PN-ACA-385

PADCO

PLANNING AND DEVELOPMENT COLLABORATIVE INTERNATIONAL

Geographic Information Systems Manual:
Interpretation of Aerial Photographs
Housing Typology
Digitizing
Map Production and Plotting
Advanced Training

UMS No. 7

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Bob Kehew
PADCO, Inc.
1025 Thomas Jefferson Street, NW, Suite 170
Washington, DC 20007
Tel: (202) 944-2506; Fax: (202) 944-2351; E-Mail: rkehew@padcoinc.com

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Geographic Information Systems Manual: Interpretation of Aerial Photographs Housing Typology Digitizing Map Production and Plotting Advanced Training

Prepared for

USAID/Jamaica

Prepared by

Gerald G. Erbach
PADCO, Inc.
1025 Thomas Jefferson Street, NW
Suite 170
Washington, DC 20007
April 1993

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Prepared for

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INTERPRETATION OF AERIAL PHOTOGRAPHS

Prepared by

Gerald G. Erbach
PADCO, Inc.
1012 N Street, NW
Washington, DC
20001

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INTERPRETATION OF AERIAL PHOTOGRAPHS

Introduction

The ability to interpret aerial and satellite photographs for planning and housing purposes depends on several factors. Included among these are the interpreter's visual aptitude, observational habits, experience with housing and urban development, and specialized training in planning and/or photo interpretation.

Part of being trained (or of training oneself) in photo interpretation involves learning the signs or "signatures" of objects on the ground as they appear from the air. This involves a change in the observer's point of view that requires a keen sense of size and scale, skills related to visual perception and deduction, the ability to interpret height and vertical relationships based on shade and shadow, and in some cases, stereoscopic vision.

The most effective way to begin developing the necessary skills for successful photo interpretation is to study large scale, plain vertical aerial photographs of an area with which one is already thoroughly familiar (e.g. the neighborhood surrounding one's place of residence or work). Recognizing familiar features on the ground from the unfamiliar viewpoint of the aerial photograph helps one to develop a basic understanding of what can and cannot be interpreted from the photo image. It also helps provide an initial vocabulary of conditions that can be seen and identified on the aerial photographs (e.g. expanse, form, pattern, markings, specific objects and activities, etc.), as well as conditions on the ground that cannot be discerned very easily through remote sensing.

Notes should be made during this exercise concerning objects that can be identified on the photographs and how they compare to the results of field work or "ground truth". This interpretation/verification process not only provides a means of checking the reliability of the interpretation, but also encourages the interpreter to examine the reasoning process behind each conclusion. It turns initial training in photo interpretation into a "hands on" experience that differs very little whether training is formal or informal in nature.

The degree of information that can be obtained from the interpretation of aerial photographs or satellite imagery will depend mainly on the knowledge base or "reference level" of the interpreter. The more that an interpreter knows about

the area under study, the more accurate will be the results obtained through photo interpretation.

Levels of Photo Interpretation

Three distinct levels of photo interpretation can be defined that require different levels of local knowledge and experience in interpretation. These include:

- a basic level of interpretation that involves the simple detection and identification of objects visible on the photo image. Emphasis is placed on the identification of ground level features or characteristics that are clearly observable on aerial photographs or through other forms of remote sensing. These characteristic features serve as "signatures" or "keys" to the identification of objects. This basic level of analysis requires a general knowledge of local conditions and at least an elementary knowledge of the photo interpretation process.
- an intermediate level of interpretation that involves the identification and analysis of discrete sets of objects that relate to specific information needs. This intermediate level of analysis requires more specialized knowledge of both the subject area and photo interpretation techniques.
- an advanced level of interpretation that involves the use of deduction, classification and idealization in order to develop information on conditions that may not be directly observable but rather implied by information obtained through "interpretation." This advanced level of analysis requires a thorough knowledge of the local situation and a relatively high level of skill and accuracy in photo interpretation.

The ability to identify objects in a photo image, even for experienced interpreters, will vary considerably because the photograph shows only a "representation" of the object. What the interpreter can see will be based not only on the inherent visibility of the object itself, but also on the type, scale and quality of the aerial photographs or other types of remote sensing that are being studied. These conditions will have an equally important impact on the visibility of objects and the extent to which they can be identified.

Roads, buildings and water bodies, for example, have a high visibility and are relatively easy to identify. Urban activities, soil conditions, housing quality, etc. have a much lower visibility and are consequently more difficult to identify. Housing conditions and detailed land use are also much easier to identify and analyze on large scale aerial photographs than on satellite images. The addition of color to the photographs facilitates the interpretation process even further. The Montego Bay Case Study, for example, has benefitted from

the availability of recent, well-flown, large scale, color photographs of very good quality.

Finally, film-filter combinations, the inclination of camera axis (i.e. either vertical or oblique), the type of camera lens, the quality of the image (i.e. detail contrast and overall density) and the exposure time, also have an important influence on detection possibilities.

Aerial photographs at a scale of 1:15000 or larger provide a good representation of the spatial characteristics required for most analysis related to housing and urban development.

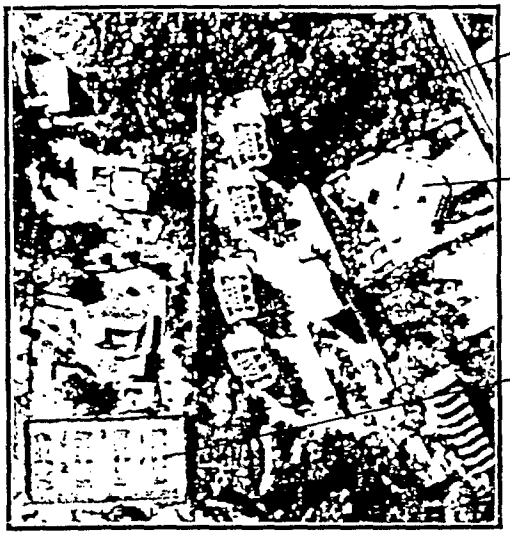
Photo-Interpretation Level I: Basic Detection and Identification of Objects on Aerial Photographs

Virtually all large-sized, urban features with well-defined outlines can be identified on aerial photographs having a scale of 1:15,000 or larger (see **Figure 1**). Examples of identifiable objects include: lots, buildings, roads, water bodies, etc. The advantage of using large scale photographs for urban analysis (as compared to satellite imagery) is twofold. First, photo interpretation is made easier and more accurate. And secondly, measurements and the counting of certain types of objects (e.g. housing units) can be made with confidence. For this reason, the cost of good quality photo enlargements is often justified when they are used for more than one purpose.

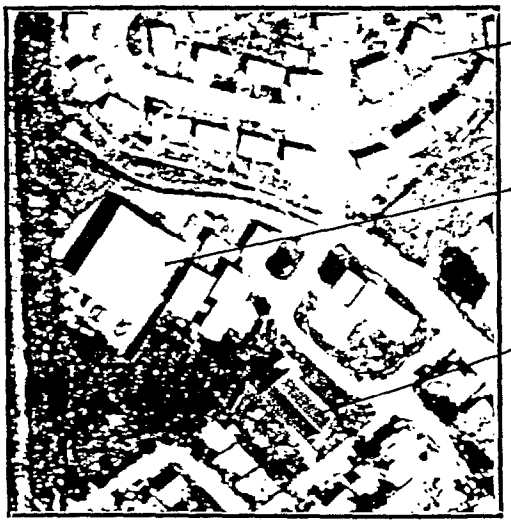
The identification of housing units depends not only on the size and shape or "footprint" of the building, but also on their location within the city and the type of access to them (e.g. roads or pedestrian paths). Additional clues concerning the use of particular buildings can be obtained from the visible activities that take place immediately around them (e.g. type and extent of parking, type of set backs and gardens, etc.) It may still be difficult, however, to identify housing units in areas where there is a considerable a mix of land uses (e.g. low income squatter areas where small buildings may be used for commercial and/or craft activities). Field checks will be needed in these areas to substantiate the results of photo interpretation. The advantage of the photo interpretation approach, even in complicated cases however, is that it substantially reduces the time, effort and costs of doing what was once done entirely in the field.

Residential plot boundaries also can be identified when garden walls and/or plantings on the edges of plots are visible on the photo image. Roads, streets

PHOTO INTERPRETATION EXAMPLES



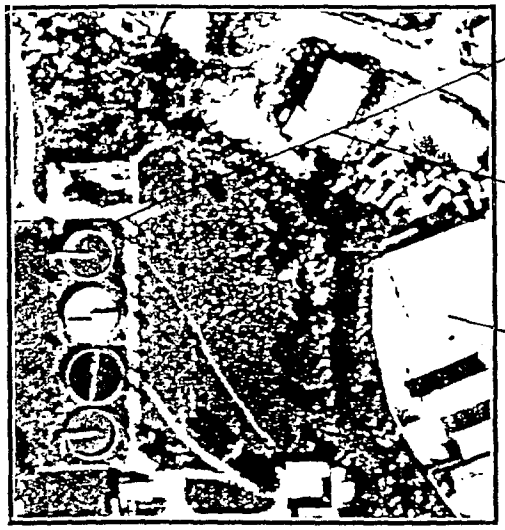
- Apartment blocks often appear as a series of very similar, multi-story buildings arranged together on a site
- Small hotels often appear as very large, three to four story houses with ample parking facilities and several outbuildings around them.
- Tennis courts can be seen by the lines defining the active playing area



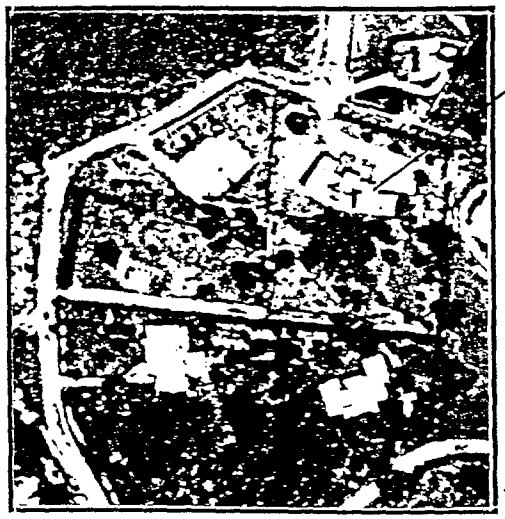
- Public housing projects can be identified by the uniform size and shape of housing units.
- Community facilities in residential areas can be seen by their large size and generally simple shapes.
- Churches can be determined by their size and rectangular shape, distinctive roof structure and the grounds around them.

Figure 1

PHOTO INTERPRETATION EXAMPLES (Cont.)



- Sewage treatment facilities are easily identified by the circular shape of their filtration beds, their rotating sprinkler arms and open space around the facility.
- Auto repair shops appear as moderate sized buildings with an unusual number of vehicles parked around them.
- Industrial buildings are large in size with generally simple shapes; activities observable around the building also provide clues.

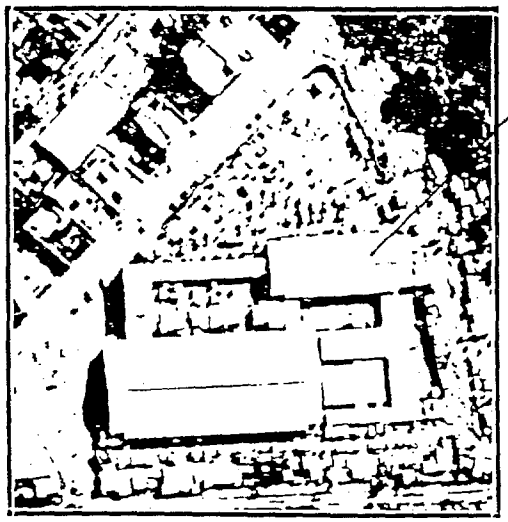


- Villas appear as large, distinct housing units with unique shapes. They often are built on large plots that are separated by visible boundary walls and/or plantings.

Figure 1, cont'd

PHOTO INTERPRETATION EXAMPLES (Cont.)

- Informal housing can be identified by the small size of the building, dense irregular distribution of houses and lack of visible boundaries between plots. There are also many smaller outbuildings.



- Commercial centers can be identified by groupings of large and moderate sized buildings that often are connected. Large parking areas with many cars are a sure sign of these areas.

Figure 1, cont'd

and paths are easy to identify in formal housing areas. Interpretation clues for the provision of infrastructure include power poles, water coming out of drainage ditches, garbage collection points, etc.

Measurements on Photographs

A number of basic measurements can be made from aerial photographs, once the scale of the photograph has been determined and the distortions inherent in vertical aerial photographs have been taken into account (see **Figure 2**). These measurements include:

- lengths and widths of lots, blocks, buildings and streets;
- distances between objects;
- height of buildings and terrain;
- slopes; and
- areas of delineated areas such as built-up urban areas, vacant land, industrial zones, etc.

Photo Scales

The scales of aerial photographs vary with: 1) the focal length of the camera, 2) the altitude of the aircraft above the ground at the time of exposure, 3) any tip of the camera from the vertical and 4) ground relief.

"Natural scale" is the average scale of the entire vertical photograph computed from the focal length and altitude that is normally marked on every photograph, or listed for each set of aerial photographs taken one immediately after another without interruption.

"Contact scale" reflects the fact that the photographic print or positive is made by the contact method, i.e. the negative is placed in contact with the photographic paper in order to produce the positive or print. Negative and positive are therefore the same size and scale. Contact scale is used for quick or preliminary reviews and for studies that do not require a precise determination of distances on the ground.

"Corrected scale" is a more exact scale that can be determined when a known ground distance between objects can be applied to the plain vertical photograph. This is done by comparing measurements made on maps with those made on the plain vertical photographs. The distance between selected objects seen in the photograph should be as long as possible, with the measurement

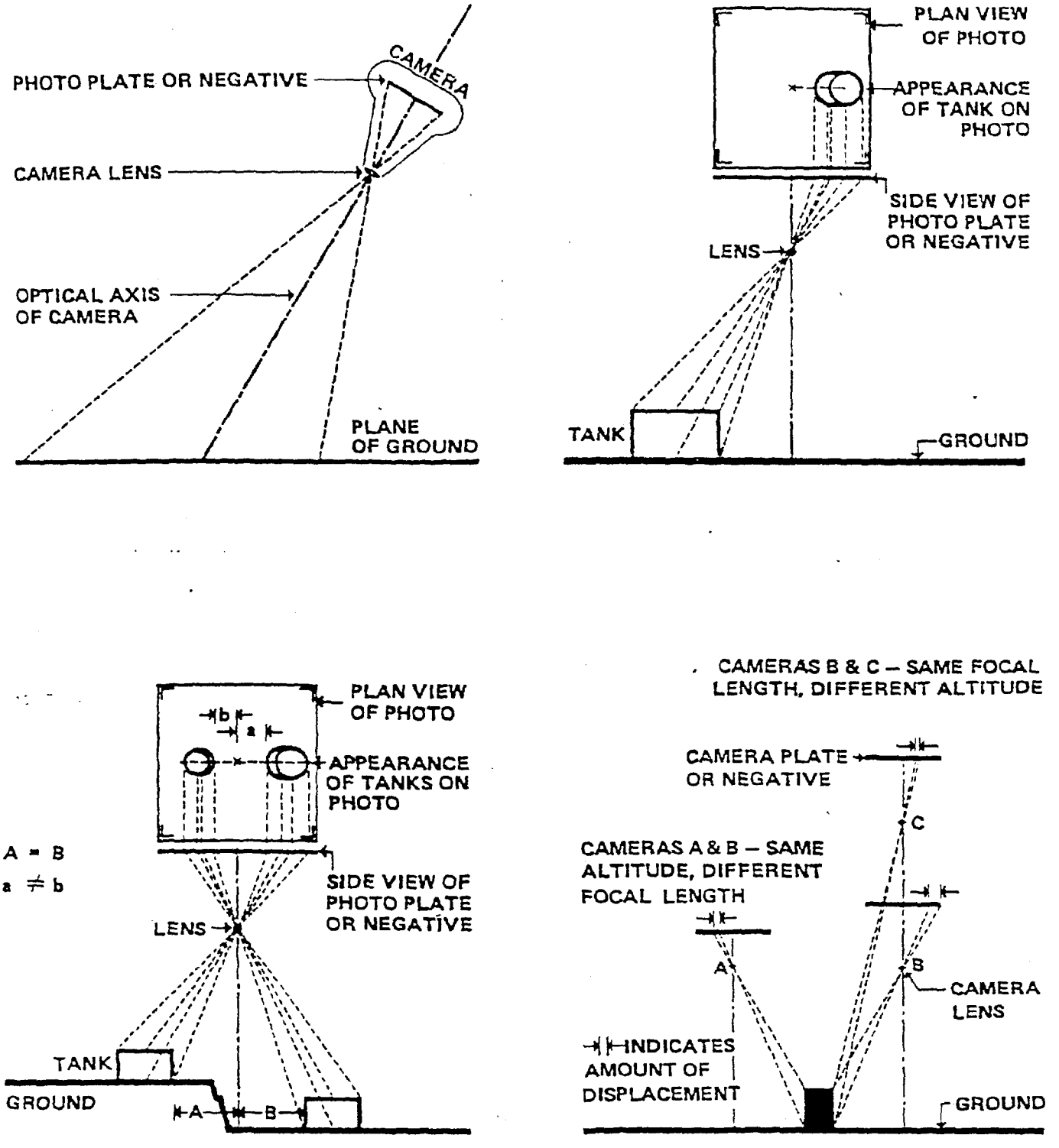


PHOTO PLATE OR NEGATIVE
CAMERA
CAMERA LENS
OPTICAL AXIS OF CAMERA
PLANE OF GROUND
PLAN VIEW OF PHOTO
APPEARANCE OF TANK ON PHOTO
SIDE VIEW OF PHOTO PLATE OR NEGATIVE
LENS
TANK
GROUND
PLAN VIEW OF PHOTO
b
a
APPEARANCE OF TANKS ON PHOTO
A = B
a ≠ b
SIDE VIEW OF PHOTO PLATE OR NEGATIVE
LENS
TANK
GROUND
A
B
CAMERAS B & C – SAME FOCAL LENGTH, DIFFERENT ALTITUDE
CAMERA PLATE OR NEGATIVE
C
CAMERAS A & B – SAME ALTITUDE, DIFFERENT FOCAL LENGTH
A
B
CAMERA LENS
INDICATES AMOUNT OF DISPLACEMENT
GROUND

13

Figure 2

extending across the photograph and passing near its center. In addition, the objects at either end of the measurement should be as close to the same elevation as possible. For greatest accuracy, several sets of objects or distances are selected and an average computed as the final corrected scale.

