Assessing and Improving Positional Accuracy and Its Effects on Areal Estimation at Coleambally Irrigation Area

Tom G. Van Niel and Tim R. McVicar

Rice CRC Technical Report P1-01/00
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Project 1105: Remote Sensing of Crop Types and Crop Area Management
Rice CRC Program 1: Sustainability of Natural Resources

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Authors:
Tom G. Van Niel¹ and Tim R. McVicar²

¹ CSIRO Land and Water, PO Box 1666, Canberra, ACT, 2601, Australia
  thomas.van.niel@cbr.clw.csiro.au
  Ph: 61-2-6246-5816   Fax: 61-2-6246-5800

² CSIRO Land and Water, PO Box 1666, Canberra, ACT, 2601, Australia
  tim.mcvicar@cbr.clw.csiro.au
  Ph: 61-2-6246-5741   Fax: 61-2-6246-5800

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Cover figure description:

The true location of the same road intersection (green point) is compared to its own position on two different Geographic Information System (GIS) datasets (yellow points). The yellow point on the top represents the position of the road intersection based on the Digital Topographic Data Base (DTDB) roads layer, that is ‘before’ correction. The yellow point on the bottom represents the position of that same road intersection based on the final image product of this application, that is ‘after’ correction. The old geographic reference layer is about 97 m from its true position at this point. The new geographic reference is about 10 m from its true position at this point. The continuity of the background image to the roads layers in both images demonstrates the improved accuracies.

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A PDF version is available at: http://www.ricecrc.org/
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PREFACE

The Cooperative Research Centre (CRC) for Sustainable Rice Production Project 1.1.05 titled “Remotely Sensed Measurement of Irrigated Crop Types Area: Its Implication for Regional Water Balance” started in earnest in January 2000 with the appointment of Tom Van Niel. Tom was previously with Utah State University, College of Natural Resources, Remote Sensing / Geographic Information System Laboratory where he worked on rangelands applications.

This report documents the assessment and subsequent positional improvements of digital aerial photographs, which are used as the baseline Geographic Information System data set, over the entire Coleambally Irrigation Area. An important aspect of assessing uncertainty is determining how accurate your data is. Spatial accuracy is often forgotten in environmental monitoring and modelling, especially when the modelling becomes complex. This work was not scheduled in the project proposal; however, assessing positional accuracy, and more importantly improving accuracy, is important to the overall project aims.

A significant component of this project is technology transfer. To achieve this, the listing of the code, all written by Tom Van Niel, is found in Appendix B, and the user notes in Appendix C. Digital versions of the code and the ArcView extension are downloadable from the Rice CRC’s internet site (http://www.ricecrc.org/).

Tim McVicar
Canberra
September 2000
ABSTRACT

If management decisions are based on geospatial data that have not been assessed for spatial accuracy, then debate about both the measurements and the decisions themselves can occur. Having to resolve such disagreements can be avoided, at least in part, by assessing the positional accuracy of geospatial data, leading to increased confidence (decreased uncertainty) in both the data and the decisions made from them.

In this study, we assessed the positional accuracy of two Geographic Information System (GIS) baseline datasets at the Coleambally Irrigation Area (CIA): (1) high-resolution digital aerial photography acquired in January 2000 and (2) the Digital Topographic Data Base (DTDB) roads data. We also assessed areal error of paddock measurements from an improved accuracy version of the high-resolution digital aerial photography. Positional accuracies were assessed by comparing well-defined features from both baseline datasets (original aerial photography and DTDB roads) to highly accurate Differential Global Positioning System (DGPS) data for the same features. This assessment showed that neither baseline dataset met the National Mapping Council of Australia’s standards of map accuracy.

Consequently, we processed the original digital photography to create an improved dataset, which was over 2.5 times more accurate than the original photography, and over 4 times more accurate than the DTDB data. The improved dataset also met the map accuracy standard for Australia. We also assessed areal error by comparing paddock boundaries delineated from the improved dataset to those delineated from a DGPS associated with paddock soil surveys. The 90% confidence interval measured from the improved data for any individual paddock is approximately at the ±5% target error set by Coleambally Irrigation Limited (CIL). The 95% confidence interval is roughly ±6%. Overall areal error of multiple paddocks is much lower than the individual case with the 95% confidence interval for 2 paddocks being from about ±4% error, reducing to less than ±2% for 8 or more paddocks. Knowledge of both positional and areal accuracies of the improved high-resolution digital aerial photography provides a way to more effectively manage environmental compliance of rice farmers at CIA and gives the CIL added confidence in making management decisions from this spatial data.
RECOMMENDATIONS

1. The final improved image mosaic of digital aerial photographs, being the most accurate full-coverage dataset of the Coleambally Irrigation Area (CIA) to date, should be treated as the new Geographic Information System (GIS) baseline. When new data are created, they should be digitised directly from this baseline whenever possible, or corrected to the baseline if direct digitisation is not possible.

2. Coleambally Irrigation Limited (CIL) should develop a plan for both correcting GIS data to the baseline and testing GIS data positional accuracy. Any GIS data used for making management decisions should be corrected and tested first, leaving less critical data for later. Positional accuracy should be reported to the standard of the U.S. National Standard for Spatial Data Accuracy (NSSDA) since there is no current Australian standard for reporting accuracy of geospatial data.

3. For environmental compliance issues, areal estimation error of paddocks should be defined by an appropriate confidence interval, not the mean. Management decisions should be made with the understanding that individual paddock measurements made from the new baseline data are accurate to about 94%, $\pm 6\%$ error at the 95% confidence interval. When adding the areas of two paddocks, the resulting measurement is about 96% accurate, $\pm 4\%$ error at the 95% confidence interval. The error approaches zero as more paddocks are combined.

4. Recommendation 3, above, has direct implications on environmental compliance measurements for CIL. Based on the error calculated from the 95% confidence interval, paddock area measurements from the improved GIS baseline cannot be considered greater than 69 ha until they exceed:
   a. 73.14 ha for a single paddock;
   b. 71.76 ha for the combined area of 2 paddocks;
   c. 71.07 ha for the combined area of 3 to 5 paddocks; and
   d. 70.38 ha for the combined area of 6 or more paddocks.
When the area measurements made from the improved baseline data exceed these values, it is recommended that CIL staff measure the area of the paddocks in question using a Differential Global Positioning System (DGPS) and discuss results with the appropriate farmer(s). If these values prove to be cumbersome for practical management of CIA, more suitable confidence intervals may be used to define different allowable areas (see Discussion for details).

5. Alternative methods of achieving the same positional and areal estimation accuracy for less effort and cost should be inspected. For example, integration of fine-resolution vector GIS data with mid- to coarse-resolution remote sensing data may provide the desired accuracies at less data acquisition cost.
6. If a fine-resolution digital aerial photograph dataset is to be acquired again:
   a. acquire an abundance of Differential Global Positioning System (DGPS) points over the CIA for both geo-correction and positional accuracy assessment. That is, 15 or more DGPS points per tile to be used in geo-correction of the imagery and 3 or more DGPS points per tile to be used for positional accuracy assessment. Since CIA is approximately 96,000 ha and a tile is about 9,400 ha, at least 153 DGPS points should be collected for geo-correction and at least 31 DGPS points for accuracy assessment. DGPS points should be evenly distributed about the CIA and represent readily identifiable permanent features (preferably road–road, road–canal, canal–canal intersections);
   b. specify in the contract that the delivered imagery product be one image mosaic over the whole CIA with little to no visible stitch lines (one 4-m pixel size image and one 2-m pixel size image) in an image format compatible with ArcView (the current GIS software that CIL uses). CIL will need to ensure that they possess adequate computer resources to manage this image file size;
   c. require the positional accuracy of the final mosaic to be at least as accurate as the improved 2000 digital aerial photography. This will require the contractor to run an accuracy assessment;
   d. require the imagery be delivered in the appropriate projection parameters; and
   e. require the imagery to be delivered with Australian and New Zealand Land Information Council (ANZLIC) or Federal Geographic Data Committee (FGDC) compliant metadata, specifically reporting processing steps.
1 INTRODUCTION

Land managers are now more accountable for land use decisions than ever before, receiving pressure from both public views and government policy on environmental issues (Kessler et al., 1992). The irrigation water manager must not only contend with the difficulty of dealing with large areas, regulations on certain crop growth, and multiple land uses, but now must face growing concerns about shallow water tables, waterlogging, and salinisation (Christen and Skehan, 1999). To meet the mounting demand to make management decisions that are environmentally and economically sustainable, many irrigation managers are now using remote sensing and Geographic Information System (GIS) technologies.

The Coleambally Irrigation Limited (CIL), as the manager of the Coleambally Irrigation Area (CIA) in southern New South Wales (NSW), is one such company that puts a large effort into managing their land efficiently with spatial data. Consequently, spatial data plays a major role in making critical decisions for them. The current application of positional accuracy assessment at CIA is also relevant to the management of the Murrumbidgee and Murray Irrigation Areas (Figure 1), while the procedures developed and documented are more generically relevant to any application using geospatial data.

One important issue confronted by CIL every year, and the one focused on in this report, is determining the amount of rice planted by each farmer. This database is used to verify environmental compliance standards, which are:
   a. no more than 30% or 69 hectares of a farm can be planted in rice; and
   b. rice must be planted only in areas deemed suitable (Tiwari, 2000).

There are three classes of soil suitability:
   a. suitable;
   b. marginal (can be grown 1 year in 4); and
   c. unsuitable (Tiwari, 2000).

In the past, one limitation to monitoring environmental compliance has been the inability to know with confidence the accuracy of the spatial data on which management decisions are based. This has resulted in debates about management decisions. For example, if a farmer was assessed to have planted 72 hectares of rice in a particular year, it has not been known whether the accuracy of the data has been good enough to tell the farmer to reduce the crop area by 3 hectares in the next year, or if the magnitude of the difference was too small to be accurately captured by the data. It has also been costly to acquire and process the fine-scale remote sensing (digital aerial photography) data every year.

The goal of this research is to be able to manage the environmental compliance of rice farmers every year, eliminating from contention measurement methodology and management decisions due to questions of spatial data accuracy. Specific objectives of the research in order to obtain this goal are to:
   a. create a reference GIS data layer from which all other GIS data can be created from or corrected to;
   b. determine the positional accuracy of this reference;
   c. determine the influence of positional accuracy on area estimation of paddocks from the new GIS reference;
   d. determine the positional accuracy of the Digital Topographic Data Base (DTDB, old reference) data and the original imagery delivered to CIA by private contractors; and
   e. transfer technology (data and computer programs) to CIL and any other rice-based irrigation GIS managers.
Figure 1. Coleambally Irrigation Area (CIA) and surrounds in southern New South Wales. The Murrumbidgee Irrigation Area (MIA) is north of CIA and the Murray Irrigation Limited (MIL) is south. Heavy lines at 1° intervals represent the 1:250,000 scale map sheet boundaries and lighter intermediate grid lines represent the 1:100,000 scale map sheet boundaries.

Acquiring and analysing high-resolution spatial data to determine environmental compliance to this level is expensive, but is generally worth the effort to ensure a high standard of management. One problem, however, is that even when costly data are acquired and processed, management decisions can only be made to the accuracy of the data. The CIL has set a goal for accuracy that areal measurements of paddocks be within 5% of ‘truth’ (that is, 95% areal accuracy). This report outlines the steps taken to determine the accuracy of the baseline data, any adjustments made to the current data, and recommendations and data requirements for future management and research to obtain accurate results while targeting more efficient spatial analysis.

Efficient analysis of spatial data for this application calls for an understanding of spatial data concepts as well as the strengths and weaknesses of the types of data used in the analysis. The concepts relevant to this discussion include discrete boundaries, positional accuracy, subjectivity, and temporal invariance. Particular strengths and weaknesses of GIS and coarse satellite remote sensing (RS) data are also discussed in the context of producing higher quality spatial data. Those who are intimate with spatial data concepts may wish to skip the following section.
2 SPATIAL DATA CONCEPTS

The tendency in cartography to represent spatial data boundaries as infinitely thin lines has implications on user perception of accuracy of the data, which can affect subsequent analyses. In the real world, these boundaries are not perfectly sharp, which means that their position is interpreted, making them subjective. One concern, then, when dealing with spatial data is the perception of exact positional accuracy.

Positional accuracy is defined as the difference in the position of a feature in a GIS or on a map compared to the feature’s real world or ‘true’ position. The position of the discrete boundary line or feature on the map is most likely not the same as it is in the real world. Map boundaries should be visualised as a belt or swath around the line on the map, which contains the ‘true’ position. Generally, this swath will have a width that is inversely related to the scale of the source. This rule becomes apparent when positional accuracy is quantified. In the Australian standard for map horizontal positional accuracy, maps are deemed ‘reliable’ only if no more than 10% of well-defined features are in error by more than 0.5 millimetres on the map scale. As map scale decreases (area representation gets larger), the allowable error recognised by the National Mapping Council of Australia (NMCA) increases, verifying our general rule. Being able to express (or display) GIS data at any scale should not be confused with the original data scale of the GIS layer and, therefore, its subsequent positional accuracy. The general rule is maintained: horizontal positional accuracy of a GIS layer will be inversely related to the geographic scale of its source.

Because the definition of geographic scale is often misrepresented, it is beneficial to characterise what the definition of geographic scale is and, therefore, what is meant by scale in this document. Geographic scale can be expressed as the representative fraction (rf), which can be thought of as a mathematically fraction (e.g., 1/100,000). The numerator of this fraction represents the number of units on the map that are represented by the denominator’s number (in the same units) on the ground. For example, if rf = 1/100,000, then 1 cm on the map represents 100,000 cm or 1 km on the ground. Since smaller-scale maps represent larger ground areas, large and small scales are often transposed in the map user’s vocabulary. In other words, because the area that a 1:250,000 map covers is larger than the area that a 1:100,000 scale map covers (see Figure 1), it is often thought of as a larger scale. This is not true, 1:100,000 scale is a larger scale than 1:250,000. If the whole fraction is considered, the geographic definition of scale is easily understood, for, mathematically, 1/100,000 is larger than 1/250,000. To avoid this confusion, it is usually better to replace the word ‘scale’ with terms such as ‘extent’ or ‘resolution’ whenever applicable.

Another concept that must be considered about boundary lines is that they retain the subjectivity of the delineation itself. The concept of subjectivity can be thought of as a measure of the ambiguity of a boundary in the real world. For example, the placement of lines on a map representing boundaries that tend to be relatively unclear, like a vegetation or groundwater classification, are often more subjective than the placement of many man-made features, such as roads or agricultural fields, where boundaries are more discrete and hence less subjective (all else being equal). Spatial data users often try to visualise subjectivity using ‘fuzzy membership’. Fuzzy membership can be described here as the ability to assign a single object to more than one class (Burrough et al., 1997). For example, an area on a map in a traditional classification might be forced into one class, say ‘forest’, when 75% or more of the area is covered with trees. Using fuzzy membership, this area can be assigned 75% to the ‘forest’ class and also 25% to the ‘grassland’ class. This can lead to a more realistic view of the earth. Unfortunately, fuzzy logic often does not express subjectivity adequately because
the fuzzy logic model only attempts to find the best boundary by allowing multiple membership assignments, where subjectivity itself may mean that there is no boundary at all. This perceived boundary might instead be a side-effect of the interpreter’s preconceived biases, life experiences, or opinions.

In one sense, this concept of subjectivity can be likened to the post-modernistic view of multiple realisations or the syndrome ‘it is reality if it is true for me’. If scale changes, then reality may indeed change. Likewise, changing from one application of spatial data to another may result in boundaries becoming real where they were not real before, and vice versa. Although this multiple realisation mapping is useful when trying to describe boundaries at different scales or for different applications, it can be quite prohibitive when mapping the same piece of ground for the same application at the same scale. This subjectivity leads to non-reproducible results and is problematic, since boundary lines with very little subjectivity are usually drawn in the same manner as those with very high subjectivity. To make matters worse, like so much post-modernistic research, subjectivity is almost impossible to quantify. Although subjectivity is not commonly sampled, since it would most likely not be cost-effective, it is not impossible. Quantification of the differences (distance) of independent interpretations of boundary lines, although inefficient, could put a value to subjectivity. Realistically, actual sampling of subjectivity will continue to be replaced by the ‘feel’ that people generally have for the amount of subjectivity of a dataset. This, fortunately, is often enough to lead to better decisions in spatial data analysis.

Temporal invariance describes the amount of change (through time) that the feature being mapped has endured. This has direct implications on the longevity of the spatial information being represented on the map. That is, for how long do the features on the map represent a realistic image of the real world? Temporal invariance is high for ‘permanent’ or ‘semi-permanent’ features and low for highly variable features. For example, the temporal invariance of a geologic map would be high as opposed to the low temporal invariance of an air-temperature map. This concept can be very important, yet like subjectivity, is often not given much consideration when dealing with spatial data. This is partly due to the way in which the data is expressed: a GIS layer representing permanent features is usually expressed in the same manner as very transitory phenomena. This can result in the perception that the permanence of the mapped features is the same in both cases (high and low temporal invariance), which is not true. This reveals an issue in GIS that the fourth dimension, time, is not often well-represented (Langran, 1992; Mitasova et al., 1995; Peuquet, 1994; Peuquet, 1995).

It is also important to understand the strengths and weaknesses of different types of data with respect to these spatial data characteristics. The inability to do so has previously, and will continue to lead to, inappropriate data analyses. If we consider the strengths and weaknesses of GIS and RS data in relation to these spatial data concepts, we can come up with some very general rules, especially when considering integrating GIS and RS, which promote more pragmatic use of the spatial data. Like any generalisation, there are many exceptions to these rules and this, therefore, reveals the importance of the data user’s knowledge of spatial concepts. For example, users of either hyperspectral or hyperspatial RS data will most likely disagree with the assumptions made about RS. This is because the RS described here is for coarse earth observing satellite RS, which has different data characteristics to both hyperspectral and hyperspatial data.

So, it is essential to represent specific spatial data with the data model that best suits its characteristics. The vector GIS model best expresses geographic features where high positional accuracy is achievable, boundaries have low subjectivity, and features have high
temporal invariance (for example, a road). Boundaries should be well defined for the vector data model, which is best at describing discrete boundaries and gets worse at describing boundaries as they get less discrete. Boundaries should not be highly variable because the effort expended in producing accurate GIS data is generally high; this effort is usually only worth expending if the data is valid for a long enough period of time.

Mid to coarse RS is better at capturing scenarios where positional accuracy of boundaries is not extremely important, boundaries have higher subjectivity, and features have low temporal invariance. In other words, it is often very effective to use this kind of RS data for phenomena that have unclear boundaries, or phenomena that have boundaries that can change over a relatively short period of time. Phenomena with boundaries that are unclear and quickly changing are often not described well in the vector data model and, therefore, should not necessarily be forced into one (for example, an area experiencing a drought). For a detailed discussion of RS and its interaction with GIS, see McVicar and Jupp (1998).

