provincial and district staff in a target village. General rules and recommendations on land surveying and mapping were compiled, for use in the village and land allocation mapping process and for the final design of the Manual on Participatory Land Use Planning and Land Allocation. Field visits were undertaken in Luang Prabang and Savannakhet provinces. At the end findings were presented at a short workshop.

Terms of Reference and Job Description, appendix A.

General rules and recommendations on cadastral surveying and mapping, appendix B.

Notes on training course in land surveying, appendix C.

1.1 Background

The Lao-Swedish Forestry Program is assisting the Department of Forestry (DoF) to develop models for participatory land use planning and land allocation which can be adopted and expanded through the government land use planning (LUP) and land allocation (LA) program. This assistance is being provided through the Land Use Planning Sub-program, which has appointed a core team of staff from the National Office for Forestry Inventory and Planning (NOFIP).

The core team works in selected villages with Provincial and District staff to develop and improve procedures, methods and practises which are documented and submitted to DoF decision-makers for approval and inclusion in regular programs. The core team also undertakes training for departmental staff at central, provincial and district levels. The LUP and LA activities result in the production of temporary land certificates for upland parcels, and in some cases land which will be converted to paddy fields. The certificates are issued by a Land Committee, comprising members from concerned sectors in land management at provincial, district and village level. The certificate can be transferred into a permanent land title after a three years period, should the family use the land in accord with appropriate land use practice.

The Department of Lands and Housing Management is the authority finally responsible for the land certificate. Surveying and issuance of land other than upland, i.e. construction land, paddy fields and others, is the responsibility of the Department of Lands and Housing Management.

During the last year constraints to effective LUP and LA activities at field level have been identified, one of
which is lack of staff capability in field survey and mapping methods. The DoF is concerned that the quality of measurement and mapping of agricultural fields being undertaken under the LUP and LA program will be inadequate for future land records and for the land titling program which has started in Lao PDR. The need has been identified to examine options for land survey methods adequate for land titling purposes, appropriate for LUP and LA and able to be adopted and used by field staff. Questions relating to the registration and recording of land use transfers and rights need to be investigated more carefully especially when temporary land use transfers are going to be replaced with permanent certificates.

1.2 Main Purpose

The main purpose of the assignment is to consider land survey options for use in LUP and LA, provide recommendations and conduct training for the LUP core team and some District staff.

For detailed information, see Job Description, appendix A.

1.3 Outputs

The expected outputs of the assignment are

- Recommendations for future land survey, aerial photography and mapping methods for LUP and LA and for further studies regarding land registration, and
- Assign a report on findings, result of the training exercise and recommendations for future land survey, mapping and registration methods.

2.0 METHODS FOR CADAstral SURVEYING AND MAPPING

2.1 General

Land registration for land management purposes requires cadastral surveying and mapping. Cadastral surveying and mapping includes the procedures to demarcate and identify boundaries of parcels allocated to different users with some kind of right, for instance the right to use the parcel for a specified purpose. The boundaries are surveyed in the field and described on the map.

The parcel is given a unique identification number, which forms the base for the registration of the parcel, the user and other information about the allocated rights in a public registry. The specific maps of each parcel are usually compiled to maps, displaying the distribution of land use rights over larger areas, so called cadastral index maps. The purpose of land registration is usually to provide security of tenure for the land user and provide information on land use rights for land administration and taxation to be used by different responsible authorities and the general public.

Cadastral surveying and mapping need to be undertaken for each parcel in cooperation between the land user and responsible authorities. The process is usually based on or integrated with land use planning, identifying the purpose for which the land user is allowed to use the land. It is a rather cumbersome procedure, which requires access to considerable resources. It is therefore essential to adopt the methodology for surveying and mapping to the circumstances, defined by the topography, the land use, land values, size of parcels, potential risks for land disputes and available human technical and financial resources. Modern technology opens possibilities to increase the speed and ease the costs for cadastral surveying and mapping, especially when undertaken systematically over large areas. Substantial investments in technology and training of staff are however needed.

Cadastral surveying and mapping can also be undertaken for bigger parcels identifying areas used by an ethnic groups or other communities without identifying individual user rights.

Cadastral data need to be updated whenever a change of the boundaries or of the user rights connected to the parcel occur.

Ground survey methods

Classical cadastral surveying and mapping has traditionally been based on ground survey. This includes the survey of the boundaries by measurement of bearings and distances, which are compiled to a map either
graphically, by drawing the reduced bearings and distances on the map or by calculation of coordinates and drawing the map from these.

Depending on the required accuracy and available skill and technology, various methods can be used for the surveys. The most simple way of measuring bearings is by using a compass. More accurate methods include the use of plane tables, which represents a simple but efficient way, especially as the map is constructed on the map table directly. More sophisticated methods include the use of theodolites, which can be either manual or electronic. Distances can be measured with help of tapes, optical survey of angels, and by Electronic Distance Measurement (EDM) instruments. Modern instruments combine survey of bearings and distances in one operation, so called total stations.

The coordinate method requires connection to a coordinate-system, which can be local for the area or national for the whole country. The calculations can be made by hand or by using computers. In modern systems, data are collected in digital form and then loaded into a computer, which can calculate the coordinates, construct the map and plot it on a plotter. Once data are available in digital form, they can be used for further applications using Geographical Information System (GIS).

The compilation of cadastral index maps, requires a number of national solutions to questions related to geodetic datum, map sheet divisions and map numbering system. Surveys need to be connected to an established national geodetic control system.

Land registration requires a national system for unique identification of each parcel.

**Methods based on aerial photography**

Aerial photography is increasingly used for cadastral surveys, especially when undertaken systematically for larger areas. The method is based on the identification of visible boundaries or other features in the aerial photography and plotting of the parcels from this interpretation. The simplest and fastest way is to use enlarged aerial photos as they are. However, the scale and location of an enlarged aerial photo is only known approximately as the aircraft will tilt during the flight and the elevation of the terrain will change under the flight strip. The photo map can therefore only be used for approximate calculations of areas and distances, which in certain circumstances might be sufficient.

In order to obtain an accurate photo map, the image must be corrected with help of known coordinates or distances between identified known control points through a rectification. The rectification can be done by establishing a plane with the same tilt as the aircraft at the time of exposure. This is usually sufficient in plain areas. In mountainous areas the image also needs to be compensated for differences in the elevation of the terrain through the production of an orthophoto. The best accuracy is received if the image is transferred to a map projection in a stereo plotter.

Today orthophotos and stereometric maps can be produced digitally, for instance in analytic plotters or through digital photogrammetry. This is a fast and accurate methodology. It requires substantial investments in equipment and training, which only can be motivated for large projects.

**Global Positioning System (GPS)**

The GPS technology means that the surveys are carried out in reference to at least four special satellites. The method represents a fast way for surveys of details in the terrain. The technology is based on complicated technology and calculations, but simple receivers are available, which manage the calculations automatically. These receivers can give an accuracy of about 100m, which can be sufficient for location of an area or for surveys of rather large parcels. To receive better accuracy, more expensive equipment is needed, which also need connection to simultaneous surveys from control points, longer observation periods and more complicated calculations, so called differential GPS.