Distortions

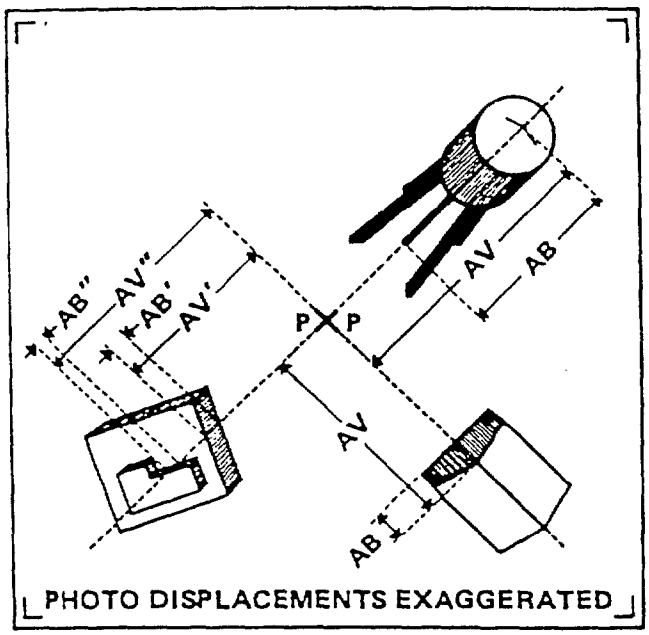
Distortions (or "displacements") are inherent to plain vertical photographs as a result of the way in which photographs are taken. These displacements also enable aerial photographs to be viewed stereoscopically and accurate measurements to be made of slopes and/or the heights of objects (see **Figure 3**). Five basic considerations will increase one's understanding of photo displacements and the degree to which plain vertical photographs can be used for precise measurements. These considerations are:

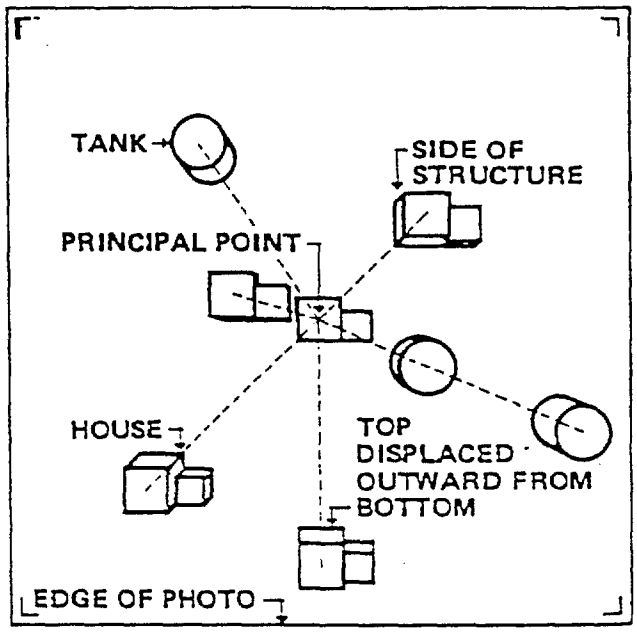
- displacements are radial from the Principal Point of the photograph,
- displacements become greater as the distance from the Principal Point of the photograph increases,
- displacements become greater as the difference in elevation from the mean datum plane on the ground increases,
- displacements increase as the scale of the photograph increases using a camera with a given focal length, and
- accurate angular measurement can be made only of those lines that pass through the Principal Point of the photograph.

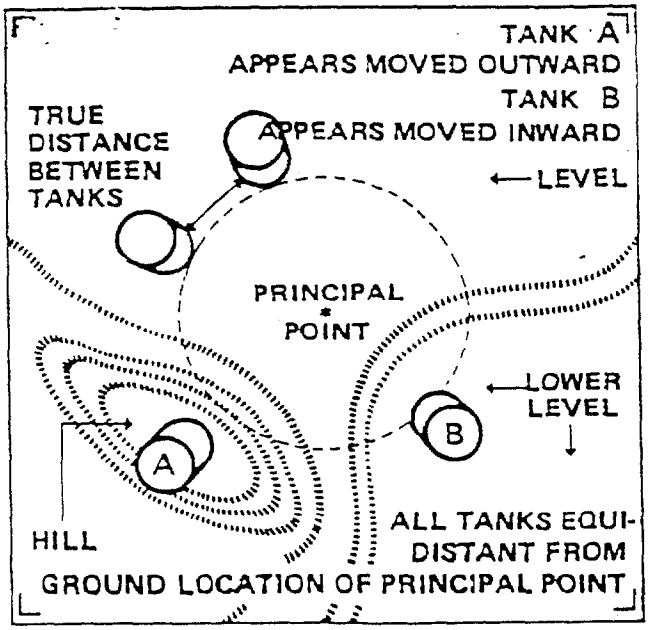
Area Measurements

Areas on maps or aerial photographs can be measured using either a traditional polar planimeter or transparent dot grid or through the use of a digitizing board into a GIS (Geographic Information System) or CAD system. In order to do this, the outlines of areas to be studied (e.g. neighborhood, housing category, lots, industrial zones, etc.) should be traced on the photographs, mosaics or maps.

Dot grids (i.e. systematically spaced dots drawn on transparent material) can be placed over the area to be measured and used in the following way. Each dot represents an area that can be computed when the scale of the photograph and the distance between dots are known. The total number of dots counted within the defined area is then multiplied by the area that the dot represents in order to estimate the surface of the area. The accuracy of the dot grid measurements can then be computed using a formula based on the binomial distribution.







Displacements

Photo displacements permit one to see one or two sides of structures that are located towards the edge of the aerial photographs. The height of these objects can be calculated from the difference in displacement between their top and bottom, radially from the Principal Point of the picture.

Minimizing displacements accounts for much of the careful work required to make photo mosaics that are visually satisfactory and do not appear distorted where the different pictures are joined. This is also important when digitizing from photographs into a GIS.

Figure 3

One of the advantages of using dot grids is that they can be constructed specifically to fit the areas to be measured and/or the nature of the information to be obtained (size of grid, spacing of dots, size of dots, etc.). In practice, the spacing of dots should not be less than 2 mm and the size of the dots very small in order to minimize decision errors.

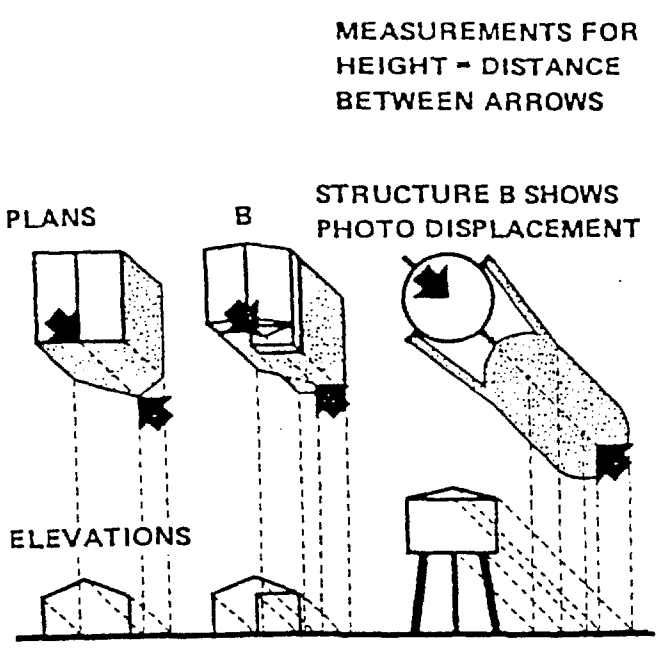
Outlines of features can be digitized into a GIS or CAD system which can automatically calculate feature areas and dimensions, e.g. perimeter. The map or photo is placed onto an electronic board (digitizer) which through a fine wire mesh records x,y coordinates entered via a puck or cursor. These coordinates are then stored in the computer and form the basis of lines, points, and polygons.

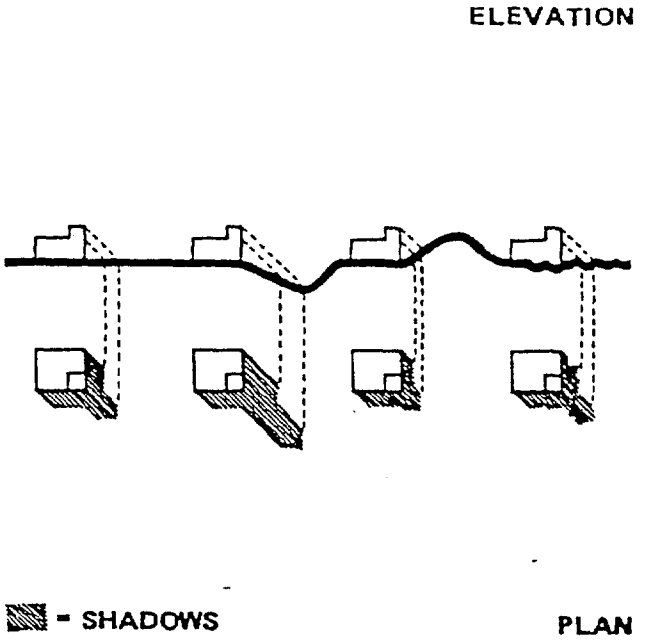
Determining Vertical Heights

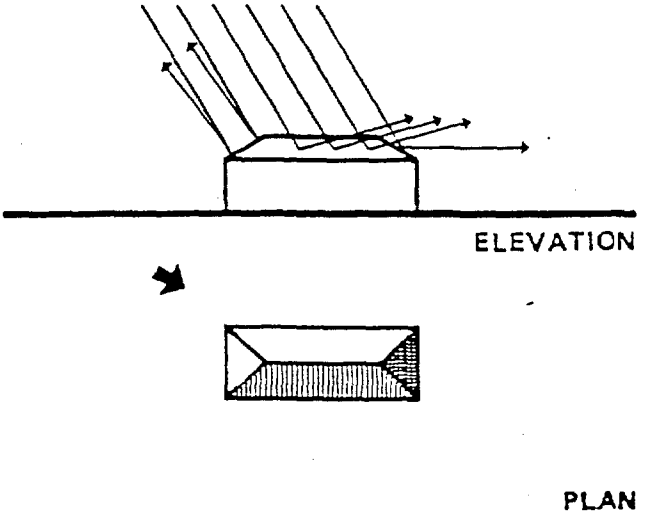
A general interpretation of the relative heights of buildings and other structures shown on a plain vertical photograph can be made with the naked eye based on an adequate knowledge of the way in which shadows are cast and the values of light and dark. This ability to estimate or "read" heights is essential to a thorough understanding and detailed study of photographs for urban areas.

If the height of one building on approximately level ground is known, the heights of other structures can be found quickly by comparing the lengths of their shadows (see **Figure** 4). A structure on level ground, for example, casting a shadow one-half inch long will be 60 feet high if another building, also on level ground and known to be 30 feet in height, casts a shadow one-quarter of an inch in length. Care must be taken that 1) only those shadows are utilized which fall on relatively flat terrain, 2) measurements are taken in the direction in which light is falling, and 3) the length of shadow is scaled to represent the true height of the structure. Accuracy requires that shadows are sufficient in length to permit precise measurement; the shorter the shadow and more uneven the ground on which it falls, the greater will be the error.

A second means of calculating building height as a base reference involves displacements in a plain vertical photograph due to differences in elevation. A building or structure on the aerial photograph is selected that has a sufficiently large outward displacement from the Principal Point to allow measurements within several one-hundredths of an inch. The largest displacements are usually found in tall structures at the edge of the photograph.





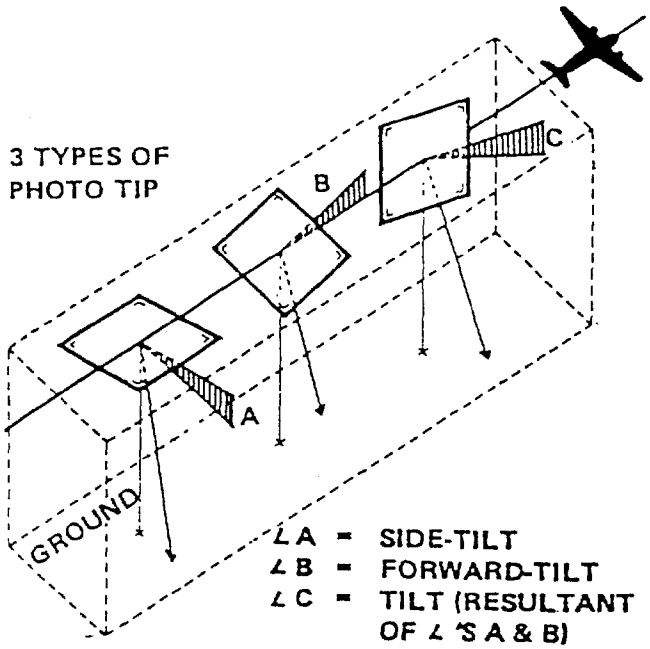


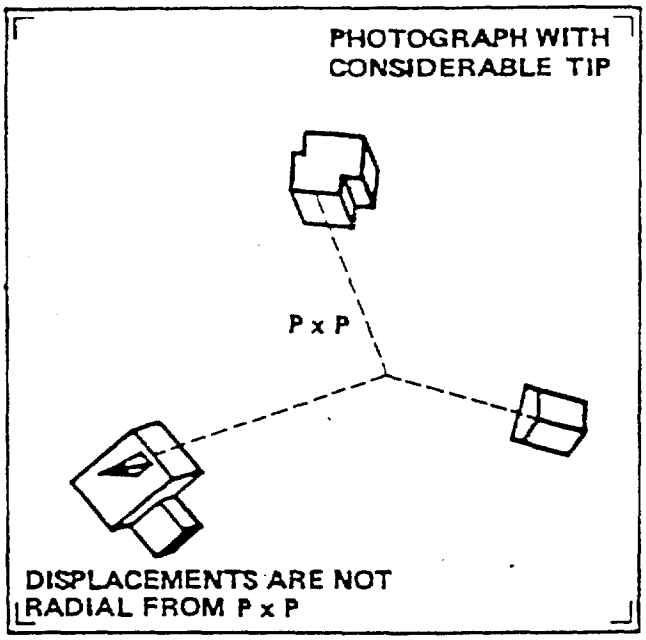
Shadows

Shadows are often more than merely a clue to the form of ground objects shown in the vertical photographs for their correct interpretation can reveal vertical characteristics precisely. The length and precise outline of shadows depend on the nature of the terrain on which they fall, as well as the form of the object by which they are cast. Only those shadows falling on approximately horizontal surfaces can be used for height determination.