The critical concept for this application, then, is to most efficiently manage important features on the ground based on the interactions of the spatial data concepts of positional accuracy, subjectivity, and temporal invariance by taking advantage of the strengths of both GIS and RS in line with the objectives of the project.

3 SPATIAL DATA ACCURACY STANDARDS

Understanding the positional accuracy of geospatial data is critical for proper spatial analysis. Without this knowledge, management decisions based on the spatial data cannot be made with much confidence, cannot be justified scientifically, and spatial models developed from the data are all but useless. Hence, guidelines have been developed in an attempt to standardise the quantification and summarising of positional accuracies in spatial data. Prior to digital geospatial data, map accuracies were concentrated on, but with the rise in popularity of GIS, digital geospatial standards have also been addressed. Australian and United States map-accuracy standards are discussed below to provide a context to the history of geospatial accuracy standards as well as new Unites States geospatial accuracy standards to provide more recent considerations about digital data.

3.1 National Mapping Council of Australia Standards of Map Accuracy

The National Mapping Council of Australia (NMCA) has set standards for map accuracy (NMCA, 1975) in the following form:

The horizontal accuracy of standard published maps shall be consistent within the criterion that not more than 10% of points tested shall be in error by more than 0.5 millimetres.

This limit of accuracy shall apply in all cases to positions of well-defined points only. “Well defined” points are those that are easily visible or recoverable on the ground. In general what is “well defined” will also be determined by what is plottable on the scale of the map within 0.25 millimetres.

The allowable error distance calculated for common Australian and U.S. scales is shown in Table 1. Details of U.S. standards are described below in section 3.2.
Table 1

Allowable distances calculated for common map scales by Australian and U.S. map-accuracy standard specifications.

<table>
<thead>
<tr>
<th>Map Scale</th>
<th>Allowable Distance (m) Australia</th>
<th>Allowable Distance (m) USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:10,000</td>
<td>5.00</td>
<td>8.47</td>
</tr>
<tr>
<td>1:20,000</td>
<td>10.00</td>
<td>10.16</td>
</tr>
<tr>
<td>1:24,000*</td>
<td>12.00</td>
<td>12.19</td>
</tr>
<tr>
<td>1:50,000</td>
<td>25.00</td>
<td>25.40</td>
</tr>
<tr>
<td>1:100,000</td>
<td>50.00</td>
<td>50.80</td>
</tr>
<tr>
<td>1:250,000</td>
<td>125.00</td>
<td>127.00</td>
</tr>
<tr>
<td>1:1,000,000</td>
<td>500.00</td>
<td>508.00</td>
</tr>
<tr>
<td>1:2,000,000*</td>
<td>1,000.00</td>
<td>1,016.00</td>
</tr>
<tr>
<td>1:2,500,000</td>
<td>1,250.00</td>
<td>1,270.00</td>
</tr>
</tbody>
</table>

* common scale in USA

3.2 United States National Map Accuracy Standards (USNMAS)

The United States Bureau of Budget (USBB) issued the United States National Map Accuracy Standards (USNMAS) for all federal agencies producing maps in 1941. The current version was issued in 1947 (USBB, 1947) and states:

With a view to the utmost economy and expedition in producing maps that fulfil not only the broad needs for standard or principal maps, but also the reasonable particular needs of individual agencies, the Federal Government has defined the following standards of accuracy for published maps:

1. Horizontal accuracy. For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as benchmarks, property boundary monuments; intersections of roads and railroads; corners of large buildings or structures (or centre points of small buildings). In general, what is well defined will also be determined by what is plottable on the scale of the map within 1/100 inch. Thus, while the intersection of two roads or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. This class would cover timberlines and soil boundaries.

2. Vertical accuracy, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error by more than one-half the contour interval. In checking elevations taken from the
map, the apparent vertical error may be decreased by assuming a horizontal
displacement within the permissible horizontal error for a map of that scale.

3. The accuracy of any map may be tested by comparing the positions of points
whose locations or elevations are shown upon it with corresponding positions as
determined by surveys of a higher accuracy. Tests shall be made by the producing
agency, which shall also determine which of its maps are to be tested, and the
extent of such testing.

4. Published maps meeting these accuracy requirements shall note this fact in their
legends, as follows: "This map complies with National Map Accuracy Standards."

5. Published maps whose errors exceed those aforestated shall omit from their
legends all mention of standard accuracy.

6. When a published map is a considerable enlargement of a map drawing
(manuscript) or of a published map, that fact shall be stated in the legend. For
example, "This map is an enlargement of a 1:20,000-scale map drawing," or "This
map is an enlargement of a 1:24,000-scale published map."

7. To facilitate ready interchange and use of basic information for map
construction among all Federal mapmaking agencies, manuscript maps and
published maps, wherever economically feasible and consistent with the use to
which the map is to be put, shall conform to latitude and longitude boundaries,
being 15 minutes of latitude and longitude, or 7.5 minutes, or 3.75 minutes in
size.

Refer to Table 1 for allowable error distances calculated for USNMAS at some common map
scales.

3.3 United States National Standard for Spatial Data Accuracy (NSSDA)

More recently, the U.S. Federal Geographic Data Committee (FGDC) published the National
Standard for Spatial Data Accuracy (NSSDA), which outlines positioning accuracy standards
and the methodology for estimating positional accuracy of points on maps and in digital
geospatial data (FGDC, 1998a; FGDC, 1998b). These new standards were initiated to provide a
common reporting system for direct comparison of data sets as well as providing a more
relevant measurement for digital geospatial data accuracies than publication scale or contour
interval (FGDC, 1998b). These new standards for spatial accuracy include the following:

The NSSDA uses root-mean-square error (RMSE) to estimate positional accuracy.
RMSE is the square root of the average of the set of squared differences between
dataset coordinate values and coordinate values from an independent source of
higher accuracy for identical points.

Accuracy is reported in ground distances at the 95% confidence level. Accuracy
reported at the 95% confidence level means that 95% of the positions in the
dataset will have an error with respect to true ground position that is equal to or
smaller than the reported accuracy value. The reported accuracy value reflects all
uncertainties, including those introduced by geodetic control coordinates,
compilation, and final computation of ground coordinate values in the product.
The preferred method of testing horizontal accuracy is by an independent source of higher accuracy (the highest accuracy feasible and practicable) (FGDC, 1998a). The horizontal accuracy is tested by comparing planimetric coordinates of at least 20 well-defined points. NSSDA guidelines state that:

A well-defined point represents a feature for which the horizontal position is known to a high degree of accuracy … [and] “is easily visible or recoverable on the ground, on the independent source of higher accuracy, and on the product itself.

The report generated from these points should be included in the FGDC compliant metadata structure in the ‘Data_Quality_Information’ section along with a full description of the method used for testing (FGDC, 1998a; FGDC, 1998b).

3.4 Computation of Positional Accuracy Statistics

For a detailed listing of statistics and worked examples of positional accuracy assessments, please refer to the ‘Positional Accuracy Handbook’ (MPLMIC, 1999), and the NSSDA report (FGDC, 1998b). The three statistics of importance for this application are:

a. Mean difference;
b. RMS error difference; and
c. 95% confidence level about the mean RMS error difference.

The mean difference is the overall average of the Euclidean distance between the reference points and their associated input data points. This statistic is described by the following two equations:

If:

\[ \bar{d} = \frac{\sum_{i=1}^{n} d_i}{n} \]

\[ d_i = \sqrt{(x_{i_{ref}} - x_{i_{data}})^2 + (y_{i_{ref}} - y_{i_{data}})^2} \]

\[ \bar{d} = \frac{\sum_{i=1}^{n} d_i}{n} \]

where:

- \( x_{i_{ref}} \) and \( x_{i_{data}} \) are the x coordinates of reference and input data for the \( i \)-th point, respectively;
- \( y_{i_{ref}} \) and \( y_{i_{data}} \) are the y coordinates of reference and input data for the \( i \)-th point, respectively;
- \( d_i \) is the distance between two points;
- \( \bar{d} \) is the mean difference distance; and
- \( n \) is the sample size (number of point pairs).

The Root Mean Square (RMS) error is the square root of the mean squared of a variable (in this case, the distance between points). This statistic is calculated as:

\[ RMS_d = \sqrt{\frac{\sum_{i=1}^{n} d_i^2}{n}} \]

where:

- \( d_i \) is the distance between the \( i \)-th pair of points;
- \( RMS_d \) is the Root Mean Square error for the distance; and
- \( n \) is the sample size (number of point pairs).
The 95% confidence level of the RMS error describes the error value (in distance) that 95% of the positions in the dataset will be at or below. This statistic assumes that the error is normally distributed and independent in the x- and y-components. This calculation is given by:

\[
RMS_{d95\%} = 2.4477 \times \frac{RMS_d}{1.414} = 1.7308 \times RMS_d
\]  

(4)

where:

- 2.4477 is the number defined from the \( t \)-table used to calculate a 95% confidence level;
- \( RMS_d \) is the Root Mean Square error for the distance; and
- 1.414 is the square root of 2 (since \( RMS_d \) equals the square root in the x- and y-directions).

### 4 STUDY SITE

The CIA is located on the alluvial riverine plain of the Lachlan, Murrumbidgee, and Murray rivers in south-eastern Australia (Hornbuckle and Christen, 1999). The general topography of the area is flat with localised relief in the form of sand dunes and hills characterised by differing soil groups based on the interaction of ancient alluvial and wind blown clay deposits (Hornbuckle and Christen, 1999). Soils are mainly red-brown earths and grey and brown soils of heavy texture on the plains (Hornbuckle and Christen, 1999).

The CIA occupies approximately 95,000 ha, comprising over 500 farms surrounding Coleambally. The principal crops grown are rice, soybeans, and winter cereals as well as some horticulture and pasture for grazing (CIL, 1999). The CIA is one of three Land and Water Management Plan (LWMP) areas that are managed by the CIL.

### 5 METHODS

Exactly 151 aerial photographs were acquired around the CIA on January 8 and 9, 2000, and processed by Airesearch Pty Ltd (www.airesearch.com.au), 36 of which cover the main CIA area. The aerial photography was acquired using a Leica RC30 camera (serial number 5228) with a 152 mm lens (s.n. 13244). The camera is permanently mounted in a vertical position in a Cessna C421c. The flying height for this acquisition was 7742 m. The scale of the photography was 1:50,000. The exposure of the photography was 1/1000 sec. at f/4.0 and the format of the negative was 230 × 230 mm. Some radial distortion was removed from the photographs, which were digitised at a resolution of 300 dots per inch (DPI) using a UMAX Mirage D16L scanner running Binuscan software. Digital image geo-referencing was achieved using a ZIImagine product called IRAS-C in conjunction with Microstation SE (Jones, 2000).

Airesearch geo-referencing of individual images was accomplished using Ground Control Points (GCPs) provided by CIL. GCPs were delineated by CIL from well-defined features on a Digital Topographic Data Base (DTDB) 1:50,000 scale GIS coverage in the northern part of CIA and from Differential Global Positioning System (DGPS) points in the southern part of CIA. DGPS points were collected by CIL because the DTDB was believed to be substandard in the south of CIA, whereas the DTDB in the north of CIA was believed to be more reliable (Duffy, 2000).

The processed digital images were then provided to CIL as geo-referenced JPEG format (herein called tiles). The tiles had 2 × 2 m pixel size over the CIA and 4 × 4 m pixel size in the surrounding areas. Tiles were planned to have about 66% overlap side-to-side and 33%
overlap top-to-bottom. CIL provided these tiles to the Cooperative Research Centre for Sustainable Rice Production (Rice CRC) project 1.1.05 for further processing and analysis.

5.1 Field Work

Exactly 85 GCPs were collected over the CIA using a Trimble Pro XRS DGPS from 5–8 May 2000 (Figure 2). GCPs were identified prior to the field trip from 1:250,000 and 1:100,000 scale map sheets to define identifiable points that would provide an adequate distribution over the study area. Since CIL collected DGPS points in the south of CIA in 1999 to correct the DTDB GIS data, more GCPs were currently gathered in the north to create an even distribution of points north and south. Features were chosen that should be plottable at 0.25 mm on the aerial photograph’s source scale, or 12.5 m at 1:50,000 scale, as per the Australian national map accuracy standards. GCPs identified on the maps were road–road intersections and canal–road intersections. Points collected in the field matched the points identified on the maps whenever possible. Points collected in the field that were not previously identified on the maps were described in the field notes and marked on the appropriate map sheets. These GCPs were then digitised in ArcView and saved as ArcView shapefiles, including detailed location descriptions. Fields included in the DGPS GIS coverage are displayed in Table 2. The contents of the GIS coverage table are also listed in Appendix A. These can be used as a guide for further DGPS point collection at CIA as they outline critical information that should be noted at the time of point collection. These points were also provided to CIL digitally.

![Figure 2. DGPS points collected at CIA. Filled circles were used for registration, while open circles were used for accuracy assessment.](image)
Table 2

Field and attribute description of DGPS GIS layer.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Attribute Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>Point coordinate information (generated by ArcView)</td>
</tr>
<tr>
<td>ID</td>
<td>Unique identification number for every point</td>
</tr>
<tr>
<td>GPSnorth</td>
<td>‘Northing’ information from DGPS</td>
</tr>
<tr>
<td>GPSeast</td>
<td>‘Easting’ information from DGPS</td>
</tr>
<tr>
<td>Pdop</td>
<td>Position dilution of precision (PDOP) from DGPS</td>
</tr>
<tr>
<td>Ron</td>
<td>Whether ‘R’ option from DGPS was on</td>
</tr>
<tr>
<td>SV</td>
<td>Number of Space Vehicles (SVs) used in DGPS position calculation</td>
</tr>
<tr>
<td>Time</td>
<td>Time DGPS point was collected</td>
</tr>
<tr>
<td>Descript</td>
<td>Description of DGPS point (e.g., name of roads intersecting)</td>
</tr>
<tr>
<td>Comments</td>
<td>Comments about DGPS point (e.g., which corner of the intersection)</td>
</tr>
<tr>
<td>Date</td>
<td>Date DGPS point was collected</td>
</tr>
<tr>
<td>Contact</td>
<td>Person who collected DGPS point</td>
</tr>
<tr>
<td>GPSunit</td>
<td>Type of GPS unit used</td>
</tr>
<tr>
<td>Projectn</td>
<td>Projection information GPS unit was set to when points were collected</td>
</tr>
</tbody>
</table>

5.2 Digital Image Processing

Exactly 36 of the JPEG tiles covering the CIA were converted to Erdas Imagine image format. Initially, because of the large east–west overlap, every other whole tile, 18 in total, was used to create one contiguous or mosaic image. This mosaic resulted in some incongruent stitch lines that were aesthetically unpleasant. This data was not used in any further analysis.

Next, the central 50% of all 36 tiles (east–west) were subset out and used to create a second mosaic image, denoted ‘Mosaic’ in section 6.1, Table 3. This process was meant to improve the internal geometry of the mosaic as evident by more harmonious stitch lines. The complete length of the tiles was maintained, since there was not enough overlap top-to-bottom to cut any of the images in this direction. This mosaic image was then re-registered using 64 of the 85 DGPS
points; 21 points were set aside to independently test the horizontal positional accuracy of both the original mosaic and the resultant re-registered mosaic. This image is referred to as ‘Mosaic/Re-Registered’ in section 6.1, Table 3.

Since the northern and southern tiles of CIA were originally geo-registered from two separate data sources (points digitised from a DTDB GIS layer in the north and DGPS collected by CIL in the south), the mosaic image was re-registered again to see if better accuracies could be obtained by processing the north and south independently. This was to allow for a block offset to be applied to the southern section and a separate block offset to be applied to the northern section. After these sections were re-registered, they were joined together again using 64 of the 85 DGPS points to form a second re-registered mosaic image, referred to as ‘Mosaic/Re-Registered N and S’ in section 6.1, Table 3. The same 21 DGPS points were held back again to test the horizontal accuracy of this image.

5.3 Horizontal Positional Accuracy Assessment

A horizontal positional accuracy assessment tool was created in ArcView’s object-oriented programming language, Avenue. These scripts were turned into an ArcView extension, which is more portable and thus facilitates technology transfer. The extension is designed to assist in the reporting of positional (horizontal) accuracy to national map accuracy standards in both the United States and Australia. The extension relies on the user to define two input-point GIS layers: (1) the ‘reference’ layer and (2) the ‘input’ layer. The reference points represent ‘trusted’ or ‘true’ positions of well-defined features, while the input theme represents positions of the same features on a map or GIS layer. The input layer’s positions are then compared to the reference layer’s positions. The output report meets the horizontal positional accuracy requirements for both the Federal Geographic Data Committee (FGDC) metadata standards and the Australian and New Zealand Land Information Council (ANZLIC) metadata standards. A full listing of the Avenue code is included in Appendix B, while a copy of the help/tutorial is included in Appendix C. Metadata, or ‘data about data’, was created for the final output mosaic image (‘Mosaic/Re-Registered N and S’ in section 6.1, Table 3) to meet the more stringent FGDC standards using a freeware ArcView metadata extension from the U.S. National Oceanic and Atmospheric Administration (NOAA). This metadata is listed in Appendix D.

This accuracy assessment tool was used to generate all positional accuracy reports for this application. Accuracy assessment was run for:

- the DTDB roads GIS layer;
- the image mosaic of the 36 subset tiles;
- the re-registered mosaic of subset tiles; and
- the second re-registered mosaic of subset tiles with independent north and south processing.

The ‘reference’ layer source for all of these data is the DGPS points collected at CIA described in section 5.1. The same 21 DGPS points were used to calculate positional accuracy for the imagery, while 39 road intersection points were used as ‘reference’ for the assessment of the DTDB roads layer. The 21 points were chosen more or less randomly (every fourth point) and were left out of any re-registration calculations so that they would be an independent validation. The 39 points chosen to test the DTDB layer were all the DGPS points that represented road intersections. The associated ‘input’ points were digitised off the imagery or GIS layer for the series of mosaicked images and the DTDB data, respectively.
Prior to 2000, the DTDB 1:50,000 scale GIS layers have been used as the reference or ‘baseline’ to which all other GIS data have been compared to. The original tiles in the northern part of CIA were registered to the DTDB data. As such, the DTDB was considered representative of the most reliable GIS data available for CIA. In order to assess the accuracy status of CIL GIS data prior to this application, the horizontal positional accuracy of a DTDB GIS layer was calculated. This assessment will be compared to the accuracy of the baseline GIS data from this application in order to quantify accuracy improvement. Results are presented in section 6.1 below.

5.4 Paddock Area Difference Analysis

If positional accuracy is measured on a single image that contains no radial distortion, the horizontal inaccuracy could be envisioned as a single block offset (see Figure 3a). When two or more images are stitched together, the continuity between the images (termed internal geometry) can cause a more complicated interaction of positional accuracy between contiguous images and thus result in differing effects on areal estimation (see Figure 3b, 3c, and 3d).