GPS is also used in connection with aerial photography which can reduce the need of ground control for rectification of the images considerably.

**Choice of method**

The choice of method for cadastral surveying and mapping must be done against the background of the needed accuracy as described above. The methods can be combined in various ways, for instance GPS can be combined with very simple compass surveys or with simple enlarged aerial photos, in order to give the desired result within a reasonable length of time and costs.
Another important factor is the land registration system and the intended further use of the data for various applications, for instance if the record keeping will mainly be based on manual registration in books and paper maps or if the data are to be stored in computerised systems.

2.2 Current Methods

In the process of land use planning and land allocation within the Land Use Planning Sub-program, field measurements are carried out of boundaries of villages and village land parcels being allocated. The configuration of the measured units are determined, but not their location in relation to one another, although the program makes attempt to do this.

The survey equipment used is compasses for measurement of bearings, tapes for distance measurement and clinometers for slope measurement. By running a chain traverse along the village boundaries and around each land parcel, their appearance and shape are determined. The accuracy of the applied methods and tools might in all be estimated to a few metres per 100 metres.

The adopted survey methods are for the time being probably sufficiently accurate for planning and allocation of upland areas in Laos. The measurements are likely to give stability and security in future considerations on what was intended in the survey, considering they are conducted properly. The basic problem is not the poor accuracy in measuring of the individual parcels, but to know where these are located within the village and in relation to each other. A suitable solution has to be found for the latter issue.

Specific features for the current methods

The requirements for the survey methods that may be used in the project for land use planning and land allocation can be summarised as follows.

- Result in a reasonably accurate map of the surveyed area
- Accuracy and design sufficiently distinct to avoid future land and boundary disputes
- Be useful for future cadastral mapping
- Methods should be fast, simple and efficient
- Survey instruments should be uncomplicated, cheap and easy to bring to field and able to be used by forestry and agricultural extension staff at district level, given that they receive adequate training

2.3 Suitable Methods

As mentioned above it is essential to adopt the methodology to the circumstances, considering all aspects involved. The land surveying activities within the project do not need to be sophisticated, but should fill the needs at reasonable cost.

The ground survey methods used today are giving a fairly accurate picture of the individual land parcel and of the village boundaries with small means. It does however not give a very accurate picture of the location of land parcels in relation to each other and to the village boundaries. As this information is the base for all future activities concerning land and land transfer, it is important that the standard of this part of the map information improves. To achieve this, more comprehensive measurements have to be made. The tools, compass, clinometer and tape, might be sufficient, but the time for the ground survey activities will increase by at least 50%, unless no other means or method can be found. In these circumstances it seems imperative to look into the alternative methods mentioned above and combinations of these.

3.0 TRAINING

The training requested on land survey methods and mapping was carried out at central level from 21 - 24 January. Follow-up field training in mapping and field measurement was undertaken in a target village, Ban Siinglekhol in Atsaphangthong district, Savannakhet province, with central, provincial and district staff from 1 - 6 February.

The following subjects have been considered and discussed in the training activities.
The map and its appearance and contents;
Coordinate systems;
Land survey methods in general;
Introduction of specific land survey methods;
Distance measurement;
Slope reduction;
Units of measure;
Measurement with compass, tape and clinometer;
Drawing of measured data;
Area calculation with planimeter, coordinates and graphically;
Mapping methods for drawing of the village map;
Scale conversion, enlargement and reduction;
The Cadastre.

Notes and advise on the training issues have been compiled into a booklet, appendix C. It should be translated to Lao and printed, thus becoming useful particularly in provinces and districts.

4.0 LAND LEGISLATION IN LAOS

Laws and regulations relating to land have been extensively analysed elsewhere and need not be repeated here. A brief account for the most relevant land legislation is however considered appropriate and is hence given below:

- Constitution, Article 15. Land is the property of the national community. It does, however, grant organisations and individuals of Lao PDR the right of use, transfer and succession in conformity with the law.

- Decree 99 on land. The land is the property of the national community. All Lao citizens have the right to possess and use land. Land titles can be issued and land can be transferred by sale or inheritance. The Ministry of Finance is entrusted to issue regulations for registration, assignment, transfer, inheritance, lease and so on.

- Decree 169. Management and use of forests. Defines all land that is not permanent agriculture land as forest land under the mandate of Ministry of Agriculture and Forest. Traditional tenure rights continue to be recognised and user rights can be granted to families, groups, collectives and enterprises.

- Decree 186. Emphasises the promotion of tree planting and the protection and rehabilitation of natural forests. Land for plantation can be allocated to villagers or enterprises (up to 100 ha by district authorities, up to 1,000 ha by provincial approval). Forest land with tree plantations may be sold and inherited. Land used for intensive tree growing is exempted from land tax. Village forest an be set aside for household use, ruling out commercial purposes.

- Ministerial Direction 990/MoF. Full land title can be granted after 20 years occupation. After receiving provisional land title a full title can be granted after 1 year. Summary, see next page.

- Ministerial Direction on land parcel registration system. The Land Parcel Registration System is an official system for recording and maintaining up to date information about land parcels, such as: location, boundaries and possession and use rights. The land possessors and users officially rights are recognised. The records of the system are comprised of the Land Register Book, Land Parcel Register Index, Land Certificate, Cadastral Map, Individual Land Parcel Survey Plan and Land Plan. The Land Register Book contains information regarding each land parcel, such as: the location, Land Certificate identification number, the unique land parcel identification number and the identity of the land possessor and user.

- Draft Law on Land, 10 April 1996. The law has not yet been approved.
5.0 LAND ALLOCATION AND LAND REGISTRATION IN LAOS

Land allocation and registration in Lao PDR has started only recently. The process is the responsibility of the Department of Land and Housing Management within the Ministry of Finance. Land allocation is also undertaken by the Ministry of Agriculture and Forestry.

5.1 Department of Land and Housing Management

The Department of Land and Housing Management (DOLHM) within the Ministry of Finance is the national agency responsible for the design and implementation of land management and administration programs. DOLHM has divisions for cadastral surveying, land and housing registration and taxation, and is mandated to carry out land registration and titling through its provincial-level offices, the Land and Housing Management Offices (LHMO), and under the national and provincial Land Re-Management Committees. DOLHM is undertaking a land titling program in urban areas.

The land titling project

The Land Titling Project, under DOLHM with support from the World Bank, started up the activities in 1996. The objective is to issue 300,000 land titles in five provinces over a seven year period. So far 1,500 titles have been issued in Vientiane. In the first four years the activities are taking place in urban areas. After that rural areas will be included too.

The survey work is based on rectified air photos, so called photo maps on which the land parcels are identified and measured with tape. Map scales in use are at 1:1,000 or 1:4,000. UTM grids are drawn on each photo map. The size of the photo map is 50 cm × 50 cm. Cement pillars are used for demarcation of land parcel corners. The land parcels are numbered on the photo map, starting with 1 in the upper left corner, running to the right and down, with the last number in the bottom right corner. Each photo map has an identification number based on the 1:50,000 topographical sheet number.