While knowing how to analyze shadows permits their full utilization as aids to photo interpretation, the average comprehension derived from everyday observation is sufficient for most purposes.

Figure 4


3 TYPES OF
PHOTO TIP
A
B
C
GROUND
∠A = SIDE-TILT
∠B = FORWARD-TILT
∠C = TILT (RESULTANT
OF ∠'S A & B)


PHOTOGRAPH WITH
CONSIDERABLE TIP
P x P
DISPLACEMENTS ARE NOT
RADIAL FROM P x P

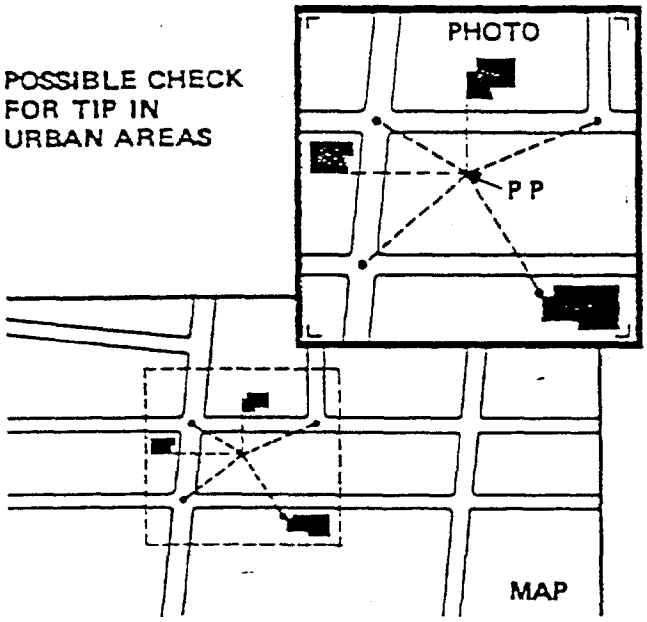

POSSIBLE CHECK
FOR TIP IN
URBAN AREAS
PHOTO
P P
MAP

Figure 5

Counting Objects on Photographs

Aerial photographs and/or satellite images can be used in counting objects in urban areas such as lots, buildings, number of floors, etc. Counting these objects becomes much easier, however, when relatively large scale photographs or enlargements are used, and resolution of photographs/imagery used is important.

An estimate of the average size of parcels or buildings (based for example, on dot grid measurements) also can be used when the identification of individual units proves difficult. Again, various GIS software tools can assist with measurements as well as provide the ability to zoom and view individual features.

Buildings frequently are more difficult to count than plots, since buildings can be irregular in size and shape and may not be clearly separated in densely built-up areas. Roofs provide one of the most important clues in counting buildings because of the different shapes and grey tones they present on aerial photographs.

In some cases, emphasis may be placed on knowing the number of dwelling units. Field checks and/or additional information from other sources may be required to develop the necessary accuracy in this type of information. The combination of photo interpretation with specific checks in the field can provide a very efficient and adequate way of counting dwelling units.

Buildings under construction (i.e. those having walls but no roofs) are relatively easy to identify and count when using large scale plain vertical photographs. The use of a stereoscope can further improve the accuracy of this task since one can actually "see" into the rooms.

Because vertical aerial photographs are central projections, the number of floors may be more difficult to count. Building facades are easiest to see around the edges of the photograph, where relief displacement is the most pronounced. Instead of simply trying to count the number of floors by viewing the photograph, it may be more reliable to use stereoscopic interpretation if available. Special small-scale instruments (e.g. parallax wedge or bar) can be used to measure the heights of buildings and determine slopes on photographs.

Finally, housing and population densities can be calculated using the area measurements of residential and/or built-up areas and then counting the number of plots, buildings, dwelling units and/or floors. Part of the Montego

Bay Case Study for example, has been involved in determining actual residential densities by relating census data to area measurements for different housing types.

Determining Physical Change Over Time

Physical change can be detected rather simply by comparing two or more series of photos of the same area that are taken at different times. Clear indications of change can be seen by studying buildings, roads, building construction, etc. A careful visual comparison of the different sets of photographs can provide an overall impression of the change that has occurred.

If the photographs are at roughly the same scale, a transparent overlay can be made that marks the limits of buildings, occupied plots or general built-up area as seen on the older photographs. This overlay is then placed over the new photographs to determine where new construction and development has occurred. Recent development will not be covered by the areas outlined on the overlay. If scale differences exist between the two sets of photographs, the overlay should first be reduced or enlarged to the scale of the more recent photograph. Similar comparisons can be made between aerial photographs and maps, or by using a GIS. This in fact has been done in the Montego Bay Case Study to determine housing areas built between 1982 and 1991.

Identifying the use or function of objects seen on aerial photographs is an important part of the photo interpretation process. The ability to identify these uses is largely dependent on the background knowledge of the interpreter and on how the function or use of an object is expressed through its physical characteristics. Among the most important of these characteristics are size, shape, value and pattern.

Photo-Interpretation Level II: Use and Interpretation Based on a Particular Orientation

The interpretation process can be expanded to include broader, more sophisticated forms of analysis having more specific purposes and/or orientations. This level of analysis involves assigning visible objects to categories based on predetermined criteria. The knowledge level of the interpreter must be adequate to ensure that the right decisions are made. Some basic applications using this intermediate level of interpretation include:

- delimiting areas with predominant morphological structures;

- monitoring site adaptations and/or improvements in roofs, buildings and physical conditions inside a parcel of land, internal open space and the layout of dwellings;
- analyzing the usage of space based on visible physical features that provide indications of activities;
- monitoring urban transportation systems including the characteristics and patterns of transportation lines, vehicle movement, and circulation densities;
- determining road accessibility based on distances, the physical characteristics of roads and streets, and their dynamic characteristics;
- determining the location of objects and activities based on the measurement of distances between places;
- determining the topography of an area and its relationship to settlement patterns and possibilities for future urbanization;
- determining the location of specific building sites for schools, specialized buildings, markets, recreational areas, etc.;
- determining the existence of infrastructure networks for sewers, drinking water, electricity, solid waste removal and public transportation; and
- analyzing short term future changes as witnessed by the storing of building materials in open air, types of construction in progress, factors that indicate deterioration, etc.

Identification of an object using only the characteristics of the object itself may not provide all the information that is needed to determine existing land use or the type of housing. In most cases, however, more decisive information can be obtained by studying objects and the visible features of areas immediately around them. A factory building, for example, can be identified by its location, its road and railroad connections, its products or raw materials stored in the open air or visibly transported, its pollution effects on the surrounding area and so on.

Photo interpretation using auxiliary information should be carried out according to the following basic steps:

1. the general area of the city represented in the photographs should be scrutinized for interpretation clues;
2. as much information as possible should be derived from the image of the object itself;

3. the immediate surroundings of the delineated object should be studied to obtain supporting information;
4. additional information should be derived from the object's wider surroundings;
5. all relevant information should be summarized and combined in a deliberate manner;
6. the nature of the object or other reasonable possibilities should be identified; and
7. decisive conclusions should be reached from the results of the photo-interpretation.

Photo-Interpretation Level III: Classification and Deduction

Advanced photo-interpretation is essentially aimed at reducing the amount of time, effort and expense to obtain desired information that is normally required for surveys and field work. This is done by making full use of data derived from photo interpretation and by extracting as much additional information from this data as possible. The approach allows information to be developed using less time and lower manpower costs than would normally be required.

Deduction and classification therefore play an important role in advanced applications of photo interpretation. Deduction primarily relies on converging evidence drawn from observable objects, or from a group of elements that give partial information on the nature of correlative indications. Classifications are made based on the comparison of objects whose identities are outlined and grouped by analysis. Deductions may be executed at different levels in order to establish the difference or similarity in the nature of objects or elements that, in many cases, are not visible (e.g. housing quality, socioeconomic characteristics of households, etc.)

Basic rules for establishing sound classifications include the following:

- The classification must be clear, easily understandable and relatively simple.
- The classification must be based on a single subdividing principle or on a combination of two or more subdividing principles.

- The number of classes must be useful and manageable. If the number is too small, the classification may be of little use. If the number of classes is too large, the division into classes may become too complicated.
- No element may fall into more than one class.

Elements such as location, topography, the size and shape of the plot, and the existence and quality of urban infrastructure and services can all be used to classify homogeneous residential areas. Elements such as size and shape of the building, quality of construction and age of the neighborhood can be considered in studying the housing units themselves.

Some examples of advanced photo interpretation include the delimitation of homogeneous residential areas, monitoring changes in housing and urban development, analyzing environmental conditions and executing population studies. The United States, for example, uses the interpretation of remote sensing information to update its population data between census.

Delimitation of Homogeneous Residential Areas

Characteristics of an area that relate to a specific point of view can be derived from deduction and comparison using classification keys. These keys are based on what can be observed on the aerial photographs or satellite images. They provide the necessary criteria, for example, to delineate homogeneous residential areas and to develop inventories related to these areas that can then be used to study housing supply, population, land use, transportation, location of public and commercial facilities, etc.

Results from this initial analysis can then be used as a framework for further study. The basic assumption in applying this approach is that characteristics of homogeneous areas have visible components in common. While this assumption is generally true, care should be taken to avoid oversimplification and careless mistakes.

Homogeneous residential areas can be established based on classifications related to photo-interpretation. Key delineating characteristics include: 1) house and plot size, 2) site conditions and location and 3) road access. Spatial aspects of the resulting housing typology can be shown on a map and used as a basis to:

- organize and select samples for household and housing related field surveys,
- determine the distribution of income levels throughout the city,

- plan investments for infrastructure and urban services in residential areas
- determine the effectiveness of housing delivery systems, and
- estimate growth rates for different types of housing and households.

A strong correlation usually exists between housing/residential development patterns and levels of income, economic activity and household consumption. This relationship can be used to deduce the socioeconomic profiles of visibly homogeneous residential areas. The background and local knowledge of the interpreter must be substantial in order to carry out this interpretation process successfully. Field checks must also accompany the interpretation in order to assure accuracy in cases that are not evident.

The basic steps in identifying and delineating homogeneous residential areas are the following:

- Scan the photos or photo mosaic of the entire area and begin to delineate different residential areas based on generic classifications.
- Limit the number of types and/or sub-types to no more than ten in order to keep the approach manageable.
- Identify the visible characteristics of typical patterns and classify areas according to type.
- Make descriptions of each type based on average data for each type of area.
- Conduct field checks by visiting specific areas within the different classifications. Use these field checks to verify and complete the description of each classification.
- Delineate and code the areas on the mosaic or on transparent overlays.
- Review and discuss the results with other knowledgeable professionals.
- Complete the interpretation and measure the delineated residential areas using a planimeter, dot grid or computerized GIS.

Given the predominance of detached houses throughout Jamaica and across all income groups, it was decided that Census classifications alone (i.e. "detached," "semi-detached," "apartments," etc.) would not be adequately informative in describing residential development, housing conditions or the socioeconomic characteristics of inhabitants. Detached housing under the Census definition, for example, would include both formal villas and informal squatter housing. A typology was developed that is based on what can be seen

on aerial photos and can be related to the type of households that live in the different types of residential neighborhoods (see **Figure 6**).

Monitoring Urban Change

Aerial photography is perhaps the most useful means to monitor physical change occurring in urban areas. Aerial photographs provide time-referenced "snapshots" of urban conditions that can be repeated over the years in order to monitor the evolution of land use and activities within the city. No other source of information (for example, administrative records, maps, etc.) can be used as easily to reconstruct these changes. This advantage is particularly true for informal settlements or squatter areas, and for areas that have been damaged by natural disasters. Even in situations where a well-developed urban administration is in place, neighborhood changes may be recorded in different records so that any reconstitution of these changes will be difficult and time consuming. Most of the major physical change over time can be identified very easily through the interpretation of aerial photographs taken at different times.

There are basically three methods that can be used to detect urban changes on aerial photographs:

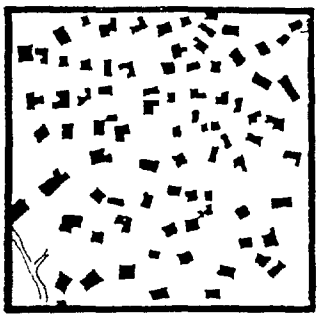
1. Make a complete interpretation from all photographs and register all relevant features on a map. Interpretations from different years are compared to identify major differences. This method reduces interpreter's bias but can be tedious and time consuming.
2. Use two stereoscopes with a stereo pair of year "a" oriented under the first stereoscope and a stereo pair of year "b" oriented under the second. The two stereo images are compared and interpreted for changes.
3. Use two photographs from different years that have approximately the same scale. Form a stereo pair and orient the photographs under a single stereoscope. Areas where there have been no changes will show a stereo image, while areas where there has been change will "twinkle." By alternately closing one eye followed by the other, these changes can be recorded and marked on an overlay that has been placed on one of the photographs (see **Figure 7**). This type of interpretation cannot be done when the scales of the two sets of photographs are different.

Environmental Analysis

An aerial photo or satellite image provides a wealth of information on the relationship between man and his environment. This is particularly true in regard to the spatial aspects of these relationships. Both morphological and

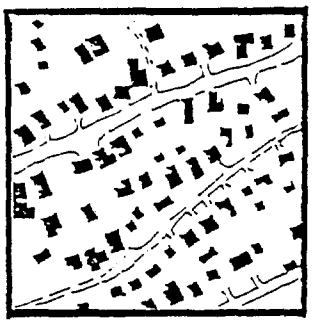
HOUSING TYPOLOGY FOR MONTEGO BAY

TYPE 1



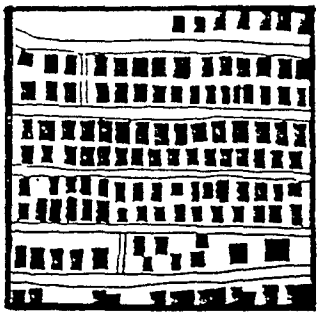
Informal, high density housing on steep slopes.

TYPE 2



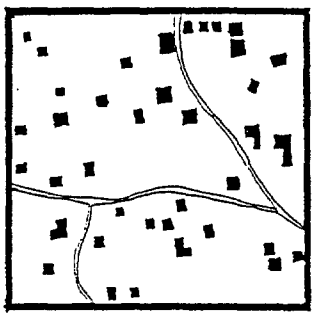
Informal, high density housing with basic road access

TYPE 3



Traditional, inner city. high density housing

TYPE 4

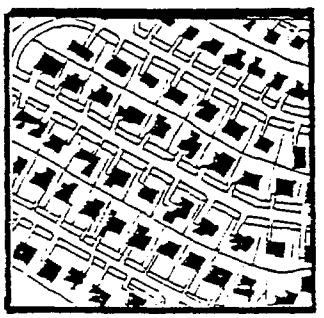


Informal, semi-rural, low density housing

TYPE 5

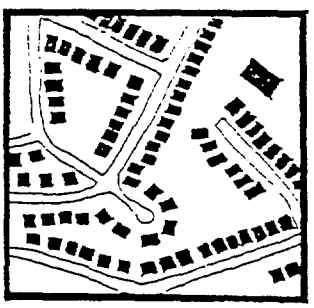
Formal, inner city, multi-family housing in mixed use areas

TYPE 6



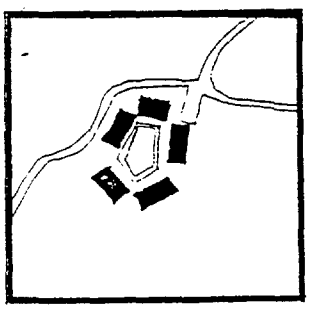
Formal, individual housing units in subdivided areas

TYPE 7



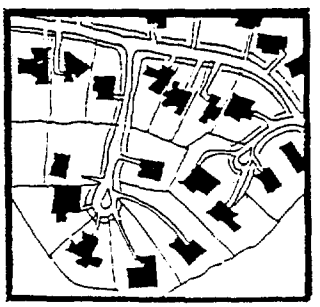
Formal public sector housing projects.