In the first single image case, the areal estimate of a paddock, for example, should not be affected by positional accuracy. The only effect will be that the position of the paddock measured from the image in relation to the paddock’s true boundary will be offset (Figure 3a). This is not so with the second multiple image mosaic case, for the positional offsets can potentially be additive (Figure 3b), resulting in increased area estimation, negative (Figure 3c), resulting in decreased area estimation, or both (Figure 3d), resulting in similar area estimation.

Since the influences of the internal geometry of the mosaic image are already included in the calculation of the positional accuracy (expressed in RMS error), the effects of the positional accuracy on areal estimation could be estimated for different paddock sizes through a purely theoretical exercise. This ‘average case’ or ‘worst case’ calculation would make actual ground samples of areal error non-compulsory. However, it was determined that a better assessment of the impact of positional accuracy on areal estimation of paddock sizes would be achieved by a comparative sample of field and image measurements. A sample of highly accurate paddock boundary measurements were compared to the delineation of the same paddocks made from the final image product. This is more realistic than either a ‘worst case’ or an ‘average case’ scenario.

Many highly accurate paddock boundaries were delineated using a DGPS for an on-going Electromagnetic (EM-31) survey project at the CIA. The EM-31 data are used for groundwater recharge estimation (Hume et al., 1999). In this EM-31 survey, a DGPS unit is mounted on a four-wheel drive motorbike (Robertson, 2000). The survey starts by outlining the edge of a paddock and transects are run every 20 m until a uniform coverage of the paddock is attained (Robertson, 2000). The paddock boundaries are then digitised to within 5 m of the survey outline (Robertson, 2000). Some 30 of the EM-31 paddock boundaries were used in this study as the reference (or ‘truth’) to which the estimates made from the final image mosaic were compared (Figure 4). These 30 paddocks were evenly distributed over the CIA and were of varying sizes, providing a good sample of both internal-geometry and paddock-size effects on areal estimation.
Figure 3. Potential effects of positional accuracy on areal estimation of the true position of a paddock (solid line), to the position seen on an image (grey area); the dashed line representing the paddock’s original position on the image is included in all figures for reference. Figure 3a demonstrates the effects of a single block offset due to positional accuracy on a single image, which results in same area estimation and no areal error. Figure 3b shows the additive effect of opposed block offsets from two adjacent images (fine dashed line), which results in increased area estimation and increased areal error. Figure 3c illustrates the negative effect of inversely opposed block offsets from two adjacent images, which results in smaller areal estimation and increased areal error. Figure 3d demonstrates both an additive and negative effect from two adjacent images, which results in same or similar areal estimation and no or little areal error.
The mean difference between the area of the EM-31 paddocks were compared to the area of the same paddocks delineated from the final image mosaic (equation 5). This analysis results in an estimation of the mean percent areal accuracy and is expressed mathematically as:

\[
\text{Accuracy}_{\text{areal}} = \frac{\sum_{i=1}^{n} (EM_{\text{area}} - IM_{\text{area}})}{n} \times 100
\]  

(5)

where:
- \( EM_{\text{area}} \) is the area of a paddock delineated from a DGPS during an EM-31 survey;
- \( IM_{\text{area}} \) is the area of the same paddock delineated from the final image mosaic, that is ‘Mosaic/Re-Registered N and S’ in Table 3;
- \( n \) is the sample size (30); and
- \( \text{Accuracy}_{\text{areal}} \) is the mean percent areal accuracy estimate for CIA.

Statistics generated from these 30 samples allow the 90% and 95% confidence intervals to be calculated (equations 6 and 7). These confidence intervals around the mean difference reveal a
safer estimate than the mean for use in management. In other words, 90% and 95% of the areal error measurements will be at or below the values calculated from:

\[
\text{Accuracy}_{\text{areal}90\%} = \text{Accuracy}_{\text{areal}} \pm (1.645 \times s),
\]

and

\[
\text{Accuracy}_{\text{areal}95\%} = \text{Accuracy}_{\text{areal}} \pm (1.960 \times s)
\]

respectively, where:
1.645 is the value from the \( z \)-table for 90% confidence interval;
1.96 is the value from the \( z \)-table for 95% confidence interval;
\( \text{Accuracy}_{\text{areal}} \) is the mean percent areal accuracy of the sample population;
\( s \) is the standard error (or the standard deviation calculated from the sample); and
\( \text{Accuracy}_{\text{areal}90\%} \) and \( \text{Accuracy}_{\text{areal}95\%} \) are the 90% and 95% confidence interval for the mean percent areal accuracy estimate for CIA, respectively.

6 RESULTS

Results of this report have been separated into two main sections: (1) positional accuracy assessment, which outlines the accuracies of the iterations of the digital imagery and then compares the final product to the current baseline data; and (2) areal measurement accuracy assessment, which summarises the effects of positional accuracy on areal estimations made from the digital imagery.

6.1 Positional Accuracy Assessment

The positional accuracy statistics for the current baseline data (DTDB), and the iterations of the mosaicked tiles for the 2000 aerial photographs are summarised in Table 3. The data are listed in sequential order; the current baseline data, labelled ‘DTDB Road Intersections’ are listed first with the products of the chronological image processing steps listed after that.

What can be seen clearly is that each level of processing improved the accuracy of the data. The image mosaic of the 36 subset tiles, labelled ‘Mosaic’ is the least accurate of the processed image mosaics (mean difference = 20.0 m), but is a considerable improvement over the current baseline data (mean difference = 32.2 m). The re-registered mosaic of subset tiles, labelled ‘Mosaic/Re-Registered’ is yet again more accurate than the previous two (mean difference = 13.5 m). Finally, the second re-registered mosaic of subset tiles, which was processed independently in the north and south, labelled ‘Mosaic/Re-Registered N and S’, is the most accurate dataset (mean difference = 8.1 m).

Australian national map accuracy standards require not more than 10% of well-defined points to be in error by more than the distance defined by 0.5 mm on the original map scale. Since the current DTDB baseline data and the 2000 aerial photographs are both 1:50,000 scale, this allowable error distance is 25 m (Table 1). As seen in Table 3, the current DTDB baseline data and the original mosaic of tiles do not meet these requirements. Both these layers are very far off the mark; the DTDB layer has 21 of 39 points (53.9%) exceeding this allowable error, while the original mosaic has 10 of 21 points (47.6%) exceeding the allowable distance. The last two mosaic images both meet the Australian national map accuracy standards: the first re-registered mosaic has 2 of 21 points (9.5%) exceeding the allowable distance and the final mosaic has 0 of 21 points (0.0%) exceeding the allowable distance.
### Table 3
Horizontal positional accuracies calculated at CIA.

<table>
<thead>
<tr>
<th>Name</th>
<th>Mean Difference (m)</th>
<th>RMS Difference (m)</th>
<th>RMS X (m)</th>
<th>RMS Y (m)</th>
<th>NSSD A 95% (m)</th>
<th>Number Exceeded</th>
<th>Percent Exceeded</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTDB Road Intersections</td>
<td>32.18</td>
<td>39.26</td>
<td>24.02</td>
<td>31.05</td>
<td>67.95</td>
<td>21 of 39</td>
<td>53.85</td>
</tr>
<tr>
<td>Mosaic</td>
<td>20.00</td>
<td>23.01</td>
<td>16.96</td>
<td>15.56</td>
<td>39.83</td>
<td>10 of 21</td>
<td>47.62</td>
</tr>
<tr>
<td>Mosaic/Re-Registered</td>
<td>13.51</td>
<td>15.43</td>
<td>8.19</td>
<td>13.08</td>
<td>26.71</td>
<td>2 of 21</td>
<td>9.52</td>
</tr>
<tr>
<td>Mosaic/Re-Registered N and S</td>
<td>8.07</td>
<td>9.12</td>
<td>6.23</td>
<td>6.66</td>
<td>15.78</td>
<td>0 of 21</td>
<td>0.00</td>
</tr>
</tbody>
</table>

1. *DTDB Road Intersections* refers to the previous baseline dataset from DTDB roads GIS layer.
2. *Mosaic* refers to the original mosaic of tiles.
3. *Mosaic/Re-Registered* refers to the re-registered mosaic based on the 64 DGPS points not used for validation.
4. *Mosaic/Re-Registered N and S* refers to the final mosaic re-registered with the 64 DGPS points, but with the north and south of CIA processed independently.
5. *Mean Difference* refers to the average Euclidean distance between the input and the reference points.
6. *RMS Difference* refers to the Root Mean Square error of all the difference distance values between the input and the reference.
7. *RMS X* refers to the Root Mean Square error of all the difference distance values between the input and the reference in the x direction.
8. *RMS Y* refers to the Root Mean Square error of all the difference distance values between the input and the reference in the y direction.
9. *NSSD A 95%* refers to the 95% confidence level of the RMS Difference value. Accuracy reported at this level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than this value.
10. *Number Exceeded* refers to the number of points that exceeded the allowable error distance outlined in the Australian national map accuracy standards (calculated by 0.5 mm on the data source scale).
11. *Percent Exceeded* refers to the percent of points exceeding the allowable error distance. Australian national map accuracy standards state that not more than 10% of well-defined points should exceed this distance.

The final mosaic image (‘Mosaic/Re-Registered N and S), is 3.99 times more accurate than the current baseline by measurement of mean difference, and 4.31 times more accurate by measurement of RMS (total RMS of difference distance, or RMS of difference distance at the 95% confidence level). This final mosaic is also much more accurate than the original tiles: 2.48 times more accurate when measuring mean difference and 2.52 times more accurate when measuring...
RMS. However, the mosaic of the original tiles was also an improvement over the current DTDB baseline by 1.69 times when measuring mean difference and 1.71 when measuring RMS.

6.2 Areal Measurement Accuracy Assessment

The 30 EM-31 paddocks had a mean size of 251,159.36 m² and a standard deviation of 140,381.61 m². The cumulative area was 7,534,780.66 m². The area for the same 30 paddocks identified from the digital aerial photography had a mean of 251,719.39 m² and a standard deviation of 141,063.36 m². The cumulative area was 7,551,581.74 m². The cumulative area agrees to 99.78% of the cumulative EM-31 area. This statistic is reported as the analysis of area accuracy by many previous authors (Fang et al., 1998; McCloy et al., 1987; Okamoto and Kawashima, 1999; Quarmby et al., 1992). However, due to errors of underestimation and overestimation cancelling each other out, this cumulative area percentage statistic has minimal relevance for this application.

A more robust way to analyse the two measurement methods is to assess the paddock differences, in units of sq. m and the relative error of the paddock size. For the 30 paddocks these data are shown in Table 4.

The difference between the two measurement methods of the 30 paddocks (EM-31 minus Aerial Photograph) has a mean of –560.04 m² and a standard deviation of 6,595.94 m². The maximum and minimum differences are 12,301.25 and –12,829.64 m², respectively. The relative difference of the two measurement methods of the 30 paddocks has a mean of –0.33% and a standard deviation of 2.97%, the maximum and minimum relative differences are 5.30 and –6.54%, respectively. The ratio of the Root Mean Squared Deviation divided by the mean of the EM-31 observations is 1.94. From Table 4 it should be noted that small paddocks usually have a higher relative error.

The distribution of the relative differences in paddock area is near normal (Figure 5). This allows standard confidence intervals to be defined. $\text{Accuracy}_{\text{areal}}$ ranges from –5.22% to +4.86%, or approximately ± 5%. That is, 90% of the paddocks sampled are in the range –5.22% to +4.86%. $\text{Accuracy}_{\text{areal}}$ ranges from –6.15% to +5.49%, or roughly ± 6%. That is, 95% of the paddocks are in the range –6.15% to +5.49%.

The influence on areal error when adding more than one paddock is summarised in Figure 6. The mean and upper limit of the 95% confidence interval of the absolute (unsigned) mean percent difference between the area measured from the EM-31 paddock(s) minus the same paddock(s) from the improved image mosaic are displayed. Thirty single paddocks (expressed as 1 ‘Paddock Combination Number’ in Figure 6) up to 30 combinations of 15 paddocks added together (expressed as 15 ‘Paddock Combination Number’ in Figure 6) are shown.

Figure 6 reveals the percent areal errors expected from farm rice area estimates made from multiple paddocks. The decrease in error seen in Figure 6 is due to the errors of overestimation approximately offsetting errors of underestimation. The more paddocks that are measured in the overall area calculation, the more these errors cancel each other out.
Table 4

Area difference statistics between paddock delineations based on the EM-31 surveys and the final image mosaic.

<table>
<thead>
<tr>
<th>Paddock</th>
<th>EM-31 Area (m²)</th>
<th>Image Area (m²)</th>
<th>Difference (m²)</th>
<th>Difference (Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49756.62</td>
<td>47119.74</td>
<td>2636.88</td>
<td>5.30</td>
</tr>
<tr>
<td>2</td>
<td>80220.34</td>
<td>85470.47</td>
<td>−5250.13</td>
<td>−6.54</td>
</tr>
<tr>
<td>3</td>
<td>102063.12</td>
<td>105951.71</td>
<td>−3888.59</td>
<td>−3.81</td>
</tr>
<tr>
<td>4</td>
<td>102212.51</td>
<td>105546.77</td>
<td>−3334.26</td>
<td>−3.26</td>
</tr>
<tr>
<td>5</td>
<td>126999.95</td>
<td>127166.44</td>
<td>−166.49</td>
<td>−0.13</td>
</tr>
<tr>
<td>6</td>
<td>129157.18</td>
<td>129947.42</td>
<td>−790.24</td>
<td>−0.61</td>
</tr>
<tr>
<td>7</td>
<td>154713.13</td>
<td>156979.22</td>
<td>−2266.09</td>
<td>−1.46</td>
</tr>
<tr>
<td>8</td>
<td>177213.31</td>
<td>170289.19</td>
<td>6924.13</td>
<td>3.91</td>
</tr>
<tr>
<td>9</td>
<td>192043.20</td>
<td>191675.30</td>
<td>367.91</td>
<td>0.19</td>
</tr>
<tr>
<td>10</td>
<td>199972.97</td>
<td>205335.89</td>
<td>4637.08</td>
<td>2.21</td>
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<tr>
<td>11</td>
<td>211643.80</td>
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</tr>
<tr>
<td>12</td>
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<td>666.94</td>
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</tr>
<tr>
<td>13</td>
<td>228494.53</td>
<td>226909.97</td>
<td>1584.56</td>
<td>0.69</td>
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<td>14</td>
<td>240373.47</td>
<td>253203.11</td>
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<td>−5.34</td>
</tr>
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<td>15</td>
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<td>241103.31</td>
<td>7509.30</td>
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<tr>
<td>17</td>
<td>250193.66</td>
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Figure 5. Frequency distribution of the percent difference between EM-31 paddock areas and the same paddock areas delineated from the final image mosaic.

Figure 6 (caption opposite)
7 DISCUSSION

Increased positional accuracy was seen from the original mosaic to the re-registered mosaic. This is because the re-registered mosaic was corrected to highly accurate DGPS points as opposed to reference points defined from a 1:50,000 scale GIS layer as is the case in the northern half of the original photography. The positional accuracy expected from a 1:50,000 map or GIS layer is 25 m. From the positional accuracy assessment of the DTDB layer, we know that this data was substandard, and thus, we could not even expect this level of accuracy. Notable improvement occurred, without surprise, when the overall image was corrected to the DGPS points instead of the DTDB points.

The increased accuracy from the first re-registered mosaic (discussed above) and the second re-registered mosaic (the final product) was due to the dichotomy present in the processing of the original tiles. Since the northern tiles of the CIA were geo-corrected to DTDB points and the tiles in the southern section were geo-corrected to DGPS points, the overall image mosaic was, essentially, two different products. This difference was prominent in the accuracy assessment of the original image mosaic; much better accuracies were found in the south than in the north. The best overall accuracy was obtained when these two sections were processed independently. Processing these sections separately allowed for an appropriate shift of the ‘like-processed’ imagery without negatively affecting the imagery of the other section. After the two sections were recombined and the neat line along the join matched well, they resulted in the most accurate dataset. This processing essentially corrected both the north and the south to DGPS points and allowed for a uniformly accurate image mosaic.

Both the original baseline data sets (DTDB GIS layer and Airesearch imagery) were not compliant to Australian national map accuracy standards. This means that neither the previous baseline GIS data nor the originally delivered digital aerial photographs for 2000 were reliable maps regarding positional accuracy. The final image product of this application does meet these map accuracy standards and for this reason is considered both more reliable and defensible.

The overall areal error measured during this application for all 30 paddocks is 0.22%, which falls well below the target error set by CIL. This error is extremely low because of the overestimation/underestimation error cancellation discussed earlier. That is, when several areas are added together, the overestimates are often almost exactly offset by the underestimates, resulting

Figure 6 (opposite). Influence of multiple paddock additions on areal error determined from the summation of 30 measured paddocks. Absolute mean percent difference measurements were made for 1–15 paddock combinations. Each paddock combination consists of 30 samples randomly combined. The first paddock combination represents the 30 EM-31 survey paddock areas compared to the areas of the same paddocks delineated from the improved image mosaic. Every combination from 2 to 15 is a randomly generated summation. That is, paddock combination of 2 represents the mean percent difference of 30 samples of 2 randomly selected paddocks added together. Likewise, paddock combination of 15 represents the mean percent difference of 30 samples of 15 randomly selected paddocks added together. The grey error bars represent the upper limit of the 95% confidence interval for these samples. Precisely 100 computer-generated runs were summarised at each paddock combination number.
in a good overall estimation of area (Fang et al., 1998; McCloy et al., 1987; Okamoto and Kawashima, 1999; Quarmby et al., 1992). However, when estimating individual paddock area, the error increases. This can be seen by the 90 and 95% confidence intervals being approximately ±5% and ±6%, respectively.

This error drops considerably when the area of more than one paddock is added together (Figure 6). This is a realistic scenario for CIA, where a farmer usually has more than one paddock of rice planted. That is, when the area of a single paddock is being measured, we are 95% confident that the area is within ±6% of the actual size. When two or more paddocks are added together, the error drops considerably below this. For example, adding the area of 2 paddocks results in approximately a ±4% error threshold defined by the 95% confidence interval. Based on the analysis, when 4 paddocks were added together, the error threshold dropped to approximately ±3% defined by the 95% confidence interval. So, when a farm’s overall rice area is estimated by the measurement of more than one paddock, the areal error is expected to be below ±4% at the 95% confidence interval. Since this error approaches zero as the number of paddocks added together becomes larger (Figure 6), the land manager at CIL should have more confidence in the overall areal estimation as the number of paddocks added together increases.