The land parcels are registered in the land record, appendix D, getting a second identification in the record, referring to the Record Book number and folio number. Land certificates are finally issued by the provincial Finance Division and Head of Land and Housing Management Office, appendix E.

The adopted method is characterised by simplicity, emphasising the juridical issues and legal security. Decisions on contents of registers, system and so on are the official ones that should be observed according to stipulated laws and regulations.

5.2 Ministry of Agriculture and Forestry

Land use planning and land allocation activities are carried out in rural areas by provincial and district offices of the Ministry of Agriculture and Forestry. The activities are carried out on a regular basis and with assistance from the Land Use Planning Sub-program and the German Agency for Technical Cooperation (GTZ) in the Nam Ngum Watershed Management and Conservation Project (NAWACOP).

The Land Use Planning Sub-program

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Land allocation within the Land Use Planning Sub-program has so far been implemented in six villages. The activities have not been coordinated with the Land Titling Project.

The applied working procedure and methods are described in a draft manual on participatory land use planning and land allocation. Basically a survey is at first carried out of the district boundaries. Then the land parcels are surveyed and a village map is produced. Different kinds of forest land are identified, protection forest, conservation forest and production forest. The land available for allocation is then identified and finally the land parcels allocated in participation with the villagers.

Mainly the upland agriculture fields are allocated in the process. Residential land, paddy fields, orchards and commercial trees are usually not included in the process. This land has already often been allocated by DOLHM and Tax Certificates issued, on which owner, type of land and area are noted. For residential land there is a sketch map with the size of the plot. The boundaries have been decided in the process of issuing the Tax Certificates.

Finally a temporary Land Certificate is issued by a Committee comprising members from Lands and Housing department in province and district, agroforestry officials and officials from province, district and village. The temporary certificate can be turned into a permanent one after three years, provided the land has been managed properly.

The land use planning and land allocation process as applied in the Subprogram is in fact a simple cadastre, resulting in a map and a land register of the village. As there are many similarities with the officially decided land titling process, it should incorporate as much methodology as possible from that process. There will naturally be inconsistencies between the two, as they are meant for different areas of development, urban area and rural area respectively. In fact, a lot more information is collected in the participatory process, but it is essential that the process as much as possible is similar to the official process. For instance should the land records contain the same information and the land certificates should have the same design.

6.0 THE CADASTRE

As pointed out in section 5, the participatory land use planning and land allocation process will result in a simple cadastre, comprising its basic components. It is therefore appropriate to give some information on the cadastre in this report on definition and its merits.

**Definition of the cadastre**

A Cadastre can be defined as *a methodically arranged public inventory of data of all land parcels within a certain area, based on a survey of their boundaries.*

The parcels are systematically identified by means of some separate designation. The parcel boundaries and identifiers are normally shown on large scale maps, which, together with registers, may show for each separate parcel the legal rights, the nature, use, size and value.

The system comprises in principle two basic parts:

1. A cartographic part, consisting of large scale maps, based on cadastral surveying, indicating the division into parcels of an area along with appropriate parcel identifiers, and
2. A descriptive part, containing registers or files which record legal facts and other physical or abstract attributes concerning the parcels represented on the map.

In every cadastral system, the basic land unit is the cadastral parcel.

The classical cadastral map usually contains information on the shape, size and location of land units. The plain cadastral map can be quite simple, only containing the administrative boundaries and the boundary lines of land parcels. Often some geographical features are displayed in addition, to simplify identification of the position of the land parcel. The cadastral map might in this case be referred to as a fiscal cadastral map.

*The main point of a cadastre is that it will be complete.* It will be largely worthless unless it is substantially complete within a particular geographical area. To attain this goal, cadastres and land registers must be kept simple and concentrate on the essentials. Furthermore, the work must have a solid foundation and costs must
be kept reasonable in relation to expected benefits.

The contents of the cadastral map is in the end determined by political decisions on the purpose of the cadastre. Will it be used only for tax purposes, or will it be a part of a major land information system?

Merits

The merits of having a cadastral system can be related to the individual or citizen on one hand, and the society or state on the other hand. [Henssen: Cadastre, indispensable for development].

To the individual

The merits for the individual result from four effects of a cadastre:

1. The documented evidence of land ownership, which a cadastre provides, supplies security, reduces or eliminates the risk of eviction and thus enhances the incentive to invest in the land and property.
2. This legal security effects the availability of resources for financial investment. The supply of credit, especially from banks and other formal resources, depends usually on the borrower's ability to provide cadastre documented evidence of ownership. In the formal credit market, land or property is a collateral for long-term and cheap credit, unlike the informal market in which credit becomes expensive.
3. Dealings in land become easier, cheaper, faster and safer. Access to land is consequently improved.
4. Increased legal security results in a decrease in title and boundary disputes and related litigation, which saves costs for both state and individuals and promotes good relations between neighbours.

The influence of these four effects of cadastres on investments, give in turn higher output or benefit from the land or property. This again results in higher income, higher value and ultimately results in improvement of the economy, expressed in growth of the gross national product.

To the state

1. A cadastral system enables the government to establish an efficient and equitable system for levying land or property taxes.
2. For land development the data from the cadastral system provide an inventory of the existing land use to be used in determining the desired future situation and its implementation and management.
3. A mechanism becomes available to the state to assure that transactions meet the requirements of planning and management.
4. The collected basic data of the cadastral map can serve as a basis for other large scale maps, which in the long run will result in considerable savings of time and costs.
5. A cadastral system can provide the basis for geographical or land information systems and thus serve as part of a multipurpose map and land information system.

7.0 Findings

In this report has been concluded that the participatory land use planning and land allocation process in fact results in a simple cadastr, comprising its basic components, a map displaying the land parcels and a textual register with information on the land and its users. Further has been emphasised that it is essential to adopt the methodology for surveying and mapping to the circumstances, defined by the topography, the land use, land values, size of parcels, potential risks for land disputes and available human technical and financial resources. Based on these requirements, discussions with staff in the land use planning and land allocation process, training activities and experience gained by field visits, a number of observations, reflections and findings are given below.

The participatory land use planning and land allocation

The process is for each target village started by a 3 days training course for provincial and district staff. One of the days deals with land surveying and mapping issues. The planning and allocation is then taking place in the target village over a very short period of time, about 2 weeks. Considering that the staff will carry out a very severe task and at the same time adopt a lot of new information and implement new technique, not only in surveying and mapping but also in other subjects related to the planning and allocation process, the time is indeed very short. A secure and proper result might easily be jeopardised. More time for preparation seems
The village base map

Before any land survey activities can be carried out on the ground, the village base map has to be prepared. The map is either at scale 1:10,000 or 1:5,000 and has up till now generally been constructed by enlargement of the topographical map at the scale 1:100,000. Sometimes the information from aerial photos have been used too.