TYPE 8



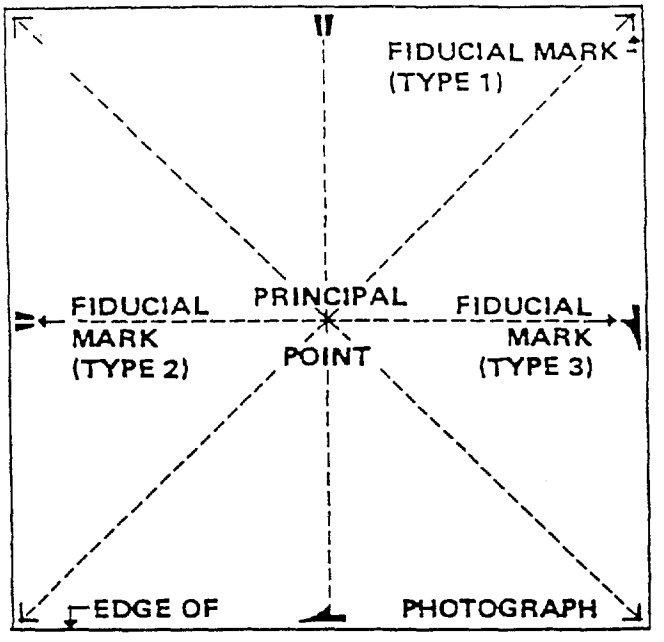
Formal apartment buildings and row houses

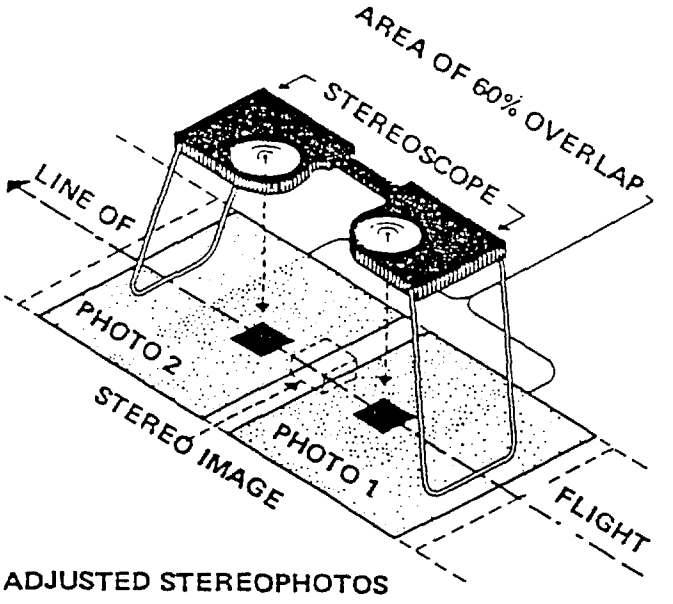
TYPE 9



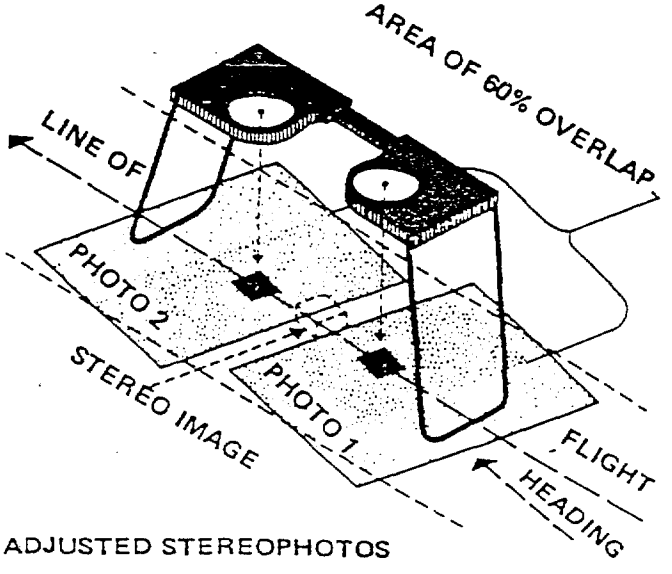
Formal villas, low density housing

Figure 6





ADJUSTED STEREOPHOTOS



ADJUSTED STEREOPHOTOS

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Figure 7

functional boundaries contribute to the determination of land use and are generally observable through photo interpretation. Photographs taken at different times can be used to identify environmental and land use changes, as well as the rate and/or location of urban growth. An inventory of physical urbanization in a country can be made that essentially outlines where public services should be provided. Comparisons between the rate of growth of urban areas and the urban population can be made.

Using this information, the optimum location of projected growth and development can be investigated in order to better serve both man and the environment. The location of roads, for example, can be better adapted to environmental conditions based on information obtained from aerial photographs, than by simply using maps.

Population Studies

Population estimates can be made by demarcating residential areas, measuring their area, assuming an average density for that particular type of residential fabric, and multiplying the two together in order to obtain the population.

A more accurate population estimate would involve counting the number of housing units in each type of residential area, assuming an average number of persons per lot or dwelling, and computing the population figure. Demarcating homogeneous residential areas and determining the average lot or dwelling unit occupancy should be done with considerable care. Cross-checks with the Census should be made in order to verify the reliability of the estimates.

Prepared for

United States Agency for International Development Kingston, Jamaica

HOUSING TYPOLOGY MANUAL

Prepared by

Gerald G. Erbach
PADCO, Inc.
1012 N Street, NW
Washington, DC
20001

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Introduction

Residential development patterns or "fabrics" based on common physical characteristics can be observed on aerial photographs and/or on satellite imagery. These fabrics provide the basis for developing a systematic housing classification or "typology." Common characteristics for residential fabric types that can be seen on aerial photographs include:

- housing unit size and type
- plot size and building coverage
- on-plot activities
- road widths and pavement characteristics
- visible infrastructure networks (e.g. street lighting and sidewalks), garbage bins and so on.

Setting up a Housing Typology

The first step in developing a housing typology involves the careful examination of available aerial photographs and/or satellite images. If recent aerial photographs are not available, information from earlier photographs and/or maps can be updated through:

- small format aerial photography using 35 mm photography taken from small engine, private airplanes;
- carefully executed field checks, windshield surveys and/or photographs taken on the ground or from higher elevations around the city;
- application of local knowledge about more recently developed areas; and/or
- reference to recently updated maps.

Satellite images can be obtained from commercial dealers (e.g. SPOT, ERDAS, etc.) in monochrome, color (including false color, infra-red) and digital format.

Advantages of using satellite images for urban applications are:

- Both recent and previous images for specified dates can be obtained.
- Distortion and map joining difficulties are reduced compared to those encountered when working with aerial photographs. This is simply because satellite images cover a much larger area.

Disadvantages of using satellite imagery for urban applications, however, are that:

- Less information can be seen on the image due to its much smaller scale.
- Detailed photo interpretation is more demanding and subject to greater interpretation error.

The advantages of using both aerial photographs and satellite images would be obtained by developing housing typology categories and photo interpretation "keys" from the most recently available set of aerial photographs for a particular area or city, and then using the results of these interpretations to set up interpretation controls for working with satellite images. The more detailed information from aerial photographs would be used for local level planning purposes and then aggregated into more generic "core" categories for use with satellite images and in meeting national planning needs.

Making a Photo Mosaic of the City

An uncontrolled photo mosaic should first be assembled in order to provide an overall or "city-wide" view of residential land development patterns or "fabrics." This is particularly important when interpreters have little experience in photo interpretation and/or only limited knowledge of the local housing situation. Photo mosaics are made by carefully cutting and fitting together aerial photographs so that the best match of detail is obtained. Once a mosaic is completed and pinned up on a wall, residential development patterns or fabrics begin to become evident within this overall view of the city. The photo mosaic then becomes the primary working document in applying the housing typology approach, whether it is used for monitoring urban growth and housing development or for implementing housing related surveys.

In cases where aerial photographs may be difficult and/or expensive to obtain, these photo mosaics can be constructed using good quality photocopies of the actual photographs. The use of photocopies prevents damage to the original photos made by cutting and pasting and provides a very cost effective way to develop photo mosaics for multiple purposes. Detailed photo interpretation of specific areas can be done using stereo pairs (i.e. two adjacent photographs set up for stereoscopic viewing) because the original photographs are still intact.

Interpretation results and notes can be written directly on the photocopies without concern about damaging the original photographs.

Identifying Residential Fabric Types

The initial classification of residential areas should be carried out while considering generic categories that can apply to the city or country as a whole. The most common residential fabrics found in developing countries include:

- Informal housing areas that lack basic urban infrastructure and services (e.g. paved roads, piped water supply, sewers, etc.) and have individual plot boundaries that are not clearly visible or defined. Some older or upgraded informal neighborhoods may be provided with infrastructure and/or have high levels of small scale commercial activity along major roads. Informal housing areas generally are inhabited by low income households.
- City center areas with mixed commercial and residential uses. Many of the housing units in these areas are apartments located above commercial activities. Depending on local conditions, these areas may house low and/or moderate income households.
- Government housing projects including sites and services projects and/or core housing units. These projects are distinguishable by their formal planning and infrastructure, regular and well-defined plot sizes, and rather uniform housing units. They may house both low and middle income households.
- Apartment buildings and row houses. These buildings generally house middle to upper income households.
- Small scale subdivisions that have been formally planned and approved. These areas are identifiable by their paved streets, visible parcel boundaries and individually-built, detached housing units. They generally house middle income households.
- Villas that are distinguishable by large, identifiable plots; large, detached houses of varying shapes and orientation; paved roads and basic infrastructure services. Invariably, these residential areas house upper income households.
- Semirural housing that can be found on the periphery of the city, either distributed along roads leading into the city or on land previously considered unsuitable for housing development.

Variations or sub-types can be added to this generic classification in response to local conditions. Examples of potential sub-types may include historic downtown housing areas, distinct types of new middle class housing develop-

ment (e.g. semi-detached or row-housing, multi-story detached units, etc.) and so on. The total number of types, however, should not exceed 10 or 12 in order to keep the typology meaningful and manageable.

It should also be noted that each residential fabric type will have characteristics that will vary slightly when applied to different cities due to local conditions. The fact that these differences exist should not be considered a weakness of the approach. They make it possible to more meaningfully compare housing conditions and delivery systems across various cities and between countries. The fact that public housing projects or villas in one city differ from those in another city says a great deal about local standards and the delivery of affordable housing.

Professional judgement and local knowledge are essential in determining the boundaries for the areas of specific fabric types within a city. Colored markers can be used to outline these boundaries directly on the photo mosaic which will reduce delimitation mistakes and errors in counting the number of housing units. The resulting photo mosaic for a particular city should present a clear overview of residential fabric types that can serve as a basis for discussion and/or verification on the existing housing situation. Explanatory notes can be added and questionable areas indicated that require further field survey or information. Completion of this task for a medium sized city should take only a few days.

Verifying the Residential Fabric Type for Each Area

At this point, a thorough review of the preliminary classification by fabric type for each of the different residential neighborhoods should be carried out. Borderline cases and/or areas whose category is unclear should be resolved before going any further in the analysis. The decision process for each of these problem areas should be documented and saved for future reference.

Description of Fabric Type Characteristics

The distinguishing characteristics of each fabric type should be written down once the residential fabric types have been identified and agreed upon. Defining characteristics generally include:

- plot size
- housing unit type, size and construction
- means of access to housing units (for example, footpaths or roads, paved or unpaved, widths of ROW's characteristics of paved areas, plantings, etc.)

- presence of infrastructure networks (for example, potable water and electricity) and so on.

Careful thought and consideration in identifying and describing key defining characteristics for each fabric type will help eliminate ambiguities, minimize overlap between types and enable meaningful results to be obtained through computer analysis of the results.

Coordinating the Housing Typology with Household Survey and Implementation

Part of the value in setting up and using a housing typology is that it can serve as a framework for housing and household related surveys. For this reason, survey questionnaires and potential responses should be developed, keeping in mind the need to distinguish between the different residential fabric types. This is done most easily by simply including a question on the fabric type in the questionnaire. There also should be several questions in the survey instrument that concern the defining characteristics for the various fabric types. This will allow survey results to be checked with those from other surveys and studies in which the housing typology approach was not applied. Visual observations on the housing unit and the neighborhood environment, as well as carefully measured plans of the housing unit itself, provide additional information that can be used in planning and housing.

Determining the Total Population Within Each Fabric Type

Once the different residential fabric types are established and the areas for each type traced on the photo mosaic or map, the total number of households can be determined for each area as a basis for drawing the survey sample. It is unlikely that the number of households for each urban fabric type will be readily available from existing data. The counting of housing units within each area, therefore, combined with a good idea of the number of households per housing unit, will be required to establish a reasonable estimate of the number of households in the overall sample. There should be a clear agreement on the definitions for "housing unit" and "household" in order to make this estimate as accurate as possible.

Counting Housing Units Using Aerial Photographs

Two types of counting on aerial photographs can be employed to determine the number of housing units within a given area. These include:

- counting housing units directly from visual inspection of the photographs
- systematic application of dot sampling techniques.

Even when GIS and census data are available, this counting process of housing units identifiable on aerial photographs is important in developing knowledge about housing in the area and checking the application of census data to reality.

Both these counting techniques require sound local knowledge of the residential areas under study. Additional verification may be required in some cases, since physical conditions observable on aerial photographs do not always give clear indications of residential use. A number of housing units in informal areas, for example, may have been converted to small scale commercial or handicraft use, while buildings originally designed as residential apartments may be used for offices. In addition, mixed use, multistory buildings may have apartments on some floors, with commercial and office activities on others. A quick field check of the areas in question will enable a more accurate count of housing units to be carried out.

Careful inspection of aerial photographs will provide indications on plot size, building or housing unit size, number of floors, room layout (if there are parapet walls), presence of outbuildings, etc. Stereoscopic photo interpretation can be useful in providing additional information on the number of floors and building height. In most cases, multi-unit buildings are relatively easy to identify and the number of housing units can be determined through photo interpretation.

A dot sampling technique can be used for densely built up areas where it is difficult to identify individual housing units. In this approach, a transparent dot grid is constructed that involves decisions on the size of the grid, size of dots, spacing of dots, etc. In practice, the spacing of dots should not be less than 2 mm, with a square grid of 2 cm on a side. Each square normally contains 100 dots. The dots themselves should be very small in order to minimize decision errors. Rules for dots landing on the boundaries between land uses should be applied systematically (for example, land use to the right or left, considering a specific point on the dot, etc.)

The dot sampling approach to determine the number of housing units in residential areas can be applied as follows:

- Develop a simple land use classification of no more than 4-5 categories (for example, nonresidential use, main housing unit, outbuildings, open plot area, circulation space, etc.).
- Carefully delineate the residential area to be studied and, if necessary, divide this area into smaller segments that can be covered entirely by the transparent grid.

- Place the transparent dot grid over the study area on the photograph and carefully mark the corners of the grid on the photograph as reference points.
- Interpret land use based on the simple classification developed above. A magnifying glass can be used to carry out this inspection if stereoscopic viewing is not possible.
- Count the number of dots for each type of land use. Counting should be done in a systematic way in order to avoid losing one's place and mis-counting dots. Counting normally is done by row, from top to bottom within each square. If working alone, the easiest and most accurate way to record counting results is to read them into a small portable tape recorder and then write them down from the playback. In reading results into a tape recorder it is important to continually indicate where one is in counting (e.g. "Top row, second square from right, end of third line from top").
- Add up the total number of dots for each classification.
- Determine the range of error through application of statistics. Move the grid slightly and redo the sample if necessary in order to double the number of dots and improve accuracy.
- Multiply the total number of dots for each category by the area that each dot represents in square meters. This will give the actual area in square meters for each category. For a grid of 100 dots within a 2 cm square and an aerial photograph having an average scale of 1:5000, for example, each dot would represent 100 m^2. However, since each aerial photograph has a different, or even several different scales within the same photograph, a simpler approach would be to equate the total number of dots counted to exactly the same area measured off a map. For example, if 1905 dots covered an area of 20 hectares, each dot would be equal to 105 m^2.
- Divide the total area for the built up area of housing units by the average housing unit size in order to obtain an estimate of the number of units. Doing this for several typical or "test" areas in each residential fabric type will provide ratios for land use that can be applied to other homogeneous areas within the same fabric type. The size of each area can then be multiplied by the number of housing units per hectare in order to establish the number of households that make up the sample population for each fabric type.

Although somewhat tedious, this approach can also be combined with field checks as a means to verify unclear housing situations and improve local knowledge of the situation. It should be clear by now, in fact, that a good measure of professional judgement, local knowledge and experience are

necessary to carry out the counting of housing units within the different residential fabric types.

Comparison of House Counts with Existing Data

Housing unit and household counts should be compared to other available housing data in order to check the consistency of the counting with other data. Residential fabric/housing types can be grouped in ways that will enable survey results to be compared to census and/or other key data. GIS analysis provides another means of verifying the size of areas within residential fabrics. Once it becomes operational, the GIS database will make the task of determining the number of housing units for each category of the typology considerably easier.