If the current calculation of allowable areas (recommendation 4) proves ineffective for practical management of environmental compliance at CIA, CIL may want to alter the confidence interval used. A change to a 99% confidence interval will result in overall higher allowable area numbers than listed in a–d of recommendation 4. This would mean that fewer farms would need to be checked with a DGPS (recommendation 4), but potentially more farms exceeding 69 ha would go unchecked. If the values are recalculated using a 90% confidence interval, less farms that exceeded 69 ha would go unchecked, but this would mean more manual checking of paddocks on the ground. CIL should define these values according to their best judgment.

8 CONCLUSIONS

Acceptable statistics for reporting positional accuracy are:

- mean difference distance;
- Root Mean Square (RMS) error of the difference distance;
- the 95% confidence level of RMS error of the difference distance; and
- the percent exceeding the allowable distance defined by 0.5 mm on the map scale.

Since map accuracy standards are not always appropriate nor very descriptive for digital geospatial data (FGDC, 1998b), and there are no standards as yet in Australia for dealing specifically with digital geospatial data accuracy, it is recommended that positional accuracy be reported by the NSSDA standard 95% confidence level of RMS error. This will allow for direct comparison of positional accuracy between multiple sources and scales of data.

Since the final mosaic is the most accurate full-coverage dataset to date, this should become the new GIS baseline. This means that all GIS data of lower accuracy (which is most likely everything except DGPS points) should be corrected to this layer. As a long-term plan, it is also recommended that an accuracy report be generated for all corrected and newly created data according to the accuracy test guidelines defined by the FGDC (FGDC, 1998b). When new data are created, it should be digitised directly from this baseline whenever possible. It is reasonable for the positional accuracy reports for data generated from the baseline to not be calculated, since the baseline accuracy is known. In these cases, the accuracy reports should state ‘compiled to meet’
instead of ‘tested’ (FGDC, 1998b). When this is not appropriate, the new data accuracy should be tested and reported. For further assistance with positional accuracy testing, refer to the positional accuracy handbook published by the Minnesota Planning Land Management Information Center (MPLMIC, 1999).

The upper limit of the 90 or 95% confidence interval (not the mean) should be used to define the sensitivity of areal measurements of paddocks for environmental compliance issues. This should allow a realistic sense of the high-end of the range of error that can be expected for a large majority of paddocks, and, hence, allow for appropriate management actions to be undertaken in regards to the error sensitivity of the spatial data. When one paddock is being measured from the improved image mosaic, the ±5% or ±6% threshold should be used. When more than one paddock is being measured and the overall area is being assessed, it is reasonable to consider the error to be much smaller (Figure 6) due to overestimation/underestimation error cancellation.

Future research should be applied to test whether the same positional and areal estimation accuracy for less effort and expenditure can be achieved. For example, integration of fine-resolution vector GIS data with mid- to coarse-resolution remote sensing data may provide the desired accuracies for reduced data acquisition expenditure.

In general, summarisation of positional accuracy of the baseline GIS data at CIL should help management effectiveness. It will allow CIL to make more educated spatial management decisions as well as give them a scientific justification for their actions. Increasing the positional accuracy of their baseline data by over 4 times should also allow for better overall management of the system. Providing them with a tool for positional accuracy quantification will help them maintain this level of effectiveness in the future as new spatial data are incorporated into their GIS database. Increasing the accuracy of the baseline dataset increases the utility of GIS greatly for monitoring environmental compliance at CIL. Quantified accuracies allows for the proper use of the data as well as justification for specific management decisions made from that data.

The 95% confidence interval of the percent error for area measurements of individual paddocks from the baseline data fall just above the ±5% target error that was set by CIL. However, when more than one paddock is added together, the overall area measurement drops well below the target error threshold. The calculation of the areal estimation error of a sample of paddocks is valuable in the management of environmental compliance. CIL now has a scientifically justifiable reason for making specific management decisions. That is, since the sensitivity of the data is known, management decisions can be made in accord with this sensitivity.

9 ACKNOWLEDGEMENTS

This research was funded by the Cooperative Research Centre for Sustainable Rice Production and CSIRO Land and Water. The authors would like to thank Arun Tiwari, Janelle Dufty, and Greg Robertson of Coleambally Irrigation Limited for assistance in this project. Their responsiveness and professionalism is greatly appreciated. Thanks also to Ray Jones at Airesearch Pty Ltd for the technical information concerning the original air photo acquisition and processing, to Kevin Bartsch at Utah State University for partnership in development of the original horizontal accuracy ArcView script, and to Jeff Wood, CSIRO Mathematical and Information Sciences, for statistical advice.
10 REFERENCES


Dufty, J., 2000. Perceived positional accuracy of DTDB at CIA. (personal communication)


APPENDIX A:

GPS POINTS ATTRIBUTE TABLE
## Appendix A: GPS Points Attribute Table

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APPENDIX B:

HORIZONTAL ACCURACY ARCVIEW SCRIPTS

'----------------------------------------------------------------------'
'DiskFile     : acattdlg.ave : Accuracy (Attribute Dialog)
'Programmer   : Van Niel
'Organization: CSIRO Land and Water
'Created      : 01-Jun-2000
'Revisions    :
'
'Function     : Allows user to make an "Edit" Dialog based on selected fields in a user-specified table (from all tables in project). A new table is generated containing all specified fields.
'Called By    : Accuracy Edit Dialog
'Calls        :
'----------------------------------------------------------------------

' Initialize variables
aView = av.GetActiveDoc
aProj = av.GetProject
aDocList = aProj.GetDocs
inpTableList = List.Make
dfltString = "Data Entry Form for"
screenSize = system.ReturnScreenSizePixels
screenX = screenSizeGetX
screenY = screenSizeGetY
rowWidth = 125
x = 0
y = 230
largestWidth = 0
largestHeight = 0
screenYFlag = FALSE
aTableList = List.Make
idList = List.Make
refPntList = List.Make

' set up the initial scale
aScale = aView.ReturnScale
aDisplay = aView.GetDisplay
aDisplay.ZoomToScale(aScale)

' Filter through Docs to retrieve tables
For each d in aDocList
  If (d.GetClass.GetClassName = "Table") then
    aTableList.Add(d)
  End
End

' Error Handling
If (aTableList.Count = 0) then
  MsgBox.Info("No Tables in Project","Add Table to Project")
  Return Nil
End

' Get the "Input" Table & list of fields to update from the User

33
inpTable = MsgBox.ListAsString(aTableList,"Choose Data Entry Table (""Input"" Table)","Table Input")
If (inpTable = Nil) then Return Nil End
inpVtab = inpTable.GetVtab
inpFieldList = inpVtab.GetFields

' If table is an Ftab, then exit
inpShpFld = inpVtab.FindField("Shape")
If (inpShpFld <> Nil) then
  MsgBox.Info("Data Entry Program Will not Alter Ftabs, export Ftab to dbf file and try again.","Exiting")
  Return Nil
End

' Allow user to choose X and Y fields to interact with the view
xFld = MsgBox.ListAsString(inpFieldList,"Choose ""X"" Field",""X"" Field Input")
If (xFld = Nil) then Return Nil End
yFld = MsgBox.ListAsString(inpFieldList,"Choose ""Y"" Field",""Y"" Field Input")
If (yFld = Nil) then Return Nil End

' Get User input about Reference Table
refTable = MsgBox.ListAsString(aTableList,"Choose Table representing the ""Reference""",""Table Input")
If (refTable = Nil) then Return Nil End
refVtab = refTable.GetVtab
refFieldList = refVtab.GetFields

' If table is not a Point Ftab, then exit
refShpFld = refVtab.FindField("Shape")
If ((refShpFld = Nil) or (refVtab.GetShapeClass.GetClassName <> "Point")) then
  MsgBox.Info("Reference Table must be a Point Ftab.","Exiting")
  Return Nil
End

' Allow user to choose unique field to pan/zoom to
idFld = MsgBox.ListAsString(refFieldList,"Choose identifier Field used for pan/zoom","Field Input")
If (idFld = Nil) then Return Nil End

' Put all identifiers and pnts into a list
cnt = 0
For each rec in refVtab
  id = refVtab.ReturnValue(idFld,cnt)
  refPnt = refVtab.ReturnValue(refShpFld,cnt)
  idList.Add(id)
  refPntList.Add(refPnt)
  cnt = cnt + 1
End

' Make Data Entry Dialog
aDialog = Dialog.Make(false,true,true,true,true)
aControlPanel = aDialog.GetControlPanel

' Scale Button for view
scaleButton = LabelButton.Make
scaleButton.SetLabel("Set Scale from View")
scaleButton.SetName("Set Scale from View")
scaleButton.SetClick("Accuracy (Set Scale from View)")
setScaleButton.SetEnabled(FALSE)
scaleButton.SetHelp("Set Scale from View.")
aControlPanel.Add(scaleButton,Rect.Make(1@1,150@20))

' Scale TextLine
cScaleTextLine = TextLine.Make
cScaleTextLine.SetName("ScaleTextLine")
cScaleTextLine.SetLabel("Scale 1:")
cScaleTextLine.SetEnabled(FALSE)
cScaleTextLine.SetChanged("Accuracy (Set Scale from TextLine)")
cScaleTextLine.SetText(aScale.SetFormat("d.dddd").AsString)
aControlPanel.Add (scaleTextLine,Rect.Make(1@30,150@10))
scaleButton.AddListener(scaleTextLine)

' Pan Textline linked to Reference theme
idListBox = ListBox.Make
idListBox.SetName("PanListBox")
idListBox.DefineFromList(idList)
idListBox.SetEnabled(FALSE)
idListBox.SetSelect("Accuracy (Pan from ListBox)")
aControlPanel.Add (idListBox,Rect.Make(1@50,120@80))

'start editing button
'aDialog = Dialog.Make(false,true,true,true,true)
'aControlPanel = aDialog.GetControlPanel
startButton = LabelButton.Make
startButton.SetLabel("Start Editing")
startButton.SetName("Start Editing")
startButton.SetClick("Accuracy (Dialog Start)")
startButton.SetEnabled(TRUE)
startButton.SetHelp ("Start Editing Table")
aControlPanel.Add(startButton,Rect.Make(1@140,120@20))

' commit changes button
commitButton = LabelButton.Make
commitButton.SetLabel("Commit Data to Table")
commitButton.SetName("Commit Data to Table")
commitButton.SetClick("Accuracy (Dialog Commit)")
commitButton.SetEnabled(FALSE)
commitButton.SetHelp ("Commit current contents of textlines to table.")
aControlPanel.Add(commitButton,Rect.Make(1@160,120@20))

'stop editing button
stopButton = LabelButton.Make
stopButton.SetLabel("Stop Editing")
stopButton.SetName("Stop Editing")
stopButton.SetClick("Accuracy (Dialog Stop)")
stopButton.SetEnabled(FALSE)
stopButton.SetHelp ("Stop Editing Table.")
aControlPanel.Add(stopButton,Rect.Make(1@180,120@20))

' XY tool
getTool = Tool.Make
getTool.SetIcon(Icon.MakeFromResName("Icons.XY2"))
getTool.SetName("Get X,Y from View")
getTool.SetApply("Accuracy (Get XY)")
getTool.SetHelp ("Get XY coordinates from view.")
getTool.SetEnabled(FALSE)
acControlPanel.Add(getTool,Rect.Make(1@200,20@20))
startButton.SetListeners({scaleButton,scaleTextLine,idListBox,commitButton,stopButton,getTool})

' "Input" Data Fields TextLines
For each fld in inpFieldList
    aName = fld.AsString
    aWidth = fld.GetWidth
    If (aWidth > 25) then
        aNum = 25
    Else
        aNum = aWidth
    End
    aType = fld.GetType
    aTypeString = aType.AsString.Substitute("FIELD_ ","")
    aTextLine = TextLine.Make
    aLabel = aName++"("+aTypeString++aWidth.AsString+")"
    aTextLine.SetName(aName)
    aTextLine.SetLabel(aLabel)
    aWidth = aWidth+aLabel.Count+rowWidth
    aTextLine.SetEnabled(FALSE)
acControlPanel.Add(aTextLine,Rect.Make(x@y,aWidth@10))
startButton.AddListener(aTextLine)
If (aWidth > largestWidth) then
    largestWidth = aWidth
End
y = y + 25
If (y > screenY) then
    y = 0
    x = x + largestWidth+20
    largestWidth = 0
    largestHeight = screenY
    screenYFlag = TRUE
ElseIf (screenYFlag = FALSE) then
    largestHeight = y + 25
End
End

' Set more dialog properties
aDialog.SetTitle("Enter Data for
"+inpVtab.GetBaseTableFileName.GetBaseName.AsString.Quote)
aDialog.SetExtent(rect.Make(1@1,x+largestWidth+15@largestHeight))
aDialog.SetObjectTag({inpVtab,refVtab,inpFieldList,refFieldList,aView,xFld,yFld,aScale,scaleTextLine,idListBox,refPntList})
av.GetProject.AddDialog(aDialog)
aDialog.Open
startButton.BroadcastUpdate

' ----------------------------------------------------------------------
' DiskFile     : accDlgCt.ave : Accuracy (Dialog Commit)
' Programmer   : Van Niel
' Organization: CSIRO Land and Water
' Created      : 23-Feb-2000
' Revisions    :
' 
' Function     : Commits data entered in Data Entry Dialog to the table specified by the user.
' Called By    : Data Entry Dialog
'----------------------------------------------------------------------

' Initialize variables
aDialog = self.GetDialog
aProj = av.GetProject
aControlList = aDialog.FindByClass(Textline)
aFieldStringList = List.Make

' Retrieve the table's Vtab from the object tag
aVtab = aDialog.GetObjectTag.Get(0)
aFieldList = aDialog.GetObjectTag.Get(2)
aVtab.SetEditable(TRUE)
For each fld in aFieldList
    aFieldStringList.Add(fld.AsString)
End

' Remove Scale Textline from the list
aControlList.Remove(0)

' Check to make sure user has write permission to table
' If true, start editing and enable other buttons and textlines, else exit
aRecord = aVtab.AddRecord
For each cntrl in aControlList
    aString = cntrl.GetText
    aFldName = cntrl.GetName
    anIndxNum = aFieldStringList.FindByValue(aFldName.AsString)
    aFld = aFieldList.Get(anIndxNum)
    If (aFld.IsTypeNumber) then
        If (aString.IsNumber) then
            aVtab.SetValueNumber(aFld,aRecord,aString.AsNumber)
        Else
            MsgBox.Info("Text entered into "+aFldName.AsString++"Text Line cannot be converted to a number","Entering a -1")
            aVtab.SetValueNumber(aFld,aRecord,-1)
            cntrl.SetText("-1")
        End
    Else
        aVtab.SetValueString(aFld,aRecord,aString)
    End
End
aVtab.SetEditable(FALSE)

'----------------------------------------------------------------------

' DiskFile     : accDlgSt.ave : Accuracy (Dialog Start)
' Programmer   : Van Niel
' Organization: CSIRO Land and Water
' Created      : 23-Feb-2000
' Revisions    :
'
' Function     : Enables Editing of the table specified by the user. Checks to make sure user has write permission to table. Exits if false.
' Called By    : "Metadata Data Entry" Dialog

' Initialize variables
aDialog = self.GetDialog
aProj = av.GetProject
aControlList = aDialog.FindByClass(Control)

'Retrieve the table's Vtab from the object tag
aVtab = aDialog.GetObjectTag.Get(0)

' Check to make sure user has write permission to table
' If true, start editing and enable other buttons and textlines, else exit
If (aVtab.CanEdit) then
    aVtab.SetEditable(TRUE)
    For each cntrl in aControlList
        cntrl.SetEnabled(TRUE)
    End
    self.SetEnabled(FALSE)
Else
    MsgBox.Info("You do not have write permission to
" + aVtab.GetBaseTableFileName.GetBaseName.AsString, "Exiting")
    Return Nil
End

' Initialize variables
aDialog = self.GetDialog
aProj = av.GetProject
aControlList = aDialog.FindByClass(Control)

'Retrieve the table's Vtab from the object tag
aVtab = aDialog.GetObjectTag.Get(0)

' Check to make sure user has write permission to table
' If true, start editing and enable other buttons and textlines, else exit
If (aVtab.CanEdit) then
    aVtab.SetEditable(FALSE)
    For each cntrl in aControlList
        cntrl.SetEnabled(FALSE)
    End
    aDialog.FindByName("Start Editing").SetEnabled(TRUE)
Else
    MsgBox.Info("You no longer have write permission to
" + aVtab.GetBaseTableFileName.GetBaseName.AsString, "Exiting")
    Return Nil
End
' Initialize variables
aDialog = self.GetDialog
aProj = av.GetProject

'Retrieve the table's Vtab from the object tag
aVtab = aDialog.GetObjectTag.Get(0)
 aValue = aDialog.GetObjectTag.Get(4)
x Fld = aDialog.GetObjectTag.Get(5)
y Fld = aDialog.GetObjectTag.Get(6)

' Get User Point
thePoint = aValue.GetDisplay.ReturnUserPoint

' Find the x and y textlines
x TextLine = aDialog.FindByName(x Fld.AsString)
y TextLine = aDialog.FindByName(y Fld.AsString)

' Put coords in x and y textlines
x TextLine.SetText(thePoint.GetX.SetFormat("d.dd").AsString)
y TextLine.SetText(thePoint.GetY.SetFormat("d.dd").AsString)

' ' DiskFile : acMkNew.ave : Accuracy (Make New Table)
' Programmer : Van Niel
' Organization: CSIRO Land and Water
' Created : 01-Jun-2000
' Revisions :

' Function : Allows user to make a new table based on selected fields in a specified table from all
 tables in project. A new table is generated containing all specified fields plus a new x and y field to
 place coordinates in later.
' Called By : Menu
' Calls :

' Initialize variables
a View = av.GetActiveDoc
a Proj = av.GetProject
a DocList = a Proj.GetDocs
a TableList = List.Make
dfltString = "Attribute Dialog"
xDefList = {"X","12","4"}
yDefList = {"Y","16","4"}
labelsList = {"Field Name","Field Width","Decimal Places"}

aDialog = aProj.FindDoc(dfltString)
If (aDialog <> Nil) then
MsgBox.Info("Please Remove or Rename Dialog called"++dfltString.Quote,"Specified Data Entry Dialog Already Exists")
    Return Nil
End

' Filter through Docs to retrieve tables
For each d in aDocList
    If (d.GetClass.GetClassName = "Table") then
        aTableList.Add(d)
    End
End

' Error Handling
If (aTableList.Count = 0) then
    MsgBox.Info("Making New Input Table Requires Accessing Reference Table. Please Add Reference Table to Project","No Tables in Project")
    Return Nil
End

' Get the Table & list of fields to update from the User
aTable = MsgBox.ListAsString(aTableList,"Choose Reference Table","Table Input")
If (aTable = Nil) then Return Nil End
aVtab = aTable.GetVtab
refFieldList = aVtab.GetFields.DeepClone

' Get list of fields to copy from reference table
shpFld = aVtab.FindField("Shape")
If (shpFld <> Nil) then
    refFieldList.RemoveObj(shpFld)
End
aFieldList = msgBox.MultiListAsString(refFieldList,"Choose Field(s) to retain in New Table. Must Select at Least One Field to Link Input to Reference","Field(s) Selection")
If (aFieldList = Nil) then Return Nil End
If (aFieldList.Count = 0) then Return Nil End

' Get x and y fields to add from user
xFldList = MsgBox.MultiInput("Enter 'X' Field Characteristics","Adding """"Field","labelsList,xDefList)
If (xFldList.Count = 0) then Return Nil End
yFldList = MsgBox.MultiInput("Enter 'Y' Field Characteristics","Adding """"Field","labelsList,yDefList)
If (yFldList.Count = 0) then Return Nil End
'Make Fields
xFld = Field.Make(xFldList.Get(0),#FIELD_DECIMAL,xFldList.Get(1).AsNumber,xFldList.Get(2).AsNumber)
yFld = Field.Make(yFldList.Get(0),#FIELD_DECIMAL,yFldList.Get(1).AsNumber,yFldList.Get(2).AsNumber)

'Merge other fields into the field list
aFieldList = {xFld,yFld}.Merge(aFieldList)

'Make New Table
newFN = av.GetProject.GetWorkDir.MakeTmp("inptab","dbf")
newStrng = msgbox.Input("Enter Output File Name (.dbf)","Table Name",newFN.asString)
If (newStrng = NIL) then return NIL End
newStrng = newStrng.Trim().Substitute(" ","")
newFN = FileName.Make(newStrng)
newVtab = Vtab.MakeNew(newFN,dBase)
If (newVtab.HasError)
    MsgBox.ERROR("New Vtab has error. May be invalid directory, exiting.","Vtab Error")
    return NIL
End

'Add Fields to New Vtab
newVtab.AddFields(aFieldList)

'Ask User if want to add new table to project
If (MsgBox.MiniYesNo("Add New Table To Project?",TRUE)) then
    newTab = Table.Make(newVtab)
    newDocWin = newTab.GetWin
    newTab.SetName("Table"++newFN.asString)
    if (newDocWin.IsOpen.Not) then
        newDocWin.Open
    end
End

av.ClearStatus
av.ShowMsg("Created new file"++newFN.asString+").")