The topographical map

The topographical map is of French origin from the 1960's. Although up-dated by air photos in the early 1980's, the quality of the map is not very good. Enlargement by 10 or even 20 times of the original map scale will also enlarge any error just as much and result in a map that is so inaccurate that it cannot really be called a map, but rather a sketch map. This map has to be improved to a certain extent by measurements in the field of roads, foot-paths, streams and similar features, which are inserted on the base map with reference to other features on the map. The allocated land parcels are located and fitted on the base map after they have been surveyed on the ground.

Discrepancies of several kilometres between different map material were detected in the field exercise, mainly due to the quality of the topographical map. Enlargement of this map should therefore be used only as a last solution when no other means are available.

The enlarged 1:100,000 topographical map is not a map, but merely a sketch map, outlining the main features of the ground with a quality that is much less than required in the process.

Aerial photos

Aerial photos at scale 1:30,000 or larger are available over all the area where the land allocation process is undertaken. As an alternative to the above described map, enlarged air photos might be used. Even if these aren't rectified, the quality will most certainly be far better than that of the enlarged topographical maps. Furthermore, the location of upland land parcels can often be located on the photo, thus avoiding comprehensive, cumbersome and costly measurements for fitting the parcels on the map.

Preparation of the base map

At present way of working the base map is prepared in the field. The working conditions and tools are so poor that the quality of the map becomes less accurate than it should have been if it was constructed under better conditions.

Village boundaries

One of the first actions when arriving to the target village is to find out the position of the village boundaries and draw them on the base map.

The boundary will many times be a river, a road, run between two peaks along a ridge or similar features. It will in these cases simply be drawn on the base map, following the topographical features. Its position will not be measured on the ground. Sometimes the boundary will pass through a forest. If the forest has low value it seems as the villagers are not very concerned about its exact location. No time will in such a case be spent on demarcation of the boundary and thorough measurement of its position. This might however not be the case if the forest has a high value.

The village boundary might merely be regarded as a nominal line that is not fixed as a line between points on the ground. The boundary is sprung from customary use, rather than administrative decisions. Determination and drawing of the village boundaries will therefore vary due to the circumstances. It is however important to show the boundary with a line on the map and also make a written statement and agreement of its position.

Field measurement

Field measurement of individual land parcels are conducted by use of compass, clinometer and tape. The measurements give as a result a reasonably accurate picture of the land parcel to be drawn in the temporary land certificate and on the base map. The method of measurements results in an accuracy to several metres
for individual land parcels, provided the measurements have been conducted properly. The misclosure of a chain survey is dependent on its total length. A largest permissible misclosure should be calculated by a formula, developed from theory and experience.

**Current methods**

The current survey and mapping methods are characterised by simplicity and fastness, not being very accurate in terms of common requirements for accuracy in land surveying techniques. The specific features are given in section 2.2.

A chain survey (closed traverse) is run around each individual land parcel. The position of the land parcel on the village base map is identified by natural features (roads, rivers, heights, and so on). For the current need, a quick and legally secure land allocation, the methods must be considered appropriate. Most important is that the methods are secure and can be used in a final cadastral surveying with no land disputes occurring.

**Slope reduction**

As the map is a plane reproduction of the earth, slope distances have to be reduced to the plane. This has not been done in previous exercises. Especially in steep areas, the slope reduction is essential to achieve a correct result.

**Drawing**

Drawing of the field measurements is done graphically without any numeric calculation for check of the result. Consequently it is very important that the drawing is performed with utmost carefullness and proper drawing tools in order to obtain the best possible result and not loose accuracy from the measurements. When closing the chain survey on the drawing-paper, the misclosure (gap) must be within a permissible limit.

**Area calculation**

Land parcel areas are determined graphically in the field. The method is not very accurate, but even so it seems difficult to find another way in the present circumstances and working conditions with heavy time constraint. The use of planimeters and other area calculation methods requires better working facilities (plane table surfaces, illumination, and so on).

**Location of land parcels on the village base map**

To achieve the simple cadastre and thus avoid future remeasurements and uncertainty, it is essential to insert the surveyed land parcels on the village base map in reasonably accurate positions. This can be done by using geographical features represented on the map and by establishing reference points along roads and other recognisable features. In the case the aerial photography is used for construction of the base map, the land parcels can often be located on the photo, thus avoiding comprehensive measurements in the field.

**Implementation**

A lot of carelessness and lack of understanding of the measurement and mapping process have been noticed in the training sessions and field visits. There is an obvious need of thorough understanding of the process that can only be achieved from experience and training.

There are many examples of procedures that are not being followed, although necessary to follow to achieve a correct result and avoid remeasurement. For instance, surplus observations are seldom measured, lines for free sights and straight tape measures are not always cleared, field books are not used, correct and sufficient equipment is not brought to the field, and so on.

**Surveyed areas**

The areas that are being measured and mapped are sometimes hard to access. The survey lines might cross dense vegetation or steep slopes and the survey solution is not always easy to find. Extra time and effort must in these cases be spent to get an appropriate result.

**Land Registration**
The land parcels are registered by using the land owners as reference. In every cadastral system, the basic unit is however the cadastral parcel, see section 6. The officially adopted land registration system in Laos also uses the land parcel as the basic unit, see section 5.1.

**Storing**

The results of the activities are kept in the districts and provinces. A common and safe storage is to be preferred.

**New methods**

The GPS technology is rapidly improving and is likely to be the leading land survey technique in the future. The technology is described in section 2.1.

The Forest Management and Conservation Project (FOMACOP) in Savannakhet is using GPS for delineation of territory boundaries. By handheld receivers the position of boundaries is determined with an accuracy of 100 metres. Boundary and land use lines are delineated on air photos at scale 1:10,000.

To achieve better accuracy, a more sophisticated equipment is needed. By setting up a base station within 100 km from the survey site, the handheld receivers can measure the position of a point with an accuracy of a few metres. Readings in dense forest is however not possible.

The GPS technology can be combined with other conventional survey methods, thus improving the quality of measurements.

**8.0 RECOMMENDATIONS**

There is an obvious demand for improvement of the land survey and mapping methods in the land use planning and land allocation process of the Subprogram. By small means the quality might be improved considerably. Below are given some ideas and recommendations.

**The village base map**

The village base map should in present circumstances be constructed from aerial photos, thus improving the map quality and the accuracy of the whole process.

- *Enlargement of the topographical map should be avoided and used only as a last solution when no other means are available;*
- *Use enlarged air photos whenever possible.*

**Preparation of the village base map**

In the present way of working the base map is prepared in the field. *Time and quality will be gained* if instead the map is prepared in the office prior to the field work.

- *Always prepare the village base map in the office prior to the field work.*

**Measuring the village base map**

Upon preparation of the village base map additional features and information should be collected by field measurements. If for instance the village boundaries are positioned and delineated before the land allocation process is taking place, more effort can be spent on the latter and its quality improved. Preparatory steps can at the same time be taken for future field measurements and positioning of the land parcels on the map.