Questionnaire Development Related to the Housing Typology Framework

Survey instruments used in conjunction with the housing typology approach are not much different than those used for other types of housing surveys. The questionnaire should be designed to obtain information related to question domains that reflect the purpose and nature of the survey. These domains most likely will include a "core" of standard information concerning household composition, dwelling type, existing housing conditions and the availability and use of infrastructure and services. More specific survey requirements can be addressed through a series of supplementary questions that focus on: housing expenditures (incomes, expenditures, employment, estimated value of the house, maintenance costs, etc.), general housing quality, housing improvement and expansion, residential mobility, vacant units, housing finance, overcrowding and so on.

Questionnaires from other housing related surveys, or those concerning the same area, should be reviewed in order to provide common points of reference and to benefit from previous experience. Once the questionnaire has been designed, a clear set of instructions should be developed that presents all the rules and information needed by field supervisors and interviewers to carry out the survey successfully.

Example of an Operational Case Study for Housing Typology

An example of using aerial photographs and housing typologies in a housing case study was conducted for Bangkok, Thailand. This study was carried out by the National Housing Authority and the ITC in the Netherlands. Procedures followed in implementing this study are similar to those that have been outlined in this manual. The ITC/NHA study in Bangkok may provide additional reference material if necessary.

Prepared for

United States Agency for International Development Kingston, Jamaica

DIGITIZING MANUAL

Prepared by

Melissa Connor
PADCO, Inc.
1012 N Street, NW
Washington, DC
20001

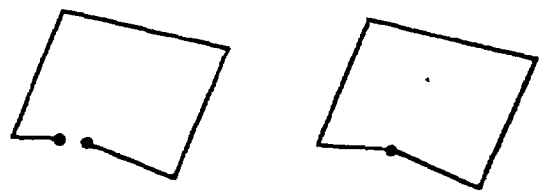
532-0149-C-00-3045-00

August 1993

SOME DIGITIZING BASICS

Tolerances

Dangling nodes	A dangling node can be moved to close a polygon.



```
Arcedit: EDITFEATURE NODE
Arcedit: SNAPDISTANCE *
Arcedit: NODESNAP ON
```

```
Arcedit: MOVE
```

Figure 1

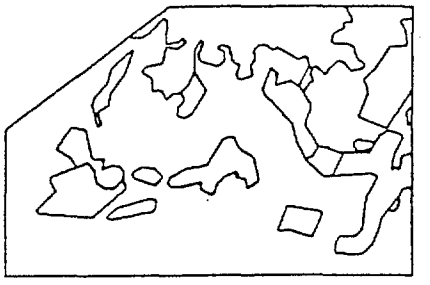
There are two important tolerances to set when beginning a digitizing session: **weed tolerance** and **snap distance**. A weed tolerance defines the minimum allowable distance between two points in a coverage. This prevents unneeded points for defining a line thus saving space needed to store a coverage. A snap distance defines the distance within which two nodes will "snap" together to a single node (see **Figure 2**). While not entirely eliminating node errors, setting a snap distance prevents dangle errors which are often time consuming to fix.

Commands to review: GENERALIZE, SPLINE, CLEAN

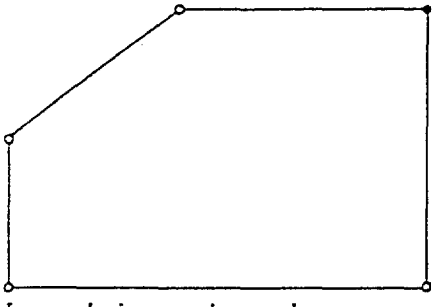
Spaghetti and Discrete digitizing

Spaghetti digitizing refers to creating arcs without placing nodes at intersections so that arcs overlap (see **Figure 3**). Nodes are created at these intersections during the CLEANing process for a polygon coverage. Spaghetti digitizing is good for simple polygon coverages and line coverages such as streams and roads.

When nodes are placed at intersections of lines during a digitizing session **discrete** digitizing is being performed (see Figure 3). This technique is useful

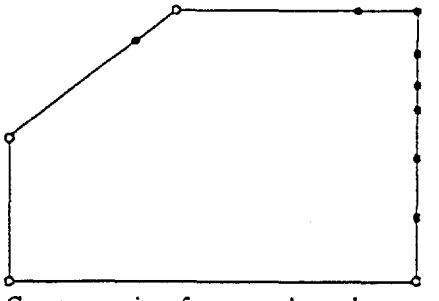


Spaghetti digitizing
(1 long arc)



Ignore the intersections and digitize the outline as one long arc.

Discrete digitizing
(several smaller arcs)



Create a series of connected arcs by digitizing each intersection as a node.

FYI

'Spaghetti digitizing' is aptly named because intersections are not explicitly identified as arcs are digitized. Thus the set of arcs overlap, much like spaghetti. This method is typically used to define predominantly straight lines, such as outlines, grids and land use data. For very precise features, or ones that curve and twist, discrete digitizing is preferred. Explicitly marking each intersection provides greater coordinate accuracy.

Figure 2

for complex coverages with many unclear intersections such as soil polygons. Discrete digitizing, with appropriate tolerances set, avoids unnecessary editing and cleaning later on.

Commands to review: GENERATE, CLEAN

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Stream mode and Point mode

Feature	Potential errors	Terminology
Arcs	Only one node at an endpoint	Dangling arc
	Node extends too far	Overshoot
	Node falls short	Undershoot
Nodes	Only one arc attached	Dangling node
	Only two arcs attached	Pseudo node
	One arc connected to itself	Pseudo node
Labels	None in a polygon	Missing labels
	More than one in a polygon	Too many labels

Figure 3. Summary of Common Digitizing Errors

Most digitizing tablets support both point and stream digitizing. Point digitizing means that the user enters the vertex of an arc individually. In stream mode, the vertex button (1) is pressed while tracing a line. Vertices are entered automatically according to the weed tolerance. Stream mode seems easier, but it can lead to sloppy digitizing particularly during a long digitizing session and on long lines. However, if nodes are marked ahead of time for long lines and the user is comfortable with the cursor, stream mode can save time when digitizing complex lines such as contours and streams. The GENERALIZE command can be used later to remove unneeded vertices (this saves space and it will take less time to draw). It is recommended to use point mode for simple lines which require few vertices.

Node errors

There are two types of node errors which may occur in the digitizing process: **overshoots** and **undershoots** (see **Figure 1**). An overshoot is a node which falls beyond an intersection with an arc while an undershoot is a node which falls short of an intersection. Since it is easier to fix overshoots at a later time, than undershoot, it is better to always overshoot an intersection, particularly when spaghetti digitizing.

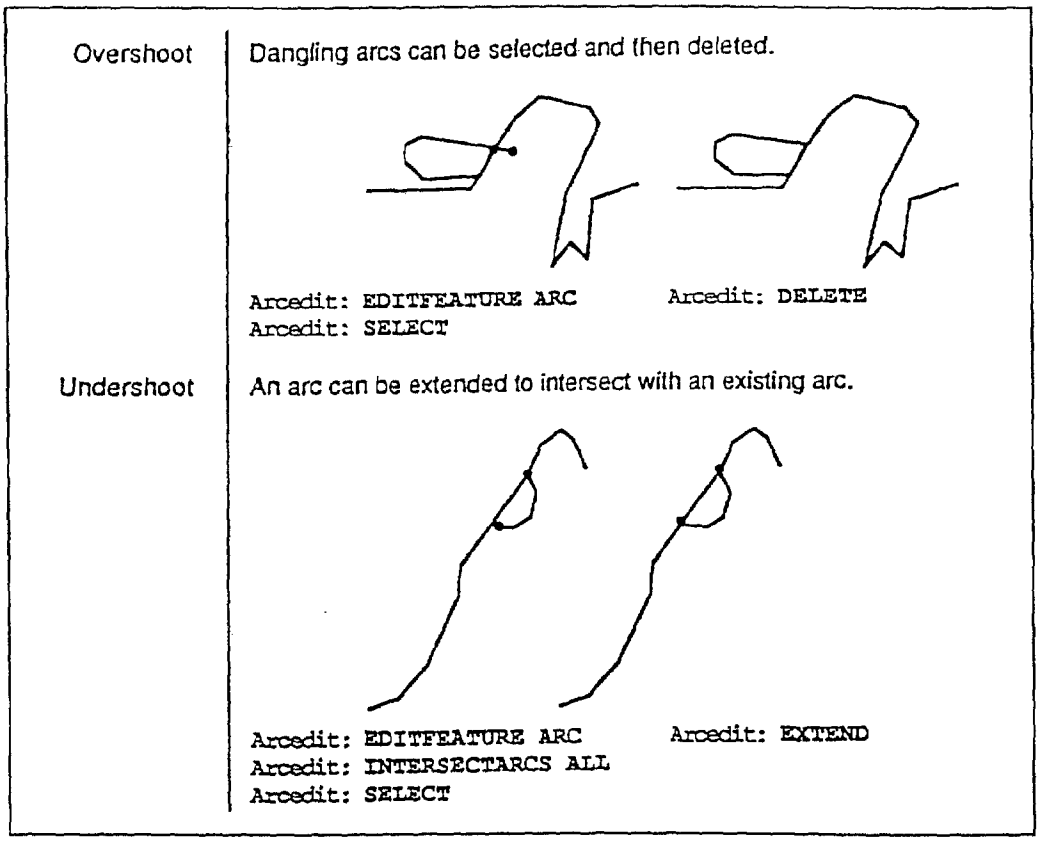

Figure 4

Additional terminology

Island Polygon: a polygon which has no boundaries intersecting with other boundaries.

RMS Error: a measure of tic registration accuracy during digitizing and coverage transformation. (from Understanding GIS, ESRI, xxxiv)

A Few Notes on Accuracy

- Source maps should be in good condition for maximizing accuracy. Wrinkles and tears affect the quality of the digital data.
- Balance the number of tics to maximize accuracy.
- Tablets are less accurate towards the edges. Try to place small source maps at the center for maximum accuracy.
- Do not begin a project without becoming comfortable with digitizing and the software.

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- Avoid digitizing for long periods. Human error is another common source of digitizing error. Always check your work and correct errors prior to using the data for display and analysis.

Accuracy and Data Sources for Digitizing

Paper maps are not the only sources for creating digital maps. Aerial photography and satellite imagery are also common sources. Upon interpretation[1] of an aerial photograph or a satellite image the boundaries for a layer to be created, such as land use, are marked on a transparent overlay, preferably mylar sheets. Mylar is preferred because it is durable, resists tearing, and is not significantly affected by changes in temperature and humidity. Keep paper maps and mylar in good condition. When possible, avoid folding and store in a safe place.

Getting Started

Once the source is prepared, it is time to begin the digital input. First secure the map or mylar to the digitizing tablet with drafting tape (other types of tape may damage the map and/or tablet). The map should lie as flat and smooth as possible to minimize error. The first step of digitizing is to select appropriate tics. A tic is a control point on the source map(s) which is used for registering a hard copy map for digitizing and for geo-referencing, transforming a coverage to real-world coordinates. At least four tics are needed for a coverage and additional tics may be chosen. It is advisable for large maps to chose additional tics, evenly spaced, to reduce error (i.e., anything larger than 20" by 20"). Mark tics clearly. You should be able to find the tics later without hesitation. This is important for maintaining accuracy when a map is registered and for additional digitizing sessions for the same coverage. At this time, you may wish to mark node points on particularly long arcs, unclear intersections, and island polygons (see **Figure 5**).

Before beginning your first data layer, you may wish to create a master tic coverage. This is useful if you are creating multiple layers from a single source map. This maintains relative accuracy among layers. Just type ADS and a coverage name (e.g., (C:\)[ARC] TICCOV) and follow the ADS prompts (this is illustrated in the following section). Once you have done this you can create a coverage using these tics by specifying the TICCOV in the ADS or CREATE commands. This is discussed in the following sections.

[1]For more information on photo interpretation see the corresponding manual.

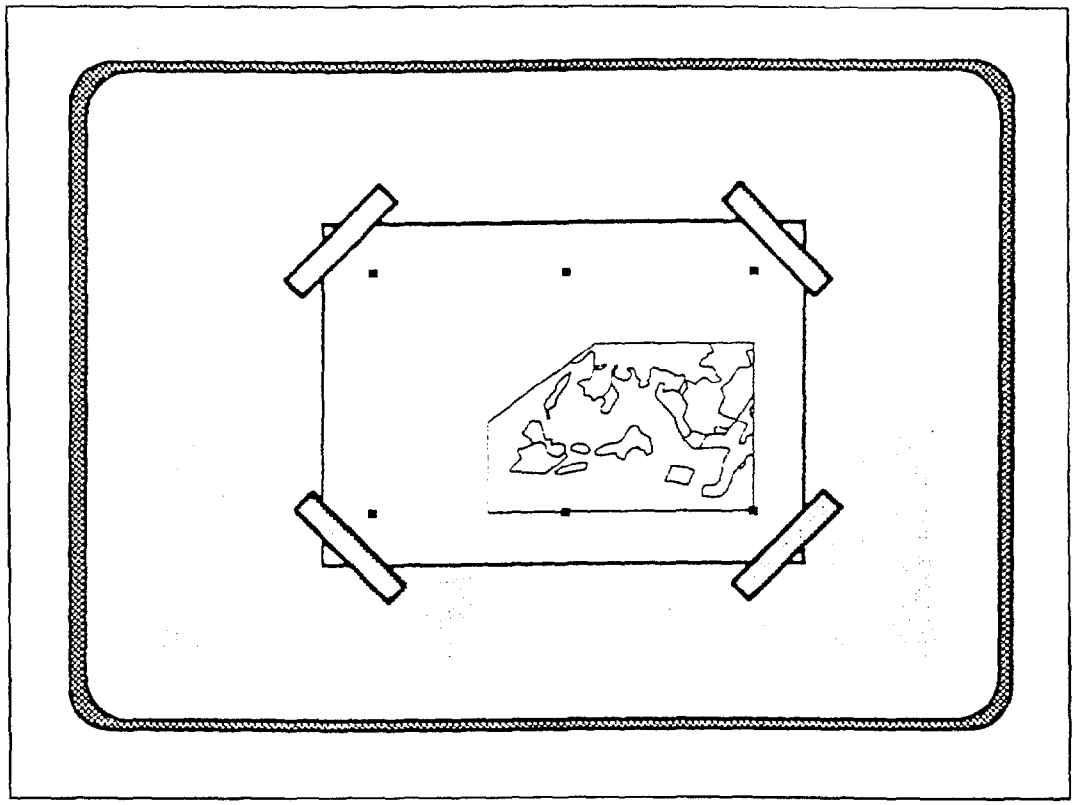


Figure 5

ADS - Arc Digitizing System

Type ADS from the ARC prompt to see the argument. You will notice that a second coverage may be specified. This option allows you to create a new coverage using the tics of an existing coverage, such as a master tic coverage.

To begin your digitizing session type ADS name tic_cover from the ARC prompt (e.g., (C:\)[ARC] ADS LAND83 TICCOV).

Next ADS prompts you to enter TIC IDs and locations. Choose the TIC ID number from your cursor and, carefully placing the crosshairs at the tic location, press the letter A. As you enter the TIC IDs and locations the following will appear on the monitor:

TIC ID: 1 *
TIC ID: 2 *
TIC ID: 3 *
TIC ID: 4 *
TIC ID: 0 *

Continue until you have entered at least four tics and then press 0 and A to signify that you have finished entering tic locations.

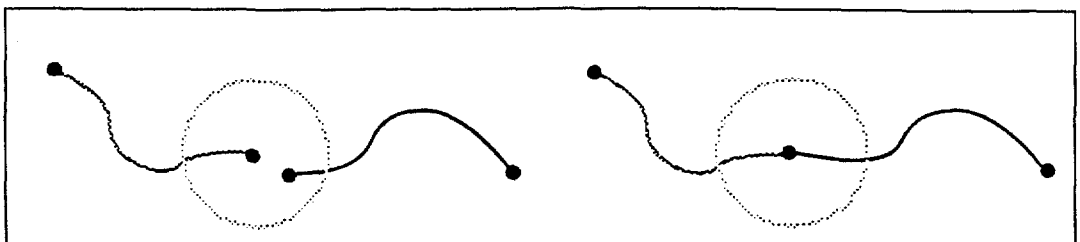
If you have used a master tic coverage, the following information will appear:

Digitizer transformation scale: 1.000
RMS Error: 0.002
Is this RMS error acceptable? <1=Y/2=N> 1

If the error is greater than 0.002 choose 2 for "No" and try re-entering the tics.
Next you are prompted to enter the boundaries as defined by opposite corners of your map:

Enter first corner of boundary (from digitizer)
Enter opposite corner of boundary

Respond to each prompt by placing the puck at one corner of the map and pressing A. The boundary should be somewhat larger than the area being digitized (See **Figure 6**).



As each new arc is added, the starting node may fall within a given distance (e.g., 0.05 inches) of an existing node.