'----------------------------------------------------------------------
' DiskFile : Accuracy (MetaData NMCA) : acmtdaus.ave
' Programmer : Van Niel
' Created    : 28-Apr-00
' Revisions  :
'
'
' Called By : Accuracy (NMCA) : acNMCA.ave
' Calls      : None
'----------------------------------------------------------------------

' Get variables from calling script
',
ref_theme = SELF.Get(0)
inp_theme = SELF.Get(1)
AvgDist = SELF.Get(2)
StdDev = SELF.Get(3)
ci90 = SELF.Get(4)
ci95 = SELF.Get(5)
ci99 = SELF.Get(6)
wkdir = SELF.Get(7)
RefPntList = SELF.Get(8)
RefxList = SELF.Get(9)
RefyList = SELF.Get(10)
InpIDlist = SELF.Get(11)
InpxList = SELF.Get(12)
InpyList = SELF.Get(13)
DistList = SELF.Get(14)
RefIDlist = SELF.Get(15)
RMSd = SELF.Get(16)
RMSx = SELF.Get(17)
RMSy = SELF.Get(18)
Scale = SELF.Get(19)
ScaleList = SELF.Get(20)
ver = SELF.Get(21)
theView = av.GetActiveDoc

' set variables
TotalCnt = InpIdList.Count
RefStrng = ref_theme.GetSrcName.GetFileName.GetFullName.AsString
InpStrng = inp_theme.GetSrcName.GetFileName.GetFullName.AsString
mtdFN = wkDir.MakeTmp(Inp_Theme.AsString,"htm")
mtdFile = LineFile.Make(mtdFN,'#FILE_PERM_WRITE)
Descriptor = "Horizontal Accuracy Assessment"
If (ScaleList <> Nil) then
   RptDistList = ScaleList.Get(0)
   RptIdList = ScaleList.Get(1)
   CntExceeded = ScaleList.Get(2).AsString
   percentExceeded = ScaleList.Get(3).AsString
   errorDistMeters = ScaleList.Get(4).AsString
Else
   RptDistList = {}
   RptIdList = {}
   CntExceeded = "Unknown"
   percentExceeded = "Unknown"
   errorDistMeters = "Unknown"
End

' write generic meta information to metafile

' write Title and links to targets within page
mtdFile.WriteElt("<html>")
mtdFile.WriteElt("<head><title>Horizontal Accuracy Report for "++Inp_Theme.AsString++"Based on National Mapping Council of Australia Map Accuracy Standards</title></head>")
mtdFile.WriteElt("<body>")
mtdFile.WriteElt("<h3>Horizontal accuracy report based on National Mapping Council of Australia Standards</h3>")
mtdFile.WriteElt("<dl>")
mtdFile.WriteElt("<dd>")
mtdFile.WriteElt("<a href=""#General Information"">General Information</a></dd>")
mtdFile.WriteElt("<dd>")
mtdFile.WriteElt("<a href=""#Distance Summary"">Distance Summary</a></dd>")
mtdFile.WriteElt("<dd>")
mtdFile.WriteElt("<a href=""#NMCA Summary"">National Mapping Council of Australia Map Accuracy Standards</a>")
mtdFile.WriteElt("<dd>")
mtdFile.WriteElt("<a href=""#Total Point Summary"">Total Points Summary</a></dd>")
mtdFile.WriteElt("</dl>")

' write general information
mtdFile.WriteElt("<h4><a NAME=""General Information"">General Information</a></h4>")
mtdFile.WriteElt("Reference:"++RefStrng)
mtdFile.WriteElt("<br>Input:"++InpStrng)
mtdFile.WriteElt("Scale of Input: 1:"++Scale)
mtdFile.WriteElt("Description:"++Descriptor++"calculated using ""Accuracy (NMCA)"" Avenue Script")
Relevant URL: "http://au.riversinfo.org/library/masters_thesis/map_stnds.html#Australian Map Accuracy Standards"

Date Processed: "Date.Now.AsString"

Version: "ver"

Distance Summary

Mean Difference Distance: "AvgDist.AsString"

Standard Deviation of Difference Distance: "StdDev.AsString"

Upper Limit for 90% Confidence Interval of Difference Distance: "ci90"

Upper Limit for 95% Confidence Interval of Difference Distance: "ci95"

Upper Limit for 99% Confidence Interval of Difference Distance: "ci99"

RMS Difference Distance: "RMSd.AsString"

RMS X: "RMSx.AsString"

RMS Y: "RMSy.AsString"

Allowable error distance is based on the National Mapping Council Map Accuracy Standards where GIS layers should not have more than 10 percent of well defined points tested in error by more than 0.5 millimetres, measured on the publication scale. This means that the distance is calculated based on the distance of 0.5 millimetres at the scale of the input GIS layer. For example, if the scale of the input GIS layer is 1:100,000, then 0.5 of a millimetre is calculated by: 1 millimetre = 100,000 millimetres, so 1/2 millimetres = 100,000/2 = 50,000 millimetres = 50 metres"

Allowable Error Distance (meters): "errorDistMeters"

Number of Points Exceeding Allowable Error: "CntExceeded" of "TotalCnt.AsString"

Percent of Points Exceeding Allowable Error: "percentExceeded"

For each ExclInd in 0..(RefIdList.Count - 1)

End

End

Total Point Summary

For Each RefInd in 0..(RefPtList.Count - 1)

End

Dir = DirList.Get(RefInd)

ExclX = ExclList.Get(ExclInd).SetFormat("d.dddd")

ExclY = ExclList.Get(ExclInd).SetFormat("d.dddd")

InpInd = InpIdList.FindByValue(RefId)

InpX = InpXList.Get(InpInd).SetFormat("d.dddd")

InpY = InpYList.Get(InpInd).SetFormat("d.dddd")

Dist = DistList.Get(RefInd)
mtdFile.WriteElt("<br>+RefID.AsString+","+RefX.AsString+","+RefY.AsString+","+InpX.AsString+","+InpY.AsString+","+Dist.AsString)
End
mtdFile.WriteElt("<br><a href="#Top">[Top]</a>")
mtdFile.WriteElt("<br>_______________________________________________")
mtdFile.WriteElt(</body>)
mtdFile.WriteElt(</html>)
Return mtdFN

' ----------------------------------------------------------------------
' DiskFile   : Accuracy (MetaData USNMAS) : acmtdus.ave
' Programmer : Van Niel
' Created    : 28-Apr-00
' Revisions  :
'
' Function : Makes Meta Data File for horizontal accuracy assessment for US National Map Accuracy Standards
'
' Called By : Accuracy (USNMAS) : acusnmas.ave
' Calls     : None
'
' Get variables from calling script
'
ref_theme = SELF.Get(0)
inp_theme = SELF.Get(1)
AvgDist = SELF.Get(2)
StdDev = SELF.Get(3)
ci90 = SELF.Get(4)
ci95 = SELF.Get(5)
ci99 = SELF.Get(6)
wdir = SELF.Get(7)
RefPntList = SELF.Get(8)
RefxList = SELF.Get(9)
RefyList = SELF.Get(10)
InpIDlist = SELF.Get(11)
InpxList = SELF.Get(12)
InpyList = SELF.Get(13)
DistList = SELF.Get(14)
RefIDlist = SELF.Get(15)
RMSd = SELF.Get(16)
RMSx = SELF.Get(17)
RMSy = SELF.Get(18)
Scale = SELF.Get(19)
ScaleList = SELF.Get(20)
ver = SELF.Get(21)
NSSDA = SELF.Get(22)
NSSDAnot = SELF.Get(23)
RMSEmax = RMSx.Max(RMSy)
RMSEmin = RMSx.Min(RMSy)

' set variables
TotalCnt = InpIdList.Count
RefStrng = ref_theme.GetSrcName.GetFileName.GetFullName.AsString
InpStrng = inp_theme.GetSrcName.GetFileName.GetFullName.AsString
mtdFN = wkDir.MakeTmp(Inp_Theme.AsString,"htm")
mtdFile = LineFile.Make(mtdFN,#FILE_PERM_WRITE)
Descriptor = "Horizontal Accuracy Assessment"
If (ScaleList <> Nil) then
  RptDistList = ScaleList.Get(0)
  RptIdList = ScaleList.Get(1)
  CntExceeded = ScaleList.Get(2).AsString
  percentExceeded = ScaleList.Get(3).AsString
  errorDistMeters = ScaleList.Get(4).AsString
Else
  RptDistList = {}
  RptIdList = {}
  CntExceeded = "Unknown"
  percentExceeded = "Unknown"
  errorDistMeters = "Unknown"
End

' write generic meta information to metatile

' write Title and links to targets within page
mtdFile.WriteElt("<html>")
  mtdFile.WriteElt("<head><title>Horizontal Accuracy Report for "++Inp_Theme.AsString++"Based on United States National Map Accuracy Standards<title></head>")
  mtdFile.WriteElt("<body>"
    mtdFile.WriteElt("<h3>Horizontal accuracy report based on United States National Standard for Spatial Data Accuracy (NSSDA) and United States National Map Accuracy Standards (USNMAC)</h3>")
    mtdFile.WriteElt("<dl>
      mtdFile.WriteElt("<dd>
        mtdFile.WriteElt("<a href="#General Information">General Information</a></dd>
      mtdFile.WriteElt("<dd>
        mtdFile.WriteElt("<a href="#Distance Summary">Distance Summary</a></dd>
      mtdFile.WriteElt("<dd>
        mtdFile.WriteElt("<a href="#USNMAS Summary">United States National Map Accuracy Standards</a></dd>
      mtdFile.WriteElt("<dd>
        mtdFile.WriteElt("<a href="#NSSDA Summary">National Standard for Spatial Data Accuracy</a></dd>
      mtdFile.WriteElt("<dd>
        mtdFile.WriteElt("<a href="#Total Point Summary">Total Points Summary</a></dd>
    mtdFile.WriteElt("</dl>"
  mtdFile.WriteElt("<h4><a NAME="General Information"></a>General Information</h4>")
    mtdFile.WriteElt("Reference:"++RefStrng)
    mtdFile.WriteElt("<br>Input:"++InpStrng)
    mtdFile.WriteElt("<br>Scale of Input: 1:"+Scale)
    mtdFile.WriteElt("<br>Description:"++Descriptor++"calculated using ""Accuracy (USNMAS)"
      Avenue Script")
  mtdFile.WriteElt("<br>Date Processed:"++Date.Now.AsString)
  mtdFile.WriteElt("<br>Version:"++ver)
  mtdFile.WriteElt("<br><a href="#Top">[Top]</a>"")
"
MFDIST File. WriteElt("<h4><a NAME="Distance Summary"></a>Distance Summary (in Map Units of
the View)</h4>")
MFDIST File. WriteElt("Mean Difference Distance:"++AvgDist.AsString)
MFDIST File. WriteElt("Standard Deviation of Difference Distance:"++StdDev.AsString)
MFDIST File. WriteElt("Upper Limit for 90% Confidence Interval of Mean Difference
Distance:"++ci90)
MFDIST File. WriteElt("Upper Limit for 99% Confidence Interval of Mean Difference
Distance:"++ci99)
MFDIST File. WriteElt("RMSE Difference Distance:"++RMSd.AsString)
MFDIST File. WriteElt("RMSE X:"++RMSx.AsString)
MFDIST File. WriteElt("RMSE Y:"++RMSy.AsString)
MFDIST File. WriteElt("RMSEmin/RMSEmax:"++(RMSEmin/RMSEmax).AsString)
MFDIST File. WriteElt("NSSDA 95% Confidence Level (RMSEx=RMSEy):"++NSSDA.AsString)
MFDIST File. WriteElt("NSSDA 95% Confidence Level
(RMSEx<>RMSEy):"++NSSDAnot.AsString)
MFDIST File. WriteElt("<br><a href="#Top">[Top]</a>"

MFDIST File. WriteElt("<h4><a NAME="USNMAS Summary"></a>United States National Map
Accuracy Standards Summary</h4>")
MFDIST File. WriteElt("Allowable error distance is based on the United States National Map
Accuracy Standards where GIS layers with scales larger than 1:20,000 should not have more than 10 percent
of the points tested in error by more than 1/30 inch, measured on the publication scale; for maps on
publication scales of 1:20,000 or smaller, 1/50 inch. This means that the distance is calculated based
on the distance of 1/30 or 1/50 of an inch at the scale of the input GIS layer. For example, if the scale
of the input GIS layer is 1:100,000, then 1/50 of an inch is calculated by: 1 inch = 100,000 inches, so
1/50 inch = 100,000/50 = 2,000 inches = 2,000 inches/39.37 (inches per meter) = 50.8 meters"
MFDIST File. WriteElt("<br>")
MFDIST File. WriteElt("<br-Allowable Error Distance (meters):"++errorDistMeters)
MFDIST File. WriteElt("Number of Points Exceeding Allowable
Error:"++CntExceeded++"of"++TotalCnt.AsString)
MFDIST File. WriteElt("Percent of Points Exceeding Allowable Error:"++percentExceeded)
If ((RptDistList.Count <> 0) and (CntExceeded <> 0)) then
  MFDIST File. WriteElt("<p>
For each ExcInd in 0..(RptIdList.Count - 1)
  MFDIST File. WriteElt("<br>+RptIdList.Get(ExcInd).AsString++","+RptDistList.Get(ExcInd).AsString)
  End
End
MFDIST File. WriteElt("<br><a href="#Top">[Top]</a>"

MFDIST File. WriteElt("<h4><a NAME="NSSDA Summary"></a>National Standard for Spatial Data
Accuracy Summary</h4>")
MFDIST File. WriteElt("When RMSEx = RMSEy, NSSDA value is calculated by multiplying the RMSE by
1.7308. This represents the horizontal accuracy at the 95% confidence level. This is assuming that
systematic errors have been eliminated as best as possible and that error is normally distributed and
independent in each the x- and y-component (i.e., 2.4477 * RMSEx = 2.4477 * RMSEy = 2.4477 *
RMSEr/1.4142 = 1.7308 * RMSEx). When RMSEx <> RMSEy and RMSEmin/RMSEmax is between
0.6 and 1.0 (where RMSEmin is the smaller value between RMSEx and RMSEy and RMSEmax is the
larger value), circular standard error for the 95% confidence level can be approximated by 2.4477 *
0.5 * (RMSEx + RMSEy)."
MFDIST File. WriteElt("<br><br>"
mtdFile.WriteEl("If RMSx = RMSy:")
mtdFile.WriteEl("<br>")
mtdFile.WriteEl("Tested"++NSSDA.AsString++"(map units) horizontal accuracy at 95% confidence level")
mtdFile.WriteEl("<br><br>")
mtdFile.WriteEl("If RMSx <> RMSy:")
mtdFile.WriteEl("<br>")
mtdFile.WriteEl("Tested"++NSSDAnot.AsString++"(map units) horizontal accuracy at 95% confidence level")
mtdFile.WriteEl("<br><a href="#Top">[Top]</a>")

' write total point summary
mtdFile.WriteEl("<br>")
mtdFile.WriteEl("<h4><a NAME="Total Point Summary"></a>Total Point Summary</h4>")
For Each RefInd in 0..(RefPntList.Count - 1)
    RefID = RefIDlist.Get(RefInd)
    Refx = RefxList.Get(RefInd).SetFormat("d.dddd")
    Refy = RefyList.Get(RefInd).SetFormat("d.dddd")
    InpInd = InpIDlist.FindByValue(RefID)
    InpID = InpIDlist.Get(InpInd)
    Inpx = InpxList.Get(InpInd).SetFormat("d.dddd")
    Inpy = InpyList.Get(InpInd).SetFormat("d.dddd")
    Dist = DistList.Get(RefInd)
    mtdFile.WriteEl("<br>"+RefID.AsString++","+Refx.AsString++","+Refy.asString++","+InpX.AsString++","+InpY.AsString++","+Dist.AsString")
End
mtdFile.WriteEl("<br><a href="#Top">[Top]</a>")
mtdFile.WriteEl("<br>_______________________________________________")
mtdFile.WriteEl('</body>")
mtdFile.WriteEl('</html>")
Return mtdFN

' DiskFile : Accuracy (NMCA) : accynmca.ave
' Programmer : Van Niel & Kevin P Bartsch
' Created : 06-May-99
' Revisions : 06-May-99/KPB/Initialization of program and User Input
'            : 06-May-99/TVN/Added portion of turning records in Ftabs
'            : into points and getting information out of these points
'            : 06-May-99/TVN/Allow specification of Common Field in
'            : both Reference and Input ("Inp") themes that links
'            : these themes together -- Records do not have to be
'            : in order in respect to this field
'            : 06-May-99/TVN/Calculation of Stats including avg,std
'            : deviation and Confidence Intervals
'            : 06-May-99/TVN/Output information into VTAB and finally
'            : (export) as text file
'            : 28-April-00/TVN/changed output to metadata style format
'            : and added call to metadata script - Accuracy (MetaData NMCA)
'            : 03-May-00/TVN/added RMS and Scale calculation stuff -
'            : added call to report script - Accuracy (Report NMCA)
' Function : Determines the accuracy of a coverage by comparing
' the distance between reference points in a "ref_theme"
' with corresponding points with common field values
in an "Inp_theme". National Mapping Council of Australia, Standards of Map Accuracy to generate a report file. HTML file is output to the users working directory

Called By : View GUI
Calls : Accuracy (MetaData NMCA) : acmtdaus.ave 
Accuracy (Report NMCA) : acrptaus.ave

Assumptions: Requires two themes to be loaded in a view: a reference theme (e.g., gps points of road intersections), and an input theme representing points of same locations digitized from a different layer (e.g., points of road intersections determined from roads layer). This script must be run from the views gui. Output distances are listed in Map Units except for "Allowable Error Distance", which is always reported as meters.