- *Split the field measurement activities into two parts, the first part being preparation of an accurate village base map and the second part being field measurements and positioning of the land parcels;*
- *A special land survey and mapping team should be established for the first part, to have the overall responsibility for production of proper village base maps.*
Field measurement

The final results of the field measurements depend on instruments, implementation and thorough understanding of the procedure. The land surveying technique is based on carefulness, surplus observations and proper planning, see appendix B. Below are given some examples.

- Measure always forward and backward bearings of a chain survey;
- The distances should be measured and recorded carefully in a field book;
- Measure always the slope angle of steep slopes for reduction of the slope distance to the plane.

A proposed suitable field book is included as appendix F.

Drawing

Draw the measurements carefully using proper tools.

- Use millimetre-paper, sharp pencils, protractors and scale bars;
- The misclosure (gap) of a chain traverse should not exceed

\[ \pm 3,00 + 0,25 \times \sqrt{\sum d_i} \text{ metres} \]

Area calculation

- Measurement of an area should be made several times until at least three consistent results are obtained.

Equipment

Recommended equipment for the various stages of the survey and mapping process:

- Field measurement: Compass, clinometer, tape, field book and calculator;
- Drawing: Millimetre-paper, tracing paper, protractor, set of squares, ruler, scale bar, sharp pencil, eraser and pantograph;
- Area calculation: Ruler, scale bar, calculator, area overlay and planimeter.

Training

The time for training of land survey methods and mapping is extremely limited. A proper result can hardly be expected in these circumstances. Therefore:

- As a first step one extra day should be designated for training of provincial and district staff in the initiation of the land allocation exercise;
- More comprehensive training should be given in the training centres;
- On the job training should be supervised by skilled staff.

Land registration

- The land registration within the Sub-program should be coordinated with the system used by the land titling project. The registers should at least contain the same minimum information, thus facilitating a common land register in the future.

Storing

The results of the land use planning and land allocation activities should be stored in a safe and proper way, making the data easily accessible.

- The land allocation map should be digitized and stored at central level;
- The land register should be transferred into a textual register in a database. Development of a computerised register should be assisted by a consultant with experience from this field.
New technique

The use of GPS-technique in the land allocation process should be tested.

- Trial with a GPS base station should be carried out, for instance in cooperation with FOMACOP in Savannakhet and assisted by an expert.

APPENDIX A

Terms of Reference for

Short Term Consultancy on Land Survey Methods and Training

Introduction

The Lao-Swedish Forestry Program is assisting the Department of Forestry to develop models for participatory land use planning which can be adopted and expanded through the government land use planning (LUP) and land allocation (LA) program. This assistance is being provided through the Land Use Planning Sub-Project which has appointed a core team of staff drawn from the National Office for Forestry Inventory and Planning (NOFIP).

The core team works in selected villages with Provincial and District staff to develop and improve procedures, methods and practices which are documented and submitted to DoF decision-makers for approval and inclusion in regular programs. The core team also undertakes training for departmental staff at central, provincial and district levels.

During the last year the core team and the DoF have identified constraints to effective LUP and LA activities at field level, one of which is lack of staff capability in field survey and mapping methods. Staff also lack equipment to undertake effective survey and mapping work which the sub-project is helping to rectify by supplying basic equipment such as compasses, clinometers and measuring tapes.

The DoF is concerned that the quality of measurement and mapping of agricultural fields being undertaken under the LUP and LA program will be inadequate for future land use records and for the land titling program which has started in Lao PDR. The need has been identified to examine options for land survey methods adequate for land titling purposes, appropriate for LUP and LA and able to be adopted and used by field staff. Questions relating to the registration and recording of land use transfers and rights need to be investigated more carefully especially when temporary land use transfers are going to be replaced with permanent certificates.

The LUP sub-project proposes that assistance be sought from Swedesurvey to examine the various requirements, to make recommendations and to conduct some initial training for the sub-project core team. The proposed input is also seen as a first step in developing institutional cooperation during Phase 4.

Swedesurvey is a state owned company which conducts surveying, mapping and cadastral activities in Sweden and overseas. Sweden was the first country in the world to establish a legal computer-based system for the cadastre and land registration. The company offers a wide range of services which include; land information systems, land management, land consolidation, land registration, cadastral systems, land use planning, urban and rural planning, on-the-job training, training programs, mapping, GIS, cadastral surveys, computer techniques, aerial photography etc.

An appendix is attached which describes methods for cadastral surveying and mapping. Ground survey methods, aerial photography based methods and GPS technology are discussed and comments made on considerations when choosing a methodology.

Duration of Proposed Assignment: 4 weeks commencing 6th January 1997

Main Purpose: To consider land survey options for use in LUP and LA, provide recommendations and conduct training for the Land Use Planning (LUP) core team and some District staff.
Job Description:

- Review the land survey methods and practices being used by staff implementing LUP and LA programs, including compass and tape ground survey methods and area calculation methods.
- Review the appropriateness of aerial photography to assist LUP and LA activities such as village boundary delineation, identifying land ownership and land use, delineating forest areas and planning future agricultural and forest land use.
- Review the mapping methods and practices being used in LUP and LA, including topographic maps, forest type maps, map enlargement methods, village mapping methods and requirements and the potential for using GPS having in mind the GIS capability which exists at NOFIP.
- Provide recommendations for future appropriate methods and applications for land survey methods, aerial photography and mapping methods within the LUP and LA program taking due account of the constraints encountered by the implementing staff in the field and having regard for the requirements for future land titling. In this context the consultant should consult with the Department of Land and Housing, Ministry of Finance and the National Geographic Department.
- During the assignment, provide some basic training for the LUP sub-program core team members and the district staff on the available methods and applications during a field exercise in a target village.
- Propose further investigations in the field of land registration and recording of issued temporary and permanent land use transfer certificates.
- Prepare a report presenting the findings of the reviews, the result of the training exercise and recommendations for future land survey, mapping and registration methods.
- Present findings at a short workshop for DoF and interested parties in Vientiane.

Outputs:

- Recommendations for future land survey, aerial photography and mapping methods for LUP and LA and for further studies regarding land registration.
- Assignment report as indicated above.

APPENDIX B

General rules and recommendations on cadastral surveying and mapping

General

The primary purpose of a cadastral survey is to determine for each land parcel its location, the extent of its boundaries and surface area and to indicate its separate identity both graphically on a map and physically on the ground.

Cadastral surveying falls into four easily recognisable stages:

1. **Reconnaissance**, which indicates the need to obtain an overall picture of what is required before any type of survey work is undertaken;
2. **Demarcation** of land parcel boundaries at all corner points of the boundary;
3. **Field measurement**, in which the relative position and sizes of natural and artificial features on the land are determined;
4. **Presentation**; in which collected survey data are presented on a map to be clearly interpreted and understood.

Based on these four principles, some recommendations are given below. However, before conducting the survey, preparation and planning of its implementation is needed to ascertain a good result.