This new node location will snap to the existing node if it is within the node snap tolerance.

Figure 6

Next the ADS menu will appear at the top of the screen:

1) Add Arcs	3) Add Labels	5) Draw Coverage	7) Add Tics
2) Remove Arcs	4) Remove Labels	6) Define Windows	8) Set Options
9) EXIT	Enter Function:		

Choose 5 to draw the tics. Familiarize yourself with each option in this command.

At this time chose 8 to set options. The following sub-menu appears:

1) Orient Map	3) Edit Distance	5) Snap Distance	7) Weed Distance
2) Select Many	4) Select Box	6) Split Arc	8) Last Delete
9) Exit Sub-menu	0) Restore Window	Enter Function:	

First set the snap distance by choosing option 5 from the Options sub-menu:
Modify snap distance
Current snap distance (xx.xxxx)
1 = Type new value, 2 = Digitize new value, 9 = Exit sub-menu (no change)
Type in a value or digitize a value, whichever you prefer. The distance you choose is dependent upon the scale of the source map.

Next set the weed distance by choosing option 7 from the Options sub-menu:
Modify weed distance
Current weed distance (0.02)
1=Type new value, 2=Digitize new value, 9=Exit Sub-menu (no change)

Once again, type a value or digitize, whichever you prefer (although it is generally preferable to type a value so that this distance is known).

If this is your first digitizing session, or if you have not done so before, explore each of the options in this sub-menu and the other sub-menus.

When you are done, return to the main menu. You are now ready to begin digitizing. Choose option 1 for adding arcs. The sub-menu will appear as it does in **Figure 7.**

Add arcs by pressing the 2 button on the cursor for nodes and 1 for vertices. Begin digitizing in point mode to become comfortable with the cursor.

Some additional tips:

- Avoid re-digitizing lines by marking each one as you progress.
- In stream mode the 1 button may be held down while tracing a line. To toggle between stream and point mode press *, or the A button on the cursor, at the "Add arcs" sub-menu.
- Zoom in to an area and re-draw to view the arcs you digitize in more detail. Select option 6 at the main menu and then option 5 to re-draw the coverage.
- If a node is entered at an intersection or along a long arc, an additional node is unnecessary. Just continue by entering vertices.

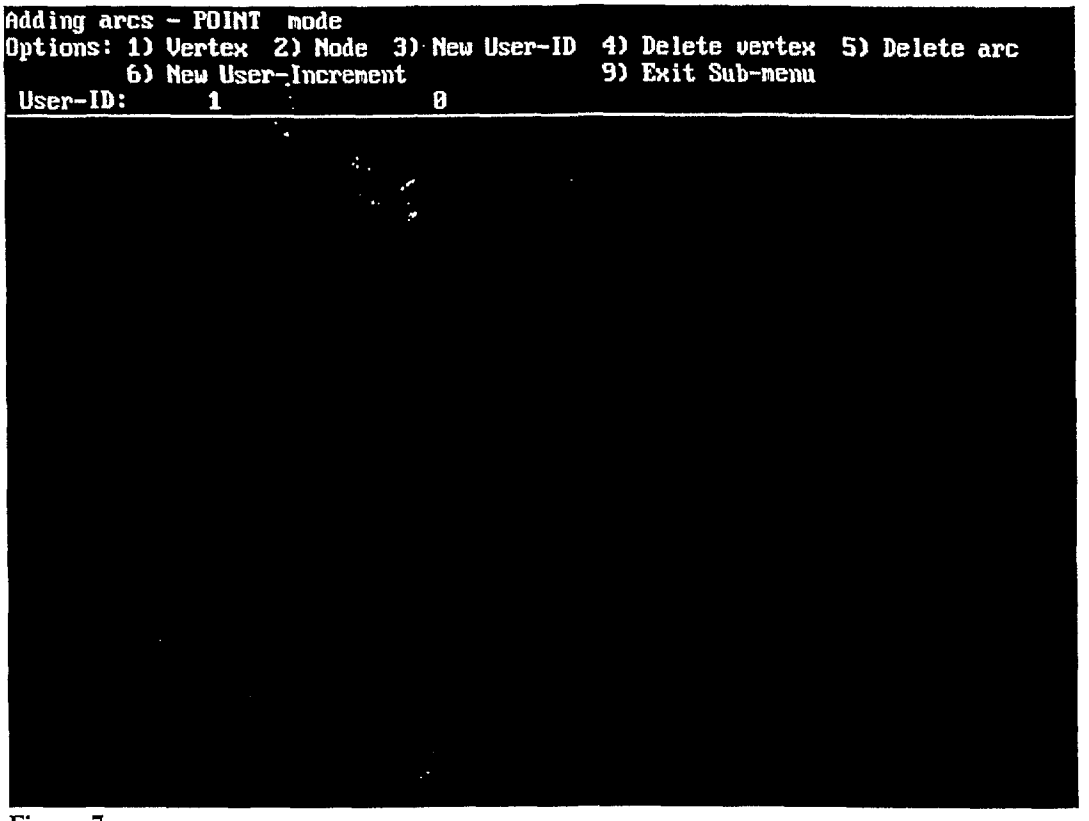


Figure 7

- If you make a mistake and wish to delete an arc you may quit by pressing 9 before entering the end node or go to the main menu and select option 2 for removing arcs.

Adding Labels

- Label points can be added to a polygon coverage during a digitizing session in ADS, in ArcEdit or with the CREATELABELS command.
- Labels can also be digitized to represent point features (e.g., wells, cities).
- In order to add label points, return to the main menu and choose option 3. This will bring up a sub-menu. Enter label locations with the 1 button on your cursor.

Saving Your Work and Ending a Session

From the main menu you can save your work by choosing 9)EXIT and responding Y to the first prompt, and N to the second prompt to continue. To quit an ADS session just respond N at the second prompt.

BE CAREFUL - SAVE YOUR WORK REGULARLY

Digitizing in ArcEdit

It is also possible to digitize from ArcEdit instead of ADS. This is useful for editing or adding arcs or label points to existing coverages.

Registering the tablet in ArcEdit

To register a coverage you are editing to the tablet, type COO DIG (COORDINATE DIGITIZER). You will be prompted to enter tics as follows:

```
:edit roads
The edit coverage is now C:\GIS\MOBAY\COV\ROADS
:coo dig
  Defaulting transformation coverage to C:\GIS\MOBAY\COV\ROADS
DIGITIZER TRANSFORMATION
Digitize a minimum of 4 tics (From the digitizer).
Signal end of tic input with Tic-ID = 0
Tic-ID:
```

Continue as you would in ADS entering the tics. You are now ready to update the coverage.

Note: Once coordinated to the tablet, the COORDINATE command can be used as desired to switch between the mouse and the tablet cursor. You will not need to re-enter tics in a given session.

Some tips for ArcEdit

- Use the EDITFEATURE command to set the feature class. Then use the ADD command to enter the digitizing menu. Note that the ArcEdit digitizing menus differ slightly from the ADS menus (see **Figure 8**).
- Take time to explore the options for creating circles, curves and square corners. These features are useful for creating logos and your own marker symbols that can be used in ArcPlot.
- Weed tolerances and snap distances are not defined via the menu, but from the command line—the commands are WEED and SNAPDIS. The value may be entered from the keyboard or interactively with the mouse or digitizer cursor. Be aware that if you change scale, the SNAPDIS does not change in proportion to changes in map extent.

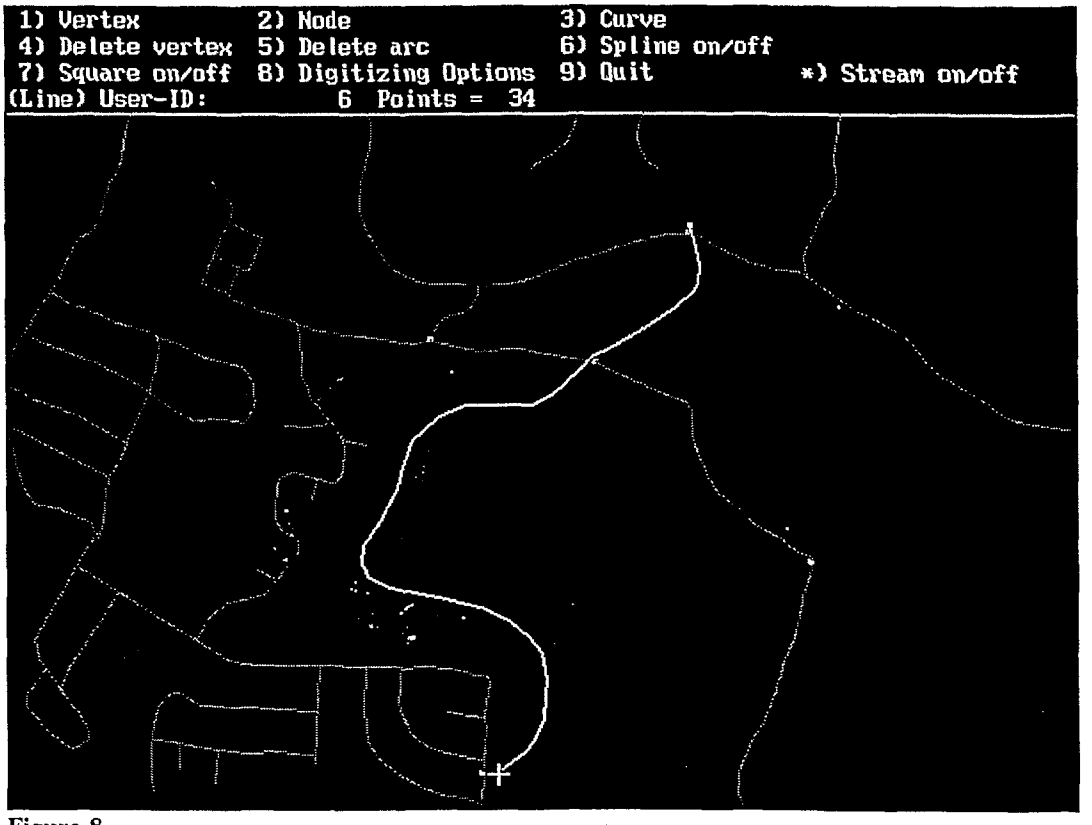


Figure 8

Specifying a back coverage

A backdrop may be drawn on the monitor with the BACKCOV command in ArcEdit (see **Figures 8** and **9**). Type the command in ArcEdit to view the argument. Notice that you may specify the color in which the background coverage is drawn. You must also use the BACKENVIRONMENT command to list the feature types to be drawn.

A background coverage is useful for updating or digitizing a coverage for which you may have to copy arcs from an existing coverage.

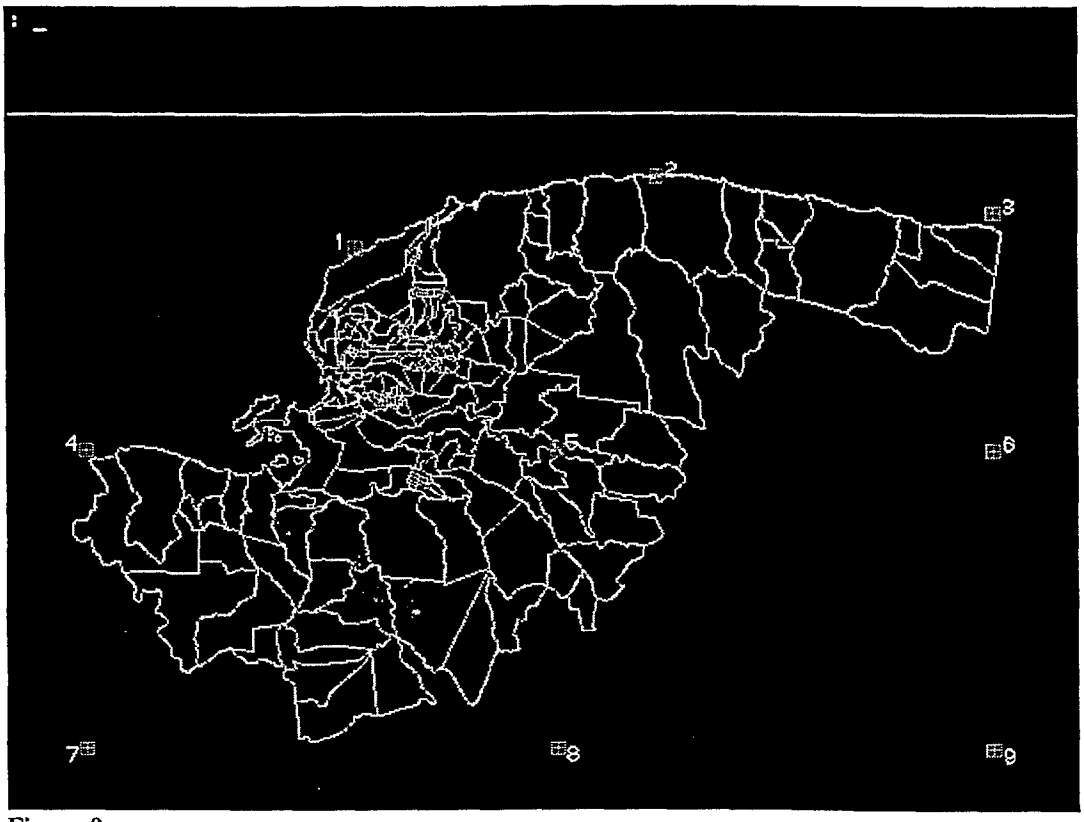


Figure 9

Prepared for

United States Agency for International Development Kingston, Jamaica

MAP PRODUCTION AND PLOTTING MANUAL

Prepared by

Melissa Connor
PADCO, Inc.
1012 N Street, NW
Washington, DC
20001

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SOME PLOTTING BASICS

Quick plots can be generated by using the EDITPLOT command from the ARC prompt or through ArcView for Windows. The following guidelines address the creation of map compositions in PC ArcPlot to communicate the results of GIS analyses.

Before Beginning a Map Composition:

- Determine what you are attempting to communicate and who your audience is. What elements are necessary to understanding the message?
- Determine a logical and communicative symbology: pattern fills, line symbols and marker symbols
- Create lookup tables using the DEFINE command in TABLES
- Create key files using a text editor
- Plan the layout of the map

Map Compositions and SMLs

Before beginning a map composition in ArcPlot it is important to plan the contents, size and layout (see the following "Tips" section for general guidelines).

Often you may wish to change the positions of specific map elements once you have displayed the initial map layout in ArcPlot. This can be accomplished interactively—using a mouse to point and click. However, for consistency within a map series, to prevent re-entering commands and parameters each time an updated version of a map is to be produced, and in order to easily reproduce a map, the use of SML files is recommended.

An SML is a text file, like a key file, which lists a series of commands (refer to **Appendix A** for an example of a plotting SML). Such a file may be called up when starting ArcPlot. This allows quick and simple re-creation of a map composition and for easy changes to a composition. Remember that this is the simplest form of an SML. The PC ARC/INFO macro language has many commands which enable the development of specialized macros for routine tasks and user interfaces for plotting, editing and more.

ArcPlot commands for starting a map composition

The following parameters are set prior to plotting coverage features and map elements. Each is listed with an explanatory note. More detailed information can be obtained in the PC ArcPlot documentation.

DISPLAY

Start out using "4" to draw all features to the screen. Once satisfied with a composition, "1039" is used to plot elements directly to an ESRI Plot file. It is possible to plot a map composition after drawing to the screen, but certain errors may arise. It is best to modify your plotting SML upon completion of a composition to plot directly to a 1039 file.

MAP

In the DISPLAY 4 mode, the MAP command can be used to save a particular composition. In order to save the map use this command prior to setting the additional parameters. Every parameter and element entered hereafter, is saved as part of the map composition.

PAGESIZE

Specifies the physical page size in width and height.

MAPPOSITION

Specifies the position of the map composition in relation to the page. For instance, typing MAPPOSITION CEN 18 12 tells ArcPlot to place the center of the composition 18 inches from the left-hand side of the page and 12 inches up. This command can be used to plot multiple compositions on a single sheet.

MAPEXTENT

Use this command to set the maximum extent of the area being shown. The area can be determined by one or more coverages, or x,y minimum and maximum values for plotting part of a coverage.

Use this command to reset the mapextent to plot logos and graphic scales.

MAPUNITS

Mapunits tells ArcPlot the units of measurement a coverage is in (e.g., feet, meters). It is important to identify mapunits before setting the map scale!

MAPSCALE

Sets the nominal scale of the map. The scale denominator is used with this command, rather than the entire ratio.

MAPLIMITS

Determines the position of the coverage in relation to the map composition. Typing MAPLIMITS CEN CEN centers the coverage extents in the composition.