' Initialize Variables

theView = av.GetActiveDoc
thePrj = theview.GetProjection
wkDir = av.GetProject.GetWorkDir
theThemes = theView.GetThemes
firstCalledScript = av.GetProject.FindScript("Accuracy (MetaData NMCA)")
secondCalledScript = av.GetProject.FindScript("Accuracy (Report NMCA)")
theMapUnits = theView.GetUnits
FList = {}
RefPntList = {}
RefxList = {}
RefyList = {}
RefIDlist = {}
InpPntList = {}
InpxList = {}
InpyList = {}
InpIDlist = {}
DistList = {}
ref_fds = {}
Inp_fds = {}
CmnFldList = {}
CmnValList = {}
ver = "1.0"

' Initial Error Handling
If (not (theView.GetClass.GetClassName = "View")) then
    MsgBox.Warning("A View must be active to use this function.","Exiting")
    Return Nil
End
If (theMapUnits = #UNITS_LINEAR_UNKNOWN) then
    MsgBox.Warning("The View's Map Units must not be "UNKNOWN", ","Exiting)
    Return Nil
End
'If (firstCalledScript = Nil) then
'    MsgBox.Warning("Necessary Script "Accuracy (MetaData NMCA)" Not Found or Not Compiled","Exiting")
'    Return Nil
'End
'If (secondCalledScript = Nil) then
'    MsgBox.Warning("Necessary Script "Accuracy (Report NMCA)" Not Found or Not Compiled","Exiting")

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' Return Nil
'End

' Put feature themes in a list
For each Thm in theThemes
   If (Thm.Is(fTheme)) then
      fList.add(Thm)
   End
End

' Error Check List
If (Flist.Count < 2) then
   MsgBox.info("No feature Themes to Select From, must add a Theme to the View","ERROR")
   Return NIL
End

' Get info from User and Error Handle

' Get Reference & Input Themes
ref_theme = MsgBox.Choice(FList,
   "Choose the Reference Theme","Reference Selection")
If (ref_theme = NIL) then Return NIL End
Inp_theme = MsgBox.Choice(FList,
   "Choose the Input Theme","Input Selection")
If (Inp_theme = NIL) then Return NIL End
If (Inp_theme = ref_theme) then
   MsgBox.Info("Can't Compare Same Theme","Please Try Again")
   Return NIL
End
ref_Ftab = ref_theme.GetFTab
Inp_Ftab = Inp_theme.GetFTab

' Put Common Fields from Ref and Inp themes in a list
refFldList = Ref_FTab.GetFields
For Each Fld in refFldList
   If (Inp_Ftab.FindField(Fld.AsString) <> NIL) then
      CmnFldList.Add(Fld)
   End
End

' Allow User to Select common Field
RefCmnFld = MsgBox.List(CmnFldList,
   "Choose Common Field in Both Ref & Input to Compare","Reference Field")
InpCmnFld = Inp_Ftab.FindField(RefCmnFld.AsString)
If (RefCmnFld = NIL) then Return NIL End

' Get Points in reftheme and put in list
For each rec in ref_Ftab
   thePnt = Point.MakeNull
   ref_Ftab.QueryShape(rec,thePrj,thePnt)
   RefIDlist.Add(Ref_Ftab.ReturnValue(RefCmnFld,rec))
   RefPntList.Add(thePnt)
   RefxList.Add(thePntGetX)
   RefyList.Add(thePntGetY)
End

' Get Points in Inp theme and put in list
For each rec in Inp_Ftab
    thePnt = Point.MakeNull
    Inp_Ftab.QueryShape(rec, thePrj, thePnt)
    InpPntList.add(thePnt)
    InpIDlist.Add(Inp_Ftab.ReturnValue(InpCmnFld, rec))
    InpxList.Add(thePnt.GetX)
    InpyList.Add(thePnt.GetY)
End

' Check to make sure Ref and Input have same numbers of records (points)
If (InpxList.Count <> RefxList.Count) then
    System.Beep
    MsgBox.Error("Reference & Input themes must have the same number of points","NUM RECORD ERROR")
    Return NIL
End

' Check to make sure Common Field in Ref & Input have same values
For Each refValue in RefIDlist
    CmnVal = InpIdlist.FindByValue(refValue)
    CmnValList.Add(cmnVal)
End
If (CmnValList.FindByValue(-1) <> -1) then
    System.Beep
    MsgBox.Error("Reference & Input themes must have identical values in Common Field","COMMON FIELD VALUE ERROR")
    Return NIL
End

' Find out if user knows scale of the Input, If so input scale
ScaleKnown = MsgBox.MiniYesNo("Is the Scale of the Input Theme Known?",TRUE)
If (ScaleKnown) then
    Scale = MsgBox.Input("Enter Scale Denominator of Input Theme","Scale Input","20000")
    If (Scale.IsNumber.Not) then
        MsgBox.Info("Must Enter a Number","Please Try Again")
        Return Nil
    Else
        Scale = Scale.AsNumber.SetFormat("d")
    End
    If (Scale.<(1)) then
        MsgBox.Info("Denominator Must be a value of 1 or greater","Please Try Again")
        Return Nil
    Else
        Scale = "Unknown"
    End
Else
    Scale = Scale.AsNumber.SetFormat("d")
End

' Get Distance between points in ref and Inp
' (make sure keep track where proper info is in list
' i.e., find proper Pnt & Dist by getting Inp index
' number by using Ref Index number)
' This Makes sure Lining up lists by the Field user choose
Cnt = 0
TotDist = 0
TotDistSq = 0
TotXsq = 0
TotYsq = 0
For each rec in RefPntList
    RefID = RefIDlist.Get(Cnt)
    RefPnt = RefPntList.Get(Cnt)
    InpInd = InpIDlist.FindByValue(RefID)
    InpID = InpIDlist.Get(InpInd)
    InpPnt = InpPntList.Get(InpInd)
    DiffDist = RefPnt.Distance(InpPnt)
    DiffX = InpPnt.GetX - RefPnt.GetX
    DiffY = InpPnt.GetY - RefPnt.GetY
    TotDistSq = TotDistSq + (DiffDist^2)
    TotXsq = TotXsq + (DiffX^2)
    TotYsq = TotYsq + (DiffY^2)
    TotDist = TotDist + DiffDist
    DistList.Add(DiffDist)
    cnt = cnt + 1
End

' Calculate Average Distance, Std Dev, RMS, & Confidence Intervals
AvgDist = TotDist/Cnt
RMSd = (TotDistSq/Cnt).Sqrt
RMSx = (TotXsq/Cnt).Sqrt
RMSy = (TotYsq/Cnt).Sqrt
SumAvgDiffsqr = 0
    For each dist in DistList
        avgDiffsqr = (Dist - AvgDist)^2
        SumAvgDiffsqr = SumAvgDiffsqr + avgDiffsqr
    End
StdDev = ((1/(DistList.Count - 1)) * sumAvgDiffsqr).Sqrt
ci90 = AvgDist + (1.645 * StdDev)
ci95 = AvgDist + (1.960 * StdDev)
ci99 = AvgDist + (2.576 * StdDev)

' Run Scale Summary Report and include in metadata file if Scale
' is Known, Else write metadata without the report
If (ScaleKnown) then
    rptList = {Scale,DistList,theMapUnits,RefIDlist}
    ScaleList = av.Run("Accuracy (Report NMCA)",rptList)
Else
    ScaleList = Nil
End

' Write Metadata File
mtdList =
    {ref_theme,inp_theme,AvgDist,StdDev,ci90.AsString,ci95.AsString,ci99.AsString,wkdir,RefPntList,
RefxList,RefyList,InpIDlist,InpxList,InpyList,DistList,RefIDlist,RMSd,RMSx,RMSy,Scale.AsString,
ScaleList,ver}
accFN = av.Run("Accuracy (MetaData NMCA)",mtdList)
av.ShowMsg("Generated Accuracy Text File"++accFN.AsString++"...")
' Function : pans view to point selected in list box
' Called By : Accuracy (Attribute Dialog)
'----------------------------------------------------------------------

' Initialize variables
aDialog = self.GetDialog
aProj = av.GetProject

'Retrieve the table's Vtab from the object tag
aView = aDialog.GetObjectTag.Get(4)
aListBox = aDialog.GetObjectTag.Get(9)
aPntList = aDialog.GetObjectTag.Get(10)

' Get User Point
aPnt = aPntList.Get(aListBox.GetCurrentRow)
If (aPnt = Nil) then
   MsgBox.Info("No Point Selected, Please Try Again.", "Try Again.")
   Return Nil
End

' Pan to the points x and y
aView.GetDisplay.PanTo(aPnt)

'----------------------------------------------------------------------
'DiskFile : accPanLbx.ave : Accuracy (Pan from ListBox)
' Programmer : Van Niel
' Organization: CSIRO Land and Water
' Created : 02-Jun-2000
' Revisions :
'
' Function : pans view to point selected in list box
' Called By : Accuracy (Attribute Dialog)
'----------------------------------------------------------------------

' Initialize variables
aDialog = self.GetDialog
aProj = av.GetProject

'Retrieve the table's Vtab from the object tag
aView = aDialog.GetObjectTag.Get(4)
aListBox = aDialog.GetObjectTag.Get(9)
aPntList = aDialog.GetObjectTag.Get(10)

' Get User Point
aPnt = aPntList.Get(aListBox.GetCurrentRow)
If (aPnt = Nil) then
   MsgBox.Info("No Point Selected, Please Try Again.", "Try Again.")
   Return Nil
End

' Pan to the points x and y
aView.GetDisplay.PanTo(aPnt)

'----------------------------------------------------------------------
'DiskFile : acrprtus.ave : Accuracy (Report USNMAS)


' Programmer : Van Niel
' Created    : 03-May-00
' Revisions  :
'
' Function   : Summarises Distances from Input to Reference in relation to the scale (according to the
US National Map Accuracy Standards)
'
' Called By : Accuracy (USNMAS) : acusnmas.ave
' Calls      : None
' Assumptions: This program reports distances in meters - it will convert the original distance units to
meters if they are not meters already.
' ----------------------------------------------------------------------
' Get variables from calling script
Scale = SELF.Get(0)
DistList = SELF.Get(1)
theViewMapUnits = SELF.Get(2)
RefIdList = SELF.Get(3)

' Initialize Variables
RptDistList = {}
RptIdList = {}

' Convert the distances in the list to meters if they are not so already
If (theViewMapUnits <> #UNITS_LINEAR_METERS) then
    ConvertedDistList = {}
For each Dist in DistList
    DistMeters = Units.Convert(Dist,theViewMapUnits,#UNITS_LINEAR_METERS)
    ConvertedDistList.Add(DistMeters)
End
Else
    ConvertedDistList = DistList
End

' Determine appropriate error width based on Scale
' (e.g., 1/30th of an inch for scales larger than 1:20,000
' and 1/50th of an inch for scales <= 1:20,000)
If (Scale.>(20000)) then
    errorDistInches = Scale/30
Else
    errorDistInches = Scale/50
End

' Convert errorDist to meters. Conversion between units is based on the
' rule that 1 meter equals exactly 39.37 inches
errorDistMeters = (errorDistInches/39.37).SetFormat("d.dd")

' Count Number of points that exceed allowable error distance
Cnt = 0
CntExceeded = 0
For each Dist in ConvertedDistList
    If (Dist.>(errorDistMeters)) then
        RptDistList.Add(Dist)
        RptIdList.Add(RefIdList.Get(Cnt))
        CntExceeded = CntExceeded + 1
    End
    Cnt = Cnt + 1
End
' Calculate per cent exceeded
percentExceeded = (CntExceeded/Cnt) * 100

Return {RptDistList,RptIdList,CntExceeded,percentExceeded,errorDistMeters}

'----------------------------------------------------------------------
' DiskFile : acscaltl.ave : Accuracy (Set Scale from TextLine)
' Programmer : Van Niel
' Created : 01-Jun-2000
' Revisions :
'
' Function : Zooms to the Scale input into the TextLine
' Called By : Dialog
'----------------------------------------------------------------------

' Initialize variables
theDialog = self.GetDialog

'Retrieve the table's Vtab from the object tag
theView = theDialog.GetObjectTag.Get(4)
scaleTextLine = theDialog.GetObjectTag.Get(8)

' Pan and Zoom to extent specified by user

theScale = scaleTextLine.GetText
If ((theScale.IsNumber).Not) then
    MsgBox.Info("Scale must be a number (representing the denominator)","Exiting")
    Return Nil
End
theDisplay = theView.GetDisplay
theDisplay.ZoomToScale(theScale.AsNumber)

'----------------------------------------------------------------------
' DiskFile : acscalvw.ave : Accuracy (Set Scale from View)
' Programmer : Van Niel
' Created : 01-Jun-2000
' Revisions :
'
' Function : Zooms to the Scale of the view
' Called By : Dialog
'----------------------------------------------------------------------

' Initialize variables
theDialog = self.GetDialog

'Retrieve the table's Vtab from the object tag
theView = theDialog.GetObjectTag.Get(4)
theScale = theDialog.GetObjectTag.Get(7)
scaleTextLine = theDialog.GetObjectTag.Get(8)

' Pan and Zoom to extent specified by user
theScale = theView.ReturnScale
theDisplay = theView.GetDisplay
theDisplay.ZoomToScale(theScale)

' Put scale in scale textline
scaleTextLine.SetText(theScale.SetFormat("d.dddd").AsString)

' ----------------------------------------------------------------------
' DiskFile   : Accuracy (USNMAS) : acusnmas.ave
' Programmer : Van Niel & Kevin P Bartsch
' Created   : 06-May-99
' Revisions : 06-May-99/KPB/Initialization of program and User Input
'            : 06-May-99/TVN/Added portion of turning records in Ftabs
'            : 06-May-99/TVN/Allow specification of Common Field in
'            : both Reference and Input ("Inp") themes that links
'            : these themes together -- Records do not have to be
'            : in order in respect to this field
'            : 06-May-99/TVN/Calculation of Stats including avg,std
'            : deviation and Confidence Intervals
'            : 06-May-99/TVN/Output information into VTAB and finally
'            : (export) as text file
'            : 28-April-00/TVN/changed output to metadata style format
'            : and added call to metadata script - Accuracy (MetaData USNMAS)
'            : 03-May-00/TVN/added RMS and Scale calculation stuff -
'            : added call to report script - Accuracy (Report USNMAS)
'            : 19-May-00/TVN/added NSSDA calculation
'            : 19-May-00/TVN/changed output to metadata style format
'            : and added call to metadata script - Accuracy (MetaData USNMAS)
'            : 06-May-99/TVN/Output information into VTAB and finally
'            : (export) as text file
'            : 28-April-00/TVN/changed output to metadata style format
'            : and added call to metadata script - Accuracy (MetaData USNMAS)
'            : 03-May-00/TVN/added RMS and Scale calculation stuff -
'            : added call to report script - Accuracy (Report USNMAS)
'            : 19-May-00/TVN/added NSSDA calculation
'            : 19-May-00/TVN/changed output to metadata style format
'            : and added call to metadata script - Accuracy (MetaData USNMAS)
'            : 03-May-00/TVN/added RMS and Scale calculation stuff -
'            : added call to report script - Accuracy (Report USNMAS)
'            : 19-May-00/TVN/added NSSDA calculation

' Function   : Determines the accuracy of a coverage by comparing
'              the distance between reference points in a "ref_theme"
'              with corresponding points with common field values
'              in an "Inp_theme". Uses U.S. National Map Accuracy
'              Standards and U.S. National Standard for Spatial
'              Data Accuracy (NSSDA) to generate a report file.
'              HTML file is output to the users working directory.
' Called By  : View GUI
' Calls      : Accuracy (MetaData USNMAS) : acmtdaus.ave &
'              Accuracy (Report USNMAS)   : acrprtus.ave
' Assumptions: Requires two themes to be loaded in a view: a reference
'              theme (e.g., gps points of road intersections), and an input
'              theme representing points of same locations digitized
'              from a different layer (e.g., points of road intersections
'              determined from roads layer). This script must be run from
'              the views gui. Output distances are listed in Map Units
'              except for "Allowable Error Distance", which is always
'              reported as meters.
' ----------------------------------------------------------------------
' Initialize Variables

theView = av.GetActiveDoc
thePrj = theview.GetProjection
wkDir = av.GetProject.GetWorkDir
theThemes = theView.GetThemes
firstCalledScript = av.GetProject.FindScript("Accuracy (MetaData USNMAS)")
secondCalledScript = av.GetProject.FindScript("Accuracy (Report USNMAS)")
theMapUnits = theView.GetUnits
FList = {}  
RefPntList = {}  
RefxList = {}  
RefyList = {}  
RefIDlist = {}  
InpPntList = {}  
InpxList = {}  
InpyList = {}  
InpIDlist = {}  
DistList = {}  
ref_fds = {}  
Inp_fds = {}  
CmnFldList = {}  
CmnValList = {}  
ver = "1.0"

' Initial Error Handling
If (not (theView.GetClass.GetClassName = "View")) then
   MsgBox.Warning("A View must be active to use this function.","Exiting")
   Return Nil
End
If (theMapUnits = #UNITS_LINEAR_UNKNOWN) then
   MsgBox.Warning("The View's Map Units must not be "UNKNOWN".","Exiting")
   Return Nil
End
'If (firstCalledScript = Nil) then
'   MsgBox.Warning("Necessary Script "Accuracy (MetaData USNMAS)" Not Found or Not
'   Compiled","Exiting")
'   Return Nil
'End
'If (secondCalledScript = Nil) then
'   MsgBox.Warning("Necessary Script "Accuracy (Report USNMAS)" Not Found or Not
'   Compiled","Exiting")
'   Return Nil
'End

' Put feature themes in a list
For each Thm in theThemes
   If (Thm.Is(fTheme)) then
      fList.add(Thm)
   End
End

' Error Check List
If (Flist.Count < 2) then
   MsgBox.info("No feature Themes to Select From, must add a Theme to the
   View","ERROR")
   Return NIL
End