**Preparation and planning**

Make sure that all equipment needed for a successful result is brought into field; maps, field measurement equipment, field books, drawing equipment, and so on. Make a check list and use it!
Before going to field, check that all equipment is working properly, that no tapes are broken, that all survey instruments are in order, and so on.

**Reconnaissance**

On the survey site, walk around it and plan the survey! Lots of mistakes are usually avoided by a thorough planning!

**Demarcation**

In most cases a permanent demarcation of the boundary is needed. It could be by concrete pillars or poles of hard wood in the corner points, a ditch, a fence or similar. Before leaving the survey site, make sure that the boundary line has been permanently demarcated.

**Field measurement**

All field measurements should be recorded in a field book clearly and legibly at the time of making the measurement.

A thoroughly drawn field sketch is a great contribution to make the survey successful.

In all survey work surplus (extra) measurements are essential to avoid mistakes. It is better to make one extra observation than have to go back and repeat the whole survey.

The bearing in compass traversing should always be observed in both directions, the forward reading and the backward reading. The readings should differ by 180 degrees exactly. Add or subtract 180 degrees to the backward bearing and the result should be the same. The difference must not exceed 2 degrees.

The closure of a traverse should not exceed a certain value, determined from the used tools and experience.

**Presentation - Mapping - Area calculation**

Choose a map scale that allows all measured features to be clearly drawn and makes the map easy to read and understand.
In the use of planimeter, pantograph and other drawing tools, in order to obtain a proper result it is important that the drawing surface used is level and the paper clean. Dust, eraser cuttings and grease will give poor results.

In determining the area by planimeter, the area should be measured until at least three consistent readings are obtained.

The planimeter should before use always be checked on an area of known size.

Area calculation by an area overlay or by subdivision of the area into smaller units should be used as a check only to a more accurate method, area by coordinates or by planimeter.

Map enlargement should if possible be avoided, due to the fact that any error in the small scale map will be enlarged to the large scale map.

APPENDIX C

Notes on Training course in land survey methods

Programme January 21 - 24, 1997

Day 1

Introduction of land survey methods

The map
Coordinate systems (Reference systems)
Common survey methods
Distance measurement
Reduction of distances to the plane

Compass measurement

Theory and practise
Drawing and adjustment of compass readings

Day 2

Units of measure

length
area
angles
scales

Area measurement

planimeter
coordinates
Day 3

The Cadastre

Land registration

Changing the map scale

pantograph
tool
coordinates
digitizing

Day 4

Drawing the village map

enlarge the topo map
prominent features from air photos and satellite images
location of land parcels on the village map
details of the village map - what to draw

Basic Training on land survey methods applicable for land use planning and land allocation

Specific features for methods in use

Specific features for the methods used in surveying of village and land parcel boundaries in land use planning and land allocation:

- Result in a reasonably accurate map of the surveyed area
- Accuracy and design sufficiently distinct to avoid future boundary disputes
- Be of use for future cadastral mapping
- Methods fast and simple
- Survey instruments uncomplicated, cheap and easy to bring to the field
- Methods which can be used efficiently

Requested training issues

1) Instructions on:
   - Compass
   - Clinometer
   - Altimeter
   - Pantograph

2) Area calculation

3) GPS applications

4) Land registration

5) Mapping methods:
   - Topo map
6) Use of aerial photos:

- Village boundaries
- Agricultural land use
- Agricultural land ownership
- Delineation of forest types and areas

The map

A map is a graphical, flat representation of the earth's surface in the plane. By geometric constructions, features on the ground are represented on a horizontal projection, thus obtaining a reduced and similar picture. In selecting a suitable scale, it is possible to describe various sizes of land areas in a convenient paper image, for instance land parcels, forests, agriculture area, houses, roads, rivers and so on.

The scale of the map depends on its purpose.

The legend explains all the symbols used in the map. The legend should also show the scale of the map, both numerically and with a scale bar.

Coordinate grids may be shown on the map, either by lines or by crossing of the grid lines. The coordinates may be given in degrees (geographical), or meters or kilometres. The coordinates on a topographical map often give the location of a point as a distance east of the Greenwich meridian and north of the equator.

Contour lines represent the altitude of the terrain, usually in meters above the mean sea level. Depending on the map scale and variation in elevation, contour lines may be drawn at 1, 2, 5, 10, 50 or 100 metres interval.

Map types

Small scale maps are commonly defined as those at scales = 1:10 000

Examples: Topographic maps for various purpose - roads, vegetation, topography, and so on.

Large scale maps are commonly defined as those at scales < 1:10 000

Examples: Town maps, cadastral maps, forest maps, land use maps, and so on.

Map projection

The earth is an irregularly shaped solid body with its surface differing from place to place (mountains, valleys, plains, seas, and so on). To reproduce the earth on to the plane map surface, a projection system will be used. The projection system defines in a mathematical way the connection between the earth and the picture on the map. For large scale mapping in Laos, the so called UTM-system (Universal Transverse Mercator projection) has been adopted.

The figure below illustrates the correction of a distance on the earth to a horizontal distance in the map plane.

The coordinate system

The position of points on the map are commonly defined by coordinates in a defined coordinate-system, which can be either geographical or rectangular. The systems can be either nation-wide (e.g. UTM) or of local design, covering a smaller area.

Rectangular plane coordinates

In land surveying the south-north direction is defined by the X-axis and the west-east direction by the Y-axis. North is the zero-direction. The X-coordinates are increasing from the south to the north and the Y-coordinates from the west to the east.
In the nation-wide system the X-coordinate is 0 at the equator and the Y coordinate 0 at any of the two central meridians at use in Laos.

Local coordinate-systems have other origins, but orientation should be the same.

**Control network**

Land surveying is based on the four underlying principles of control (or working from the whole to the part), of economy (of both time, money and effort), of consistency and of independent check.

In order to apply the first principle of working from the whole to the part, the area to be surveyed is first covered with coordinated control points. This has commonly been done by establishing so called networks, in which angles and distances are measured and coordinates calculated. The networks are of different orders, starting with the first order and a larger distance between the control points than in networks of lower order, see figure below.

**Common survey methods**

For most traditional land surveying methods angles and distances are measured in combinations. The accuracy of the measurements vary with the use of the survey and has to be determined from one case to another. Below are described some common methods which even are useful in map drawing.

**Bearing and distance - the polar method**
By measuring the angle $\alpha$ and the distance $d$, the coordinates and/or location of the measured point B can be determined in relation to the known point A.

**Traverse**

By measuring the bearings and distances to the intermediate points between the two known points A and B, the coordinates and positions of the intermediate points can be determined.

**Intersection**

By observing the bearings from the two known stations A and B towards the new point C, the position of C can be determined.

**Resection**

By observing the bearings from the unknown point P towards the known points A, B and C, the position of P can be determined.

**Offset**
By measuring the distances on the straight line between the two known points A and B to the perpendicular lines to C, D and E and the distances of the perpendiculars, the positions of C, D and E can be determined. The method can in some occasions be convenient. The measurement equipment needed is tape and an optical square.