Plotting Coverage Features

Elements must be selected from a coverage before they can be plotted. The RESEL, NSEL and ASEL commands are used to select coverage features by items in the coverage attribute table. For instance, in order to select all polygons with a land use code of 1 in the coverage PAT and shade in the selected polygons in green, you would enter the following:

```
:RESEL LAND83 POLYS
:RESEL LAND83 POLYS CODE = 1
:POLYGONSHADE LAND83 3
```

Or to plot selected point features from a coverage named ELECTRIC with a lookup table you might type:

```
:RESEL ELECTRIC LABELS
:RESEL ELECTRIC LABELS CODE = 2
:ASEL ELECTRIC LABELS CODE = 5
:MARKERSET FIELDS.MRK
:MARKERSIZE .25
:LABELMARKERS ELECTRIC CODE ELECTRIC.LUT
```

The syntax may seem confusing at first. Take a look at the example in **Appendix A**. Refer to the PC ArcPlot manual for a description of command arguments.

Map Elements and PC ARC/INFO

Graphic Scales

Graphic scales are important elements in any map. The simplest way to create a graphic scale to insert into a map composition is to create scales for feet and meters (or miles and kilometers depending upon the nominal scale), is to utilize the GENERATE command.

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For example, the following commands would create an ARC/INFO coverage which can be inserted as a scale bar later on:

```
(C:\)[ARC] GENERATE SCALE
:LINE
:0,0
:1000,0
:0,0
:0,100
:500,0
:500,100
:1000,0
:1000,100
:END
```

The x,y coordinates specify node locations creating arcs. This small coverage can be inserted into a map composition as a graphic scale by specifying mapunits, mapextents, mapscale and other parameters prior to plotting the arcs.

Legends

Choosing symbols for point, line and area features is important. It is usually best to develop standard symbols if you are going to be producing similar maps. Use key files to reduce the number of commands necessary for plotting a legend, and to make changes quick and simple.

A key file is a text file listing symbol numbers on one line and legend text on the following. For example:

```
.25
Plantations
.30
Pastures
.5
High Density Residential
.6
Medium Density Residential
.7
Low Density Residential
.10
Commercial
```

Other Elements included in a map

representative fraction - an expression of the nominal scale at which the map is shown; that is, the ratio of plotted units to real world units, is always included in a map composition. A representative fraction is free from units. For instance, when we say a map is at a scale of 1:50,000, we mean that 1 map unit represents 50,000 of the same units in the real world—1 map inch represents 50,000 inches, 1 map centimeter represents 50,000 centimeters. The denominator is used to specify the scale in the MAPSCALE command before plotting coverage features.

map source - the source of the map data, e.g., CIDA aerial photography, GOJ Survey Department map series, accompanied by a date indicating the year for which the data represented is current.

stamp - the logo of the map producer and/or for whom the map is being produced (e.g., PIOJ, GRMC). This will inform third and fourth parties of whom they can contact for additional maps or information.

Preparing a plot file

Once you have completed a map composition, modify your plotting SML to read DISPLAY 1039 instead of DISPLAY 4, and on the next line a plot file name. This will plot the elements directly to a plot file instead of to the monitor.

To increase the speed and efficiency of the plot use the SORTPLOT command on the plot file. Plot files may be sorted by color and/or pen movements.

Appendix B contains various user settings for the CalComp Pacesetter.

Some tips on map design and colors

Purpose and audience

While designing a map, think about what you are trying to communicate and what is necessary to do so. Consider the knowledge about the area your intended audience possesses. What types of features and annotation will the audience need to orient themselves.

Neatline and other borders

Generally, it is not necessary, and often distracting to place a border around the legend. Do, however, use a heavy line to draw a box around the map. The line weight should be heavier than the thickest line on the map itself.

Textfonts and annotation

Stick with simple fonts, but if you are using annotation for both physical and political features, try to differentiate the two by using two different fonts (e.g., italics for physical features).

Line symbols

Choose symbols that are intuitive. For example, double line symbols for roads, blue lines for streams, brown for contours.

Marker symbols

There are many symbols in the ArcPlot symbol sets. You can also create your own symbols in ArcEdit. Procedures are included in the documentation.

Shadesets

Shadesets can be viewed in ArcPlot using the SHADEINDEX command. For pattern fills, look through the PLOTTER.SHD and PLOTTER8.SHD shadesets. Since the shadesets are dBase files, item values for patterns can be viewed in TABLES. In order to take full advantage of a wide selection of pattern fills and all eight color possibilities, try creating your own shade set. This can be done by copying the Arc/Info default set (found in the ARCEXE\SYMBOLS subdirectory) and modifying values in TABLES or just by defining a file in TABLES with appropriate item definitions.

Most importantly, be consistent among the maps you produce, particularly with pattern fills. Review **Appendix A**, a sample plotting SML and the ESRI PC ARC/INFO quick reference guide, which illustrates the commands for creating a map composition.

Appendix A: Sample Plotting SML

```
display 1039
mobase.Plt
pagesize 42 33
mapposition cen cen
maplimits 2.25 3 39.75 32.75
mapunits feet
mapscale 15000
mape 214500 555562 260850 590183
units map
linesymbol 5
box 214500 555562 260850 590183
textset jam.txt
lineset jam.lin
shadeset jam.shd
linesymbol 11
arcs ed1991
pointmarker ed1991 1
resel ed1991 polys acres91 lt 20
textsize .05
labeltext ed1991 edno91 lr
nsel ed1991 polys
textsize .1
labeltext ed1991 edno91 lr
linesymbol 3
arcs ed1982
pointmarker ed1982 3
resel ed1982 polys acres82 lt 20
textsize .05
textcolor 3
labeltext ed1982 edno82 ul
nsel ed1982 polys
textsize .1
labeltext ed1982 edno82 ul
textcolor 1
linesymbol 6
arcs contourc
linesymbol 4
arcs hydroc
linesymbol 65
arcs roadsc
```

```
linesymbol 5
arcs border
linesymbol 94
arcs fence
annotext moanno
linesymbol 1
arcs ftgrid
annotext ftgrid
units page
linsesymbol 9
linecolor 8
box .25 .25 41.75 32.75
textquality proportional
textspacing 1.5
keybox .35 .30
textsize .25
textcolor 1
keyposition 22 3.5
keyline base1.key nobox
keyposition 29.75 3.5
keyline base2.key
textcolor 3
move 21.3 1.9
text 'wc007'
textcolor 1
move 21.3 1.4
text 'wc007'
move 22.6 1.6
text '1982 Enumeration Districts'
move 22.6  1.1
text '1991 Enumeration Districts'
textsize .25
move 28.05 3.6
text 'Legend'
textfont 8
textsize 1
textcolor 8
move 7.8 28.5
text 'Montego Bay'
textcolor 1
textsize .1
move 17.75 2.4
```

```
textfile proj2.txt
move 4.25 1.5
textfile base.txt
units map
mape padlogo
mapunits inches
mapscale 3
mapposition ll ll
maplimits .75 .75 4 3
linesymbol 1
arcs padlogo
textsize .2
mape feet
mapunits feet
mapscale 15000
mapposition ll ll
maplimits 11.1 2 16.1 4
linesymbol 5
arcs feet
annotext feet
mape meters
mapunits meters
mapscale 15000
maplimits 10.2 .5 16.5 4
linesymbol 5
arcs meters
annotext meters
units page
move 13.1 2.7
text 'Feet'
move 13 0.9
text 'Meters'
move 12.9 3.10
text '1:15,000'
linesymbol 5
box 6.85 .8 10.25 2.7
textsize .2
move 7 2.8
text 'Jamaica'
units map
mape jam
mapunits inches
```

```
mapscale .7
mapposition cen cen
maplimits 6.85 .8 10.25 2.7
linesymbol 1
arcs jam
linesymbol 2
box -77.82 18.43 -77.98 18.53
move -77.82 18.6
textsize .1
text 'Study Area'
units page
mape northarr
mapposition cen cen
mapunits inches
mapscale auto
maplimits 39 2 40 3
linesymbol 5
arcs northarr
units page
textsize .15
move 39.1 1.75
text 'Grid North'
```

Appendix B: Calcomp Pacesetter Plotter Settings

ESRI 1039 plot files
USER NUMBER: 1
PLOT MODE: FINAL - LARGE PLOT
VELOCITY: 510 mmps 20 ips
ACCELERATION: 2.8 g
ORIENTATION: Auto
SCALE: [1]/1
SCALE: 1/[1]
PEN GROUPS: Off
PLOT LIMITS: Normal
PLOT MANAGER: Yes
PORT TYPE: RS-232C
PROTOCOL: PCI
BAUD RATE: 9600
OF BITS - PARITY: 8-None
HANDSHAKE: Ack/Nak
SYNC #EOM CHK
B: 02 1 03 ON
EOP TIMER: 2 Minutes
LANGUAGE: English

AutoCAD
USER NUMBER: 2
PLOT MODE: FINAL - LARGE PLOT
VELOCITY: 510 mmps 20 ips
ACCELERATION: 2.8 g
ORIENTATION: Auto
SCALE: [1]/1
SCALE: 1/[1]
PEN GROUPS: Off
PLOT LIMITS: Normal
PLOT MANAGER: Yes
PORT TYPE: RS-232C
PROTOCOL: PCI
BAUD RATE: 9600
OF BITS - PARITY: 7-Even
HANDSHAKE: Xon/Xoff
SYNC #EOM CHK
Special format - 1

PCI # OF SYNCS: 2
PCI - SYNC CHAR:
22 dec. 16 hex.
PCI-EOM CHAR:
13 dec. D hex.
PCI-CHECKSUM: Yes
EOP TIMER: 2 Minutes
LANGUAGE: English

ArcView for Windows 1.0
USER NUMBER: 3
PLOT MODE: FINAL - LARGE PLOT
VELOCITY: 510 mmps 20 ips
ACCELERATION: 2.8 g
ORIENTATION: Auto
SCALE: [1]/1
SCALE: 1/[1]
PEN GROUPS: Off
PLOT LIMITS: Normal
PLOT MANAGER: Yes
PORT TYPE: RS-232C
PROTOCOL: PCI
BAUD RATE: 9600
OF BITS - PARITY: 8-None
HANDSHAKE: Hardware
EOP TIMER: 2 Minutes
LANGUAGE: English

Prepared for

United States Agency for International Development Kingston, Jamaica

ADVANCED GIS TRAINING

Prepared by

Margaret Mayers Norton
PADCO, Inc.
1012 N Street, NW
Washington, DC 20001

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ADVANCED GIS TRAINING

Executive Summary

The objective of this course was to provide a two-week, advanced, "hands on" PC ARC/INFO course to the Planning Institute of Jamaica (PIOJ). The material prepared for the course was based upon topics not covered in the previous training course as well as suggestions from other PADCO personnel after their missions to Kingston. The training course was well received by PIOJ personnel and the course participants surpassed the minimal requirements and gained practical experience in using GIS for a wide variety of planning applications. PIOJ was well prepared for this visit based upon the following observations: 1) rental of an additional PC in order for all of the students to have access to PC ARC/INFO, 2) moving the GIS hardware into a building with a large air-conditioned room with plenty of chairs and tables, and 3) notification of all participants of my arrival and full attendance during the entire course.

Course Topics

The following syllabus was prepared in advance and supplemented with background material and class exercises (see notebook):

Wednesday, March 10	Course Overview Coordinate Transformations Map Scales
Thursday, March 11	Map Projections
Friday, March 12	Editing Coverages with ARCEDIT Digitizing with ARCEDIT
Monday, March 15	Spatial Analysis (Review) Class Exercise on Montego Bay BUFFER Command CLIP Command UNION Command RESELECT Command

Tuesday, March 16	Spatial Analysis (Continued) Creating and Using SMLs
Wednesday, March 17	Relational Databases TABLES Importing dBase Files
Thursday, March 18	Joining Adjacent Coverages MAPJOIN Command APPEND Command
Friday, March 19	Viewing Coverages with ARCVIEW Generating Output with ARCVIEW

Course Participants

Daniel Dawkins
Beverly Lawrence
Hopeton Peterson
Sharon Nash
Jaqueline McGibbon
Dianne Gordon
Colin Williams

All participants from the initial PC ARC/INFO training course were present except for Sharon White from Montego Bay Development Corporation. Informal information gained from Nicole Pitter-Patterson led me to believe that Montego Bay Development Corp. was in financial trouble and these problems prevented Ms. White from attending. Also, a new PIOJ participant attended this course, Mr. Colin Williams. Mr. Williams was found to be very knowledgeable about relational databases and statistics. He had no problem keeping up with the other participants and spent several hours of his own time learning the basics of PC ARC/INFO.

Course Highlights

Map Projections

All course participants brought maps from their offices which they frequently use in order to understand the implications of different map projections within a GIS. We spent several hours looking at map projections used by cartographers for displaying information on different countries and discussing the

differences in geometry between these projections. The USGS poster (included in the notebook) was used for comparing map projection characteristics. At the conclusion of this exercise, the Montego Bay hydrology overlay was re-projected from Lambert Conformal Conic to Universal Transverse Mercator (UTM) and the resulting geometries of the two projections were compared. All course participants learned to be aware of existing map projections, as well as how to use PC ARC/INFO to create a GIS database with a consistent map projection.

Map Coordinates

All course participants learned the importance of selecting geographic coordinates for a GIS database as well as using PC ARC/INFO to change coverage coordinates from one system to another. The course participants changed the Montego Bay coordinates from feet to meters and also changed the Jamaica parish boundaries (which they also digitized) from digitizing inches to latitude/longitude.

Spatial Analysis

Many of the PC ARC/INFO Overlay commands were used during the Spatial Analysis segment of this course including BUFFER, INTERSECT, RESELECT, CLIP and UNION. Three different spatial analysis applications were conducted during the course: 1) to determine the total number of dwellings as well as the average dwelling density for each of the Montego Bay residential categories (High Density, Medium Density, Low Density), 2) to determine the total number of acres for each of the Montego Bay land cover categories, and 3) to determine the impact of land use on the wetland areas in Montego Bay.

Spatial Analysis Results (Also See Notebook):

- **Dwelling Units and Dwelling Density for Residential Areas in Montego Bay**

Demographic statistics which are present in the Enumeration District (ED) coverage were used to calculate the total number of dwellings and average dwelling density for each residential land cover category. PIOJ personnel were interested in understanding how these statistics compared to PADCO's air photo interpretation. The results below show that PADCO's air photo interpretation technique worked very well with classifying housing typologies from air photo interpretation.

Low Density Residential Areas:
Total Number of Dwellings in Montego Bay = 3,467
Average Number of Dwellings per acre in Montego Bay = 0.577

Medium Density Residential Areas:
Total Number of Dwellings in Montego Bay = 1,560
Average Number of Dwellings per acre in Montego Bay = 2.769

High Density Residential Areas:
Total Number of Dwellings in Montego Bay = 1,653
Average Number of Dwellings per acre in Montego Bay = 7.623

▸ Total Acreage for Land Cover Categories in Montego Bay Area

PIOJ participants used the statistical capabilities of TABLES to calculate the total acreage of each land cover category in the Montego Bay Land Cover Classification.

Land Use Category	Total Acres
Woodland	24,285.6
Agriculture	5,017.0
Low Density Residential	3,471.6
Open Areas	2,970.6
High Density Residential	1,653.5
Medium Density Residential	1,563.5
Resorts/Tourism	1,105.2
Institutional	491.9
Transportation	430.6
Industrial	358.8
Wetlands	324.6
Commercial	183.9
Parks and Recreation	17.5

▸ Wetland Proximity Application

After creating a 1000 foot buffer around the wetlands in Montego Bay, the following land cover types were found to exist at the perimeter. The land cover types are listed in the order to highest to lowest perimeter coverage. These results show that the wetlands are impacted most by Low Density Residential and Agriculture according to their proximity to the wetland areas.

	Land Cover Category
High	Low Density Residential
	Agriculture
	Transportation
	High Density Residential
	Industrial
	Open Areas
	Woodlands
	Institutional
Low	Medium Density Residential

Database Applications

One of the most important topics covered in this course was how to extract information from PIOJ's statistical databases for use within PC ARC/INFO. Statistics concerning Jamaica's parish population were joined to a parish coverage the participants had digitized. Health statistics concerning total live births for the month of March, 1991 were also joined to a point coverage which indicated the location of each public hospital in Jamaica. Finally, population statistics for major towns and cities were joined to a point coverage which showed the location of these towns and cities within Jamaica. All of these coverages are shown in the class notebook as ARCVIEW plots. The course participants used total population as well as population density values in creating their maps. All coverages and database attributes were copied onto a diskette which is stored as a backup at PADCO.

USAID Coordination

Several people from the AID office, including Ms. Pitter-Patterson and Mr. Gelman, came to observe the activities of the PIOJ training session. Several compliments were received regarding the spatial analysis projects and the course in general. AID seemed to be pleased with the training course results.

Closing Remarks

I enjoyed this consulting assignment very much and feel that the entire PADCO team has helped the PIOJ to understand what GIS is and what type of applications are possible using existing statistical information, maps, as well as imputing new database layers for spatial analysis. The course participants were found to be serious, enthusiastic, hard-working individuals. We are pleased at the groundwork they had done prior to this training visit and at their continued participation during the two weeks of the course.

CLASS NOTES

COORDINATE TRANSFORMATIONS

Review of Data Input and Coverage Composition

1. After digitizing graphic information with the digitizing tablet, what are the units of the resulting coverage?

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2. What type of units will a set of GIS coverages for the same geographic region have? How are these units defined?

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EXERCISE A

Go to the class directory, get into ARC/INFO and examine the TIC file associated with the coverage called HYDRO. Write the TIC coordinates below as well as the desired, geo-referenced coordinates.

Step 1: Turn on computer.
Step 2: At the C:\ prompt, type "cd class" and hit Enter.
Step 3: Type "arc" and hit Enter.
Step 4: To examine the contents of a TIC file, you must go into TABLES. Type "tables" and hit Enter.
Step 5: Type "select hydro.tic" and hit Enter.
Step 6: Type "list" and hit Enter.

TIC-ID	X Coordinate	Y Coordinate

Step 7: Type "quit" and hit Enter.
Step 8: Examine the paper map from which the data was digitized and locate the nine TICs. Note the associated coordinates for each TIC. These represent real-world coordinates or geo-referenced coordinates for the coverage. Write these coordinates of the following page:

TIC-ID	X Coordinate	Y Coordinate

3. Before digitizing, how should you select your TICs?

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EXERCISE B

In order to convert the digitized coordinates into real-world coordinates, you must first create a new, empty coverage containing only the desired output TICs. This is accomplished using an ARC/INFO command called GENERATE. When using GENERATE, you will create an empty coverage with the existing TIC file from HYDRO. You will then go into TABLES and edit this TIC file with the desired output coordinates. Next, you will transform your coordinates using the ARC/INFO command called TRANSFORM. After running TRANSFORM, you should have a new coverage which looks exactly like the one you started with except the coordinates will be geo-referenced. The new, transformed coverage will be called TRANS.

Step 1: At the ARC prompt, type "GENERATE TRANS" and hit Enter.
Step 2: Type "COPYTICS HYDRO" and hit Enter.
Step 3: Type "Quit" and hit Enter.
Step 4: At the ARC prompt, type "TABLES" and hit Enter.
Step 5: Type "Select TRANS.TIC" and hit Enter.
Step 6: Type "list" and hit Enter.
Step 7: Type "UPDATE" and hit Enter.
Step 8: You will be prompted for the record number:
Record Number? Type "1" and hit Enter.
Step 9: You will be prompted for the items to be updated:
Type "XTIC = (desired coordinate)" and hit Enter.
Type "YTIC = (desired coordinate)" and hit Enter.
Step 10: Hit Enter once and you will see the Record Number? prompt.
Step 11: Repeat Steps 8-10 until all 9 TICs have been edited.
Step 12: At the Record Number? prompt, hit Enter.
Step 13: Type "list" and hit Enter.
Step 14: At the Enter Command prompt, type "quit" and hit Enter.
Step 15: At the ARC command, transform your coordinates by typing "TRANSFORM HYDRO TRANS" and hit Enter.

MAP SCALES

4. What is a map scale?

5. List three ways a scale may be represented on a map:

6. What scale does the map shown by the instructor have?

7. After this map is digitized and transformed to the same coordinates as display on the grid, what scale will the **digital** coverage have?

8. How do we determine the map scale of a coverage displayed on the computer screen? How do we determine the map scale of a coverage plotted on a piece of paper?

9. What commands in ARCPLOT can we use to produce a paper map from a coverage with a desired output scale?

10. What do the terms "resolution" and "scale" mean in relation to digitized data?

11. What do the terms "small scale" and "large scale" mean in relation to map scale?

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EXERCISE C

Display the coverage TRANS on the computer screen. Try to calculate the scale of the displayed coverage. Zoom into one part of the coverage. Is the displayed portion of the coverage at a larger or smaller scale than the previously displayed map?

To display your coverage to the screen:

Step 1: At the ARC prompt, type "ARCPLOT" and hit Enter.
Step 2: Type "display 4" and hit Enter.
Step 3: Type "mapextent TRANS" and hit Enter.
Step 4: Type "arcs TRANS" and hit Enter.

Determine the map scale of the displayed coverage:

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To zoom into your displayed coverage:

Step 5: Type "mapextent *" and hit Enter.
Step 6: Use the mouse to click opposite corners of the area you would like to zoom in on.

Determine the map scale of the displayed portion of the coverage:

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Step 7: Type "quit" and hit Enter.

MAP PROJECTIONS

Map projections are mathematical formulas for transforming the curved surface of the Earth to a two-dimensional, flat surface. There are numerous map projections used by modern cartographers, however most of these projections may be classified into three types:

—Planer, or Azimuthal
—Cylindrical
—Conic

EXERCISE D

Use the globe and paper provided by the instructor to demonstrate the three types of map projections listed above.

Spheroids, or ellipsoids, represent models of the Earth's shape. It is widely accepted that the Earth is not a perfect sphere. The Earth's circumference is slightly larger at the equator and smaller at the poles. As with map projections, there are many different mathematical models for representing the Earth's sphere.

12. How many projections and spheroids are supported by ARC/INFO? (Hint—look up the PROJECT command in the manuals).

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EXERCISE E

Examine the three maps provided by the instructor. List each map's projection and spheroid (if listed);

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13. What type of map projection does the TRANS coverage have? What is the difference between map units and map projection?

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EXERCISE F

Change the map projection of the coverage TRANS from Lambert Conformal Conic to UTM using the ARC/INFO PROJECT command. The new, projected coverage will be called PROJ. Use ARCPLOT to compare the coverage before and after it was projected.

To change the coverage's projection, follow these steps:

Step 1: At the ARC prompt, type "PROJECT cover TRANS PROJ" and hit Enter.
Step 2: Type "input" and hit Enter.
Step 3: Type "projection LAMBERT" and hit Enter.
Step 4: Type "units meters" and hit Enter.
Step 5: Type "parameters" and hit Enter.
Step 6: Type "output" and hit Enter.
Step 7: Type "projection UTM" and hit Enter.
Step 8: Type "units meters" and hit Enter.
Step 9: Type "parameters" and hit Enter.
Step 10: Type "end" and hit Enter.

To look at the two coverages in ARCPLOT, follow these steps:

Step 11: At the ARC prompt, type "ARCPLOT" and hit Enter.
Step 12: Type "display 4" and hit Enter.
Step 13: Type "mapextent TRANS PROJ" and hit Enter.
Step 14: Type "arcs TRANS" and hit Enter.
Step 15: Type "linecolor 3" and hit Enter.
Step 16: Type "arcs PROJ" and hit Enter.

Describe the difference between the two coverages on the screen:

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To zoom in on your coverages, follow these steps:

Step 17: Type "mape *" and hit Enter.
Step 18: Use the mouse to select your new map extent.
Step 19: Type "clear" and hit Enter.
Step 20: Type "linecolor 1" and hit Enter.
Step 21: Type "arcs TRANS" and hit Enter.
Step 22: Type "linecolor 3" and hit Enter.
Step 23: Type "arcs PROJ" and hit Enter.

When you are done looking at your coverages, perform the last step:

Step 24: Type "quit" and hit Enter.

14. When compiling GIS layers for a project, why are map projections important?

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15. If you wanted to change the **units** of the coverage PROJ from meters to feet, which command would you use: PROJECT or TRANSFORM?

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EDITING COVERAGES USING ARCEDIT

ARCEDIT is the module of ARC/INFO used for editing coverages. Editing mistakes which occurred during the digitizing process or updating coverages with current information demonstrate two applications of ARCEDIT. Remember, only graphic information is changed during the editing process. You should use TABLES when changing attributes values.

EXERCISE G

In this exercise, you will edit a portion of the Montego Bay Enumeration Districts. The Enumeration District coverage is called ED and the land use coverage is called LAND. "Re-draw" ED (District to the given by Instructor) to more closely match the low-density residential area located on the associated land use map. You will put the land use map in the background and draw the ED map on top. Only the ED map can be edited.

Step 1: At the ARC prompt, type "ARCEDIT" and hit Enter.
Step 2: Type "display 4" and hit Enter.
Step 3: Type "mapextent ED 1991 LAND" and hit Enter.
Step 4: Type "editc ED 1991" and hit Enter.
Step 5: Type "backc LAND 5" and hit Enter.
Step 6: Type "backe all on" and hit Enter.
Step 7: Type "drawe all on node errors" and hit Enter.
Step 8: Type "draw" and hit Enter.

Now, to delete the existing boundaries of ED (District to be given by Instructor), you must first declare the type of the features you will be editing, then select the boundaries you will be changing and delete the existing ones. Finally, you will re-draw the new boundaries by "adding" new boundaries.

Step 9: Type "editf arcs" and hit Enter.
Step 10: Zoom into the area of interest by typing "mape *" and hit Enter. Use the mouse to select the area of interest.
Step 11: Type "draw" and hit Enter.
Step 12: Type "select many" and hit Enter.
Step 13: You will now take the cursor and move it to each arc which will be deleted. You will select each arc by clicking the mouse or by pushing the 1 button.
Step 14: Type "9" when you have selected all needed arcs.
Step 15: Type "delete" and hit Enter.
Step 16: If you have **incorrectly** selected your arcs, then type "undelete" and hit Enter.

To add new boundary arcs, do the following steps:

Step 17: Type "add" and hit Enter.
Step 18: Position the cursor to the beginning of the new boundary and start digitizing. You MUST start and end your arcs with a node (button 2). All points digitized in between two nodes will be vertices (button 1).
Step 19: Type "9" and exit to the Add menu.

To delete old label points and add a new one, do the following steps:

Step 20: Type "editf labels" and hit Enter.
Step 21: Type "sel many" and hit Enter.
Step 22: Select all old label points by positioning the cursor over the label and clicking the mouse.
Step 23: Type "delete" and hit Enter.
Step 24: Type "add" and hit Enter.
Step 25: Position the cursor over the new polygon and click the mouse to add a label point.
Step 26: Type "quit" and hit Enter.
Step 27: Type "y" to both responses about saving changes and leaving ARCEDIT.

To rebuild your edited coverage, you must first use the CLEAN command.

Step 28: At the ARC prompt, type "CLEAN ED #" and hit Enter.
Step 29: Duplicate steps 1-8 to see if you made any mistakes not corrected by the CLEAN command. Use the editing process discussed in this exercise as well as the ARCEDIT command called UNSPLIT to correct your errors.

16. How do you select the background color in ARCEDIT?

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17. Explain the difference between editing polygons and lines in ARCEDIT.

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18. Explain the difference between the CLEAN and BUILD commands.

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EXERCISE H

Digitizing using ARCEDIT is very similar to the process used by the ADS command; however, you have greater editing flexibility while working within ARCEDIT. In this exercise, you will learn how to digitize a coverage using ARCEDIT.

First, create an empty coverage using GENERATE called JAMAICA.

Step 1: At the ARC prompt, type "GENERATE JAMAICA" and hit Enter.
Step 2: Type "quit" and hit Enter.

Examine map and select four good TICs. Attach map to digitizing tablet. Now, get into ARCEDIT and add arcs and labels using the following steps:

Step 3: At the ARC prompt, type "ARCEDIT" and hit Enter.
Step 4: Type "display 4" and hit Enter.
Step 5: Type "mape JAMAICA" and hit Enter.
Step 6: Type "editc JAMAICA" and hit Enter.
Step 7: Type "drawe all on node errors".
Step 8: Type "draw" (nothing should happen).
Step 9: Type "editf tics" and hit Enter.
Step 10: Type "add" and hit Enter.
Step 11: Use the digitizing puck to enter the TIC-ID in first and then push the A button. Position the puck over the desired tic mark and push the 1 button. Repeat process until all four tics have been entered in. Finally, enter a TIC-ID of 0 and press the A button to end tic entry.
Step 12: Type "editf arcs" and hit Enter.
Step 13: Type "add" and hit Enter.
Step 14: Start digitizing arcs with a node (button 2) and enter vertices with button 1. End all arcs with a node. Continue process until all arcs have been entered.
Step 15: Type "editf labels" and hit Enter.
Step 16: Type "add" and hit Enter.
Step 17: Position cursor over each polygon and click with mouse to add label points.
Step 18: Type "9" to exit add menu.
Step 19: Type "quit" and hit Enter.
Step 20: Respond "y" to questions concerning saving changes and exiting ARCEDIT.
Step 21: Use the CLEAN command to build topology.
Step 22: Get back into ARCEDIT using the above commands and correct all digitizing mistakes.

19. How are the PAT (Polygon Attribute Table) and the graphic points, lines, and polygons linked?

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SPATIAL ANALYSIS

(Refer to ARC/INFO Commands in the Spatial Analysis Section.)

JOINING COVERAGES

Many times data is digitized in pieces because of limitations of the digitizing tablet, limitations in map size, and limitations in aerial photo size. When a project calls for a single coverage and data input resulted in several smaller coverages, you can use the ARC commands MAPJOIN and APPEND to join adjacent coverages.

20. Look up and read the documentation on both commands in the manuals (hint—MAPJOIN is found in the OVERLAY manual while APPEND in found in the STARTER KIT manual). What is the main difference between these two commands?

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EXERCISE I

You have four separate land cover coverages for the Montego Bay area called LAND1, LAND2, LAND3, and LAND4. Use one of the ARC/INFO commands discussed above to create a single land cover coverage. The resulting PAT should have the same number of items as the individual land cover coverages.

21. Which command did you use to join the four land cover files?

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Run BUILD on your new land cover coverages. Use ARCPLOT to display the results.

22. After viewing the result of the previous exercise, you must use the ARC/INFO command DISSOLVE to get rid of internal boundaries between identical land cover types. Read about the DISSOLVE command in the STARTER KIT manual. Which item in the PAT will you use to dissolve the unnecessary boundaries?

EXERCISE J

Use DISSOLVE to remove unnecessary boundaries. Use ARCPLOT to look.

ARC/INFO RESELECT COMMANDS

How to Reselect in ARC

Step 1: At the ARC prompt, type "RESELECT in_cover out_cover" and hit Enter.

Step 2: You will then be in a subcommand window within RESELECT. Type "RESELECT and your logical expression" and hit Enter.

Step 3: You will then need to hit Enter a second time. You will be asked if you want to re-enter your expression or add an additional expression. Answer the prompts with a "Y" or "N".

You will now have a completely new and separate coverage upon completion of this process.

How to Reselect in TABLES

Step 1: At the ARC prompt, type "TABLES" and hit Enter.

Step 2: At the ENTER COMMAND prompt, type "SELECT file of interest with a PAT extension or AAT extension, etc." and hit Enter.

Step 3: Type "RESELECT and your logical expression" and hit Enter.

Step 4: Now you may do other TABLE commands on your selected records such as STATISTICS, LIST, SORT, etc.

Step 5: When you are finished, type "ASELECT" and hit Enter.

Step 6: To exit TABLES, type "QUIT" and hit Enter.

How to Reselect in ARCPLOT

Step 1: At the ARC prompt, type "ARCPLOT" and hit Enter.

Step 2: You will see the : prompt. Type "DISPLAY 4" and hit Enter. The screen will clear and your prompt will appear at the top.

Step 3: Give the MAPE command for the coverages you wish to look at. Type "MAPE Coverage Name" and hit Enter.

Step 4: Type "RESELECT Coverage Name POLYS and logical expression" and hit Enter.

Step 5: Now to look only at the reselected polygons, type "POLYS Coverage Name" and hit Enter.

Step 6: To exit ARCPLOT, type "QUIT" and hit Enter.

How to create an ASCII file from an ARC/INFO Database

Step 1: At the ARC prompt, type "TABLES" and hit Enter.

Step 2: At the ENTER COMMAND prompt, type "SELECT filename.PAT or filename.AAT" and hit Enter.

Step 3: Type "Dump filename" and hit Enter.

How to create a dBase file from an ARC/INFO database

Step 1: At the ARC prompt, type "TABLES" and hit Enter.

Step 2: At the ENTER COMMAND prompt, type "SELECT filename.PAT or filename.AAT" and hit Enter.

Step 3: Type "SAVE filename" and hit Enter.