' Get info from User and Error Handle

' Get Reference & Input Themes
ref_theme = MsgBox.Choice(FList,  
   "Choose the Reference Theme","Reference Selection")
If (ref_theme = NIL) then Return NIL End
Inp_theme = MsgBox.Choice(FList,  

"Choose the Input Theme","Input Selection")
If (Inp_theme = NIL) then Return NIL End
If (Inp_theme = ref_theme) then
  MsgBox.Info("Can't Compare Same Theme","Please Try Again")
  Return NIL
End
ref_Ftab = ref_theme.GetFTab
Inp_Ftab = Inp_theme.GetFTab

' Put Common Fields from Ref and Inp themes in a list
refFldList = Ref_Ftab.GetFields
For Each Fld in refFldList
  If (Inp_Ftab.FindField(Fld.AsString) <> NIL) then
    CmnFldList.Add(Fld)
  End
End

' Allow User to Select common Field
RefCmnFld = MsgBox.List(CmnFldList,
                         "Choose Common Field in Both Ref & Input to Compare","Reference Field")
InpCmnFld = Inp_Ftab.FindField(RefCmnFld.AsString)
If (RefCmnFld = NIL) then Return NIL End

' Get Points in reftheme and put in list
For each rec in ref_Ftab
  thePnt = Point.MakeNull
  ref_Ftab.QueryShape(rec,thePrj,thePnt)
  RefIDlist.Add(Ref_Ftab.ReturnValue(RefCmnFld,rec))
  RefPntList.Add(thePnt)
  RefxList.Add(thePnt.GetX)
  RefyList.Add(thePnt.GetY)
End

' Get Points in Inp theme and put in list
For each rec in Inp_Ftab
  thePnt = Point.MakeNull
  Inp_Ftab.QueryShape(rec,thePrj,thePnt)
  InpIDlist.add(thePnt)
  InpCmnFld = Inp_Ftab.ReturnValue(InpCmnFld,rec))
  InpxList.Add(thePnt.GetX)
  InpyList.Add(thePnt.GetY)
End

' Check to make sure Ref and Input have same numbers of records (points)
If (InpxList.Count <> RefxList.Count) then
  System.Beep
  MsgBox.Error("Reference & Input themes must have the same number of points","NUM RECORD ERROR")
  Return NIL
End

' Check to make sure Common Field in Ref & Input have same values
For Each refValue in RefIDlist
  CmnVal = InpIDlist.FindByValue(refValue)
  CmnValList.Add(CmnVal)
End
If (CmnValList.FindByValue(-1) <> -1) then
System.Beep
MsgBox.Error("Reference & Input themes must have identical values in Common Field","COMMON FIELD VALUE ERROR")
Return NIL
End

' Find out if user knows scale of the Input, If so input scale
ScaleKnown = MsgBox.MiniYesNo("Is the Scale of the Input Theme Known?",TRUE)
If (ScaleKnown) then
  Scale = MsgBox.Input("Enter Scale Denominator of Input Theme","Scale Input","20000")
  If (Scale.IsNumber.Not) then
    MsgBox.Info("Must Enter a Number","Please Try Again")
    Return Nil
  Else
    Scale = Scale.AsNumber.SetFormat("d")
  End
  If (Scale.<(1)) then
    MsgBox.Info("Denominator Must be a value of 1 or greater","Please Try Again")
    Return Nil
  Else
    Scale = "Unknown"
  End
Else
  Scale = Scale.AsNumber.SetFormat("d")
End
If (Scale.<(1)) then
  MsgBox.Info("Denominator Must be a value of 1 or greater","Please Try Again")
  Return Nil
Else
  Scale = "Unknown"
End

' Get Distance between points in ref and Inp
' (make sure keep track where proper info is in list
' i.e., find proper Pnt & Dist by getting Inp index
' number by using Ref Index number)
' This Makes sure Lining up lists by the Field user choose
Cnt = 0
TotDist = 0
TotDistSq = 0
TotXsq = 0
TotYsq = 0
For each rec in RefPntList
  RefID = RefIDlist.Get(Cnt)
  RefPnt = RefPntList.Get(Cnt)
  InpInd = InpIDlist.FindByValue(RefID)
  InpID = InpIDlist.Get(InpInd)
  InpPnt = InpPntList.Get(InpInd)
  DiffDist = RefPnt.Distance(InpPnt)
  DiffX = InpPnt.GetX - RefPnt.GetX
  DiffY = InpPnt.GetY - RefPnt.GetY
  TotDistSq = TotDistSq + (DiffDist^2)
  TotXsq = TotXsq + (DiffX^2)
  TotYsq = TotYsq + (DiffY^2)
  TotDist = TotDist + DiffDist
  cnt = cnt + 1
End

' Calculate Average Distance,Std Dev, RMS, Confidence Intervals, & NSSDA
AvgDist = TotDist/Cnt
RMSd = (TotDistSq/Cnt).Sqrt
RMSx = (TotXsq/Cnt).Sqrt
RMSy = (TotYsq/Cnt).Sqrt
SumAvgDiffsqr = 0
For each dist in DistList
    avgDiffsqr = (Dist - AvgDist)^2
    SumAvgDiffsqr = SumAvgDiffsqr + avgDiffsqr
End
StdDev = ((1/(DistList.Count - 1)) * sumAvgDiffsqr).Sqrt
ci90 = AvgDist + (1.645 * StdDev)
ci95 = AvgDist + (1.960 * StdDev)
ci99 = AvgDist + (2.576 * StdDev)
NSSDA = 1.7308 * RMSd
NSSDAnot = 2.4477 * 0.5 * (RMSx + RMSy)

' Run Summary Report and include in metadata file if Scale Known
' is Known, Else write metadata without the report
If (ScaleKnown) then
    rptList = {Scale,DistList,RefIDlist}
    ScaleList = av.Run("Accuracy (Report USNMAS)",rptList)
Else
    ScaleList = Nil
End

' Write Metadata File
mtdList =
    {ref_theme,inp_theme,AvgDist,StdDev,ci90.AsString,ci95.AsString,ci99.AsString,mdir,RefPntList,
RefxList,RefyList,InpIDList,InpxList,InpyList,DistList,RefIDlist,RMSd,RMSx,RMSy,Scale.AsString,
ScaleList,ver,NSSDA,NSSDAnot}
accFN = av.Run("Accuracy (MetaData USNMAS)",mtdList)
av.ShowMsg("Generated Accuracy Text File"++accFN.AsString+"...")
theTableList.Add(d)
End

' Error Handling
If (theTableList.Count = 0) then
  MsgBox.Info("No Tables in Project","Add Table to Project")
  Return Nil
End

' Get the Table & list of fields to update from the User
aTable = MsgBox.ListAsString(theTableList,"Choose Table representing the
  "Reference"","Table Input")
If (aTable = Nil) then Return Nil End
aVtab = aTable.GetVtab
aFieldList = aVtab.GetFields

' If table is not an Ftab, then exit
shpFld = aVtab.FindField("Shape")
If (shpFld = Nil) then
  MsgBox.Info("Table Entered must be an Ftab ","Exiting")
  Return Nil
End

' Allow user to choose unique field to pan/zoom to
idFld = MsgBox.ListAsString(aFieldList,"Choose identifier Field used for pan/zoom","Field Input")
If (idFld = Nil) then Return Nil End

cnt = 0
For each rec in aVtab
  id = aVtab.ReturnValue(idFld,cnt)
  idList.Add(id)
  cnt = cnt + 1
End

' Make Data Entry Dialog
'scale
aDialog = Dialog.Make(false,true,true,true,true)
aControlPanel = aDialog.GetControlPanel
scaleButton = LabelButton.Make
scaleButton.SetLabel("Set Scale from View")
scaleButton.SetName("Set Scale from View")
scaleButton.SetClick("Accuracy (Set Scale from View)")
scaleButton.SetEnabled(TRUE)
scaleButton.SetHelp ("Set Scale from View.")
aControlPanel.Add(scaleButton,Rect.Make(1@1,150@20))
scaleTextLine = TextLine.Make
scaleTextLine.SetName("ScaleTextLine")
scaleTextLine.SetLabel("Scale 1:")
scaleTextLine.SetEnabled(TRUE)
scaleTextLine.SetChanged("Accuracy (Set Scale from TextLine)")
scaleTextLine.SetText(theScale.SetFormat("d.dddd").AsString)
aControlPanel.Add (scaleTextLine,Rect.Make(1@30,150@10))
scaleButton.AddListener(scaleTextLine)

' pan
idListBox = ListBox.Make
idListBox.SetName("PanListBox")
idListBox.DefineFromList(idList)
idListBox.SetEnabled(TRUE)
idListBox.SetUpdate("Accuracy (Pan from ListBox)")
aControlPanel.Add (idListBox, Rect.Make(1@60,150@80))

aDialog.SetTitle("Pan/ZoomDialog
for"+aVtab.GetBaseTableName.GetBaseName.AsString.Quote)
aDialog.SetExtent(rect.Make(1@1,170@180))
aDialog.SetObjectTag({aVtab,theView,theScale,scaleTextLine,idListBox})
av.GetProject.AddDialog(aDialog)
aDialog.Open
scaleButton.BroadcastUpdate
APPENDIX C:

HORIZONTAL ACCURACY EXTENSION HELP VERSION 1.0

Welcome to the Horizontal Accuracy Extension Help! These programs are brought to you by the Cooperative Research Centre for Sustainable Rice Production, Project 1.1.05, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Land and Water, and Utah State University, Departments of Forest Resources and Geography and Earth Resources, RS/GIS Laboratory. This extension is provided as freeware, and as such, the scripts may be freely used and redistributed with the understanding that they are provided "AS-IS" without warranty of any kind.

1.0 Description/Discussion
2.0 Assumptions
3.0 Point of Contact
4.0 Help (Tutorial)
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Description

The 'Horizontal Accuracy Extension' is an extension to ArcView designed to assist in the reporting of positional (horizontal) accuracy to national map accuracy standards in both the United States and Australia. It also calculates the accuracy to the National Standard for Spatial Data Accuracy (NSSDA) for the United States. The extension relies on the user to define two POINT themes: 1.) the "reference" theme and 2.) the "input" theme. The reference theme represents 'trusted' or 'true' positions of well-defined features, while the input theme represents positions of the same features on a map or GIS layer. The input theme's positions are then compared to the reference theme's positions. The user should also know the scale of the input theme. Click on sample output for more details. The output report should help meet the horizontal positional accuracy requirements for both the Federal Geographic Data Committee (FGDC) metadata standards and the Australian New Zealand Land Information Council (ANZLIC) metadata standards.

The first two options in the Horizontal Accuracy menu are intended to aid in the creation and attribute population of the input table. The user may wish to set up the input table in a different manner. However, the 'normal' case for which these options were designed is described next. I have assumed that in most cases, the reference theme will be generated from a Differential Global Positioning System (D-GPS). The user will have gone to well defined features in the study area and measured its 'true' location with the D-GPS. The points would have then been converted to a GIS theme and attributed with at least one field that uniquely identifies each point from all other points. At this time, the user will want to create an input theme created from some other source (e.g., a GIS layer, map sheet, etc.). If the user is going to create the input theme from a GIS layer, then the first two options of this extension may be of some help, since, in most cases, the user would digitise these points off of the screen in
ArcView. If this is not the case (e.g., you want to digitise the points off a map sheet from a digitising tablet or you have a text file of x,y locations) then the user will need to create and set up the input theme properly through other means (the first two tools will not be of much use). The output will be a horizontal accuracy report of the original source for the input theme. For example, if I compared road intersection points digitised from a USGS or AUSLIG 1:250,000 scale GIS roads coverage and compared them to D-GPS points of the same road intersections, the report would represent the 1:250,000 scale GIS coverage's horizontal accuracy.

With all of that said, the tool should be fairly straightforward. All the user needs is an attributed reference theme of points (GPS), an input theme of points (with the same field as in the reference theme and attributes to match associated points), and knowledge of the scale of the source of the input theme.

Two ArcView shapefiles have been included in acc_help.zip file to show the user how the reference and input files need to be set up and to provide a sample data set. The sample reference is called acc_ref.shp and the sample input is called acc_inp.shp. Please note, these two files do not represent real accuracy test points, but were made up for this purpose only.

Assumptions

The user must be aware of a few items to facilitate proper use of this extension.

1) Both the "reference" and "input" themes must be POINT themes.
2) Both of these themes (reference and input) must have a common field which links the points properly (e.g., if "ID" is the linking field, then the reference point with ID = 1 should represent the same feature as input point with ID = 1, and so on...).
3) The reference and input theme should have the same number of points.
4) The reference theme should be "more accurate" than the input theme (the reference theme should represent "true position").
5) The resulting output reports on the accuracy of the input points to the reference points (if the sample of points is representative of the overall area, then this relates to the accuracy of the input source).
6) The report is output to the working directory, which is set in ArcView.
7) The ArcView view's properties must be set so that the map and distance units are set to something other than "unknown".

Also, the user should be aware that some of the output distances will be expressed in the map units of the view and others will be converted to meters. These are properly labelled in the output.

Point of Contact

Van Niel
Sustainable Catchment & Groundwater Management Program
CSIRO Land and Water
C.S. Christian Laboratory
GPO Box 1666
Canberra ACT 2601
Australia
Help (Tutorial)

The extension adds a menu item to the view's Graphical User Interface (GUI) called "Horizontal Accuracy". Inside of this new menu item are four options. The first two (Make New "Input" Table and Edit "Input" Table) deal with setting up the input theme so it is easily associated with an already existing reference theme. The last two options run the horizontal accuracy report either to Australian or USA standards.

### Horizontal Accuracy

- Make New "Input" Table
- Edit "Input" Table
- Run Horizontal Accuracy (AUS)
- Run Horizontal Accuracy (USA)

Making a New "Input" Table

The Make New "Input" Table option allows a user to make an empty table with the same characteristics as the reference table. This new empty input table can then be populated using the Edit "Input" Table option. This program requires that the reference table already exists inside of the ArcView project (and that the reference table is a point Ftab (i.e., that the user has added the reference point theme and clicked on the table button to reveal the attributes of the reference theme)). The output of this program will be a dbf table that includes any fields that the user specifies from the reference as well as an "X" and "Y" field. From this table, the user should add an event theme and export this to a proper shapefile. Please NOTE, these steps can be done manually as long as the user defines an x, y, and identifier field in relation to a reference theme.

### Message Box: "Choose Reference Table"

A list of all tables in the project are displayed in this menu. The user should select the table that represents the reference's Ftab.
Message Box: "Choose Field(s) to retain in New Table. Must Select at Least One Field to Link Input to Reference"

A list of all fields in the reference Ftab are displayed in this menu. The user should select the field(s) that will be duplicated in the new "Input" table. **Do not** retain the "Shape" field.

Message Box: "Enter "X" Field Characteristics"

Enter the name, width and number of decimal places for the new field that will contain the x location of the points in the input.
**Message Box: "Enter "Y" Field Characteristics"**

Enter the name, width and number of decimal places for the new field that will contain the y location of the points in the input.

![Enter "Y" Field Characteristics](image)

**Message Box: "Enter Output File Name (.dbf)"

Enter the name of the output file. This file should have a .dbf extension.

![Enter Output File Name (.dbf)](image)

**Message Box: "Add New Table To Project?"

Press "Yes" if you want to add this new table to the Project or "No" if you do not want the table added to the project.

![Add New Table To Project?](image)

The new table should look something like this. The "x" and "y" fields and any other fields that the user selected above. The new table will be empty. The user must now populate this table with at least the x and y coordinates and an identifier attribute that links a point to its associated point in the reference.

![Table](image)
Editing "Input" Table

The Edit "Input" Table option allows a user to edit the input table while "panning" around the view based on selections from attributes in the reference identifier field. This option as well is only for convenience. The user need not use this option, but may rather populate the table in a different manner manually.

This option eventually brings up an interactive dialog box in which the user can change the scale of the view, pan to attributes in the reference theme, collect x and y locations of an input point automatically off of the view and commit the data to the input table.

This is one of the ways the user can populate the input table in preparation for final accuracy assessment against the reference. After this table is populated, the user should add it as an event theme and then export it to a proper shapefile.
**Message Box: "Choose Data Entry Table ("Input" Table)"

A list of all tables in the project are displayed in this menu. The user should select the table that represents the Input table (cannot be an Ftab at this point).

![Choose Data Entry Table ("Input" Table)](image)

**Message Box: "Choose "X" Field"

A list of all fields in the Input table is displayed in this menu. The user should select the field that represents (or will represent) x locations of input points.

![Choose "X" Field](image)

**Message Box: "Choose "Y" Field"

A list of all fields in the Input table is displayed in this menu. The user should select the field that represents (or will represent) y locations of input points.

![Choose "Y" Field](image)
Message Box: "Choose Table representing the "Reference"
A list of all tables in the project are displayed in this menu. The user should select the table that represents the Reference Ftab table.

Message Box: "Choose Identifier Field"
A list of all fields in the Reference table is displayed in this menu. The user should select the field that represents (or will represent) the identifier field (field used to link input to reference).

A dialog box should appear, after the user clicks on Start Editing, records can be added to the input table.
Once the table is populated,

The user should add the table as an event theme and then convert the table to a shapefile.
Running Accuracy Report

The Run Horizontal Accuracy options allow you to compare the input theme to the reference theme and quantify the results in html format. The user can run the report using either Australian (AUS) or United States (USA) map accuracy standards. The Australian standards are specified by the National Mapping Council of Australia which specify that no more than 10% of well-defined features on a map should be in error by larger than 0.5 mm of the map scale. The United States standards are defined by the United States National Map Accuracy Standards which specify that no more than 10% of well-defined features on a map should be in error by a distance of 1/30 inch on map scales equal to or larger than 1:20,000 and 1/50 inch on scales smaller than 1:20,000.

Message Box: "Choose the Reference Theme"

A list of all feature themes in the project is displayed in this menu. The user should select the theme that represents the reference points theme (e.g., Differential GPS points).

Message Box: "Choose the Input Theme"

A list of all feature themes in the project is displayed in this menu. The user should select the theme that represents the input points theme (e.g., points defined from a GIS layer representing the same features as the points in the reference theme).

Message Box: "Choose Common Field in Both Ref & Input to Compare"

A list of all fields in the Reference table is displayed in this menu. The user should select the field that represents the identifier field (field used to link input to reference). This field should
contain attributes that uniquely identify the points in both the reference and the input themes. In other words, if the common field is "ID", then the point that has the attribute of ID = 1 in the reference should represent the same feature as the point in the input theme that has ID = 1 (and so on). This way, the points are uniquely identifiable from other points in the same theme, but also linked to the appropriate points in the associated theme.

Message Box: "Is the Scale of the Input Theme Known?"

The user should click "Yes" if the scale of the input is known or "No" if the scale of the input is not known. If the scale is known, then the report will calculate the acceptable error distance based on the map scale, and will summarise the percent of the points that exceed this distance. If the user does not know the input theme scale, then the report will skip over this calculation and summary.