**Reduction of slope distances to the plane**

As the distances on the map are plane, the measured slope distance must be reduced to the horizontal. This is done by use of the cosine-function in a pocket calculator.

The principle of slope correction is depicted in the figure below. Instead of using the cosine of the slope angle, the slope percentage (%) might be used if measured and the cosine-value isn't available.

\[ A = \text{Horizontal distance} \]
\[ C = \text{Ground surface distance} \]
\[ \alpha = \text{Slope angle (degrees, °)} \]
\[ \text{Slope} \% = 100 \times \left( \frac{B}{A} \right) = 100 \times \tan \alpha \]

\[ A = C \cos \alpha \]
\[ A = C \left( \frac{1}{\sqrt{1 + \left( \frac{\text{Slope}\%}{100} \right)^2}} \right) \]

**Figure.** Slope correction

**Chain survey**

**Field work**

By chain survey (also called closed traverse), the land parcel is measured in the field and drawn on the map sheet that is attached to the Land Transfer and Contract forms. By measuring nearby features which can be located on the village map, the location of the land parcel is determined. The following instruments are needed:

- compass
- clinometer
- measuring tape
- ranging poles
- pegs
- copy of the village map

A compass is needed to record the bearings of the land parcel sides.
A clinometer is used for measuring the angle of the slope. The angle is expressed either in degrees (°) or in percentages (%).

A measuring tape, made of metal or plastic, is needed to measure the length of the land parcel sides.

A ranging pole is a thin pole, usually 2 meters long, with a pointed end that is easily forced into the soil. The ranging pole can be painted with bands of bright colours to facilitate sighting.

Pegs are metal or wooden sticks which are needed with a tape measurement to locate the tape ends at long distances.

The first task in the field is to walk around the land parcel and identify the corner points, which are marked by ranging poles or flagging tape. They should be clearly visible at the measurement stage. The measurements of the actual chain survey are done with a crew of at least two surveyors, the frontman and the rearman. The chain survey is started by choosing one of the corner points as the starting point, station A, see figure.

In the beginning the rearman stands at station A, whereas the frontman has moved to a location between station A and B. For each tape length the rearman measures the compass bearing and the slope, and notes it in the field form. After arriving to station B, the team proceeds to station C and D and onwards until the starting point, station A, is reached again. The land parcels are drawn on the field form during the measurement. If some sides of the land parcels are already measured and drawn onto the village map, it is not necessary to measure the bearings of these sides.

The best check of the accuracy of the chain survey is to close it, i.e. returning to the starting point when the land parcel is drawn on the final map sheet.

If the compass bearings, slope corrections and distances are measured accurately, the traverse will be closed also on the map. To increase the accuracy in the field measurements, the following points should be kept in mind:

- The compass bearings must be read accurately
- The tape measure is to be kept tight
- Pegs should be used with sides longer than the tape
- The slope angle should be measured for each tape reading

Slope reduction

Reduction of the slope distance to the plane map is simply done by use the cosine-value of the slope angle multiplied by the slope distance as illustrated below. The slope percentage might be used instead, see above under reduction of slope distances to the plane.
The slope distance measures 153.7 m and the reduced horizontal distance 127.4 m, a difference of 26.3 m. The importance of slope reduction in the steep hills of Laos is easily realised.

**Drawing the map**

Before the field measurements are drawn on the map, the slope corrections of the measured distances must be calculated. Slope corrections are needed due to the fact that maps always show the horizontal distances, whereas the distances in the field are measured on the surface. The steeper the slope is, the bigger is the slope correction, see above.

The corrected field measurements are drawn on the map in the same order as they were done in the field. First a line is drawn towards station B, using compass and the measured bearing. Then the corrected map distance is measured along this line to obtain the location of station B. The same is repeated with the line B - C, C - D, D - E and E - A.

**Graphical method for closing a gap**

When transferring the chain survey results onto the map, it often happens that there is a gap; the point does not join the starting point. Provided all the possible drawing errors have been checked and corrected, this error can be eliminated with a method called *closing a gap*, see figure below. It should be applied whenever the closing error is big.

Rough estimation indicates that readings by compass implies a measurement accuracy by a few metres at a distance of 100 metres. In addition there will be the drawing errors, also amounting to a few metres, depending on the map scale. It is evident that the method is not very accurate, but a simple method that can be used in some cases when better accuracy isn't required.
Cumulative map distances

A to B  37 mm
A to C  60 mm
A to D 100 mm
A to E 131 mm
A to F 192 mm
GAP  15 mm

The first station is A, the last F. The gap is the line from F to A.

1. Draw a small line from each station, parallel to line F - A (the gap) and in the direction of the gap (upwards in the example).
2. Make a table of cumulative map distance from station A up to F.
3. Mark cumulative distances on a straight line using the map scale.
4. At endpoint F draw a line with a length equal to gap F - A.
5. Connect the end of this line (F') to station A. From each station B, C, D, etc. Draw lines parallel to F - F' to the new line. Mark the intersections with B', C', D' and so on.
6. The short lines B - B', C - C', etc. represent the distances that each station has to be shifted in the original drawing. Mark these distances on the short lines made in step 1.
7. Connect the new stations B', C', D', etc. to the starting station A. The gap is closed. Erase the original lines.

Closing the gap is based on the assumption that the closing error can not be caused by any particular error in the survey. It is instead an accumulation of small, unavoidable errors arising during the work. The total error should therefore be distributed to each measured side in relation to their lengths. Closing the gap is most conveniently done graphically.

The should be kept within certain limits due to the unavoidable errors. The following formula is suggested as a guidance.

\[ \text{GAP} \leq ± 3,00 + 0,25 \times \sqrt{\sum d_i} \]

*Note: The formula is just suggested for trial and its relevance must be checked before it is adopted. The constant 0,25 might be changed up or down to fit the circumstances.*

**Units of measure**

**Length**

Basic unit: 1 metre

Derived units:

1 kilometre (km) = 1 000 m
1 decimetre (dm) = 0,1 m
1 centimetre (cm) = 0,01 m
1 millimetre (mm) = 0.001 m

**Area**
Basic units: 1 square metre = 1 m\(^2\) = 1m \times 1m

1 hectare = 1ha = 100m \times 100m = 10 000 m\(^2\)

**Angles**

Basic unit: The *sexagesimal* system:

the full circle = 360 degrees = 360°

1° = 60 minutes = 60’

1’ = 60 seconds = 60"

In the *centesimal* system

the full circle = 400 grades = 400g

1 grade = 100 minutes = 100c

1c = 100 seconds = 100cc

Radian: The circle = 2\(\pi\) radians

**Scale**

The scale may be expressed numerically, as a ratio 1:s, where s indicates how many times larger the distance is on the ground compared to the map distance. On a map the scale is usually also drawn as a bar, which indicates the ground distance.

Examples: The scale of a map is 1:20 000. The distance between two points on the map is measured as 6,8 cm. The distance on the ground will be:

\[20 000 \times 6,8 \text{ cm} = 20 000 \times 0,068 \text{ m} = 1 360 \text{ m}\]

The scale of a map is 1:5 000. What is the distance on the map of the ground distance 100 m?

The solution is given by dividing the ground distance by the scale 5 000 \(\Rightarrow\) 100 m / 5 000 = 0,02 m = 2 cm.

Examples on useful scale conversions are given below.

<table>
<thead>
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<th>Scale</th>
<th>1 cm on map equals</th>
<th>1 km on ground equals</th>
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<tbody>
<tr>
<td>1:1</td>
<td>1 cm</td>
<td>1 km</td>
</tr>
<tr>
<td>1:2</td>
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<tr>
<td>1:250</td>
<td>2,5 m</td>
<td>4 m</td>
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<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>1:50 000</td>
<td>500 m</td>
<td>2 cm</td>
</tr>
</tbody>
</table>
The scale of the map is, as mentioned above, often illustrated by a scale bar.

\[ \text{SCALE } I: \ldots \ldots \ldots \ldots \ldots \ldots \]

<table>
<thead>
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<th>1 cm</th>
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<td>1 cm</td>
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<tr>
<td>1:500 000</td>
<td>5 km</td>
<td>2 mm</td>
</tr>
<tr>
<td>1:1 000 000</td>
<td>10 km</td>
<td>1 mm</td>
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</table>

**Area measurement**

The area of a land parcel can be measured in several ways, the measurements resulting in various accuracy.

**The planimeter**

Planimeters are used by moving a small circle or cross in the end of the device around the mapped parcel, keeping the circle or cross all the time exactly on the boundary line. Depending on the type of planimeter, the area can either be read directly on the instrument scale, or it can be computed from the difference of the starting and ending readings. The instructions of the used instrument must be consulted for conversion of the readings into area.

**Note:** To obtain a proper result by the planimeter, the surface used should be level and the paper clean. Dust, eraser cuttings and grease effect the movement of the measuring wheel, which must also be kept clean.

Start and end at the same point on the outline of the area that is measured.

The area should be measured until at least three consistent readings are obtained.

The planimeter should always before use be checked on an area of known size.

**By coordinates**

If coordinate-values are determined for the boundary stations, the area can be calculated by the formula:

\[
A = 0.5 \times \left( \sum_{i=1}^{n} (X_i \times Y_{i+1}) - \sum_{i=1}^{n} (X_{i+1} \times Y_i) \right)
\]

where \( A \) is area, \( n \) is number of stations, and \( X_i \) and \( Y_i \) are the coordinates of point \( i \).

**Millimetre-paper or area overlay**

A very simple way of making a rough check of the measured or calculated area is to use millimetre-paper or an area overlay.

The overlay is a transparent dot-template, where each dot represents a specific area due to the scale, the value of one dot differing from scale to scale.

In measuring the area by an overlay, it should be placed randomly on the area and the dots counted at least twice with a rotation in between the countings. The readings should be repeated until at least two consistent results are obtained. The mean of the readings is the measured area.
Subdivision

By subdividing the parcel on the map into smaller units, for instance triangles and squares, the smaller figures can be measured by ruler and the area calculated. This method should be used as a check only.

Changing scale

The need to enlarge or reduce the scale of a map occurs both as a separate operation and as a step in transferring old data to a new map. It can be done by reproduction methods, by use of a pantograph or by a pair of dividers and a ruler.

Generally it is easier and more accurate to reduce the scale than to enlarge it, as in the enlarging process errors are enlarged too. Therefore, the cartographic rule is to start working at the largest scale that is to believed to be of interest - the concept-scale. At a later stage the drawing may be reproduced to suitable smaller scales.

Changing scale manually

If a figure consists of a few points only which are to be reduced or enlarged, the operation can be done manually in a geometric way. First of all a suitably situated central point has to be selected. It can be either on the outline of the figure (fig. a), or inside (fig. b) or outside (fig. c) the figure.

Projection lines are drawn from the central point to all the other points. The distances are measured and reduced to the smaller scale or enlarged to the larger scale. Then the reduced or enlarged distances are set off along the projection lines from the central point. The new points are connected in order to obtain the reduced or enlarged figure. Check that corresponding lines are parallel on the original figure and the new one.

The pantograph

The manual method is not very efficient for curved lines or irregular figures or for a great number of points. In such cases the pantograph is preferred.

The principle of the pantograph is based on the parallelogram.

For specific information of the pantograph in use, see user instructions of the instrument.

The Cadastre

A Cadastre can be defined as a methodically arranged public inventory of data of all land parcels within a certain area, based on a survey of their boundaries.

The parcels are systematically identified by means of some separate designation. The parcel boundaries and identifiers are normally shown on large scale maps, which, together with registers, may show for each separate parcel the legal rights, the nature, use, size and value.

The system comprises in principle two basic parts:

1. A cartographic part, consisting of large scale maps, based on cadastral surveying, indicating the division into parcels of an area along with appropriate parcel identifiers, and
2. A descriptive part, containing registers or files which record legal facts and other physical or abstract attributes concerning the parcels represented on the map.

In every cadastral system, the basic land unit is the cadastral parcel.

The classical cadastral map usually contains information on the shape, size and location of land units. The plain cadastral map can be quite simple, only containing the administrative boundaries and the boundary lines of land parcels. Often some geographical features are displayed in addition, to simplify identification of the position of the land parcel. The cadastral map might in this case be referred to as a fiscal cadastral map.
The main point of a cadastre is that it will be complete. It will be largely worthless unless it is substantially complete within a particular geographical area. To attain this goal, cadastres and land registers must be kept simple and concentrate on the essentials. Furthermore, the work must have a solid foundation and costs must be kept reasonable in relation to expected benefits.

The contents of the cadastral map is in the end determined by political decisions on the purpose of the cadastre. Will it be used only for tax purposes, or will it be a part of a major land information system?

The land use map in the Land Use Planning Sub-project in Lao PDR is the base for land allocation of upland in the villages. The map may be referred to as a cadastral map. It should concentrate on the following features:

- **Administrative boundaries**, i.e. village boundaries;
- **Land parcel boundaries**, configuration and location on the map;
- **Communication systems**, roads, footpaths, and so on;
- **Hydrographic systems**, rivers, streams, canals, lakes, ponds, and so on;
- **Important terrain features**, heights, pagodas, memorials and other orienting features;
- **Text**, land parcel numbers, names of villages, roads, and so on.

![The cadastral map](image)

**Figure.** The cadastral map

The land parcel identifier

Land parcels are usually identified by numbers, often combined with province name and village name. If there are many parcels in the village, it might be suitable to divide the land into blocks from geographical features such as roads and rivers.

The system for land parcel identification should be officially decided and the same all over a country.

### APPENDIX D

#### Change of Registration Certificate No

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<th>Running No</th>
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<th>Name of Receiver</th>
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<th>Sign Head of Lands &amp; Housing Registration Office</th>
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## APPENDIX E

Field Book for measurement of bearings and distances

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