Message Box: "Enter Scale Denominator of Input Theme"

If the user clicks "Yes" in the previous window, a prompt for entering the scale denominator of the input theme will be displayed. The user should fill in the denominator (bottom) of the scale. For example, on a 1/24,000 input theme, the user would type in 24000 (leaving off any commas or non-number characters).

At this point, the program runs and displays the name of the output file and where it was placed on the users’ computer. The output always goes to the users working directory. The user can change this path by going to File/Set Working Directory.
Sample Output

The sample data used in this example comes from the "Positional Accuracy Handbook" published by the Minnesota Planning Land Management Information Center. This reference should be reviewed for examples of proper positional accuracy assessment and background information.

Horizontal accuracy report based on United States National Standard for Spatial Data Accuracy (NSSDA) and United States National Map Accuracy Standards (USNMAC)

General Information

Distance Summary
United States National Map Accuracy Standards Summary
National Standard for Spatial Data Accuracy Summary
Total Points Summary

General Information

Reference: c:\temp\mnind.shp
Input: c:\temp\mntst.shp
Scale of Input: 1:3000
Description: Horizontal Accuracy Assessment calculated using "Accuracy (USNMAS)"
Avenue Script
Relevant URL: United States National Map Accuracy Standards; National Standard for Spatial Data Accuracy
Date Processed: Mon Jun 19 15:46:43 2000
Version: 1.0

Distance Summary (in Map Units of the View)

Mean Difference Distance: 0.0917255
Standard Deviation of Difference Distance: 0.0504028
Upper Limit for 90% Confidence Interval of Mean Difference Distance: 0.17489
Upper Limit for 95% Confidence Interval of Mean Difference Distance: 0.192531
Upper Limit for 99% Confidence Interval of Mean Difference Distance: 0.242934
RMSE Difference Distance: 0.104358
RMSE X: 0.0693722
RMSE Y: 0.0779615
RMSEmin/RMSEmax: 0.889826
NSSDA 95% Confidence Level (RMSEx=RMSEy): 0.180622
NSSDA 95% Confidence Level (RMSEx<>RMSEy): 0.180314

[Top]
United States National Map Accuracy Standards Summary

Allowable error distance is based on the United States National Map Accuracy Standards where GIS layers with scales larger than 1:20,000 should not have more than 10 percent of the points tested in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. This means that the distance is calculated based on the distance of 1/30 or 1/50 of an inch at the scale of the input GIS layer. For example, if the scale of the input GIS layer is 1:100,000, then 1/50 of an inch is calculated by: 1 inch = 100,000 inches, so 1/50 inch = 100,000/50 = 2,000 inches = 2,000 inches/39.37 (inches per meter) = 50.8 meters

Allowable Error Distance (meters): 2.54
Number of Points Exceeding Allowable Error: 0 of 40
Percent of Points Exceeding Allowable Error: 0

National Standard for Spatial Data Accuracy Summary

When RMSEx = RMSEy, NSSDA value is calculated by multiplying the RMSE by 1.7308. This represents the horizontal accuracy at the 95% confidence level. This is assuming that systematic errors have been eliminated as best as possible and that error is normally distributed and independent in each the x- and y-component (i.e., 2.4477 * RMSEx = 2.4477 * RMSEy = 2.4477 * RMSEr/1.4142 = 1.7308 * RMSEr). When RMSEx <> RMSEy and RMSEmin/RMSEmax is between 0.6 and 1.0 (where RMSEmin is the smaller value between RMSEx and RMSEy and RMSEmax is the larger value), circular standard error for the 95% confidence level can be approximated by 2.4477 * 0.5 * (RMSEx + RMSEy).

If RMSx = RMSy:
Tested 0.180622 (map units) horizontal accuracy at 95% confidence level

If RMSx <> RMSy:
Tested 0.180314 (map units) horizontal accuracy at 95% confidence level
## Total Point Summary

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[Top]
Table of allowable error distances for some common map scales

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<th>Map Scale</th>
<th>Allowable Distance (m)</th>
<th>Allowable Distance (m)</th>
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* common map scale in USA

Credits
The author would like to thank Kevin Bartsch (USU) for partnership in both project design and coding of initial avenue accuracy script as well as Tim McVicar (CSIRO) for valuable comments on reporting results.
APPENDIX D:

FGDC COMPLIANT METADATA

Download NOAA metadata extension at:
http://www.csc.noaa.gov/metadata/text/download.html

Digital Aerial Photographs for Coleambally Irrigation Area (2m pixels for year 2000)

Table of Contents
- Identification Information
- Data Quality Information
- Spatial Data Organization Information
- Spatial Reference Information
- Entity and Attribute Information
- Distribution Information
- Metadata Reference Information

IDENTIFICATION_INFORMATION

Citation:

Citation_Information:
- Originator: Airesearch Mapping Pty Ltd
- Publication_Date: 20000608
- Title: Digital Aerial Photographs for Coleambally Irrigation Area
  (2m pixels for year 2000)
- Edition: First

Geospatial_Data_Presentation_Form: Map

Publication_Information:
- Publication_Place: CSIRO Land and Water; C.S. Christian Laboratory; GPO Box 1666; Canberra ACT 2601; Australia
- Publisher: Van Niel

Other_Citation_Details:


Larger_Work_Citation:

Citation_Information:
- Originator: Coleambally Irrigation Limited; Rice CRC
- Publication_Date:
- Title: Coleambally Irrigation Limited GIS program

Publication_Information:
- Publication_Place:
- Publisher:

Online_Linkage:

Description:

Abstract:
The original photographs were acquired by Airesearch Mapping Pty Ltd on 8 and 9 January 2000. These photographs (at a scale of 1:50,000) were scanned in and georegistered
to AMG Zone 55, AGD66 based on ground control points collected from both Digital Topographic Data Base (DTDB) 1:50,000 GIS layers and Differential Global Positioning System (D-GPS) points provided to Airesearch by Coleambally Irrigation Limited (CIL).

The main Coleambally Irrigation Area (CIA) was covered by 40-plus digital photographs (herein referred to as tiles). Each tile was georegistered by using no less than 6 gcps (personal communication with Ray Jones of Airesearch indicated that more like 20 gcps per tile was used in georegistration). Original product delivered by Airesearch was the numerous georegistered tiles covering the main CIA area at 2m pixel size and the ‘off’ CIA area with a pixel size of 4m.

Van Niel (CSIRO Land and Water) processed the individual tiles delivered by Airesearch to reduce radial distortion and then mosaiced the tiles to produce one image with a 2m pixel size of the main CIA area, as well as a 4m resampled image of the same area. Both of these images were then re-registered using approximately 64 D-GPS points of road and drainage intersections to reduce horizontal positional inaccuracies.

Purpose:

The original data provided by Airesearch Mapping Pty Ltd was produced in order to classify and measure area of rice on the Coleambally Irrigation Area (CIA). This original data was then processed to create one mosaiced "lowest positional inaccuracy" image to provide a baseline for creation and correction of all GIS data at Coleambally Irrigation Limited.

Supplemental Information:

Time_Period_of_Content:

Time_Period_Information:

Range_of_Dates/Times:

Beginning_Date: 20000608

Ending_Date: 20000609

Currentness_Reference: ground condition

Status:

Progress: Complete

Maintenance_and_Update_Frequency: Continually

Spatial_Domain:

BoundingCoordinates:

West_BoundingCoordinate: 142.5000

East_BoundingCoordinate: 147.0000

North_BoundingCoordinate: -33.0000

South_BoundingCoordinate: -36.0000

Keywords:

Theme:
Theme_Keyword_Thesaurus: None
Theme_Keyword: air photos
Theme_Keyword: rice
Theme_Keyword: baseline
Theme_Keyword: imagery
Theme_Keyword: image
Place:
Place_Keyword_Thesaurus: None
Place_Keyword: Australia
Place_Keyword: Coleambally
Place_Keyword: Coleambally Irrigation Area
Place_Keyword: Coleambally Irrigation Limited
Place_Keyword: CIA
Place_Keyword: CIL
Access_Constraints:
The information herewith supplied to you (Van Niel) is owned by Coleambally Irrigation Limited. This information is provided to you for your personal use and may not be copied, reproduced or used for any purpose other than the purpose approved by Coleambally Irrigation Limited Purpose of Use: Aerial photography and northern paddock boundaries (1996/97) used for Fine Vector/Coarse Raster and Crop Separation satellite imagery projects. This information will also be used in assisting CIL to define an accurate 'base layer'.
Use_Constraints:
Coleambally Irrigation Limited do not authorise the use of this information in any form of commercial endeavour. Should you wish to use this information for commercial purposes you must obtain written authorisation from Coleambally Irrigation Limited. Written authorisation can be obtained by making a formal request in writing to the Company Secretary
Point_of_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: CSIRO Land and Water
Contact_Person: Thomas G. Van Niel
Contact_Position: Spatial Environmental Modeller
Contact_Address:
Address_Type: mailing and physical address
Address: Sustainable Catchment & Groundwater Management Program
        CSIRO Land and Water
City: Canberra
State_or_Province: ACT
Postal_Code: 2601
Country: Australia
Contact_Voice_Telephone: +61-2-6246 5816
DATAQUALITYINFORMATION

ATTRIBUTEACCURACY:

AttributeAccuracyReport:
NotApplicablefor"raw"imagerydata

LogicalConsistencyReport:
NotApplicablefor"raw"imagerydata

CompletenessReport:
NotApplicablefor"raw"imagerydata

PositionalAccuracy:

HorizontalPositionalAccuracy:

HorizontalPositionalAccuracyReport:
HORIZONTALACCURACYREPORTBASEDONNATIONALMAPPINGCOUNCILOFAUSTRALIASTANDARDS

GeneralInformation

Reference:d:\cia\data\shapes\cgpstest.shp
Input:d:\cia\data\shapes\cia2mr2.shp
ScaleofInput:1:50000

Description:HorizontalAccuracyAssessmentcalculatedusing"Accuracy(NMCA)"AvenueScript
DateProcessed:FriMay2616:57:452000
Version:1.0

DistanceSummary(inMapUnitsoftheView)

MeanDifferenceDistance:8.06574
StandardDeviationofDifferenceDistance:4.35575
UpperLimitfor90%ConfidenceIntervalofDifferenceDistance:15.2527
UpperLimitfor95%ConfidenceIntervalofDifferenceDistance:16.7773
UpperLimitfor99%ConfidenceIntervalofDifferenceDistance:21.133
RMSDifferenceDistance:9.11731
National Mapping Council of Australia Map Accuracy Standards Summary

Allowable error distance is based on the National Mapping Council Map Accuracy Standards where GIS layers should not have more than 10 percent of well-defined points tested in error by more than 0.5 millimetres, measured on the publication scale. This means that the distance is calculated based on the distance of 0.5 millimetres at the scale of the input GIS layer. For example, if the scale of the input GIS layer is 1:100,000, then 0.5 of a millimetre is calculated by: 1 millimetre = 100,000 millimetres, so 1/2 millimetres = 100,000/2 = 50,000 millimetres = 50 metres

Allowable Error Distance (meters): 25.00
Number of Points Exceeding Allowable Error: 0 of 21
Percent of Points Exceeding Allowable Error: 0

Total Point Summary

"ID","Xref","Yref","Xinp","Yinp","Dist"
4,409753.5000,6143930.0000,409748.3900,6143925.0650,7.10397
8,417476.0700,6152069.0300,417475.1800,6152063.8650,5.24112
12,415680.0000,6142547.0000,415688.7890,6142548.3790,8.89653
16,417813.1800,6152937.2600,417817.7180,6152936.3120,4.63596
20,418549.9800,6157779.6100,418560.4660,6157786.5480,12.5735
24,414032.9200,6156527.3400,414042.7650,6156523.1200,10.7113
28,410571.2300,6150097.5600,410573.8910,6150081.0780,16.6954
32,409699.7700,6143932.2000,409706.0470,6143923.2420,10.9383
36,401046.0300,6150424.3200,401048.0610,6150421.2120,3.71277
40,404438.7900,6154485.9400,404428.9640,6154493.2420,10.9383
44,410441.0900,6158898.5600,410440.9160,6158898.2720,0.336482
48,407029.0700,6151316.7900,407019.0810,6151313.9030,10.3978
52,406068.0200,6148975.8300,406062.1180,6148965.7190,11.7075
56,406290.0800,6143156.9100,406289.4690,6143153.2270,3.73334
60,402383.2100,6139529.7700,402372.3790,6139526.4280,11.3349
64,395604.6800,6144056.6000,395609.7710,6144044.1050,13.4923
68,386169.5000,6141585.4500,386166.7730,6141587.5070,3.41581
72,399968.0100,6131802.6400,399965.7230,6131804.0580,2.69093
76,404389.2700,6130076.1300,404387.5560,6130085.6750,9.69767
80,400385.7900,6123397.5500,400382.7500,6123399.8240,3.7964
84,412959.3200,6133709.2800,412964.9710,6133711.6510,6.12825

_____________________________
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report:
Not Applicable for this "raw" imagery data
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
   Originator: Airesearch Mapping Pty Ltd
   Publication_Date: 20000608
Title: Digital Aerial Photographs for Coleambally Irrigation Area
   (2m pixels for year 2000)
Edition: First
Geospatial_Data_Presentation_Form: map
Publication_Information:
   Publication_Place: CSIRO Land and Water; C.S. Christian Laboratory; GPO Box 1666; Canberra ACT 2601; Australia
   Publisher: Van Niel
Other_Citation_Details:
Larger_Work_Citation:
Citation_Information:
   Originator: Coleambally Irrigation Limited; Rice CRC
   Publication_Date:
   Title: Coleambally Irrigation Limited GIS program
Publication_Information:
   Publication_Place:
   Publisher:
   Online_Linkage:
Source_Scale_Denominator: 50000
Type_of_Source_Media: Photograph
Source_Time_Period_of_Content:
   Time_Period_Information:
   Range_of_Dates/Times:
      Beginning_Date: 20000608
      Ending_Date: 20000609
   Source_Currentness_Reference: Ground Condition
Source_Citation_Abbreviation:
Source_Contribution:
Source_Information:
Source_Citation:
Citation_Information:
   Originator: Airesearch Mapping Pty Ltd
   Publication_Date: 20000608
Title: Digital Aerial Photographs for Coleambally Irrigation Area
   (2m pixels for year 2000)
Edition: First
Geospatial_Data_Presentation_Form: map
Publication_Information:
   Publication_Place: CSIRO Land and Water; C.S. Christian Laboratory; GPO Box 1666; Canberra ACT 2601; Australia
   Publisher: Van Niel
Other_Citation_Details:
Beginning_Date: 20000608
Ending_Date: 20000609
Source_Currentness_Reference: Ground Condition
Source_Citation_Abbreviation:
Source_Contribution:
Source_Information:
Source_Citation:
Citation_Information:
Originator: Airesearch Mapping Pty Ltd
Publication_Date: 20000608
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Edition: First
Geospatial_Data_Presentation_Form: map
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Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication_Place: CSIRO Land and Water; C.S. Christian Laboratory; GPO Box 1666; Canberra ACT 2601; Australia
Publisher: Van Niel
Other_Citation_Details:
Larger_Work_Citation:
Citation_Information:
Originator: Coleambally Irrigation Limited; Rice CRC
Publication_Date:
Title: Coleambally Irrigation Limited GIS program
Publication_Information:
Publication_Place:
Publisher:
Online_Linkage:
Source_Scale_Denominator: 50000
Type_of_Source_Media: Photograph
Source_Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 20000608
Ending_Date: 20000609
Source_Currentness_Reference: Ground Condition
Source_Citation_Abbreviation:
Source_Contribution:
Process_Step:
Process_Description:
1.) Copied individual jpeg tiles from Janelle Dufty
2.) (CD-Roms provided by Airesearch Mapping Pty Ltd)
3.) Converted Jpegs to Erdas Imagine Format.
3.) Mosaiced full tiles together.
4.) Subset out center of all tiles to get rid of outer edges of imagery (to reduce radial displacement)
5.) Mosaiced the subset images together into one image
covering all of CIA

6.) Re-registered imagery based on 64 D-GPS points around CIA Ran horizontal positional accuracy report using 21 D-GPS points not used in re-registration (Step 6) (i.e., there was a total of 85 D-GPS points used, 64 for registration and 21 for accuracy checking).

Source_Used_Citation_Abbreviation:
Process_Date: 20000608
Source_Produced_Citation_Abbreviation:
Process_Contact:
Contact_Information:
  Contact_Person_Primary:
    Contact_Organization: CSIRO Land and Water
    Contact_Person: Thomas G. Van Niel
    Contact_Position: Spatial Environmental Modeller
    Contact_Address:
      Address_Type: mailing and physical address
      Address: Sustainable Catchment & Groundwater Management Program
      City: Canberra
      State_orProvince: ACT
      Postal_Code: 2601
      Country: Australia
      Contact_Voice_Telephone: +61-2-6246 5816
      Contact_Facsimile_Telephone: +61-2-6246 5800
      Contact_Electronic_Mail_Address: thomas.van.niel@cbr.clw.csiro.au
    Hours_of_Service:

SPATIAL_DATA_ORGANIZATION_INFORMATION

  Direct_Spatial_Reference_Method: Raster
  Raster_Object_Information:
    Raster_Object_Type: Pixel
    Row_Count: 23734
    Column_Count: 23648

SPATIAL_REFERENCE_INFORMATION

  Horizontal_Coordinate_System_Definition:
    Planar:
      Map_Projection:
      Planar_Coordinate_Information:
        Planar_Coordinate_Encoding_Method: Row and column
        Coordinate_Representation:
          Abscissa_Resolution:
Ordinate Resolution: Meters

Geodetic Model:
  Horizontal Datum Name: AGD66
  Ellipsoid Name: Other
  Semi-major Axis:
  Denominator of Flattening Ratio:

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ENTITY_AND_ATTRIBUTE_INFORMATION

Overview Description:
  Entity and Attribute Overview:
  Entity and Attribute Detail Citation:

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DISTRIBUTION_INFORMATION

Distributor:
  Contact Information:
    Contact Organization Primary:
      Contact Organization: Coleambally Irrigation Limited (CIL)
      Contact Person: Janelle Dufty
      Contact Position: GIS Officer
    Contact Address:
      Address Type: mailing and physical address
      Address: Brolga Place PO Box 103
      City: Coleambally
      State or Province: NSW
      Postal Code: 2702
      Country: AUSTRALIA
      Contact Voice Telephone: (06) 6950 2821
      Contact Facsimile Telephone: (06) 6954 4321
      Contact Electronic Mail Address: jdufty@colyirr.com.au

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METADATA_REFERENCE_INFORMATION

Metadata Date: 20000608
Metadata Review Date: 20000608
Metadata Contact:
  Contact Information:
    Contact Organization Primary: